

Geologic Resources Inventory Scoping Summary Knife River Indian Villages National Historic Site North Dakota

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August 19, 2011

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The Geologic Resources Inventory (GRI) provides each of 270 identified natural area National Park System units with a geologic scoping meeting and summary (this document), a digital geologic map, and a geologic resources inventory report. The purpose of scoping is to identify geologic mapping coverage and needs, distinctive geologic processes and features, resource management issues, and monitoring and research needs. Geologic scoping meetings generate an evaluation of the adequacy of existing geologic maps for resource management, provide an opportunity to discuss park-specific geologic management issues, and if possible, include a site visit with local experts.

The National Park Service held a GRI scoping meeting for Knife River Indian Villages National Historic Site on August 16, 2011 at the park's visitor center and headquarters building in Stanton, North Dakota. A site visit at the historic site followed the meeting. Tim Connors (NPS-GRD) facilitated the discussion of map coverage and Lisa Norby (NPS-GRD) led the discussion regarding geologic processes, features, and issues at the park. After an introduction by park superintendent Wendy Ross, Eric Brevik from Dickinson State University presented a brief geologic overview of the park and surrounding area. Participants at the meeting included NPS staff from the park, Geologic Resources Division, and Northern Great Plains Network; geologists from Dickinson State University and the University of North Dakota; and a cooperator from Colorado State University (see table 2). This scoping summary highlights the GRI scoping meeting for Knife River Indian Villages National Historic Site including the geologic setting, the plan for providing a digital geologic map, a prioritized list of geologic resource management issues, a description of significant geologic features and processes, lists of recommendations and action items, and a record of meeting participants. Please note that since the park scoping, the GRI map team has completed and posted the digital geologic map for Knife River Indian Villages National Historic Site. It is available at <https://irma.nps.gov/App/Reference/Profile/2176225>

Park and Geologic Setting

Knife River Indian Villages National Historic Site was authorized on October 26, 1974 to preserve and protect archaeological and historical resources related to Hidatsa and Mandan (Northern Plains Indians) cultures. After a boundary change on October 15, 1990, the park currently encompasses 711.58 ha (1,758.35 ac). The park preserves and interprets the remains of three earthlodge villages: Hidatsa Village (Big Hidatsa site), Awatixa Village (Sakakawea site), and Awatixa Xi'e Village (Lower Hidatsa site). All three villages are located along the banks of the Knife River just upstream of its confluence with the Missouri River (just southeast of the park) in eastern Mercer County, west-central North Dakota. Fourteen km (9 mi) upstream of the park, Garrison Dam impounds Lake Sakakawea on the Missouri River.

The park's location is just west of the maximum extent of the last Pleistocene glacial advance in North Dakota. This extent is marked roughly by the location of the present-day Missouri River, whose formerly northern-flowing (towards Hudson Bay) course was altered by the glaciers. Previous glacial events likely covered the area in ice, but surficial geologic processes of erosion and weathering have removed much of the evidence of glaciation from the landscape.

The geologic units within the park record two intervals of geologic time: the late Paleocene (59 to 56 million years ago), and the Quaternary (the past 2.6 million years). The oldest rock unit is the Sentinel Butte Formation (of the Fort Union Group). This formation contains interlayered siltstone, claystone, and sandstone, with numerous lignite coal beds. The Sentinel Butte Formation was deposited in a low-relief coastal plain with rivers, lakes, ponds, swamps, and rainforests. The entire system drained toward the east and southeast from source areas to the west and northwest (Rocky Mountains). The younger (Quaternary), unconsolidated, surficial units exposed within the park include fluvial and glacial outwash deposits, lumped together as the Oahe Formation.

The landscape of the park features large river terraces flanking floodplains and meandering river channels. Today, surficial processes such as weathering, erosion, lateral movement of the river channel, freeze-and-thaw cycles, and flooding continue to shape the landscape at Knife River Indian Villages National Historic Site. These processes may expose, destroy, or bury the archaeological resources at the park.

Geologic Mapping for Knife River Indian Villages National Historic Site

During the scoping meeting, Tim Connors (NPS-GRD) showed some of the main features of the GRI's digital geologic maps, which reproduce all aspects of paper maps, including notes, legends, and cross sections, with the added benefit of being GIS compatible. The NPS GRI Geology-GIS Geodatabase Data Model incorporates the standards of digital map creation for the GRI Program and allows for rigorous quality control. Staff members digitize maps or convert digital data to the GRI digital geologic map model using ESRI ArcGIS software. Final digital geologic map products include data in geodatabase and shapefile format, layer files complete with feature symbology, FGDC-compliant metadata, an Adobe Acrobat PDF help document that captures ancillary map data, and a map document that displays the map, and provides a tool to access the PDF help document directly from the map document. Final data products are posted at <http://science.nature.nps.gov/nrdata/>. The data model is available at <http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm>.

When possible, the GRI Program provides large scale (1:24,000) digital geologic map coverage for each park's area of interest, which is often composed of the 7.5-minute quadrangles that contain park lands (fig. 1). Maps of this scale (and larger) are useful to resource managers because they capture most geologic features of interest and are spatially accurate within 12 m (40 ft). The process of selecting maps for management begins with the identification of existing geologic maps (table 1) and mapping needs in the vicinity of the historical park. Scoping session participants then select appropriate source maps for the digital geologic data or develop a plan to obtain new mapping, if necessary.

During GRI scoping it was decided that coverage was desired for areas of the Riverdale South, Garrison Dam South, Stanton, and Stanton SE 7.5' quadrangles and the best available map for Knife River Indian Villages National Historic Site was an MS thesis by Jon Reiten (Quaternary geology of Knife River Indian Villages National Historic Site). After the August scoping, GRI staff completed digital conversion of the Jon Reiten map. The map is posted at <https://irma.nps.gov/App/Reference/Profile/2176225>. A screen capture of this map is presented in

Figure 1 and it features layers for the following:

- Morphologic units and morphologic unit boundaries
- Longitudinal ridges
- Geologic units
- Geologic contacts
- Geologic cross section lines

There is also bedrock geology available at the county level for Mercer and Oliver counties, but the terminology is quite dated and the scale is small. However, this map could be incorporated to add to the existing Knife River Indian Villages National Historic Site Digital Geologic Map.

Additionally, it was mentioned during scoping that a recent creation of a national historic landmark approximately 75 miles to the west of Knife River Indian Villages National Historic Site in Dunn County, North Dakota was designated as the Lynch Knife River Flint Quarry. The National Historic Landmark site played an important role in the trading patterns of Knife River Indian Villages inhabitants over thousands of years. The current site is not administered by the National Park Service, but the private landowners who own the site recognize the significance of the flint quarries to the story of North Dakota's first peoples. This area, covered by the Dunn Center and Werner 7.5-minute quadrangles (fig. 2), has geologic map coverage that may be of interest to resource managers as well. GRI staff will try to obtain digital coverages of these areas from the North Dakota Geological Survey to someday furnish to Knife River Indian Villages National Historic Site staff.

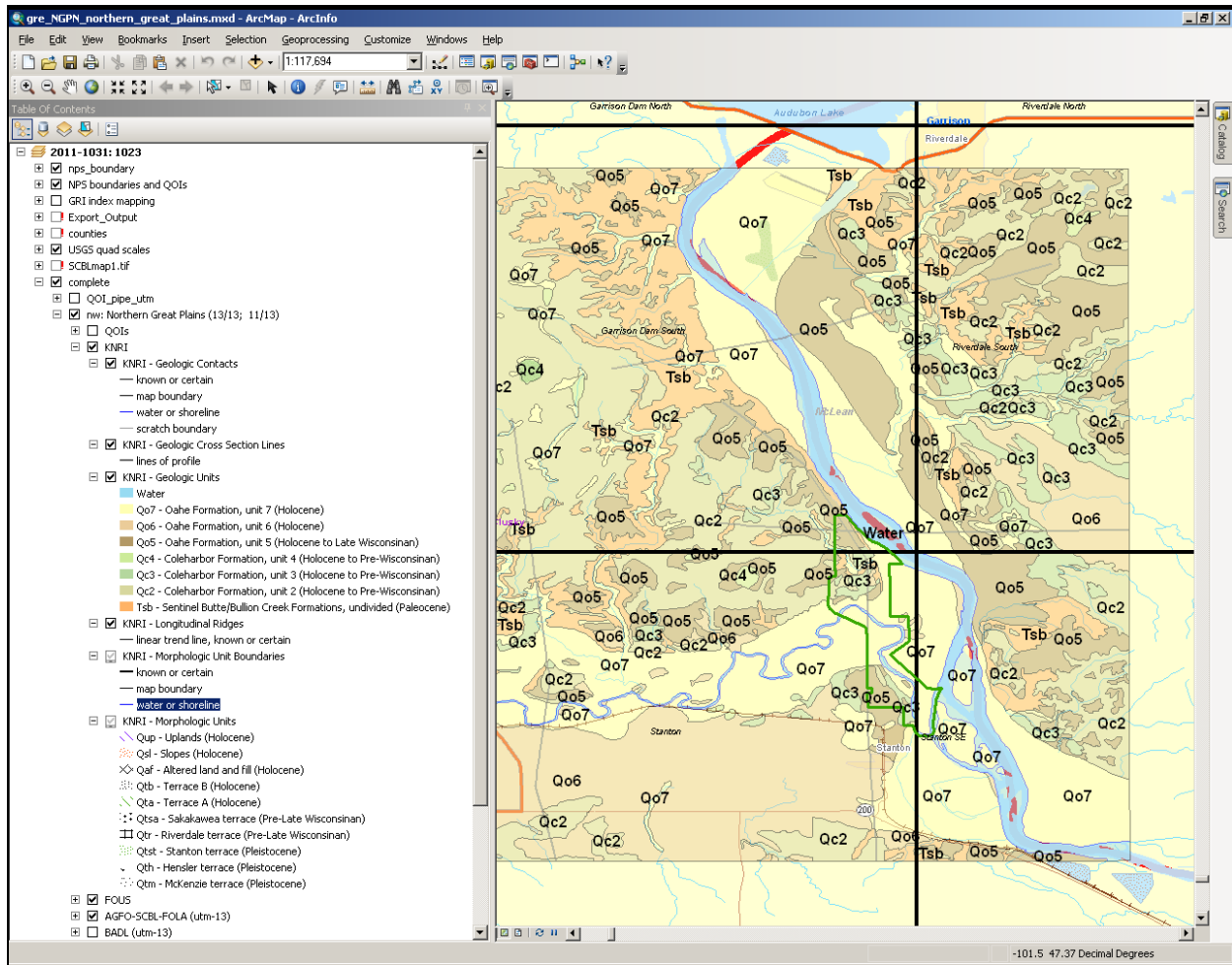


Figure 1. Screen capture of KNRI GRI Digital Geologic map extent from Jon Reiten's "Quaternary Geology of Knife River Indian Villages NHS" MS thesis

Table 1. GRI Mapping Plan for Knife River Indian Villages National Historic Site

Covered Quadrangles	Relationship to the park	Citation	Format	Assessment	GRI Action
KNRI	Covers the extent of the park	Reiten, J. 1983. Quaternary geology of Knife River Indian Villages National Historic Site (scale 1:unknown). Master's thesis. University of North Dakota, Grand Forks, North Dakota, USA.	Paper	Yes	Georeference and digitize in GRI data model
Mercer and Oliver counties, ND	Intersects the park	Carlson, G. G. 1973. Geology of Mercer and Oliver Counties, North Dakota (scale 1:126,720). Bulletin 56, part 1. North Dakota Geological Survey, Bismarck, North Dakota, USA.	Paper PDF	Maybe	Georeference and digitize in GRI data model

Covered Quadrangles	Relationship to the park	Citation	Format	Assessment	GRI Action
Dunn Center, ND	Intersects the new national historic landmark	Murphy, E. C. 2004. Surface geology – Dunn Center quadrangle, North Dakota (scale 1:24,000). 24K Series DnnC-sg. North Dakota Geological Survey, Bismarck, North Dakota, USA. https://www.dmr.nd.gov/ndgs/surfacegeo/24ksurface/dnnC_sg.pdf	PDF	Perhaps	Georeference and digitize in GRI data model
Werner, ND	Intersects the new national historic landmark	Murphy, E. C. 2004. Surface geology – Werner quadrangle, North Dakota (scale 1:24,000). 24K Series Wmnr-sg. North Dakota Geological Survey, Bismarck, North Dakota, USA. https://www.dmr.nd.gov/ndgs/surfacegeo/24ksurface/wmnr_sg.pdf	PDF	Perhaps	Georeference and digitize in GRI data model

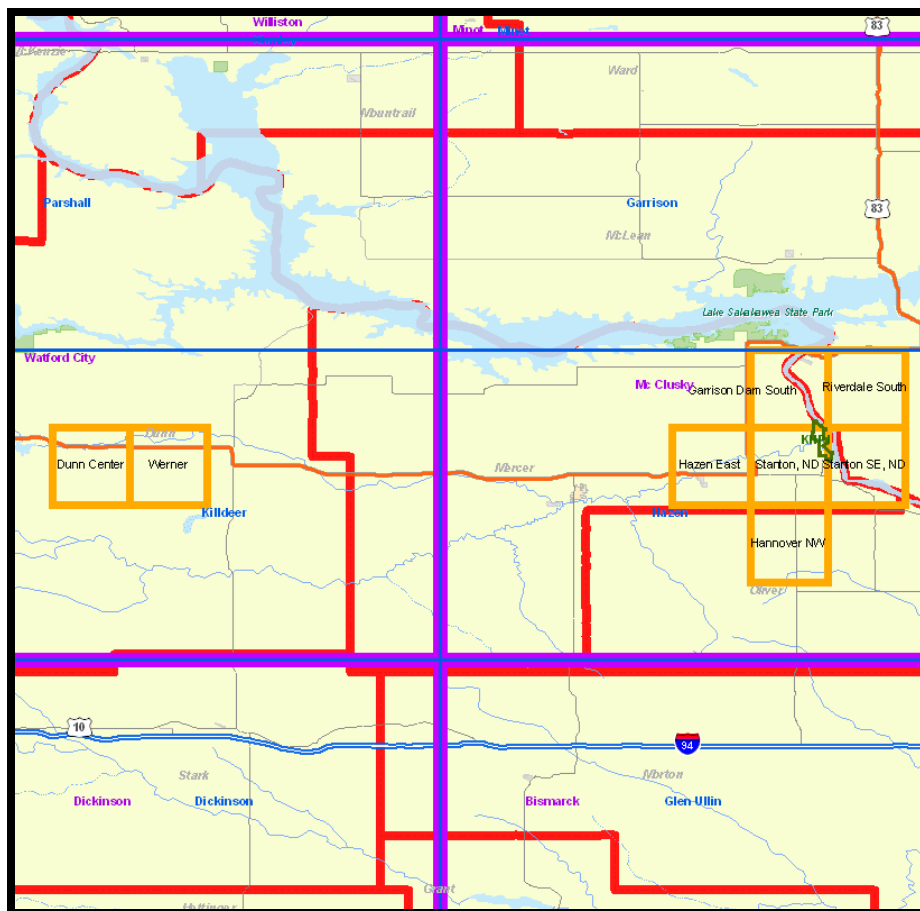


Figure 2. Relationship of new national historic landmark in Dunn County relative to Knife River Indian Villages National Historic Site, North Dakota. The 7.5-minute quadrangles are labeled in black; names and lines in blue indicate 30-minute by 60-minute quadrangles (1:100,000 scale); names in purple indicate 1 degree x 2 degree (1:250,000 scale). Green outlines indicate national historic site boundaries.

Geologic Resource Management Issues

The scoping session for Knife River Indian Villages National Historic Site provided the opportunity to develop a list of geologic features and processes, which will be further explained in the final GRI report. During the meeting, participants prioritized the most significant issues as follows:

- (1) Fluvial processes, and
- (2) Hillslope processes.

Other geologic resource management issues discussed include seismicity, disturbed lands, and coal, oil, and gas development.

Fluvial processes

Many of the archaeological sites at Knife River Indian Villages National Historic Site were constructed on high terraces adjacent to the Knife and Missouri rivers. The Hidatsa Village, Awatixa Village, and Awatixa Xi'e Village were all constructed on terraces above the Knife River just upstream of its confluence with the Missouri River. Throughout the park, the Knife River flows across intermittently broad, undulating floodplains. The rivers and associated fluvial processes are the driving forces of landscape change at the park.

Flooding along waterways in the park is relatively frequent, occurring most often during the winter months when ice dams form along the Knife River. Because the Garrison Dam is just upstream, flooding on the Missouri River is very infrequent. Garrison Dam is nearly 4 km (2.5 mi) wide, and 800 m (0.5 mi) wide at its base, making it one of the 5 largest earthen dams in the country, impounding 286-km-long (178 mi-long) Lake Sakakawea. In 2011, flooding occurred on both the Missouri and Knife rivers due to unusually high snowpack/snowmelt and high spring rainfall. The Garrison Dam spillway was used to control flow out of Lake Sakakawea for the first and only known time since its construction to reduce pressure on the rapidly filling reservoir. Normal high flow in the Missouri River is approximately 64,000 cfs; however, in 2011, flow in June and July peaked at approximately 150,000 cfs. The river was flooded for most of the summer of 2011. This caused some sedimentation in the peninsula area between the Knife and Missouri rivers. The Missouri River channel closest to the park (flanks the eastern boundary of the park) has filled in with fine silt since the record Missouri River flooding in summer 2011 (John Moeykens, NPS-KNRI, written communication December 20, 2011). Since the sediments on the peninsula area have recently been deposited by river (fluvial) processes, the peninsula contains no known archaeological remains other than what has washed downstream.

Prior to the construction of the Garrison Dam in the 1950s, the Missouri River experienced regular flooding. Overall water levels are controlled by the dam/reservoir and generally are lower on the Missouri River than pre-dam levels. Regular flooding is crucial to retaining the balance and health of the riparian zone along the rivers. Local cottonwood forests are suffering because of a lack of floodwaters that are necessary for their reproduction. Gully wash was another active fluvial process along the river corridor that is now lessened by the presence of the dam. The dam has entrained sediment which is infilling Lake Sakakawea. Sediment loads in the river downstream of the dam are very low compared to pre-dam levels. Additionally, prior to construction of the dam, the active river channel was much wider than it is today.

Several agencies and organizations are inventorying and monitoring shoreline changes along the Missouri River. In 1895, the Missouri Commission made a map of the area showing the locations of rivers prior to the construction of the Garrison Dam. The park is currently photo monitoring streambanks where many large trees have collapsed. The U.S. Army Corps of Engineers (USACE) performed aerial surveys during the summer of 2011. The park expects satellite imagery to be available in fall 2011. These data may help determine what impact the unusually wet 2011 season had on park resources.

Fluvial processes such as channel movement, erosion, and deposition have created and altered the park's landscape. Typical stratigraphy exposed in cutbanks along the Knife River may show, from bottom to top (oldest to youngest): coarse- to medium-grained channel sands; fine sand, silt, and mud; medium-grained channel and overbank sands; and overbank muds. This very fine layering can be important for archaeological correlations. Paleosols (buried soil horizons) occur in cutbank exposures along the Knife River, in particular along a stretch of the river opposite the Awatixa Village (Sakakawea site). Volcanic ash (from Yellowstone and the Cascades) may also be part of the soil profile. Volcanic ash in the soils may provide age-dates. These ancient soil and ash deposits were buried by alluvial sediments as the river meandered across the floodplain.

The Missouri and Knife rivers are constantly meandering across their broad floodplains. The modern Missouri River occupies an old Knife River channel between the confluence and Washburn, North Dakota. Flanking river terraces occur at several levels within the park. These terraces (some of which were used for building earthlodges) are an important part of the park's story. Jon Reiten's master's thesis involved mapping and correlating the local terraces and provides useful data for park resource staff (add reference).

Hillslope processes

Erosion is among the most important geologic issues facing park resource staff at Knife River Indian Villages National Historic Site. In several localities, erosion threatens archaeological sites. A GIS-based monitoring survey is currently underway under the direction of Jay Sturdevant, NPS archaeologist, and Jillien Cummings, NPS hydrologist, based in Fort Collins, Colorado.

A county road runs through the northern portion of the park allowing access to private agricultural land that is located between the park and the Missouri River. Knife River is meandering northward and is threatening the stability of the road. Areas of the road have been artificially hardened in an attempt to mitigate the erosion, but this is causing accelerated erosion in adjacent areas that are not hardened. The river cutbank is very steep and prone to sloughing (fig. 3). Similar stretches along the Missouri River were hardened prior to the establishment of the park in 1974 and was likely done to preserve farmland along the river. This hardening (jetties) is easily visible on aerial photographs and is causing accelerated erosion on adjacent streambanks.

Erosion is occurring on many scales throughout the park. The depressions marking the locations of the earthlodges are slowly being leveled by natural erosion. Burrowing animals are contributing to erosion and are unearthing archaeological resources.

Topography within the park is subtle. Badland topography occurs along stretches of the Missouri River, but not within park boundaries. The North Dakota Geological Survey is completing landslide

hazard maps for many areas of North Dakota. Ed Murphy (North Dakota Geological Survey) is a potential contact for help with any slope hazard issues within the park.

Other geologic resource management issues

Seismicity

North Dakota is not considered to be an area prone to seismic hazards. A magnitude 2 earthquake occurs in the state on average once a decade.

Disturbed lands

Knife River Indian Villages National Historic Site was established in 1974. Prior to this time, the land was used for agriculture. Relics from the farming past include piles of glacial erratics moved for plowing, and artesian wells. The top * cm (18 in.) of soil was disturbed for agriculture by sodbusters starting in the late 1800s when the land was first cultivated. After the initial sod removal, the land was consistently farmed with crops until the park's establishment in 1974. Farming also brought changes in drainage. Some eighteen older plow lines were present when the area was first cultivated. Crop rows, fencelines, and roadways stemming from early agriculture are still visible in multiple areas of the park (John Moekens, NPS-KNRI, written communication December 20, 2011).

Coal, oil and gas development potential

Coalbeds are common in the Paleocene rock units in the park area. The North Dakota state geologist (Ed Murphy) has coal resource maps, and the U.S. Geological Survey performed extensive coal resource mapping throughout the area in 1908. Coal appears as float on local sandbars. Exposed coal beds may ignite and may spread to coal seams far underground. The high temperatures form "clinker" (reddish to gray, vesicular rocks resembling volcanic scoria). Some coal companies estimate that the vast coal resources in North Dakota, if developed, could be used for up to 800 years. The Falkirk Mining Company is communicating with the park and can provide the park with a 30-year plan of activity in the area. Eight coal-fired powerplants surround the park and affect the park's viewshed. Coal mining occurs locally to the east, west, and south of the park. Draglines from a mine across the Missouri River are visible from the park. Test pits were excavated west of the park near the Lynch Knife River Flint Quarry of Dunn Center. Prior to enactment of coal mining reclamation laws, coal mining left scars such as unfilled pits, spoil piles, and drag lines. Local mining does not seem to be impacting groundwater resources or air quality. Where coal was mined underground in shafts, the potential for the development of sinkholes exists. Roads in North Dakota have been damaged where sinkholes developed into abandoned coal mine shafts.

North Dakota is currently experiencing renewed interest in oil and gas development in the Devonian–Mississippian Bakken Shale. Currently, 75% of the state's oil and gas production is from the Bakken Formation. Other units of interest to the oil and gas industry include the Devonian Three Forks Formation and Pennsylvanian Tyler Formation. There is also renewed interest in the Ordovician Red River Formation that was heavily drilled in the 1980s and 1990s. These units occur beneath the park, but have greater hydrocarbon development potential to the north and west, near the town of Williston, North Dakota. The park is on the very southern edge of the Bakken Shale oil and gas play. Approximately 2,000 wells are currently producing oil and gas in the area. Geologists estimate that development of the Bakken shale play will last at least 10 years, with proposals circulating that involve drilling another 20,000 wells to explore for and produce oil and gas from the

Bakken Formation; the website <https://www.dmr.nd.gov/oilgas/> has important statistics and information regarding oil and gas development in North Dakota.

The influx of people to support the Bakken oil and gas exploration and production effort has created many adverse effects on North Dakota. This includes development of rural and agricultural areas, increased traffic on local roads, increased crime, excessive wastewater demands, and additional impacts to soil, water and air resources. Landowners are taking advantage of the economic boom by leasing their land for RV parks and storage of oilfield materials. A notable example is a local citizen who wants to store fracking sand and drillpipe at a local ballpark.



Figure 3. Steep cutbank along Knife River adjacent to a county road that traverses the park. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University) August 16, 2011.

Features and Processes

History and geology connections

The area surrounding the confluence of the Missouri and Knife rivers has been an area of human habitation for thousands of years. The earliest evidence of human presence in the area dates back approximately 11,000 years. Paleo-Indians were quarrying nearby flint deposits. Until approximately 1,000 years ago, American Indians likely passed through the area, but did not settle in permanent communities. Prior to European contact, there were thousands of people living in the earthlodge villages. This is testament to the stability and prosperity of their society. The earliest exposure to European goods was in the early 1600s and the earliest actual contact was with fur traders in 1738. The Lewis and Clark expedition traded with the inhabitants of the village and noted a prosperous society. European contact brought contagious and often fatal disease that spread rampantly throughout the settled villages. Following years of disease (e.g. smallpox killed over 50% of the population) and cultural change, the Mandan and Hidatsa earthlodge villages at Knife River were abandoned in 1885.

The Mandan and Hidatsa people chose to settle in this area because of an abundance of natural resources and access to traversable waterways. Because of this strong connection, at Knife River Indian Villages National Historic Site natural resources became the cultural resources. Natural resources were used for cultural purposes and to make cultural resources (e.g. flint tools, described below). The abundance of local natural resources made the inhabitants wealthy and stable. They could settle, plant crops, and live in the area year-round, unlike many of their Plains Indian contemporaries. Abundant pottery shards attest to abundant local sources of clay from river deposits. Charcoal layers record past fires and abundant local coal may have been used to produce charcoal.

Knife River Flint, exposed in lag deposits west of the park, was used for tools and trade by the Mandan and Hidatsa. Silcrete chert or flint exists in the bedrock and reworked gravel deposits throughout North Dakota. Knife River Flint is brown and extremely fine-grained; remnants of organic matter indicate that the flint originated from altered peat or lignite coal deposits. The source area for this flint is in the Knife River headwaters region, but the exact location has not been accurately determined. However, the Golden Valley Formation contains silcretes similar to the Knife River Flint and is in the appropriate geographic location to be a potential source unit. Fluvial processes eroded and transported deposits of this flint as far away as Iowa. This was a major geologic resource used by the native peoples along the Knife River. This extremely fine-grained chert (siliceous - contains silica) has excellent knapping properties that are better than obsidian making it useful to produce tools such as arrowheads, knives, and scrapers. Village men would work the flint. Knapping was a respected skill among the Mandan and Hidatsa. The Mandan and Hidatsa traded their flint resource for material such as copper, obsidian, shells, beads, cloth, and metal tools. Other traded material included catlinite (pipestone material) from Minnesota (today's Pipestone National Monument (PIPE)). Knife River Flint has been found in archaeological settings throughout the United States. Pock-marked lands to the north and west (at the new Lynch Knife River Flint Quarry National Historic Landmark) attest to thousands of years of quarrying. Quarrying ended approximately 300 years ago when steel traded from the eastern United States arrived in

North Dakota. Because of the popularity of flint-lock guns, the use and value of flint continued throughout the 1800s.

Earthlodge villages were large, often containing 40–50 lodges. At the Hidatsa Village, Awatixa Village, and Awatixa Xi'e Village, earthlodges were built on higher river terraces out of local, unconsolidated river deposits and seasonal crops were planted on the fertile floodplains below the lodges. These floodplain soils are particularly fertile because floods and overland flow deposit rich alluvial material including silts (weather to release needed minerals and nutrients for plants), clays (provide cation exchange capacity), and organic materials (decompose to release plant nutrients, provide cation exchange capacity, and improve the physical condition of the soil). The earthlodges were constructed by the women, were covered in grass (fig. 4), and were expected to last until the wooden supports rotted away (or approximately 15 to 20 years). They were inhabited during the spring, summer, and fall as homes, schools, and workshops. Due to their location on high terraces, the inhabitants were able to avoid dangerous seasonal floods. During the winter, the groups moved to temporary dwellings built of wood and bark on the river bottoms. The riverine environment of well-drained, well-watered soils supports the growth of large cottonwood trees that provided building material, fuel for fires, and shelter from harsh winter winds. Due to the high sulfur and moisture content of the coals, it is likely that the Hidatsa and Mandan burned the cottonwood trees rather than the local coal deposits.

Paleontological resources

According to the paleontological resource inventory and monitoring report prepared by the Geologic Resources Division for Knife River Indian Villages National Historic Site, fossils have been documented from the museum collections within the park (Tweet et al. 2011). These are paleontological resources primarily associated with trading between the Mandan and Hidatsa people and other tribes. These fossils were found through archaeological investigations. Fossil remains associated with the various ceremonial sites include various shells. These types of remains are indicative of a vast trading network among the early inhabitants.

In-situ fossil remains in the locally-exposed Sentinel Butte Formation may include coal, silicified peat, pollen, plant roots, stumps, petrified wood, fruits, leaves, fungal spores, freshwater bivalves and gastropods, ostracodes, beetles, fish, giant salamanders, turtles, champosours, crocodilians, mammals, marsupials, primate relatives, pantodonts, and invertebrate trace fossils. The Quaternary deposits may also contain fossil resources including charcoal, burrows, pollen, spores, aquatic microfossils, and vertebrate fossils such as bison bones, mammoth, and horse remains. A formal (field-based) paleontological inventory of on-site resources has not been completed for Knife River Indian Villages National Historic Site.

Glacial features

During the Pleistocene, episodic cooler climates led to widespread glaciations. Of these, the Illinoian and later Wisconsinan events strongly influenced the development of the landscape in the vicinity of the Knife River Indian Villages National Historic Site. The park sits near the glacial terminus of the Wisconsinan event, approximately marked by the location of the current-day Missouri River, which was rerouted from its former course towards Hudson Bay by advancing glaciers. The surrounding area exhibits a glaciated landscape to the north and east a largely unglaciated landscape to the south and west.

Advancing ice during the Pleistocene dammed tributaries of the Missouri River creating proglacial lakes such as Lake McKenzie. The Knife River was likely impounded by glacial ice. Higher water levels associated with such impoundments produced higher strandlines above modern streams. Glacio-lacustrine deposits from proglacial lakes may occur in the area, but the park is too close to the Missouri River which was not impounded to have any glacio-lacustrine sediments.

Glacial outwash is part of the glacial deposits that occur in the park. Because of local fluvial erosion these types of deposits tend to be thicker away from rivers. Erosion has removed most of the local glacial deposits except for large glacial erratics. Glacial erratics are derived from sandstone or limestone, as well as some igneous and metamorphic rocks from the Canadian Shield. Any intrusive igneous or metamorphic rocks found in this area of North Dakota were transported from the north by glaciers.

Following glacial retreat and before vegetation flourished, wind transported and deposited fine silt across the landscape in deposits generally less than 1 m (3 ft) thick. Today, these loess deposits are widespread across North Dakota. They frequently form a thin layer in the soil profile. Agricultural plowing usually incorporates the silt into the soil, making it indistinguishable from other soil horizons. A soils inventory map of the park was completed in 2006–2007 by the NPS Soil Resources Inventory. This data is available from the NPS Datastore (<http://science.nature.nps.gov/nrdata/>).

Aeolian features

North Dakota is ranked as having the top wind power potential in the United States. Aeolian deposits, including dunes, occur to the west of Knife River Indian Villages National Historic Site, and to the east of the Missouri River in the vicinity of the park. These features formed over the last few thousand years during particularly arid periods. Other local features associated with wind include blowouts. These are areas where wind has removed all of the fine-grained material leaving a depression with coarser grained materials behind. These blowouts frequently occur as depressions on hilltops. Blowouts also occur near large glacial erratics which may be due to bison using the large rock for scratching and subsequently removing the vegetation around the rock, exposing the deposits to the wind. Blowouts tend to be good locations to find fossils and other resistant remnant materials such as flint.

Unique features

As discussed under “History and geology connections”, the Knife River chert and the story of its use by the earthlodge dwellers is a unique facet to Knife River Indian Villages National Historic Site’s story. Knife River lends its name to this important natural and archaeological resource.



Figure 4. Vegetation-covered earthlodge reconstructed outside of the visitor center at Knife River Indian Villages National Historic Site. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University) August 16, 2011.

Recommendations

1. Consult U.S. Geological Survey website regarding the seismic risk in the Knife River Indian Villages National Historic Site area.
2. Conduct a field-based paleontological survey of Knife River Indian Villages National Historic Site.
3. Consult with NPS-GRD for recommendations for stabilizing the riverbank in sensitive resource areas.
4. Consult the North Dakota Geological Survey website for general geologic guidance and mineral resources development information.
5. Download soils and GRI geologic digital maps from the NPS Datastore (<http://science.nature.nps.gov/nrddata/>) for use in resource management.
6. Contact the state geologist (Ed Murphy) for coal resource maps.
7. Obtain oil and gas development information from the North Dakota Oil and Gas Division website (<https://www.dmr.nd.gov/oilgas/>).

Action Items

1. GRI report author will note the preference of using Paleogene, Eocene, etc. in lieu of Tertiary on the Map Unit Properties Table in the final GRI report.
2. GRI report author will note nomenclature differences of geologic units between state surveys, academics, and USGS. A map by Johnson and Kunkel has an appropriate stratigraphic column.
3. GRI report author will consult publications such as Clayton, L., W. B. Bickley, and W. J. Stone. 1970. Knife River Flint. *The Plains Anthropologist* 15(50):282–290 when discussing Knife River Flint.
4. GRI report author will consult Metcalf, F. 1994. Knife River: Early Village Life on the Plains. *OAH Magazine of History* 9(1):34–47.
5. GRI report author will obtain copies of the archaeological report for the park, and works by David Keen, Jay Sturdevant, Thomas Theissen, Betts, and Shultz.
6. GRI report author will obtain a copy of Johnson and Kunkel (1959).
7. GRI report author will use copy (provided by L. Norby) of Ellis, L. 2005. Geomorphological Assessment of Bank Erosion along the Knife River near Knife River Indian Villages National Historic Site (KNRI) North Dakota. *Geoscientists-in-the-Parks* document 2005-KNRI. National Park Service, Denver, Colorado, USA.

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Table 2. Scoping Meeting Participants

Name	Affiliation	Position	Phone	E-Mail
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