

Geologic Resource Inventory Scoping Summary

Niobrara National Scenic River, Nebraska

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December 16, 2008

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The Geologic Resource Inventory (GRI) Program 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 Niobrara National Scenic River (NIOB) and Missouri National Recreational River (MNR) on August 20, 2008 at the University of South Dakota, Vermillion, South Dakota. Lisa Norby (NPS GRD) facilitated the meeting and led the discussion regarding geologic processes and features at Niobrara National Scenic River. After Pam Sprenkle (NIOB) presented an overview of the Niobrara National Scenic River, Tim Connors (NPS GRD) led the discussion of map coverage. Scott Lundstrom (USGS) presented an overview on the geological controls on river ecology and the relevance of these controls on adaptive management. Matt Joeckel (NE Geological Survey) discussed mineral occurrences related to recent weathering in the Missouri and Niobrara valleys. Participants at the meeting included NPS staff from the park and Geologic Resources Division (GRD) and cooperators from the South Dakota Geological Survey (SD Geological Survey), Nebraska Geological Survey (NE Geological Survey), USGS, and Colorado State University. This scoping summary highlights the GRI scoping meeting for Niobrara National Scenic River including the geologic setting, the plan for providing a digital geologic map, geologic resource management issues, a description of significant geologic features and processes, mapping recommendations, and a record of meeting participants (table 1).

Park and Geologic Setting

Beginning in the high plains of eastern Wyoming, the Niobrara River flows 861 km (535 mi) to its confluence with the Missouri River in northeastern Nebraska. The river drains 32,600 sq km (12,600 sq mi) of Nebraska and is fed by hundreds of springs as it flows through the Sand Hill region of western Nebraska, one of the largest grass-stabilized dune regions in the world. East of Valentine, the Niobrara River has cut a valley 60-120 m (200-400 ft) deep and 0.8-3 km (0.5-2 mi) wide. The Niobrara is the only river in Nebraska to flow directly over its bedrock substrate.

The oldest exposed rock unit in the Niobrara River Valley is the Cretaceous Pierre Shale that was deposited in a shallow marine environment approximately 98 million year ago (Ma). Miocene (5.33-23.0 Ma) units overlie the Pierre Shale and include, from oldest to youngest: Rosebud Formation, Valentine Formation, and Ash Hollow Formation. These younger units are composed primarily of sandstone and siltstone that were deposited in floodplain environments. The Sand Hills began forming about 10,000 years before present (BP), with the most active period forming the largest dunes from unconsolidated alluvial sands approximately 5,000-8,000 years BP.

Geologists have located more than 230 waterfalls along the Niobrara National Scenic River. In general, the waterfalls occur where streams flow over the erosion resistant Rosebud Formation and tumble into the Niobrara River or its tributaries. At Smith Falls, the state's highest waterfall, water plunges more than 19 m (63 ft) from a cliff before flowing into the river.

Overview of Niobrara National Scenic River (Pam Sprengle)

The designated stretch of the Niobrara National Scenic River is 122 km (76 mi) long. Dams both within and outside of park boundaries have contributed to instream flow issues and concerns over recreation, fish abundance and migration, and wildlife habitat. Spencer Dam lies downstream from NIOB and upstream from the Missouri National Recreational River. This operational facility flushes sediment from its head gates in the spring and fall. Two upstream dams, the Box Butte Dam about 160 km (100 mi) upstream from the park on the Niobrara River and the Merritt Dam on the Snake River, are used for irrigation and flood control. Water is held within the reservoir during the Spring irrigation season.

The 4-5 m (12-15 ft) high Cornell Dam that is located approximately 8 km (5 mi) downstream from the western boundary of the park has not been operational since 1984, and sediment has filled in the reservoir. Although Cornell Dam now exists as a "run-of-the-river" dam, it still impedes upstream migration of aquatic species and continues to alter the hydrology of the upper portion of the scenic river. Management hopes to remove the dam as soon as possible. Abundant sediment from the Sand Hills is transported by the Niobrara River and sediment, bedload, and bedform studies have been conducted by the University of Nebraska – Lincoln.

Considerable paleontologic studies were conducted prior to the designation of the Niobrara as a National Scenic River in 1991, and paleontology is one of the park's outstandingly remarkable values. However, major research projects have not been initiated in the Niobrara River valley since 1994. A paleontology inventory is being prepared for the park by the GRD.

Geologic Mapping for Niobrara National Scenic River

During the scoping meeting, Tim Connors (NPS GRD) showed some of the main features of the GRI Program's digital geologic maps, which reproduce all aspects of paper maps, including notes, legend, 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, a Windows HelpFile that captures ancillary map data, and a map document that displays the map, and provides a tool to access the HelpFile 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 and mapping needs in the vicinity of the park. Scoping session participants then select appropriate source maps for the digital geologic data or develop a plan to obtain new mapping, if necessary.

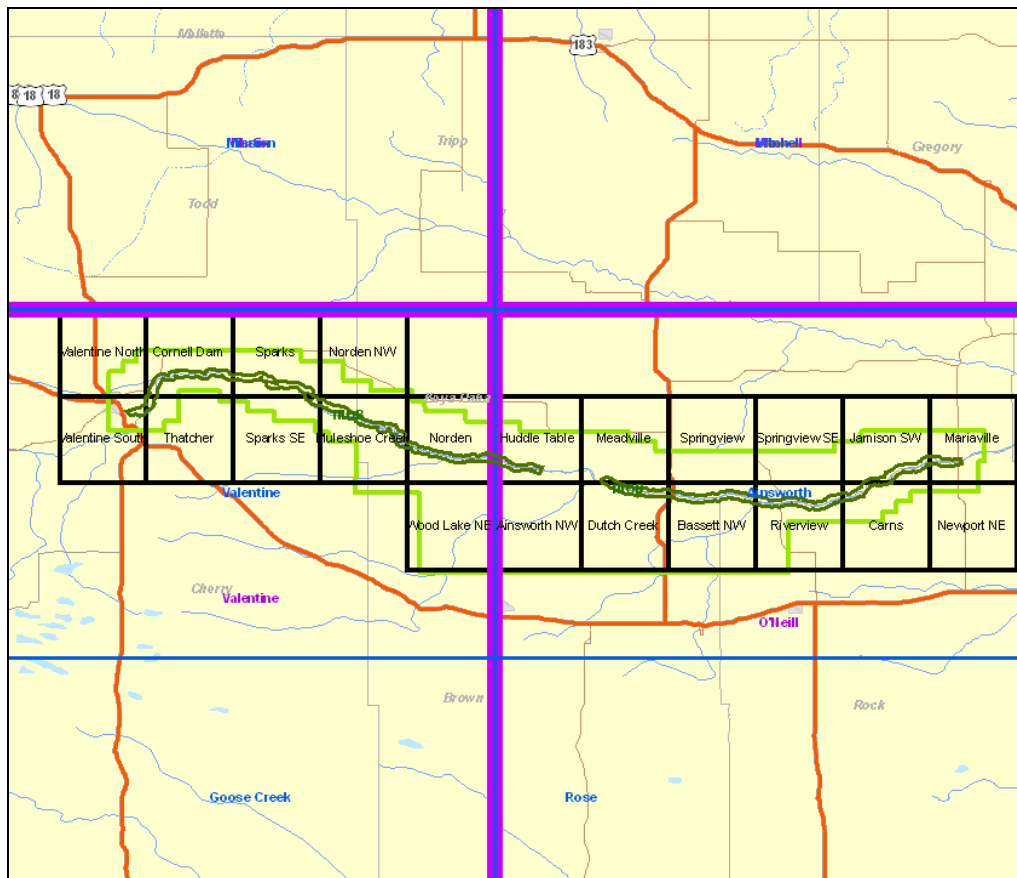


Figure 1. Area of interest for Niobrara National Scenic River, Nebraska and South Dakota. The 7.5-minute quadrangles are labeled in black outlined polygons; names in blue indicate 30-minute by 60-minute quadrangles; names in purple indicate 1x2 quadrangles. Dark green outlines indicate monument boundaries and the lime green line indicates the desired maximum extent of geologic mapping for NIOB. Please note NIOB boundary is present event though there is break in polygon in Huddle Table and Meadville quadrangles.

After the scoping a group was convened to discuss desired mapping extent and arrived at the following consensus from comments from USGS, SDGS, and NPS staff: construct a geologic map with a minimum of one mile outside the park boundary, but in most areas the boundary is one mile beyond the valley wall. The boundaries are squared to the nearest section line.

Portions of the following 7.5' quadrangles involved are as follows: Norden NW, Sparks, Cornell Dam, Valentine North, Mariaville, Jamison SW, Springview SE, Springview, Meadville, Huddle

Table, Norden, Muleshoe Creek, Sparks SE, Thatcher, Valentine South, Newport NE, Carns, Riverview, Bassett NW, Dutch Creek, Ainsworth NW, and Wood Lake NE.

The 30x60 sheets this area covers are the Ainsworth and Valentine.

The 1x2 sheets covered are the O'Neill and Valentine.

Based upon this desired extent, NPS staff are now working with USGS Scott Lundstrom to find ways to incorporate his existing projects in the region to producing a dedicated NIOB digital geologic map. NPS-GRD staff (Bruce Heise and Tim Connors) will be in communications regarding this matter and will report back to the group. Scott estimates a minimum of two years to complete such a project. It is likely a formal scope of work will need to be developed for this project and will likely result in a USGS open-file publication.

From an abstract of GSA 2006 comes the following regarding this mapping project currently for the MNRR: "New Geologic Mapping along the Missouri National Recreational River" (http://gsa.confex.com/gsa/2006AM/finalprogram/abstract_111600.htm):

In cooperation with the National Park Service, South Dakota Geological Survey, Nebraska Conservation and Survey Division, and university partners, the U.S. Geological Survey began a geologic mapping project of the Missouri River corridor region along the Missouri National Recreational River (MNRR) of southeast South Dakota and northeast Nebraska. The geologic framework of the river corridor, especially the glacial and postglacial geology emphasized in our work, dominates the geomorphic and hydrogeologic bases of the physical habitat and ecology. The area of the corridor spanned by the MNRR includes several geologically significant terrains. The river valley, with a width of 3-6 km throughout most of the Dakotas and eastern Montana, expands markedly below Yankton, SD to a width of 10-16 km. The expanded reach coincides with the southernmost extent of the James River lobe of the late Wisconsinan Laurentide Ice sheet. In the uplands south of the river valley in eastern Nebraska, a much older and morphologically distinctive pre-Illinoian glacial terrain is partially mantled by loess. Both terrains include extensive glacial-buried-valley aquifers, which are contiguous with the alluvial-outwash aquifer that underlies the river and its valley.

The geomorphology of the river valley is dominated by post-glacial Holocene deposits and by the presently active fluvial system. Before the dam system was built during the mid 1900s, the river episodically transported large but variable fluxes of sediment from the extensive drylands upstream of the study area. Particularly in the expanded part of the valley, numerous crosscutting packages of meander-scroll morphology provide a record of changing fluvial processes that reflect response of basin hydrology and sediment yield that we are testing with mapping and chronology studies. Exposures enhanced by incision of the sediment-poor post-dam river commonly show well-sorted sand of point bars and channels overlain by overbank sediments and well-bedded channel fills dominated by silt, clay, and mud. In contrast, sparse exposures of glacial outwash have much coarser gravel dominated by crystalline lithology. At riverbank exposures of outwash, we observed an unusual abundance of native mussels that suggest a potential control on local water chemistry and ecology by these gravels through enhanced groundwater flux to the river.

Additional items of interest related to MNRR area geologic mapping:
South Dakota Geological Survey has 1:100,000 scale county-based surficial geology available.

Geologic Controls on River Ecology – Relevance to Adaptive Management (Scott Lundstrom)

Scott's presentation focused primarily on the Missouri River and is more thoroughly documented in the scoping summary for Missouri National Recreation River, but he did touch upon the geohydrostratigraphy of the region and some of the geologic controls associated with the Niobrara National Scenic River. High fluvial terraces and stabilized sand dunes are two primary Quaternary features in the area. The Sand Hills provide an efficient groundwater recharge zone. In the Tertiary Ogallala Group, the Valentine Formation is a good aquifer and very fossiliferous. The Ash Hollow Formation provides a caprock to the Valentine aquifer. Surface seeps are located at the contact of the Valentine Formation with the underlying, relatively impermeable Rosebud Formation, a formation within the Arikaree Group.

The Rosebud Formation also controls the location of the waterfalls such as Smith Falls. Rocky Ford Rapids may be the result of a monocline in the silica-cemented orthoquartzite of the Valentine Formation, and the Pierre Shale is exposed along the river bank in the downstream part of the park.

Mineral Occurrences Related to Recent Weathering, Missouri and Niobrara Valleys, Nebraska (Matt Joeckel)

Studies of recent mineral weathering address acid-rock weathering, phosphate mineral genesis and occurrence, and the association of hydrous iron oxide with weathering. Mineral occurrences associated with weathering are important for the following reasons:

- Segregation and liberation of ions
- Changing pH of solutions
- Formation, transformation, and destruction of minerals
- Biochemical process

Acid-rock weathering sites in the Cretaceous of Nebraska include the contacts of the Dakota Sandstone with the Graneros Shale, Carlile Shale, and Pierre Shale. Hydration of sulfates has produced minerals such as alunogen, copiapite, epsomite, gypsum, and the rare mineral slavikite. Oxidation of pyrite in the Pierre Shale has formed gerisite, gypsum, jarosite, aluminum sulfates, and other minerals. In Dixon county, approximately 20-30% of the Carlile Shale outcrop face of Volcano Hill is composed of the yellow jarosite with a pH of 2.5. Weathering of pyrite in the Carlile has also produced halotrichite and melantrichite, hydrated sulfates which break down to sulfuric acid. A previously unreported locus of new mineral formation has been found at the contact of the Carlile Formation with the Niobrara Formation where aluminum-sulfate minerals such as aluminite, with a pH of 4-5, are forming. In the Pierre Shale, the aluminum-phosphate-hydroxide mineral, vashegyite, may be forming. Vashegyite is known only from about 15-20 sites around the world. Phosphate nodules such as fluorapatite (calcium halophosphate) and brushite (calcium phosphate, or kidney stones) have been discovered in the Pierre Shale, also.

Acid-rock weathering affects the vegetation and microbial habitat and may influence the geochemistry of groundwater. One measurement of surface water recorded a pH of 1.82. Many of these acid-rock weathering minerals are rare and there is potential for developing and interpreting the unique mineralogy sites.

Geologic Resource Management Issues

The potential sediment loading of the Niobrara River and its affect on the riparian ecosystem should the abandoned Cornell Dam fail was the main issue identified by the participants at the scoping session although a bigger concern should be the potential failure of the Merritt Reservoir dam. The dam has been abandoned since 1984, and the reservoir behind the dam has filled with sediment. The Niobrara River transports abundant sediment eroded from the Sand Hills, and sediment load and sediment distribution is a concern for management.

Other potential geologic resource management issues discussed at the scoping session included flooding, bridge replacement, impacts of visitors on waterfalls, slope instability, and potential seismic impacts to bridges. Unnatural down-cutting and subsequent isolation of flood terraces is of great concern with regard to cottonwood regeneration and other riparian vegetation. Muleshoe Creek and other creeks may flood nearly every year and wash out county roads. Most private campgrounds are in flood-prone areas susceptible to rare hydrologic events or flooding due to ice jams. Bank erosion and faults may influence the location of bridges, which are always an issue with regards to a national scenic river. Only a few waterfalls are accessible; most are on private property, some have been impacted by visitors more than others with regards to vegetation and soil degradation. Erosion is a potential issue with visitors climbing on the Rosebud and Valentine Formations. Earthquake potential poses a minor risk, but faults are present in the area. One fault near Meadville, Nebraska, may impact bridge placement, and a fault has been recognized at Spencer Dam, approximately 48 km (30 mi) downstream from the scenic river, but recent movement along the fault has not been recognized. These faults may not have been active since their formation during the Laramide Orogeny, approximately 35-75 Ma.

Features and Processes

The scoping session for Niobrara National Scenic River provided the opportunity to develop a list of geologic features and processes, which will be further explained in the final GRI report. The features and processes at Niobrara National Scenic River include:

- Fluvial processes and dynamic bedforms associated with the Niobrara River, including Rocky Ford Rapids and the Norton Chute, downstream from Rocky Ford Rapids
- Waterfalls, 230 have been identified, including the state's highest waterfall - Smith Falls
- Thick deposits of Pleistocene lacustrine (lake) deposits
- Miocene strata
- Tertiary-age (Miocene) vertebrate and plant fossils, especially in the Valentine Formation, and Cretaceous-age invertebrate fossils in the Pierre Shale
- Pseudo-karst caused by piping (subsurface erosion caused by percolating groundwater) in the Rosebud Formation
- Minerals, some rare, formed through acid-rock weathering processes

- Type section of the Cornell Dam Member of the Valentine Formation; type section for the Niobrara Formation is not designated, but is named from the cliffs along the Niobrara River at its confluence with the Missouri River, Knox County, NE.
- Aeolian dunes in the Sand Hills offer an interpretive opportunity. The dune field is the largest in the western hemisphere, was created in the Pleistocene from glacial outwash eroded from the Rockies, stabilized by vegetation, and portions of the dune field have been destabilized during the last 10,000 years. The dunes provide a recharge zone for groundwater and refugia for plant and animal species.

Recommendations

- Meet with local experts to decide on the area to be mapped.

References

Diffendal, R. F., Jr., and M. R. Voorhies. 1993. Geologic framework of the Niobrara drainage basin and adjacent areas in South Dakota generally east of the 100th meridian West Longitude and west of the Missouri River. University of Nebraska-Lincoln, Research Symposium Environmental and Natural Resources of the Niobrara River Basin.

Niobrara National Scenic River. 2008. <http://www.nps.gov/niob>.

Table 1. Scoping Meeting Participants

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