Map Unit Properties Table: Lake Meredith National Recreation Area and Alibates Flint Quarries National Monument

Colored map units are mapped within Lake Meredith National Recreation Area and/or Alibates Flint Quarries National Monument (colors match those on GRI poster [in pocket]). Bold text refers to sections in report.

Age (millions of years ago)	Map Unit (Symbol)	Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History
QUATERNARY PERIOD Holocene Epoch (0.01–0)	Alluvium (**Qal**)	No description provided with respect to rock type or geologic materials, but Holocene alluvium typically consists of unconsolidated clay, sand, silt, and gravel deposited by modern streams. **Qal** only mapped within Lake Meredith National Recreation Area. **Qt** (see description below) mapped along intermittent Alibates Creek within Alibates Flint Quarries National Monument.	**Canadian River**—**Qal** consists of channel and floodplain deposits and includes lowest terrace along the Canadian River. **Paleontological Resources**—**Qal** has yielded some fossil material within Lake Meredith National Recreation Area. Many of these paleontological resources are associated with archeological sites.	**Changes to Hydrology**—in the absence of unregulated flows and floods, salt cedar (*Tamarix* spp.) has spread along the Canadian River corridor. **Paleontological Resource Inventory, Monitoring, and Protection**—park staff should observe exposed rock and sedimentary deposits for fossil material while conducting their usual duties; photo-document and monitor in situ fossils; document fossils in cultural contexts; and contact the NPS Geologic Resources Division for technical assistance, as needed.	**Canadian River Valley**—**Qal** represents modern fluvial activity in the Canadian River Valley and its tributaries. Many tributaries also contain **Qt** (see description below).
QUATERNARY PERIOD Holocene Epoch (0.01–0)	Windblown sand, sheet (**Qs**)	Sand and silt, in sheets; locally modified by surface wash (overland flow). At scale 1:250,000, **Qs** was not mapped within the parks, but sand sheets are known to occur there.	**Paleontological Resources**—sand sheets have yielded some fossil material within Lake Meredith National Recreation Area. Many of these paleontological resources are associated with archeological sites. **Aeolian Features and Processes**—one of three types of aeolian features in the GRI GIS data; the other two are sand dunes (**Qsd**) and loess (**Ql**).	**Oil and Gas Production**—blowing sand is a concern at oil and gas operations that lack vegetation. **Off-Road Vehicle Use and Disturbed Land Restoration**—blowing sand is a concern where off-road vehicle (ORV) use has denuded vegetation and kicks up sand, making it available for aeolian transport. **Wind Erosion and Dust Storms**—blowing sand is a concern in areas that permit ORV use and at oil and gas operations. **Paleontological Resource Inventory, Monitoring, and Protection**—park staff should observe exposed rock and sedimentary deposits for fossil material while conducting usual duties; photo-document and monitor in situ fossils; document fossils in cultural contexts; and contact the NPS Geologic Resources Division for technical assistance, as needed.	**Canadian River Valley**—aeolian processes continue to the present day, depositing windblown sand as sheets (**Qs**).
QUATERNARY PERIOD Holocene Epoch (0.01–0)	Windblown sand, dunes (**Qsd**)	Dunes and dune ridges; locally modified by surface wash (overland flow). At scale 1:250,000, **Qsd** was not mapped within the parks, but sand dunes are known to occur there.	**Paleontological Resources**—sand dunes have yielded some fossil material within Lake Meredith National Recreation Area. Many of these paleontological resources are associated with archeological sites. **Aeolian Features and Processes**—one of three types of aeolian features in the GRI GIS data; the other two are sand sheets (**Qs**) and loess (**Ql**). Notable sand dunes occur in the Rosita area at the south end of Lake Meredith National Recreation Area.	**Oil and Gas Production**—blowing sand is a concern at oil and gas operations that lack vegetation. **Off-Road Vehicle Use and Disturbed Land Restoration**—blowing sand is a concern where ORV use has denuded vegetation and kicks up sand, making it available for aeolian transport. **Wind Erosion and Dust Storms**—blowing sand is a concern in areas that permit ORV use. **Paleontological Resource Inventory, Monitoring, and Protection**—park staff should observe exposed rock and sedimentary deposits for fossil material while conducting usual duties; photo-document and monitor in situ fossils; document fossils in cultural contexts; and contact the NPS Geologic Resources Division for technical assistance, as needed.	**Canadian River Valley**—aeolian processes continue to the present day, depositing windblown sand as dunes (**Qsd**).

Colored map units are mapped within Lake Meredith National Recreation Area and/or Alibates Flint Quarries National Monument (colors match those on GRI poster [in pocket]). Bold text refers to sections in report.

Age (millions of years ago)	Map Unit (Symbol)	Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History
QUATERNARY PERIOD Pleistocene Epoch (2.6–0.01)	Fluviatile terrace deposits (**Qt**)	Composed of gravel, sand, and silt. Gravel—sandy, composed of pebbles and cobbles of much older quartz, quartzite, chert, igneous rock, metamorphic rock, caliche, and rare abraded oyster (*Gryphaea*) fossils. Sand—fine to coarse-grained quartz, cross-bedded to massive, lenticular, reddish brown, pink, gray. Silt—sandy, lenticular. Mapped in both parks.	**Paleontological Resources**—**Qt** has yielded a bison (*Bison latifrons*) skull, mammoth bones, rodent burrows, and gastropods. **Qt** gravel hosts reworked Cretaceous oyster (*Gryphaea*) fossils. **Canadian River**—**Qt** is a significant fluvial feature deposited by the Canadian River and its tributaries. **Qt** provides a record of fluvial activity during the wetter Pleistocene Epoch.	**Abandoned Mineral Lands and Borrow Site**—borrow site in Lake Meredith National Recreation Area may occur in **Qt**.; may need further investigation. **Paleontological Resource Inventory, Monitoring, and Protection**—park staff should observe exposed rock and sedimentary deposits for fossil material while conducting usual duties; photo-document and monitor in situ fossils; document fossils in cultural contexts; and contact the NPS Geologic Resources Division for technical assistance, as needed.	**Canadian River Valley**—**Qt** provides a record of incision that has been active throughout the past few tens of thousands of years, including incision of the Canadian Breaks. Inclusion of much older gravel (e.g., *Gryphaea* fossils) provides evidence that a stream system incised into and flowed through Cretaceous rocks (deposited in the Western Interior Seaway) that are no longer present in the area.
QUATERNARY PERIOD Pleistocene Epoch (2.6–0.01)	Playa deposits (**Qp**)	Composed of clay and silt. Sandy, light-gray, deposits in shallow depressions. Mostly covered by thin deposit of Holocene sediment. Significant feature in the Texas Panhandle though not mapped within the parks.	**Aeolian Features and Processes**—**Qp** is a source of loess (**Ql**).	**Wind Erosion and Dust Storms**—wind likely erodes areas mapped as **Qp**, redepositing that material elsewhere.	**Canadian River Valley**—**Qp** developed in areas with poor drainage. Developed at the time of the most recent ice age ("Wisconsinan glaciation").
QUATERNARY PERIOD Pleistocene Epoch (2.6–0.01)	Loess (**Ql**)	Windblown silt. Derived primarily from material eroded during dry periods between ice ages. At scale 1:250,000, **Ql** was not mapped within the parks, but loess is known to occur there.	**Alibates Dolomite and Alibates Flint**—"chertification" or the replacement of dolomite by silica (possibly from windblown ash) resulted in the development of Alibates flint. **Aeolian Features and Processes**—one of three types of aeolian features in the GRI GIS data; the other two are sand dunes (**Qsd**) and sand sheets (**Qs**). Subsequent to prehistoric mining, the flint quarries have partially filled with windblown dust (**Ql**).	**Off-Road Vehicle Use and Disturbed Land Restoration**—blowing dust is a concern where ORV use has denuded vegetation and kicks up sand, making it available for aeolian transport. **Wind Erosion and Dust Storms**—high winds transport **Ql**, resulting in diminished visibility.	**Canadian River Valley**—**Ql** originated during the alternating cold-and-wet and warm-and-dry climates of the past 2.6 million years. Ongoing transport of loess, including dust storms and dust devils, continues to the present day.
QUATERNARY PERIOD Pleistocene Epoch (2.6–0.01)	Blackwater Draw Formation (**Qbd**)	Composed of sand. Fine to medium-grained quartz, silty, calcareous, caliche nodules, massive, pink to grayish red, reddish brown, olive gray. Thickness 8 m (25 ft), feathers out locally.	**Aeolian Features and Processes**—composed of "cover sands" in an aeolian mantle over the Ogallala Formation (**To**).	None reported.	**Ogallala Formation**—**Qbd** represents significant aeolian sedimentation and soil formation on the Southern High Plains following deposition of **To**.

Colored map units are mapped within Lake Meredith National Recreation Area and/or Alibates Flint Quarries National Monument (colors match those on GRI poster [in pocket]). Bold text refers to sections in report.

Age (millions of years ago)	Map Unit (Symbol)	Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History
TERTIARY* PALEOGENE AND NEOGENE PERIODS (66.0–2.6)	Ogallala Formation (**To**)	Composed of sand, silt, clay, gravel, and caliche. Locally includes Ogallala sand that has moved downslope covering older formations. Sand—fine to coarse-grained quartz, silty in part, caliche nodules locally, cemented locally by calcite and by silica, locally cross-bedded, various shades of gray, brown, and red. Minor silt and clay with caliche nodules, sandy in places, massive, white, gray, olive-green, brown, red, and maroon. Gravel, not everywhere present, composed of pebbles and cobbles of quartz, quartzite, minor chert, igneous rock, metamorphic rock, limestone, clay balls in lower part, and abraded oyster (*Gryphaea*) fossils in channel deposits and in basal conglomerate. Caliche, not everywhere present, sandy, pisolitic, white, gray, pink, comprises four or five beds up to 4 m (12 ft) thick in upper part, forms ledges and caprock. Maximum thickness 170 m (550 ft), thins westward. Mapped in both parks. *Original source used "Tertiary." The Paleogene (66.0 million–23.0 million years ago) and Neogene (23.0 million–2.6 million years ago) periods are the formally designated terms that cover this segment of geologic time.	**Alibates Dolomite and Alibates Flint**—"chertification" or the replacement of dolomite by silica (from overlying rocks, possibly **To**) resulted in the development of Alibates flint. **Ogallala Formation**—contains Ogallala aquifer. **Paleontological Resources**—**To** yielded bones of turtles and other vertebrates in Alibates Flint Quarries National Monument. In Lake Meredith National Recreation Area, **To** yielded a proboscidean tooth, and a bonebed with unspecified remains; possibly also root casts, grass anthoecia, *Celtis* endocarps, gastropods, insect burrows, fish impressions, vertebrate material, and reworked Cretaceous oysters (*Gryphaea*) and fossiliferous limestone (provenance unclear). **Canadian River**—the river and tributaries cut into **To** and underlying Triassic (**Trdj** and **TRdv**) and Permian rocks (**Pqw**). **Canadian Breaks and Caprock Escarpment**—**To** forms the rim of the Canadian Breaks and Caprock Escarpment.	**Changes to Hydrology**—draw down of water table (in the Ogallala aquifer) impacts springs and base streamflow into Lake Meredith and the Canadian River. **Paleontological Resource Inventory, Monitoring, and Protection**—park staff should observe exposed rock and sedimentary deposits for fossil material while conducting usual duties; photo-document and monitor in situ fossils; document fossils in cultural contexts; and contact the NPS Geologic Resources Division for technical assistance, as needed.	**Ogallala Formation**—**To** sediments distributed by rivers and winds across the western plains. Inclusion of much older gravels (e.g., *Gryphaea* fossils) provides evidence that a stream system incised into and flowed through Cretaceous rocks (deposited in the Western Interior Seaway) that are no longer present in the area.
TRIASSIC PERIOD (252.2–201.3)	Trujillo Formation (**TRdj**)	Composed of conglomerate, sandstone, and shale. Conglomerate—sandy, granules and pebbles of quartz, limestone, sandstone, siltstone, minor chert, and fragments of petrified wood, massive, gray and brown. Sandstone—conglomeratic, fine to coarse grains of quartz and limestone, micaceous, calcareous locally, cross-bedded to massive, gray, greenish gray, and brown. Shale—micaceous, occurs as thin beds, gray and red. Forms scarp. Thickness of formation 9 m (30 ft), truncated locally. **TRdj** is mapped only in the western part of Lake Meredith National Recreation Area.	**Geologic Structures**—**TRdj** is part of the sediment package that was deposited in the Anadarko and Palo Duro basins. Covers the now-buried Amarillo uplift. **Alibates Dolomite and Alibates Flint**—"chertification" or the replacement of dolomite by silica (from overlying rocks, possibly **TRdj**) resulted in the development of Alibates flint. **Paleontological Resources**—conglomerate contains fragments of petrified wood. **Dissolution of Red Beds**—**TRdj** collapses into dissolution voids, forming "chimneys." **Canadian River**—the river and tributaries cut through **To** and into **TRdj** (as well as **Trdv)** and underlying Permian rocks (**Pqw**). **Canadian Breaks and Caprock Escarpment**—**TRdj** is exposed in the Canadian Breaks.	**Paleontological Resource Inventory, Monitoring, and Protection**—park staff should observe exposed rock and sedimentary deposits for fossil material while conducting usual duties; photo-document and monitor in situ fossils; document fossils in cultural contexts; and contact the NPS Geologic Resources Division for technical assistance, as needed.	**Terrestrial Rocks**—**TRdj** was deposited in continental environments such as lakes and streams before the breakup of the supercontinent Pangaea.

Colored map units are mapped within Lake Meredith National Recreation Area and/or Alibates Flint Quarries National Monument (colors match those on GRI poster [in pocket]). Bold text refers to sections in report.

Age (millions of years ago)	Map Unit (Symbol)	Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History
TRIASSIC PERIOD (252.2–201.3)	Tecovas Formation (**TRdv**)	Composed of shale, clay, siltstone, and sand. Sandy in places, micaceous, calcareous locally, reddish brown, various shades of red, maroon, gray, greenish gray, yellow, and purple. Sand—fine to medium-grained quartz, unconsolidated, massive, lenticular, white and light gray. Thickness 84 m (275 ft), truncated eastward. **TRdv** is exposed only in the western part of Lake Meredith National Recreation Area.	**Geologic Structures**—**TRdv** is part of the sediment package that was deposited in the Anadarko and Palo Duro basins. Covers the now-buried Amarillo uplift. **Alibates Dolomite and Alibates Flint**—"chertification" or the replacement of dolomite by silica (from overlying rocks, possibly **TRdv**) resulted in the development of Alibates flint. **Triassic Rocks**—Tecovas jasper was a dominant tool-making material along the eastern Caprock Escarpment. **Paleontological Resources**—sand layer contains petrified logs. **Dissolution of Red Beds**—**TRdv** collapses into dissolution voids, forming "chimneys." **Canadian River**—the river and tributaries cut through **To** and into **TRdv** (as well as **Trdj)** and underlying Permian rocks (**Pqw**). **Canadian Breaks and Caprock Escarpment**—**TRdv** is exposed in the Canadian Breaks. Tecovas jasper occurs along the escarpment.	**Paleontological Resource Inventory, Monitoring, and Protection**—park staff should observe exposed rock and sedimentary deposits for fossil material while conducting usual duties; photo-document and monitor in situ fossils; document fossils in cultural contexts; and contact the NPS Geologic Resources Division for technical assistance, as needed.	**Terrestrial Rocks**—**TRdv** was deposited in terrestrial (as opposed to marine or coastal) environments such as lakes and streams before the breakup of the supercontinent Pangaea.
PERMIAN PERIOD (298.9–252.2)	Alibates Dolomite (**Pqwa**)	An upper and lower dolomite separated by shale. Dolomite locally replaced by chert ("Alibates flint"), which is banded and mottled red, pink, pale blue, pale purple, gray, brown, and black. Lower dolomite forms ledges. Upper dolomite less resistant to weathering than lower dolomite and is locally absent. Average thickness of entire unit is 5 m (15 ft). Mapped as a linear geologic unit in GRI GIS data. Mapped in both parks.	**Geologic Structures**—**Pqwa** is part of the sediment package that was deposited in the Anadarko and Palo Duro basins. Covers the now-buried Amarillo uplift. **Permian Red Beds**—**Pqwa** contains red bed between upper and lower dolomite members. **Alibates Dolomite and Alibates Flint**—lower dolomite member forms local "capstone." Upper dolomite member locally removed by erosion. Flint is most abundant in the upper dolomite member but is not confined to any particular bed or stratigraphic horizon. Most exposures of **Pqwa** in the national monument yield flint. "Chertification" or the replacement of dolomite by silica resulted in the development of Alibates flint. The Canadian River has transported pieces of Alibates flint downstream into western Oklahoma. Ancient peoples carved petroglyphs onto boulders of **Pqwa**. **Paleontological Resources**—**Pqwa** contains algal mats. **Canadian Breaks and Caprock Escarpment**—**Pqwa** is exposed in the Canadian Breaks. **Aeolian Features and Processes**—subsequent to prehistoric mining, the flint quarries have partially filled with windblown dust (**Ql**).	**Slope Movement Hazards**—**Pqwa** breaks into dolomite boulders that may break away and fall from cliffs or travel in leaps and bounds down slopes. **Paleontological Resource Inventory, Monitoring, and Protection**—park staff should observe exposed rock and sedimentary deposits for fossil material while conducting usual duties; photo-document and monitor in situ fossils; document fossils in cultural contexts; and contact the NPS Geologic Resources Division for technical assistance as needed.	**Red Beds**—two members of dolomite separated by a red-bed member indicate a sequence of sea level rise when dolomite was deposited, followed by sea level fall when red beds were deposited, then rise (dolomite) again.

Colored map units are mapped within Lake Meredith National Recreation Area and/or Alibates Flint Quarries National Monument (colors match those on GRI poster [in pocket]). Bold text refers to sections in report.

Age (millions of years ago)	Map Unit (Symbol)	Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History
PERMIAN PERIOD (298.9–252.2)	Quartermaster Formation, Cloud Chief Gypsum, and Whitehorse Sandstone, undivided (**Pqw**)	Interbedded sandstone, sand, siltstone, shale, gypsum, and dolomite. Sandstone and sand—fine-grained quartz, scattered to locally abundant frosted and polished coarse quartz grains, silty, massive, friable to indurated, various shades of red and orange, orange brown, and grayish green. Siltstone and shale—sandy in part, indistinctly bedded to massive, indurated, thin beds and veins of satin spar in upper part, various shades of red and orange, reddish brown, and grayish green. Gypsum—white, gray, and pink. Dolomite—see description for Alibates Dolomite (**Pqwa**). Maximum thickness of formation 200 m (650 ft). Mapped in both parks.	**Geologic Structures**—**Pqw** is part of the sediment package that was deposited in the Anadarko and Palo Duro basins. Covers the now-buried Amarillo uplift. **Permian Red Beds**—exposures of **Pqw** form the dramatic red bed landscape of the parks. **Dissolution of Red Beds**—**Pqw** is the unit most susceptible to dissolution at the parks. **Karst**—parks are karst areas resulting from the dissolution of mostly gypsum in Permian rocks. **Rock Shelter**—Permian strata are the most likely to host the rock shelter at Rosita; needs further investigation. Rock shelter is thought to have formed as a result of erosion of a less resistant rock layer below a more resistant rock layer and not associated with dissolution typical of a karst area. **Canadian River**—after cutting through **To** and underlying Triassic rocks (**TRdj** and **TRdv**), the river and tributaries cut into **Pqw**. **Canadian Breaks and Caprock Escarpment**—**Pqw** is exposed in the Canadian Breaks.	**Accelerated Erosion and Sedimentation**—fine-grained sediment washed from slopes composed of **Pqw** creates slippery mud and poses a hazard for people and vehicles at Stilling Basin Road and the Sanford-Yake boat ramp. **Wind Erosion and Dust Storms**—when lake level is high, waves erode **Pqw** along the Lake Meredith shoreline. **Slope Movement Hazards**—slumping and rockfall occur in **Pqw**. **Sinkhole Collapse and Erosion**—sinkhole in the Plum Creek area is a result of dissolution of **Pqw**. **Cave Resource Management**—development of a park-specific cave management plan would evaluate the significance of the rock shelter and the need for monitoring and protection.	**Red Beds**—deposited about 260 million years ago in Panthalassa, a global ocean surrounding much of the supercontinent Pangaea. **Canadian River Valley**—heightened groundwater recharge during the Pleistocene Epoch accelerated dissolution of Permian evaporites, triggering widespread vertical collapse and the formation of "chimneys."