U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science Directorate
Geologic Resources Division

Fort Larned National Historic Site

GRI Ancillary Map Information Document

Produced to accompany the Geologic Resources Inventory (GRI) Digital Geologic Data for Fort Larned National Historic Site

fols_geology.pdf

Version: 6/26/2015

Geologic Resources Inventory Map Document for Fort Larned National Historic Site

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Geologic Resources Inventory Map Document

Fort Larned National Historic Site, Kansas

Document to Accompany Digital Geologic-GIS Data

fols_geology.pdf

Version: 6/26/2015

This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Fort Larned National Historic Site, Kansas (FOLS).

Attempts have been made to reproduce all aspects of the original source products, including the geologic units and their descriptions, geologic cross sections, the geologic report, references and all other pertinent images and information contained in the original publication.

National Park Service (NPS) Geologic Resources Inventory (GRI) Program staff have assembled the digital geologic-GIS data that accompanies this document.

For information about the status of GRI digital geologic-GIS data for a park contact:

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About the NPS Geologic Resources Inventory Program

Background

Recognizing the interrelationships between the physical (geology, air, and water) and biological (plants and animals) components of the Earth is vital to understanding, managing, and protecting natural resources. The Geologic Resources Inventory (GRI) helps make this connection by providing information on the role of geology and geologic resource management in parks.

Geologic resources for management consideration include both the processes that act upon the Earth and the features formed as a result of these processes. Geologic processes include: erosion and sedimentation; seismic, volcanic, and geothermal activity; glaciation, rockfalls, landslides, and shoreline change. Geologic features include mountains, canyons, natural arches and bridges, minerals, rocks, fossils, cave and karst systems, beaches, dunes, glaciers, volcanoes, and faults.

The Geologic Resources Inventory aims to raise awareness of geology and the role it plays in the environment, and to provide natural resource managers and staff, park planners, interpreters, researchers, and other NPS personnel with information that can help them make informed management decisions.

The GRI team, working closely with the Colorado State University (CSU) Department of Geosciences and a variety of other partners, provides more than 270 parks with a geologic scoping meeting, digital geologic-GIS map data, and a park-specific geologic report.

Products

Scoping Meetings: These park-specific meetings bring together local geologic experts and park staff to inventory and review available geologic data and discuss geologic resource management issues. A summary document is prepared for each meeting that identifies a plan to provide digital map data for the park.

Digital Geologic Maps: Digital geologic maps reproduce all aspects of traditional paper maps, including notes, legend, and cross sections. Bedrock, surficial, and special purpose maps such as coastal or geologic hazard maps may be used by the GRI to create digital Geographic Information Systems (GIS) data and meet park needs. These digital GIS data allow geologic information to be easily viewed and analyzed in conjunction with a wide range of other resource management information data.

For detailed information regarding GIS parameters such as data attribute field definitions, attribute field codes, value definitions, and rules that govern relationships found in the data, refer to the NPS Geology-GIS Data Model document available at: http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm

Geologic Reports: Park-specific geologic reports identify geologic resource management issues as well as features and processes that are important to park ecosystems. In addition, these reports present a brief geologic history of the park and address specific properties of geologic units present in the park.

For a complete listing of Geologic Resource Inventory products and direct links to the download site visit the GRI publications webpage http://www.nature.nps.gov/geology/inventory/gre_publications.cfm

GRI geologic-GIS data is also available online at the NPS Data Store Search Application: http://irma.nps.gov/App/Reference/Search. To find GRI data for a specific park or parks select the appropriate park (s), enter “GRI” as a Search Text term, and then select the Search Button.

For more information about the Geologic Resources Inventory Program visit the GRI webpage: http://www.nature.nps.gov/geology/inventory, or contact:

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The Geologic Resources Inventory (GRI) program is funded by the National Park Service (NPS) Inventory and Monitoring (I&M) Division.

GRI Digital Map and Source Map Citation

The GRI digital geologic-GIS map for Fort Larned National Historic Site, Kansas (FOLS):

Digital Surficial Geologic Map of Fort Larned National Historic Site and Vicinity, Kansas (*GRI MapCode FOLS*)

Johnson, W.C., and Woodburn, T.L., 2015, Surficial geology of Pawnee County, Kansas; text, geologic-unit descriptions, and cross section geology by C.M. Phillips-Lander: Kansas Geological Survey, Map M-114, scale 1:50,000. (Map M-114). (*GRI Source Map ID 74981*). Cartography by John W. Dunham, Christopher R. Bieker, Hillary C. Crabb, Scott T. Klopfenstein, Charity M. Phillips-Lander, R. Zane Price, Jorgina A. Ross and Gerald Wright III.

Map Unit List

The surficial geologic units present in the digital geologic-GIS data produced for Fort Larned National Historic Site, Kansas (FOLS) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qal - Alluvium). Units are listed from youngest to oldest. No description for water is provided. Information about each geologic unit is also presented in the GRI Geologic Unit Information (FOLSUNIT) table included with the GRI geologic-GIS data.

Cenozoic Era

Holocene
Qal - Alluvium

late Pleistocene to Holocene
Qp - Upland intermittent lake (playa) deposits

Quaternary
Qds - Eolian dune sand
Qas - Active sand
Qss - Sheet sand
Ql - Loess
Qt1 - Terrace valley fill, upper
Qt2 - Terrace valley fill, lower

earliest Pliocene and Miocene
No - Ogallala Formation

Mesozoic Era

Upper Cretaceous
Kc - Carlile Shale
Kgg - Greenhorn Limestone and Graneros Shale, undivided

Lower Cretaceous
Kd - Dakota Formation

Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below.

Qal - Alluvium (Holocene)

Alluvial sediments of the major rivers and smaller streams are Holocene in age and are composed of sand, gravel, silt, and clay (McLaughlin, 1949). In the Pawnee River valley, the upper part of the alluvium consists primarily of clay with some sand and silt. Thicknesses range from 15 to 50 ft (5 to 15 m) but average about 30 ft (9 m). A thick deposit of sand and gravel lying beneath the upper clay deposits yields large quantities of water to wells in the valley. The total thickness of the Pawnee River alluvium ranges from 65 to 138 ft (20 to 42 m), with an average thickness of 105 ft (32 m) (McLaughlin, 1949). In contrast to the Pawnee River alluvium, the Arkansas River alluvium contains no thick clay deposits, although localized clay layers may occur. The Arkansas River alluvium contains sandy soils overlying thick beds of sand and gravel. As a result, the recharge rate of wells is greater in the Arkansas River valley than in the Pawnee River valley. The Arkansas River alluvium ranges from 18- to 135-ft (6- to 41-m) thick, with an average thickness of about 61 ft (19 m) (McLaughlin, 1949). (*GRI Source Map ID 74981)* (Map M-114).

Qp - Upland intermittent lake (playa) deposits (late Pleistocene to Holocene)

Shallow basins, also known as playas or buffalo wallows, have developed in the upland loess deposits, mainly south of the Pawnee River. The origin of these features is usually attributed to wind deflation, animal activity, dissolution, or some combination of these processes. The age of the playas probably ranges from late Pleistocene to Holocene. Playa basins range in size from less than an acre to tens of acres. The basin fill consists of re-deposited silt and fine sand from the loess. In the larger basins, a caliche layer typically develops a few feet below the basin floor. The average thickness of the basin fill is approximately 6 ft (2 m). (*GRI Source Map ID 74981)* (Map M-114).

Qds - Eolian dune sand (Quaternary)

Inactive sand dunes are present in much of the area south of the Arkansas River in Pawnee County and are Pleistocene to Holocene in age. The dune areas closest to the Arkansas River are grass-covered, moderately steep, irregular hills surrounding relatively small, undrained basins. A few active dunes may occur locally. The dune sand is composed of moderately well-rounded fragments of quartz with lesser amounts of silt and clay and is mostly derived from the Arkansas River valley (McLaughlin, 1949; Arbogast, 1998). The thickness of the dunes ranges up to 50 ft (15 m) (McLaughlin, 1949). (*GRI Source Map ID 74981)* (Map M-114).

Qas - Active sand (Quaternary)

Active sand areas are currently being reworked and re-deposited by wind. Active sand areas are typically expressed as blowouts within the sand dune map unit. (*GRI Source Map ID 74981)* (Map M-114).

Qss - Sheet sand (Quaternary)

The sheet sands are older remnants of the sand-dune topography characterized by a much flatter surface of broad, undulating swells and swales. The sheet sands have developed a thick, heavy soil that is extensively cultivated (McLaughlin, 1949). The thickness of the sheet sands is approximately 12 ft (4 m). (*GRI Source Map ID 74981)* (Map M-114).

Ql - Loess (Quaternary)

Uplands in the county are mantled by loess composed of wind-deposited silt and minor amounts of clay and fine sand. The loess is calcareous and buff in color. The age of the loess ranges from late Pleistocene to Holocene. It has an average thickness of about 6 to 10 ft (2 to 3 m). (*GRI Source Map ID 74981)* (Map M-114).

Qt1 - Terrace valley fill, upper (Quaternary)

Terrace valley fill is primarily derived from the stream erosion of sedimentary rocks locally and west of Pawnee County and occurs along the Pawnee and Arkansas rivers. The fill consists of light-tan to brown clay and silt containing some caliche and interbedded fine to coarse sand with some gravel. Clays are blocky and typically brown, but range in color from white to bright green and blue. Silt is poorly consolidated except where cemented by calcium carbonate. Sand and gravel are poorly sorted, containing fragments of sandstone, limestone, and ironstone derived from weathering of the Greenhorn Limestone, Carlile Shale, and Dakota Formation (McLaughlin, 1949). Two terraces (Qt1 and Qt2) within the Pawnee River valley have been differentiated and lie 20 ft (6 m) (Qt1) and 50 ft (15 m) (Qt2) above the valley floor (McLaughlin, 1949; Mandel, 1994). (*GRI Source Map ID 74981)* (Map M-114).

Qt2 - Terrace valley fill, lower (Quaternary)

Terrace valley fill is primarily derived from the stream erosion of sedimentary rocks locally and west of Pawnee County and occurs along the Pawnee and Arkansas rivers. The fill consists of light-tan to brown clay and silt containing some caliche and interbedded fine to coarse sand with some gravel. Clays are blocky and typically brown, but range in color from white to bright green and blue. Silt is poorly consolidated except where cemented by calcium carbonate. Sand and gravel are poorly sorted, containing fragments of sandstone, limestone, and ironstone derived from weathering of the Greenhorn Limestone, Carlile Shale, and Dakota Formation (McLaughlin, 1949). Two terraces (Qt1 and Qt2) within the Pawnee River valley have been differentiated and lie 20 ft (6 m) (Qt1) and 50 ft (15 m) (Qt2) above the valley floor (McLaughlin, 1949; Mandel, 1994). (*GRI Source Map ID 74981)* (Map M-114).

No - Ogallala Formation (earliest Pliocene and Miocene)

The Ogallala Formation is Miocene and earliest Pliocene in age and is composed of silt, sand, and gravel sediments transported by streams flowing eastward from the Rocky Mountains. These sediments are variously cemented (ranging from unconsolidated to caliche-type deposits) with calcium carbonate. Throughout the Ogallala, thick caliche beds, referred to regionally as “mortar beds,” are irregularly and discontinuously exposed (Moss, 1932). Silt dominates the Ogallala and commonly occurs in poorly sorted and lenticular bodies. Thin, isolated outcrops of Ogallala occur only in the extreme south west corner of the county. (*GRI Source Map ID 74981)* (Map M-114).

Kc - Carlile Shale (Upper Cretaceous)

The Cretaceous Carlile Shale is composed of three members, in descending order: the Codell Sandstone Member, Blue Hill Shale Member, and Fairport Chalk Member. The Codell sandstone and Blue Hill shale members have not been observed in the county (McLaughlin, 1949; Hattin, 1962; McKellar, 1962; Wallace and Nelson, 1988). The **Fairport Chalk Member** is an olive-gray to dark-gray, blocky, fossiliferous, chalky shale with flat concretions intercalated with chalk and chalky limestone beds and a few thin bentonite beds (Moss, 1932; Hattin, 1962). Thicker, more resistant beds of chalky limestone are more common near the base of the Fairport chalk and form small benches. The upper beds erode more easily and form rounded, soil-covered hills (Fish el, 1952). Outcrops occur along stream valleys in the northern part of the county. The total thickness of the Carlile Shale in Pawnee County is hard to determine because of poor exposures, but now here is it believed to be more than 100 ft (30 m) thick (McLaughlin, 1949). (*GRI Source Map ID 74981)* (Map M-114).

Kgg - Greenhorn Limestone and Grameros Shale, undivided (Upper Cretaceous)

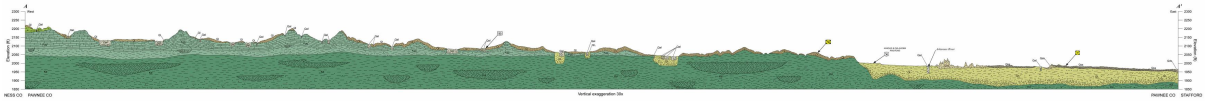
In Pawnee County, the Greenhorn Limestone and Graneros Shale are poorly exposed and undifferentiated. The **Greenhorn Limestone** has four members, in descending order: the Pfeifer Shale Member, the Jetmore Chalk Member, the Hartland Shale Member, and the Lincoln Limestone Member. Lack of good exposures makes differentiating the members difficult. Generally, the Greenhorn Limestone is composed of alternating beds of thinner (usually less than 1 ft [0.3 m]) beds of chalky to crystalline limestone and thicker beds of gray, chalky shale that contain thin beds of bentonitic clay (McLaughlin, 1949). The Fence-post limestone bed is located at or near the top of the formation (McLaughlin, 1949; Hattin, 1975). The thickness of the Greenhorn averages 100 ft (30 m) in Rush County (McNellis, 1973) and is thought to be of similar thickness in Pawnee County. The underlying **Graneros Shale** is a dark-gray to black, fissile, argillaceous shale that may contain sandy shale and sandstone (McLaughlin, 1949). Where the Graneros outcrops in north - central and west-central Kansas, the thickness ranges from 24 to 40 ft (7 to 12 m), averaging about 30 ft (9 m) (Hattin, 1965). McLaughlin (1949) believed the thickness does not exceed 35 ft (11 m) in Pawnee County. (*GRI Source Map ID 74981)* (Map M-114).

Kd - Dakota Formation (Lower Cretaceous)

Several isolated outcrops of the Dakota Formation occur in Pawnee County, most notably near Burdett, Garfield, and Larned. Based on limited outcrops and cuttings from more than 100 test holes, McLaughlin (1949) described the Dakota as buff, yellow-brown, and brown fine-grained, lenticular sandstone and variegated sandy clay and clay. The sandstone may be thin-bedded to massive but generally is strongly ripple-marked and cross-bedded. Although sandstone dominates the outcrops, the Dakota is predominately clay and sandy clay (Plummer and Romary, 1942; Fish el, 1952). Topographic expression is variable and depends on cementation. Well-cemented portions of the Dakota form bluffs near Larned, while low, smooth hills are characteristic where the sandstone is poorly cemented. In a few places in the county, zones of hard, calcite cemented “quartzitic” sandstone weather out as rounded boulders or form resistant ledges (McLaughlin, 1949). The Dakota underlies most of Pawnee County, where the average thickness is thought to be about 200 ft (61 m) (McLaughlin, 1949). (*GRI Source Map ID 74981)* (Map M-114).

Geologic Cross Section

The geologic cross section present in the GRI digital geologic-GIS data produced for Fort Larned National Historic Site, Kansas (FOLS) is presented below. Cross section graphics were scanned at a high resolution and can be viewed in more detail by zooming in (if viewing the digital format of this document).



Extracted from: Map M-114

KGS Map M-114

Johnson, W .C., and Woodburn, T.L., 2015, Surficial geology of Pawnee County, Kansas; text, geologic-unit descriptions, and cross section geology by C.M. Phillips-Lander: Kansas Geological Survey, Map M-114, scale 1:50,000. (*GRI Source Map ID 74981*). Cartography by John W. Dunham, Christopher R. Bieker, Hillary C. Crabb, Scott T. Klopfenstein, Charity M. Phillips-Lander, R. Zane Price, Jorgina A. Ross and Gerald Wright III.

Geology Summary

General Geology

Pawnee County covers an area of approximately 755 mi^2 (1,955 km^2) (McLaughlin, 1949), of which about 0.38 mi^2 (0.98 km^2), or 0.05%, is surface water. The surficial sedimentary rocks are Cretaceous to Neogene in age and are dominated by shales, chalky shales, chalks, chalky limestones, and some sandstone. The dip of the strata is generally to the west. The oldest rocks exposed in the area— from the Dakota Formation— were deposited in a near-shore environment that was subsequently covered by seas represented by the deposition of the Graneros Shale, Greenhorn Limestone, and Carlile Shale (McLaughlin, 1949). The Ogallala Formation, the youngest unit, was deposited by streams that carried debris from the Rocky Mountains (McLaughlin, 1949). The unconformity between the Cretaceous and Neogene rocks represents a period of erosion and/or non-deposition that lasted about 75 million years. Unconsolidated materials overlying the Ogallala— loess, sheet sand, dune sand, playa deposits, terraces, and alluvium— are Pleistocene and Holocene in age. Currently, alluvium is being deposited along streambeds, and some dune areas have active blowouts.

Geomorphology

Pawnee County is represented by three physiographic regions: the Smoky Hills, High Plains, and Arkansas River Lowlands. The area north of the Pawnee River lies within the Smoky Hills (Schoewe, 1949), which take their name from the haze that sometimes forms in the valleys in the early morning (Kansas Geological Survey, 2014a). The southwest portion of the county lies within the High Plains physiographic region. The Arkansas River Lowlands, roughly defined as the area southeast of the Arkansas River, was created by fluvial erosion and deposition over the past 10 million years (McLaughlin, 1949; Schoewe, 1949). Pawnee County is relatively flat and has maximum topographic relief of about 380 ft (116 m) (McLaughlin, 1949). The highest topographic area (approximately 2,300 ft [701 m]) is located in the southwest part of the county. The lowest elevation (approximately 1,920 ft [585 m]) occurs where the Arkansas River exits the county at the Barton-Pawnee county line.

Fluvial erosion and dissection of the surficial geology by streams is the primary control on the geomorphology of the area and has resulted in the development of the wide Arkansas River and Pawnee River valleys. Numerous smaller creeks dissect and drain the upland regions in the northern and southwest portions of the county. The Pawnee River is the largest tributary to the Arkansas River. Early travelers and soldiers stationed at Fort Larned on the Santa Fe Trail used the Pawnee River and one of its oxbow lakes as natural protection for the fort (Keller-Lynn, 2008). The fort’s buildings were built out of sandstone from the Dakota Formation, with window sills made from the Fence-post limestone bed of the Greenhorn Limestone. Sandstone from the Dakota was quarried at Jenkins Hill about 2.5 mi (4.0 km) east of the Fort Larned Historic Site (Keller-Lynn, 2008).

The southeast portion of the county, in contrast, is dominated by wind-blown landforms, including dunes, sheet sands, and blowout features. Small, localized lakes form when water collects in the blowout depressions.

Mineral Resources

Sand and gravel, used primarily for road metal, is currently mined from terrace and alluvial deposits in the Pawnee River and Arkansas River valleys in Pawnee County (McLaughlin, 1949; Kansas Geological Survey, 2014b). The Fence-post limestone bed of the Greenhorn Limestone has historically been used for fence posts and building stone. The Dakota Formation was also used for building material (McLaughlin, 1949; Keller-Lynn, 2008).

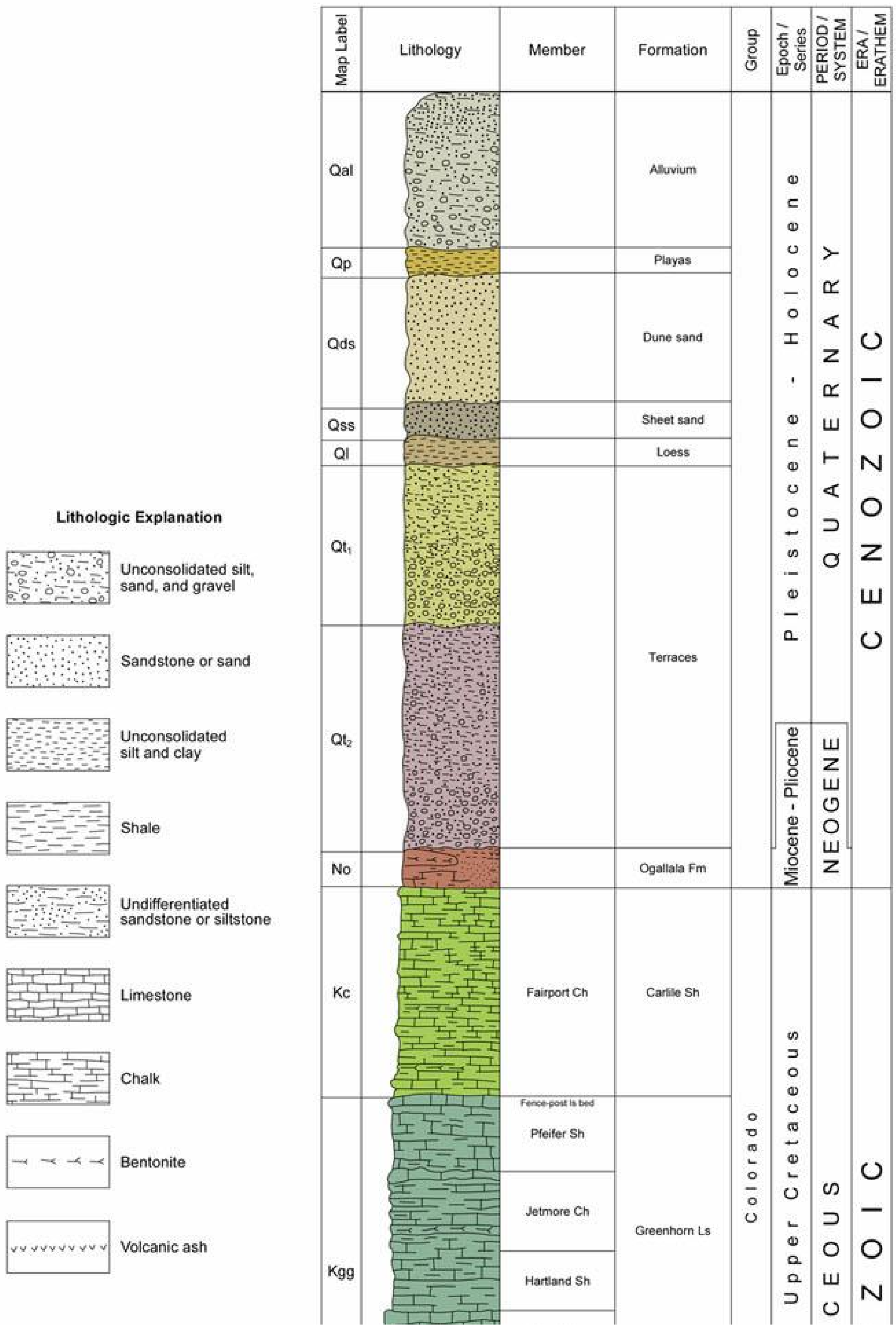
Oil and gas are important resources in Pawnee County. Oil production had declined to a low of 110,690 barrels of oil from 136 wells in 2005 but has since increased to 369,227 barrels from 195 wells in 2014. In addition, 758,017 million cubic feet (mcf) of gas from 115 wells was produced in 2014. Cumulatively, more than 47,000,000 barrels of oil and 140,000,000 mcf of gas have been produced in Pawnee County (Kansas Geological Survey, 2014c).

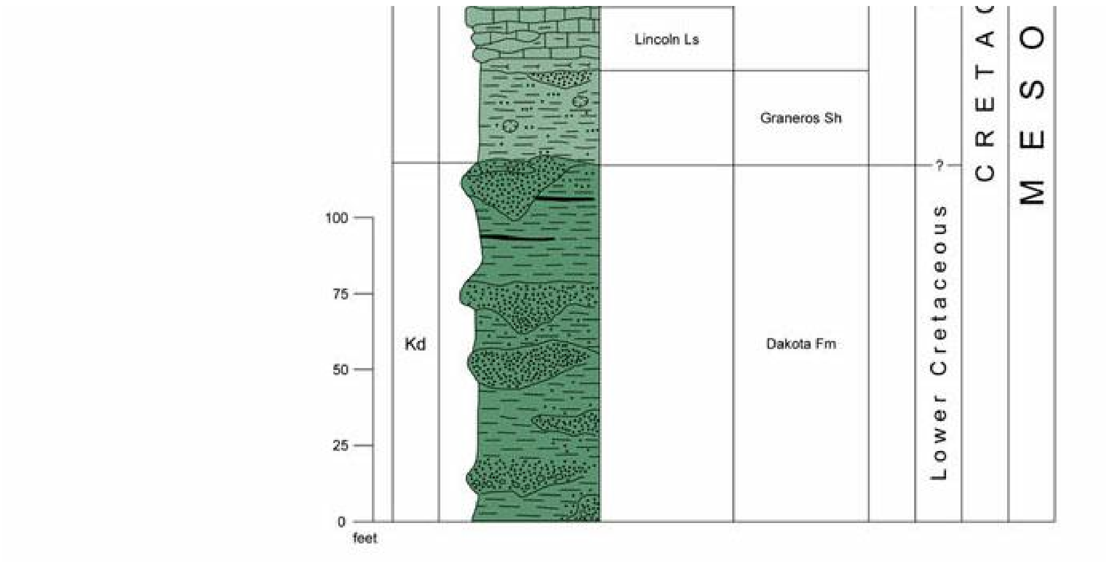
Water Resources

Groundwater supplies irrigation, domestic, stock, industrial, and municipal water in Pawnee County, mainly from the unconsolidated sediments in the Pawnee River and Arkansas River valleys. Numerous irrigation wells occupy the Pawnee River and Arkansas River valleys (Kansas Geological Survey, 2014d). Sandstones in the Dakota Formation are also important sources of irrigation water, mainly around and south of Rozel. The Dakota is also used for small domestic and stock wells (McLaughlin, 1949). The Greenhorn Limestone and Carlile Shale provide small, unreliable quantities of water to a few domestic and stock wells in northern Pawnee County (McLaughlin, 1949). Several deep (400 to 750 ft) wells in Permian rocks have flowed salt water to the surface (McLaughlin, 1949).

Extracted from: (Map M-114).

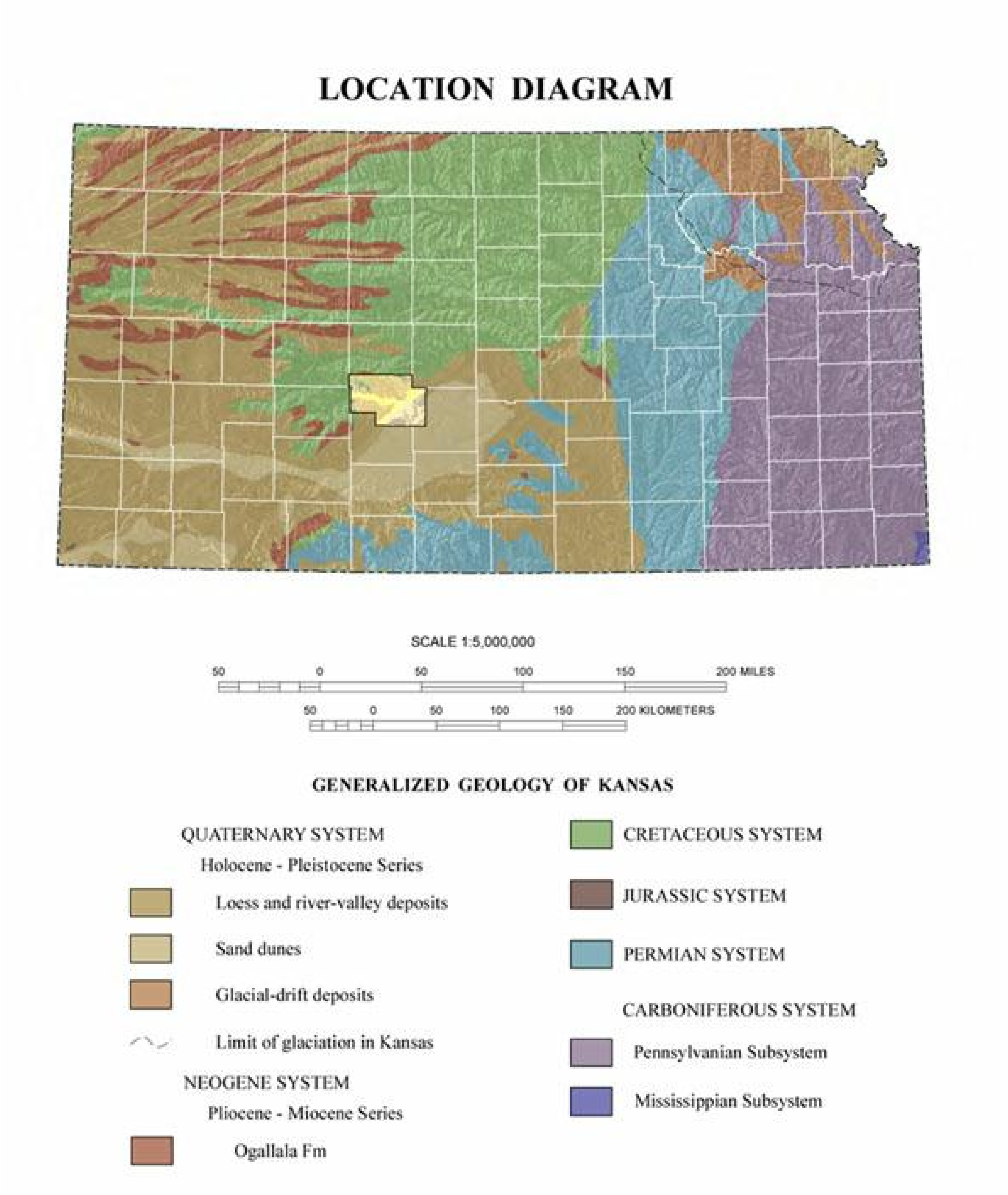
Stratigraphic Column





Extracted from: (Map M-114).

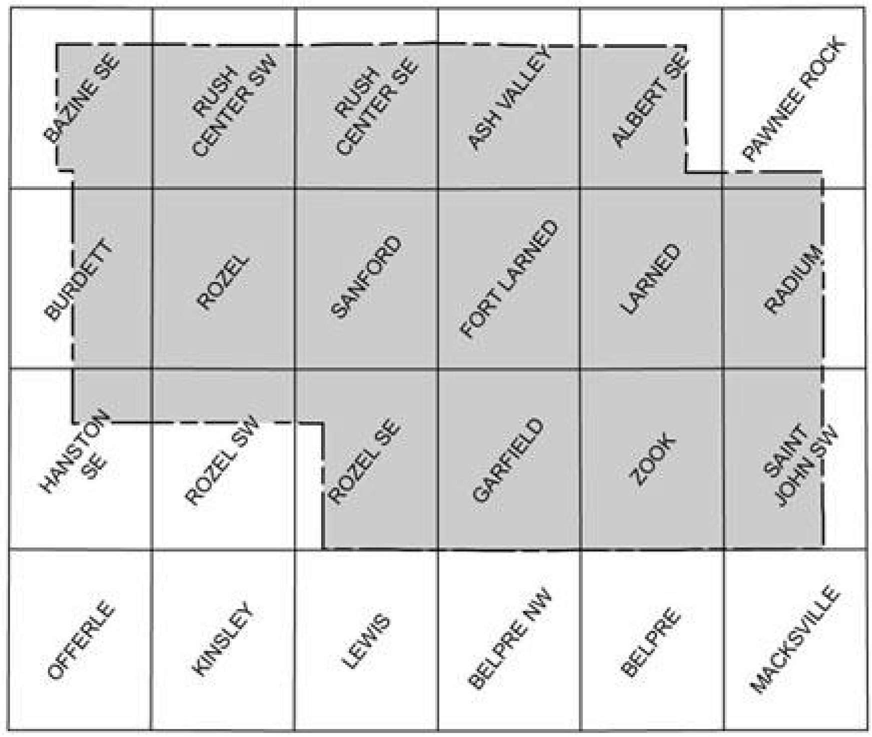
Location Diagram with Generalized Geology of Kansas



Extracted from: (Map M-114).

Index Map

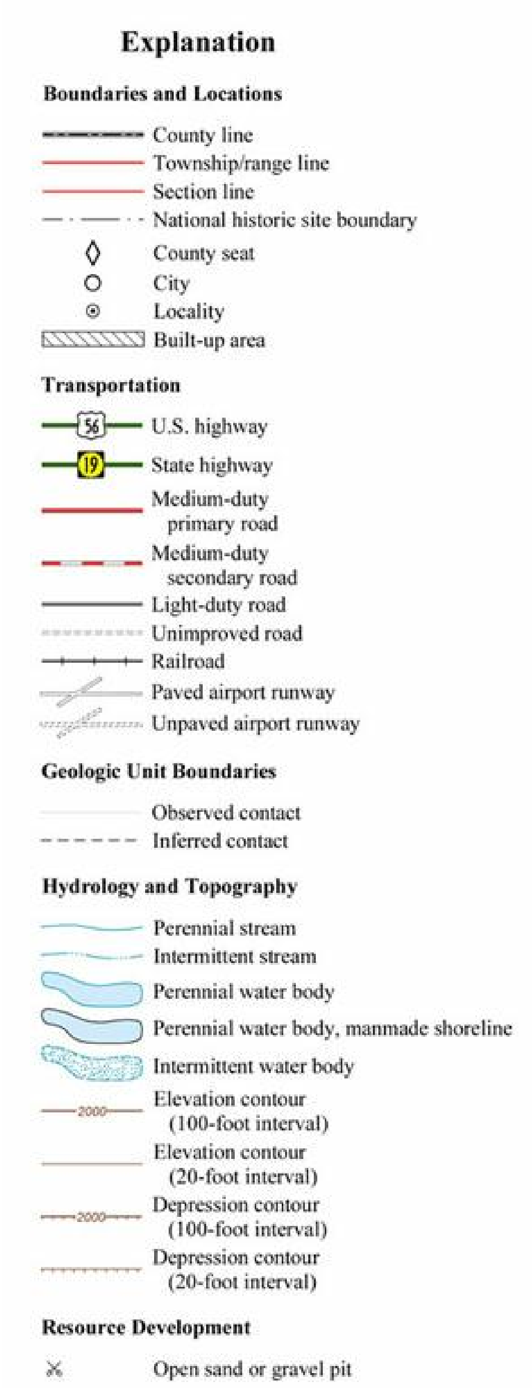
Index to 1:24,000 scale USGS quadrangle maps



Map shows the locations of the 24 quadrangles used in the digital compilation of the Pawnee County map. The index shows the names of each individual 7.5 -minute quadrangle map.

Extracted from: (Map M-114).

Map Symbol Explanation



Extracted from: (Map M-114).

Note that only geologic and mining (resource development) features are present in the GRI digital geologic-GIS map product. All other non-geology features symbolized above only appear on the KGS source map publication.

Cited References

Arbogast, A. F., 1998, Late Quaternary paleoenvironments and landscape evolution on the Great Bend Sand Prairie: Kansas Geological Survey, Bulletin 242, 74 p.

Fishel, V. C., 1952, Ground-water resources of Pawnee Valley, Kansas: Kansas Geological Survey, Bulletin 94, 144 p.; http://www.kgs.ku.edu/Publications/Bulletins/94/index.html.

Hattin, D. E., 1962, Stratigraphy of the Carlile Shale (Upper Cretaceous) in Kansas: Kansas Geological Survey, Bulletin 156, 155 p.; http://www.kgs.ku.edu/Publications/Bulletins/156/index.html.

Hattin, D. E., 1965, Stratigraphy of the Graneros Shale (Upper Cretaceous) in central Kansas: Kansas Geological Survey, Bulletin 178, 83 p.

Hattin, D. E., 1975, Stratigraphy and depositional environment of the Greenhorn Limestone (Upper Cretaceous) of Kansas: Kansas Geological Survey, Bulletin 209, 128 p.; http://www.kgs.ku.edu/Publications/Bulletins/209/ index.html.

Kansas Geological Survey, 2014a, Smoky Hills; *in,* GeoKansas: Kansas Geological Survey, http://www.kgs.ku.edu/ Extension/smoky/smoky.html.

Kansas Geological Survey, 2014b, Pawnee County; *in,* KGS Directory of Kansas Industrial Mineral Producers, http://www.kgs.ku.edu/Magellan/Minerals/index.html.

Kansas Geological Survey, 2014c, Pawnee County – Oil and gas production, http://www.kgs.ku.edu/PRS/County/nop/pawnee.html

Kansas Geological Survey, 2014d, Pawnee County — Water well completion records (WWC5) Database: http://www.kgs.ku.edu/Magellan/WaterW ell/index.html.

Keller-Lynn, K., 2008, Geologic resource evaluation scoping summary Fort Larned National Historic Site, Kansas: National Park Service, http://www.nature.nps.gov/geology/inventory/publications/s_summaries/FOLS_GR E_scoping_summary_2008-0919.pdf.

Mandel, R. D., 1994, Holocene landscape evolution in the Pawnee River valley, southwestern Kansas: Kansas Geological Survey and Kansas State Historical Society, Bulletin 236, 117 p.

McKellar, T. R ., 1962, The Codell sandstone (Upper Cretaceous) of Kansas: Unpublished M.S. thesis, University of Kansas, 92 p.

McLaughlin, T. G., 1949, Geology and ground-water resources of Pawnee and Edwards counties, Kansas: Kansas Geological Survey, Bulletin 80, 189 p.; http://www.kgs.ku.edu/General/Geology/Pawnee/ index.html.

McNellis, J. M ., 1973, Geology and ground-water resources of Rush County, central Kansas: Kansas Geological Survey, Bulletin 207, 45 p.; http://www.kgs.ku.edu/General/Geology/Rush /index.html.

Moss, R. G., 1932, The geology of Ness and Hodgeman counties, Kansas: Kansas Geological Survey, Bulletin 19, 48 p.

Plummer, N., and Romary, J. F., 1942, Stratigraphy of the pre-Greenhorn cretaceous beds of Kansas: Kansas Geological Survey, Bulletin 41, pt. 9, p. 313–348.

Schoewe, W. H., 1949, The geography of Kansas, pt. 2, physical geography: Kansas Academy of Science Transactions, v. 52, no. 3, p. 261–333.

Wallace, K. C., and Nelson, M . E., 1988, Depositional history of the Codell Sandstone Member, Carlile Shale, (Upper Cretaceous), Kansas: Fort Hays Studies, Science, Third Series, no. 10, p. 102–116

Extracted from: (Map M-114).

Additional Source

Zeller, D. E., ed., [1968] 2013, Classification of rocks in Kansas, revised by Kansas Geological Survey Stratigraphic Nomenclature Committee; *in*, The Stratigraphic Succession in Kansas: Kansas Geological Survey, Bulletin 189, 81 p., 1 plate; http://www.kgs.ku.edu/General/Strat/index.html.

Extracted from: (Map M-114).

Suggested Reference to this Map

Johnson, W.C., and Woodburn, T.L., 2015, Surficial geology of Pawnee County, Kansas; text, geologic-unit descriptions, and cross section geology by C.M. Phillips-Lander: Kansas Geological Survey, Map M-114, scale 1:50,000.

Extracted from: (Map M-114).

Additional Map Information

Elevation contours are presented for general reference. They are a product of the U.S .Geological Survey's US Topo program, and are generated from USGS national geospatial databases. In some places the contours may be more generalized than the base maps used for compilation of geologic outcrop patterns. Outcrop patterns on the map will typically reflect topographic variation more accurately than the associated contour lines. Repeated fluctuation of an outcrop line across a contour line should be interpreted as an indication that the mapped rock unit is maintaining a relatively constant elevation along a generalized contour.

The geology was mapped in the field using USGS 7.5' 1:24,000-scale topographic maps.

Roads and high ways shown on the base map as represented by data from the Kansas Department of Transportation (KDOT) and other sources. U.S. Department of Agriculture – Farm Services Agency (USDA-FSA) National Agriculture Imagery Program (NAIP) imagery also was used to check road locations.

Shaded relief is based on 1-meter hydroflattened bare-earth DEMs from the State of Kansas LiDAR Database. The DEM images, in Erdas Imagine
(.img) format, were mosaicked into a single output DEM in Esri file geodatabase raster format. That DEM was then downsampled to 2-meter resolution and subsequently converted to geographic coordinates. The output DEM was then converted to a hillshade, a multidirectional shaded-relief image using angles of illumination from 0°, 225°, 270°, and 315° azimuths, each 45° above the horizon, with a 4x vertical exaggeration.

This geologic map was funded in part by the USGS National Cooperative Geologic Mapping Program and by the National Park Service.

This map was produced using the ArcGIS system developed by ESRI (Environmental Systems Research Institute, Inc.).

The Kansas Geological Survey does not guarantee this map to be free from errors or inaccuracies and disclaims any responsibility or liability for interpretations made from the map or decisions based thereon.

Extracted from: (Map M-114).

Note that some information above is only applicable to the KGS source map publication, and not to the GRI digital geologic-GIS map product (e.g., information pertaining to non-geology GIS features and data layers like roads, highways, imagery, shaded relief).

GRI Digital Data Credits

This document was developed and completed by Georgia Hybels (Colorado State University) for the NPS Geologic Resources Division (GRD) Geologic Resources Inventory(GRI) Program. Quality control of this document by Stephanie O'Meara (Colorado State University).

The information in this document was compiled from the GRI source map, and intended to accompany the digital geologic-GIS map and other digital data for Fort Larned National Historic Site, Kansas (FOLS) developed by Georgia Hybels (Colorado State University) (see the GRI Digital Map and Source Map Citation section of this document for all sources used by the GRI in the completion of this document and related GRI digital geologic-GIS map.

GRI finalization by Stephanie O'Meara (Colorado State University).

GRI program coordination and scoping provided by Bruce Heise and Tim Connors (NPS GRD, Lakewood, Colorado).

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