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

Washita Battlefield National Historic Site

GRI Ancillary Map Information Document

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

waba_geology.pdf

Version: 4/12/2013

Geologic Resources Inventory Map Document for Washita Battlefield National Historic Site

Table of Contents

Geologic Resources Inventory Map Document 1
About the NPS Geologic Resources Inventory Program 2
GRI Digital Maps and Source Map Citations 4
Map Unit List 5
Map Unit Descriptions 6
Qa - Alluvium (Holocene) 6
Qfp - Floodplain (Quaternary) 6
Qtf - Tributary Floodplain (Quaternary) 6
Qd - Paleodunes (Quaternary) 6
Qt1 - Fluvial Terrace 1 (Quaternary) 6
Qt2 - Fluvial Terrace 2 (Quaternary) 6
Qt - Terrace deposits (Pleistocene) 7
PLMlo - Ogallala Formation (Pliocene - Miocene) 7
Pec - Elk City Sandstone (Permian) 7
Pd - Doxey Formation (Permian) 7
Pcc - Cloud Chief Formation (Permian) 7
GRI Source Map Information 9
Stahl, GSA GeoCorps unpublished, 2012 9
Mapping Procedure 9
Regional Geology 10
Statistical Analysis 10
Findings and Results 11
Bibliography 12
Figure 2: Principle rock types of the Early Pennsylvannian 13
Figure 3: Principle rock types of the Early Permian 13
Figure 4: Late Cretaceous to Tertiary rock types 14
Table 1: Statistical analysis of the geologic features based on LIDAR data. 14
Table 2: Vertical accuracy of each geologic contact unit based on TopCon GPS data. 15
Table 3: Vertical accuracy of various tie points used. 15
Plate 1: Map View and Cross Sections of Anadarko Basin (Johnson and Luza, 2008) 16
Plate 2: Paleochannel GIS Layers 18
Plate 2a: GIS layer displaying aspect or slope direction 18
Plate 2b: GIS Layer displaying flow direction 18
Plate 2c: Final map of WBNHS with geologic units draped over a LIDAR hillshade 19
Plate 2d: Final map of WBNHS with geologic units draped over a LIDAR hillshade 19
Oklahoma Geologic Quadrangle Map OGQ-78A 20
Correlation of Units 20
Quadrangle Location Map 21
Map References 21
GRI Digital Data Credits 22

Geologic Resources Inventory Map Document

Washita Battlefield National Historic Site, Oklahoma

Document to Accompany Digital Geologic-GIS Data

waba_geology.pdf

Version: 4/12/2013

This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Washita Battlefield National Historic Site, Oklahoma (WABA).

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:

Tim Connors
Geologist/GRI Mapping Contact
National Park Service Geologic Resources Division
P.O. Box 25287
Denver, CO 80225-0287
phone: (303) 969-2093
fax: (303) 987-6792
email: Tim_Connors@nps.gov

For information about using GRI digital geologic-GIS data contact:

Stephanie O'Meara
Geologist/GIS Specialist/Data Manager
Colorado State University Research Associate, Cooperator to the National Park Service
1201 Oak Ridge Drive, Suite 200
Fort Collins, CO 80525
phone: (970) 491-6655
fax: (970) 225-3597
e-mail: stephanie.omeara@colostate.edu

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:

Bruce Heise
Inventory Coordinator
National Park Service Geologic Resources Division
P.O. Box 25287
Denver, CO 80225-0287
phone: (303) 969-2017
fax: (303) 987-6792
email: Bruce_Heise@nps.gov

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

GRI Digital Maps and Source Map Citations

The GRI digital geologic-GIS maps and their source maps for Washita Battlefield National Historic Site, Oklahoma (WABA):

GRI Digital Geologic Map of Washita Battlefield National Historic Site and Vicinity, Oklahoma (*GRI MapCode WABA*)

Stahl, Julian, 2012, Geologic Map of the Washita Battlefield National Historic Site, Cheyenne, Oklahoma, Geological Society of America GeoCorps, unpublished, 1:24,000 scale. (Julian Stahl, unpublished, 2012). (*GRI Source Map ID 75647*).

GRI Digital Geologic Map of the Washita Battlefield National Historic Site Area, Oklahoma (*GRI MapCode WBAR*)

Fay, R.O., 2010, Preliminary Geologic Map of the Foss Reservoir 30' x 60' Quadrangle, Oklahoma, Oklahoma Geological Survey, Geologic Quadrangle Map, OGQ-78a, 1:100,000 scale. (Geologic Quadrangle Map OGQ-78A). (*GRI Source Map ID 75552*).**

***For the latter GRI digital geologic-GIS map only a portion of the source publication was used, and thus what is presented in the GRI digital geologic-GIS data, and this document is only a subset of the full source publication.*

Additional information concerning each source map can also be found in the Source Map Information (WABAMAP) table with the GRI digital geologic-GIS data.

Map Unit List

The geologic units present in the digital geologic-GIS data produced for Washita Battlefield National Historic Site, Oklahoma (WABA) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qa - 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 (WABAUNIT) table included with the GRI geology-GIS data.

Cenozoic Era

Holocene Period

Qa - Alluvium

Quaternary Period

Qfp - Floodplain
Qtf - Tributary Floodplain
Qd - Paleodunes
Qt1 - Fluvial Terrace 1
Qt2 - Fluvial Terrace 2
Qt - Terrace deposits

Tertiary Period

PLMlo - Ogallala Formation

Paleozoic Era

Permian Period

Pec - Elk City Sandstone
Pd - Doxey Formation
Pcc - Cloud Chief Formation

Map Unit Descriptions

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

Qa - Alluvium (Holocene)

Unconsolidated sand, silt, clay, and gravel in stream and river channels and on modern flood plains. (*GRI Source Map ID 75552*) (OGQ-78A).

Qfp - Floodplain (Quaternary)

The floodplain defines a broad flat depositional plain directly adjacent to the current Washita River. Due to its recent development, its extent is easily mapped by the first appearance of a sharp increase in slope perpendicular to the Washita River. According to the USDA Web Soil Survey, the floodplain contains both Lincoln and Westola fine sandy loam. Its parent material is calcareous sandy alluvium (Soil Survey Staff). (*GRI Source Map ID 75647*) (Stahl, 2012).

Qtf - Tributary Floodplain (Quaternary)

Tributary floodplain units were mapped along the three larger intermittent streams entering the Washita River. At each river junction the floodplains perpendicular to the main stream were the combined result of both tributary creek and Washita River floodplain. In order not to bias average floodplain elevations for the Washita River, they were mapped separately from the floodplain. The soil also consists of clay to silt. (*GRI Source Map ID 75647*) (Stahl, 2012).

Qd - Paleodunes (Quaternary)

The eolian paleodunes are composed of light grey to salmon colored, quartz rich, medium to coarse sand. They are easily distinguished based on their geomorphology observed on the LIDAR base map. They display a convex, crescent shape, rising between 10-25 feet above the surrounding surface. South of the Washita River, the dunes form elongate strips parallel to the Washita River Valley. To the north of the Washita River, the dunes are more common and occur in larger dune fields. A particularly dense accumulation of dunes occurs to the northeast of the major river bend where dunes overlie both of the terraces, the Cloud Chief and the Doxey Formation. (*GRI Source Map ID 75647*) (Stahl, 2012).

Qt1 - Fluvial Terrace 1 (Quaternary)

The terrace 1 riser was prominent enough to trace across the majority of the mapping area. At the eastern edge of the WBNHS younger dunes cover the terrace riser. Widespread dunes were also found in the northwestern section of the map. The soil consists of silt to fine sand. A section of terrace 1 to the northeast of the Washita Battlefield contains approximately 30% gravel fragments sourced from the underlying Cloud Chief Formation. The fluvial terrace displays broad, gently sloping terrain before transitioning to the steeper slopes of terrace 2. (*GRI Source Map ID 75647*) (Stahl, 2012).

Qt2 - Fluvial Terrace 2 (Quaternary)

Terrace 2 was mapped as the first appearance of well-rounded, quartzite pebbles to cobbles as well as an increase in elevation. The quartzite clasts are scattered on the surface with varying concentrations and degrees of sorting. The clasts are a surface deposit and do not persist at depth. Clay to silt sized material dominates the terrace 2 deposits with local areas of sandy soils. As a locality on the western

end of the study area, the quartzite cobbles appear on the top of a Doxey Formation knoll. Due to extensive erosion, terrace 2 deposits form elongate, discontinuous mounds perpendicular to the Washita River. (*GRI Source Map ID 75647*) (Stahl, 2012).

Qt - Terrace deposits (Pleistocene)

Unconsolidated sand, silt, clay, gravel, and volcanic ash above modern flood plains. (*GRI Source Map ID 75552)* (OGQ-78A).

PLMIo - Ogallala Formation (Pliocene - Miocene)

Gray to light-brown, fine-to medium grained sand with some clay, silt, gravel, volcanic ash, and caliche beds; locally cemented calcium carbonate. (*GRI Source Map ID 75552)* (OGQ-78A).

Pec - Elk City Sandstone (Permian)

Reddish-brown, fine-grained sandstone with minor amounts of siltstone and claystone, weakly cemented by iron oxide, calcium carbonate, and gypsum. (*GRI Source Map ID 75552)* (OGQ-78A).

Pd - Doxey Formation (Permian)

Dx - Doxey Formation (Permian)

The weak red (10R 5/6) Doxey Formation overlies the Cloud Chief Formation. It outcrops at higher elevations to the north on the flanks of the Washita River Valley as well as on the many knolls within the valley. Centimeter scale shale layers are interlayered within sub meter scale, silt to fine sandstone beds. Sedimentary structures within the Doxey Formation include planar, wavy, and ripple cross lamination as well as climbing ripples. (*GRI Source Map ID 75647*) (Stahl, 2012).

Pd - Doxey Formation (Permian)

Reddish-brown, silty shale and siltstone. (*GRI Source Map ID 75552)* (OGQ-78A).

Pcc - Cloud Chief Formation (Permian)

Cc - Cloud Chief Formation (Permian)

The yellow red (5YR 5/6), Permian Cloud Chief Formation underlies most of the fluvial terraces. Depending on the lateral and vertical position in the stratigraphic section, beds range from cm scale, fine-grained claystone to sub-meter scale siltstone. Several meter scale, resistant gypsum beds within the Cloud Chief also crop out south and north of the river. Both green/gray unoxidized shale and evaporite gypsum are discontinuously interbedded within the unit. Well-preserved sedimentary structures are found in the Cloud Chief Formation and include ripple cross laminations, and wavy laminations. The Cloud Chief Formation outcrops are rare so mapping of the unit was often based on soil containing high fractions of Cloud Chief Formation fragments. (*GRI Source Map ID 75647*) (Stahl, 2012).

Pcc - Cloud Chief Formation (Permian)
Reddish-brown to orange-brown shale with siltstone and sandstone in middle part and some dolomite and much gypsum in lower part. (*GRI Source Map ID 75552)* (OGQ-78A).

GRI Source Map Information

Stahl, GSA GeoCorps unpublished, 2012

Stahl, Julian, 2012, Geologic Map of the Washita Battlefield National Historic Site, Cheyenne, Oklahoma, Geological Society of America GeoCorps, unpublished, 1:24,000 scale. (*GRI Source Map ID 75647*).

Mapping Procedure

I used a survey grade differential GPS to create a high precision geologic map of the Washita National Historic Battlefield Site (WNHPS) and surrounding areas. Six different geologic features were mapped: the modern Washita River floodplain, tributary floodplains, paleodunes, two fluvial terraces, and two bedrock formations. The two formations, Cloud Chief Formation and Doxey Formation, crop out locally throughout the area with well-preserved sedimentary structures. Vegetation and agriculture fields cover the four other geologic units.

From August 27th to September 14th, 2012, a Top Con Hyperlite + GPS and LIDAR base map were used to construct a geologic map of the area. The high resolution LIDAR data was obtained from Jerry Swartwood at the USDA-NRCS office in Cheyenne, Oklahoma. Each day a base station was configured and placed at a fixed location for 7 hours to obtain a precise GPS coordinate. A rover GPS was attached to a backpack and carried in the field. The height of the rover was measured daily to reduce the vertical error. The different units were mapped based on geomorphology and soil characteristics. Contacts between units were traced with a GPS at a 5 second interval. Difficulty arose in heavily vegetated areas since the soil was not visible on the surface, as well as in wooded areas where the GPS signal was weak. Many regions on the map were also altered by anthropogenic use, which destroyed the characteristic geomorphology defining the terraces. Sometimes the agriculture fields outlined a specific terrace or vegetation particular to a soil helped locate the contact.

Anthropogenic alterations to the landscape and Washita hydrology have changed the landscape from its natural state and made the mapping more difficult. The installation of one of the United States' greatest flood control systems in the Washita's watershed farther upstream, due to the Flood Control Act of 1944, heavily altered the physical and hydrological properties of the river. In 1934 and 1955 the region experienced two large flooding events that carried high concentrations of suspended sediment down the stream creating many over bank deposits. After the installation of dams during the 50's, the rivers discharge and sedimentation rate decreased. The current river does not have the same discharge rate to alter its path as it did prior to the 1950's (Marston et. al., 2007). These modifications fundamentally changed the rivers geomorphology.

During the 1920's, the city of Cheyenne built a Railroad grade through what is now the WNHPS. The placement of the grade appears to coincide with the edge of terrace riser 1. This observation is largely based on the elevational differences between the floodplain and the first fluvial terrace. Although the grade probably has not altered the channels direction, it makes accurate mapping of the fluvial terrace riser difficult.

The anthropogenic alterations listed above were all considered while mapping geologic features. In areas where the GPS signal was too low for data collection, the contact was traced by hand on a LIDAR hard copy base map while in the field.

Extracted from: (Stahl, 2012).

Regional Geology

My study area lies within the northwest trending Anadarko basin (Plate 1). It is a foreland type basin that underlies approximately 60,000 km^2 of western Oklahoma and Texas. Today the basin is bounded by the Arbuckle uplift in the southeast, the Wichita-Criner uplifts to the south, and the Nemaha uplift to the east (Johnson et. al., 1991). The Washita Battlefield is located on the deep side of the basin at the southern end (Johnson & Luza, 2008). Formation of the basin began during the Middle Cambrian, when an active rift basin deposited a sequence of intrusive and extrusive igneous rocks. When extension halted during the Late Cambrian the basin transformed to a cratonic basin. Sediment accumulation rates were low through the Devonian and Mississippian and the basin remained shallow. During the Pennsylvanian tectonics drove crustal shortening resulting in a foreland basin and the growth of thrust blocks, such as the Wichita block. Differential uplift of the block caused tilting to the north. The excess load and sediment accumulation due block erosion created a 12 km deep basin (Figure 2). The uplift continued into the Permian.

The units surrounding the battlefield are part of a Permian depositional sequence within a foreland basin. The Permian stratigraphic sequence consists of interfingered shales, sandstones, and evaporates including the Cloud Chief and the Doxey Formations (Johnson, 1988). At the start of the Permian an epeiric sea filled the area overlying the Anadarko Basin depositing a marine limestone sequence (Figure 3) (Johnson, 1988). As the water regressed, a hypersaline sea inundated most of the basin depositing a sequence of evaporates and red beds. Sediments within the beds stem from the Wichita Mountains to the south and the ancestral Rocky Mountains to the west (Johnson, 1988). A continued regression and transgression deposited a sequence of sedimentary units with individual compositions dictated by the sediments source region. Many of the deposited beds were eroded during the Late Jurassic through the Late Tertiary (Johnson, 1988).

Post-Permian deposition was more subdued and not dominated by tectonic activity. Triassic and Jurassic strata consist of a combination of fluvial, deltaic, and lacustrine environments. Initial reports suggest between 150-300 m thick sequence of which only up to 60 m still exists today (Johnson, 1988). The Cretaceous included the last transgression of an epeiric sea over the Anadarko Basin. An approximately 300 m thick sequence of marine limestone, shales, and sandstones were deposited during this event (Johnson, 1988). The Late Cretaceous is dominated by the Laramide orogeny, which tilted the entire region southeastward and forced the retreat of the epeiric sea. During the epeiorogenic uplift of Late Cretaceous to Middle Tertiary time most of the Cretaceous deposits were eroded. The Tertiary strata consist of interbedded fluvial and eolian sediments deposited on a Permian unconformity (Figure 4) (Johnson, 1988). The most important member is the Ogallala Formation, which was deposited in a low-gradient alluvial environment stemming from the Rocky Mountains (Johnson, 1988). Quaternary deposits consist of alluvial, eolian, and lacustrine deposits derived from streams flowing east across the basin.

Extracted from: (Stahl, 2012).

Statistical Analysis

Basic statistical analysis was performed on the high resolution LIDAR data (Table 1). In GIS, the geologic unit shapefile was converted to a NAD 83 projection to calculate the area of each unit. The spatial analyst zonal statistics tool was used to calculate the elevation range of each unit. The GPS coordinates as well as the elevation value for all points within each geologic unit were also exported into excel. From this data the standard deviation was calculated for the Washita floodplain, tributary floodplain, terrace 1, and terrace 2 mapped units. These geologic features are characterized by low topography so the standard deviation value suggests the general range of common elevation heights.

Accuracy analysis of the TopCon GPS data was also executed. Collected base station points were post-processed with the National Geodetic Survey's Online Positioning User Service (OPUS) program. OPUS provides a vertical error on each base station point (A_{BS}). The TopCon GPS itself records the vertical accuracy between the base station and the rover ($A_{R\text{-}BS}$). The total accuracy value for a given point was calculated using the following equation:

$$Accuracy = \sqrt{(A_{SB})^2 + (A_{R-SB})^2}$$

Using this equation the overall accuracy of each measured unit was calculated (Table 2).

The same equation was used to calculate the accuracy of the tie points or controls. Since the base station was located at a different position every day, the tie points were used to connect each days worth of GPS data with at least one common point. This provides a control and vertical offset for each day (Table 3).

Extracted from: (Stahl, 2012).

Findings and Results

The first week in the field was spent with Professor Alexander Simms from University of California at Santa Barbara who familiarized me with the surrounding geology. The original goal of mapping fluvial terraces to constrain the paleochannel of 1868 was soon determined unviable. The existing terrace deposits are much older than the time of the battle. The mapping of fluvial terraces only provides a very broad constraint on the maximum lateral extend of the river. However, the LIDAR data and aerial images allowed for further paleochannel interpretation (Plate 2-c). The high resolution LIDAR data clearly depicts paleochannel courses. Two additional layers were calculated from the LIDAR data to further aid in locating paleochannels: a flow accumulation layer and an aspect layer (Plate 2 a-b). This combination makes paleochannels more visible than a simple hillshade layer. Although a time stamp cannot be placed on any of the fluvial remnants, it provides insight on the overall behavior and characteristics of the Washita River. The 1868 paleochannel location assigned by the park (red line on Plate 2-c) is not viable because the channels physical properties differ from the current channel and the historical accounts described by Jerome Greene in *Washita* reveal problems. The paleochannel's width is too narrow, especially for a higher discharge river before the installation of dam control. Also, historical accounts recorded by Greene clearly indicate that Peace Chief Black Kettle's horses were killed "south of the village and against the face of a sharply rising bluff" (Greene, 2004**)**. This sharp bluff is probably located at the east edge of the park near the dunes. The paleochannel indicated by the park does not provide enough open space on the southern floodplain for all of the horses and Tepees. The flow path of the indicated paleochannel also does not match that of a stream. The linear path outlined is unsuited for the moderately meandering Washita River. A historical image from 1936 depicts the floodplain as rangeland, suggesting that the indicated paleochannel could be a cattle track. Although many paleochannels are visible with the high-resolution data, it is not possible to determine which paleochannel represents 1868 one.

Georeferenced aerial images obtained from the Cheyenne Department of Agriculture and the NPS provide true accounts of the Washita. Paleochannels from the images were traced in GIS and combined in one layer (Plate 2d). A historical image from 1950 depicts the floodplain after a major flood. Two of the most notable paleochannels on the southern floodplain in the LIDAR were filled with water during this time (Figure 1). Again these paleochannel's narrow incision as well as the lack of space for

Peace Chief Black Kettle's camp remove both of the channels as contenders for the 1868 paleochannel. The most probable location of the Washita River in 1868 is close to the position traced on the General Lands Office Survey of 1873 conducted by H.C.F. Hackbusch.

Extracted from: (Stahl, 2012).

Bibliography

Greene, J. (2004). *Washita: The us army and the southern cheyennes*. Norman: University of Oklahoma Press.

Johnson, K. S. U.S. Geological Survey, Oklahoma Geological Survey. (1988). *Anadarko basin symposium* (0078-4397). Retrieved from University of Oklahoma Printing Services website: http://www.ogs.ou.edu/pubsDLCirculars.php

Johnson, K. S., & Luza, K. V. U.S. Geological Survey, Oklahoma Geological Survey. (2008). *Earth sciences and mineral resources of oklahoma*. Retrieved from University of Oklahoma Printing Services website: http://www.ogs.ou.edu/pubsscanned/EP9_All.pdf

Johnson, K. S., Runkle, D. L., and Becker, M. F., 1991, Hydrogeology of the Rush Springs-Marlow aquifer in the Anadarko Basin, west-central Oklahoma, U.S.A, *in* H. Ventriss, ed., Proceedings of the International Conference on Groundwater in Large Sedimentary Basins, v. 20: Canberra, A.C.T., Australia, Australian Water Resources Council, p. 100-109.

Marston, R. A., and T. Halihan. 2007. Geomorphic adjustment of the Washita River, Washita Battlefield National Historic Site, Oklahoma. Natural Resource Technical ReportNPS/NRPC/WRD/NRTR—2007/070. National Park Service, Fort Collins, Colorado.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/. Accessed [11/6/2012].

Extracted from: (Stahl, 2012)

Figure 2: Principle rock types of the Early Pennsylvannian

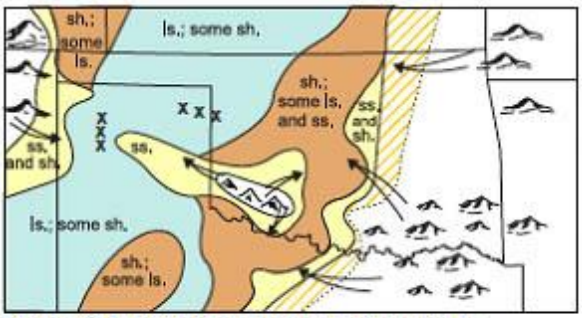


Figure 2: Principle rock types of the Early Pennsylvanian. Brown (shale), Yellow (sandstone), Hashed (rocks not eroded) (Johnson & Luza, 2008).

Extracted from: (Stahl, 2012)

Figure 3: Principle rock types of the Early Permian

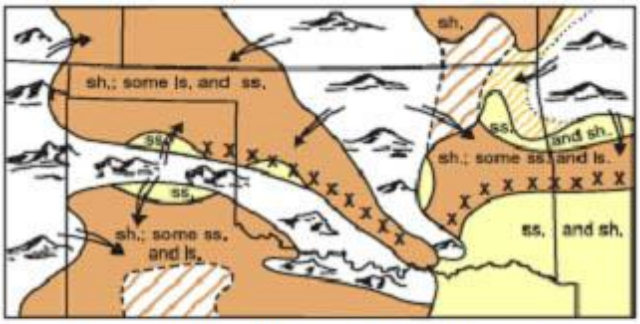


Figure 3: Principle rock types of Early Permian with epeiric sea present. Blue (limestone), yellow (sandstone), brown (shale), arrows indicate clastic input. (Johnson & Luza, 2008)

Extracted from: (Stahl, 2012).

Figure 4: Late Cretaceous to Tertiary rock types

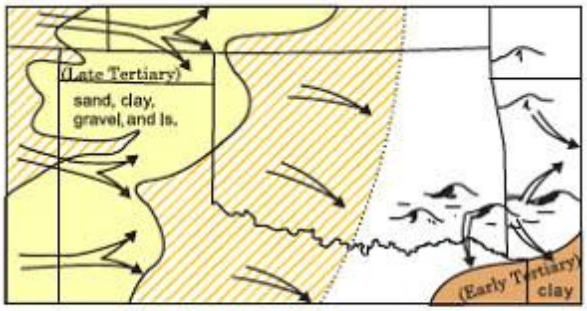


Figure 4: Late Cretaceous to Tertiary rock types with sediment input from the Rocky Mountains. (Kenneth, 2008)

Extracted from: (Stahl, 2012).

Table 1: Statistical analysis of the geologic features based on LIDAR data.

	Area (km^2)	Range (min- max) (m)	Average Elevation (m)	Elevation Standard Deviation (m)
Cloud Chief Formation	2.77	24.52	N/A	N/A
Doxey Formation	0.33	22.11	N/A	N/A
Dune	2.00	12.28	N/A	N/A
Floodplain	4.32	5.94	590.10	4.05
Terrace 1	4.29	10.05	598.36	7.23
Terrace 2	1.92	12.38	606.07	8.46
Tributary Floodplain	1.04	9.14	604.91	5.61

Extracted from: (Stahl, 2012).

Table 2: Vertical accuracy of each geologic contact unit based on TopCon GPS data.

	Vertical Accuracy (±m)
Modern Floodplain	0.029
Terrace 1	0.035
Terrace 2	0.039
Dune	0.071
Cloud Chief Formation	0.055
Doxey Formation	0.028

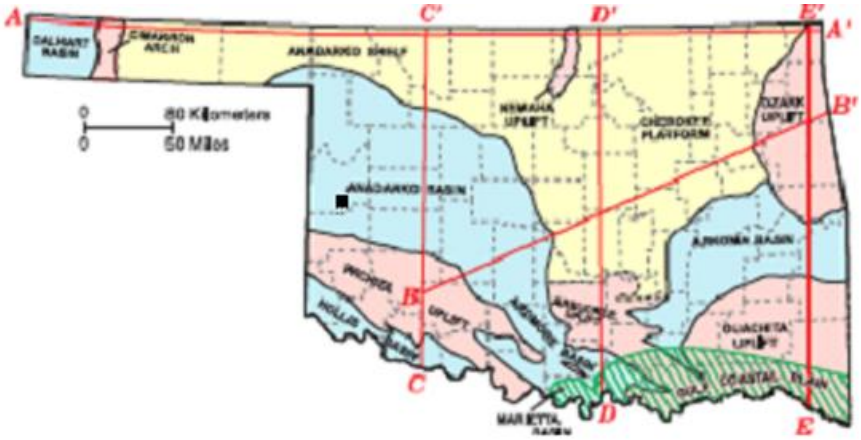
Extracted from: (Stahl, 2012).

Table 3: Vertical accuracy of various tie points used.

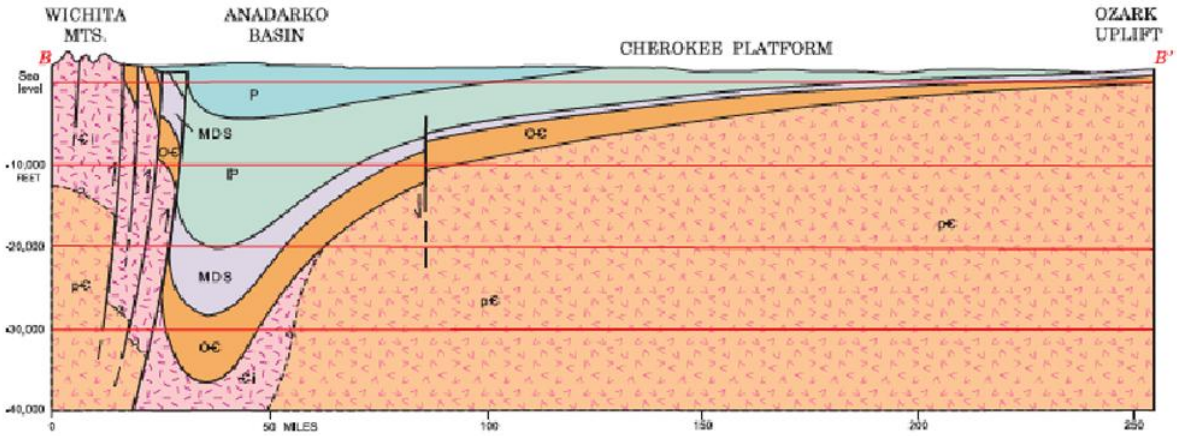
	Vertical Accuracy (±m)
Tie Point 1	0.054
Tie Point 2	0.043
Tie Point 3	0.037
Tie Point 4	0.026
Tie Point 5	0.030
Tie Point 6	0.027
Tie Point 7	0.035
Tie Point 8	0.034
Overall Vertical Accuracy (±m)	0.039

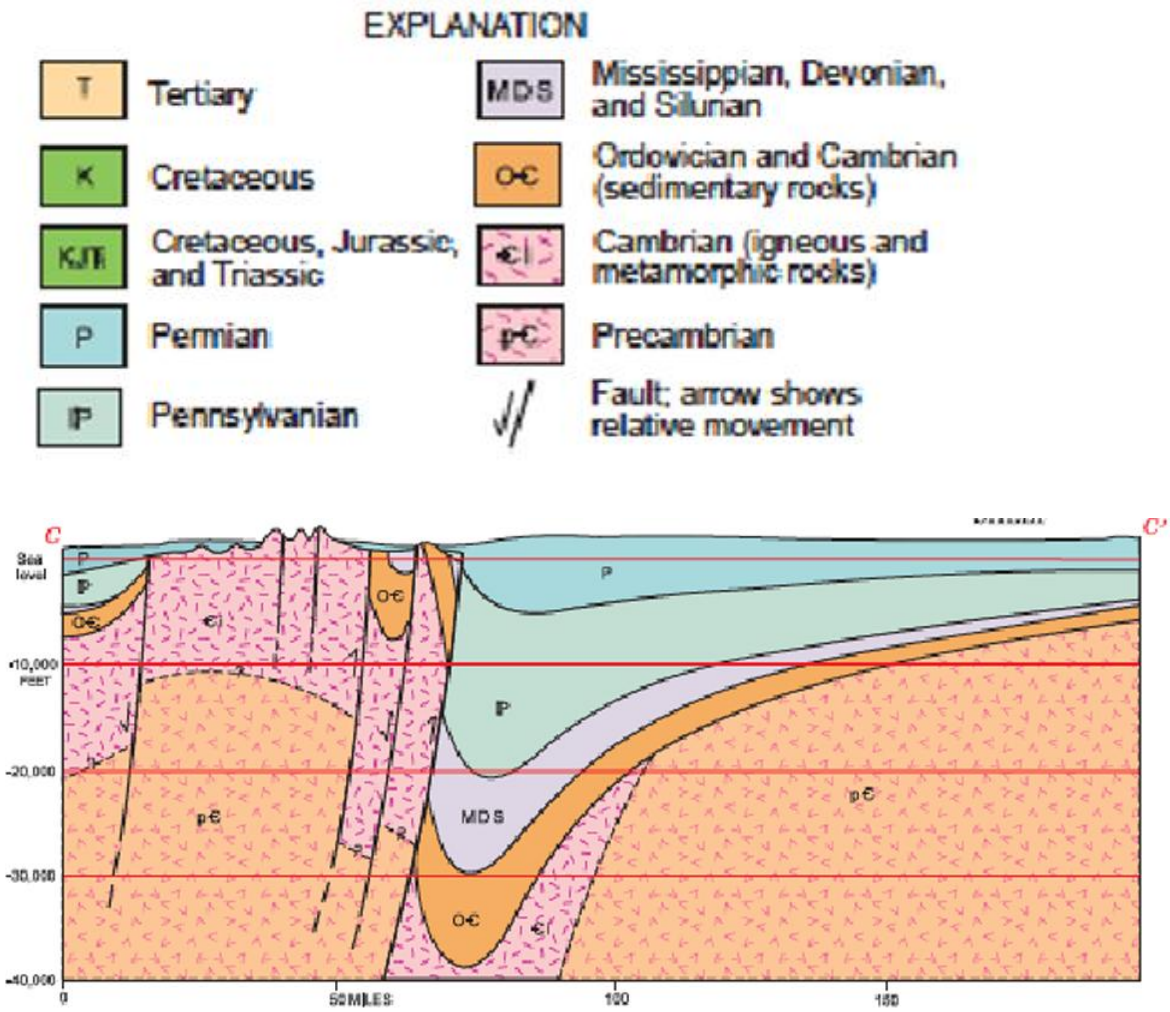
Extracted from: (Stahl, 2012).

Plate 1: Map View and Cross Sections of Anadarko Basin (Johnson and Luza, 2008)



● - Washita Battlefield Site

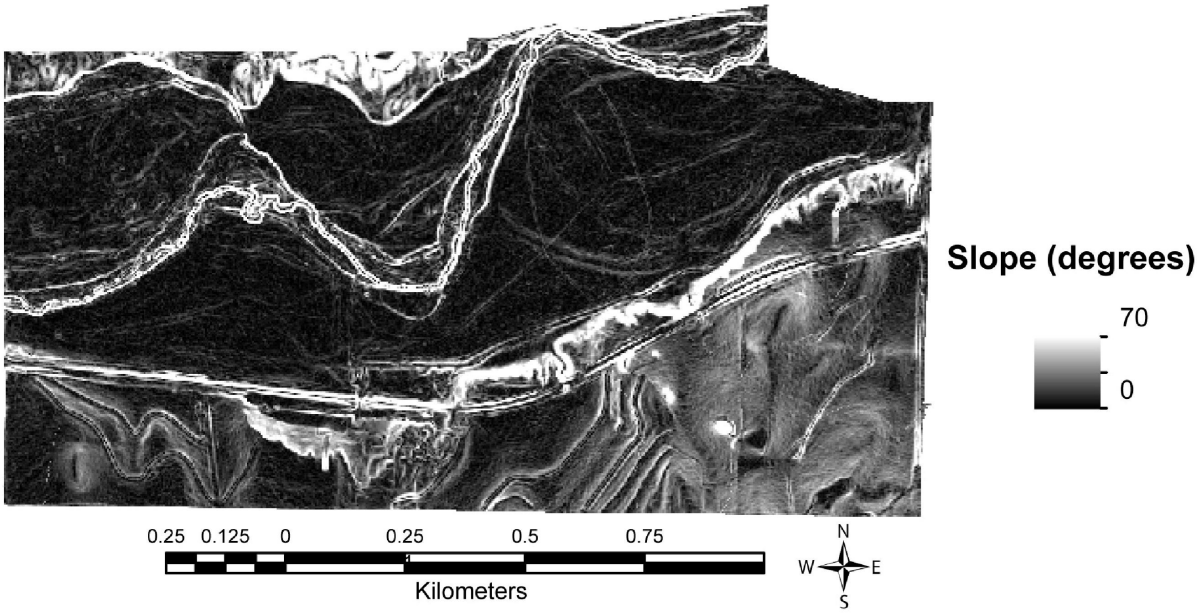




Extracted from: (Stahl, 2012).

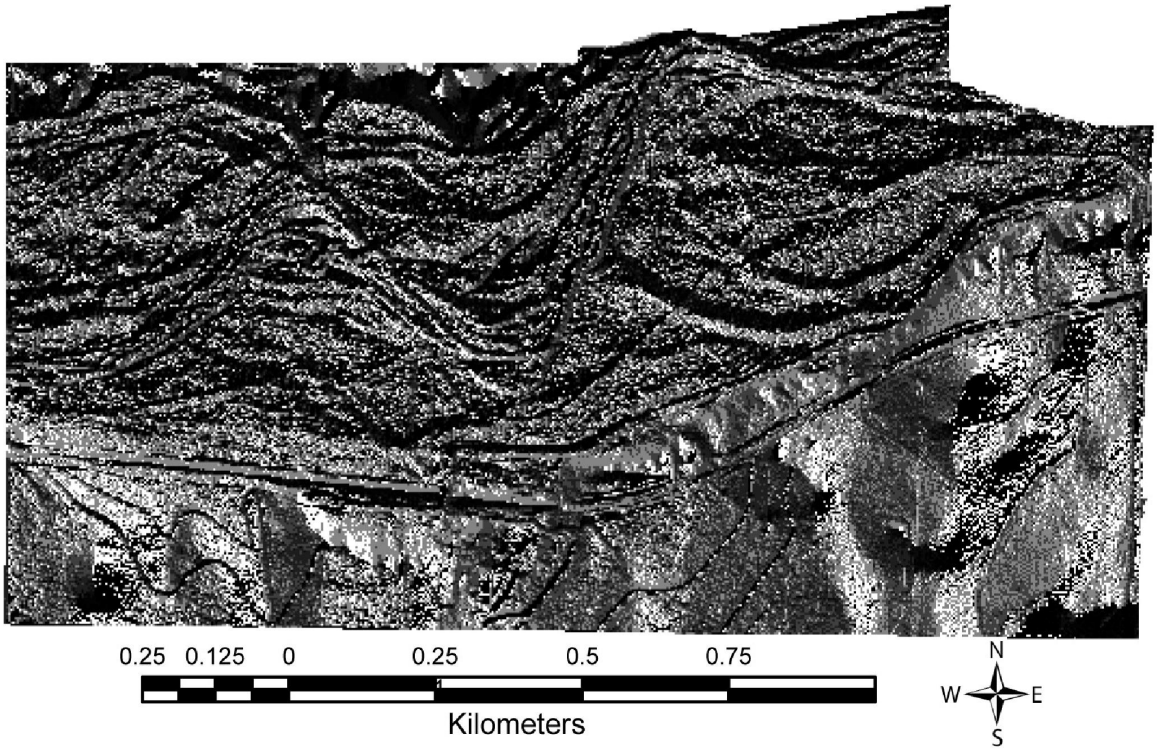
Plate 2: Paleochannel GIS Layers

Plate 2a: GIS layer displaying aspect or slope direction



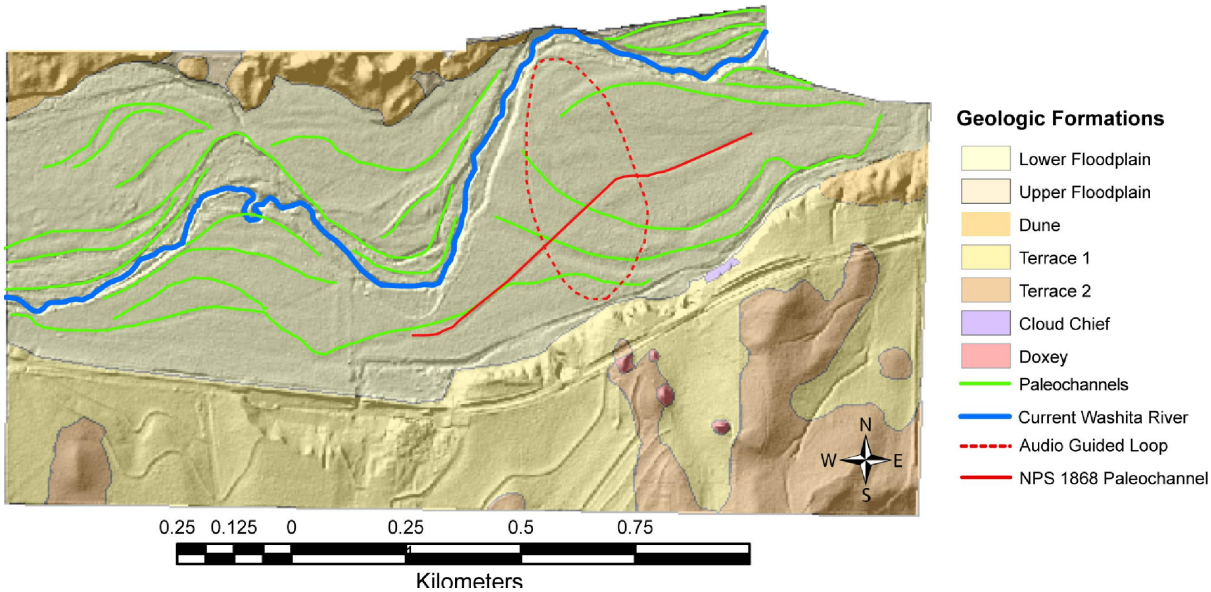
Extracted from: (Stahl, 2012).

Plate 2b: GIS Layer displaying flow direction



Extracted from: (Stahl, 2012).

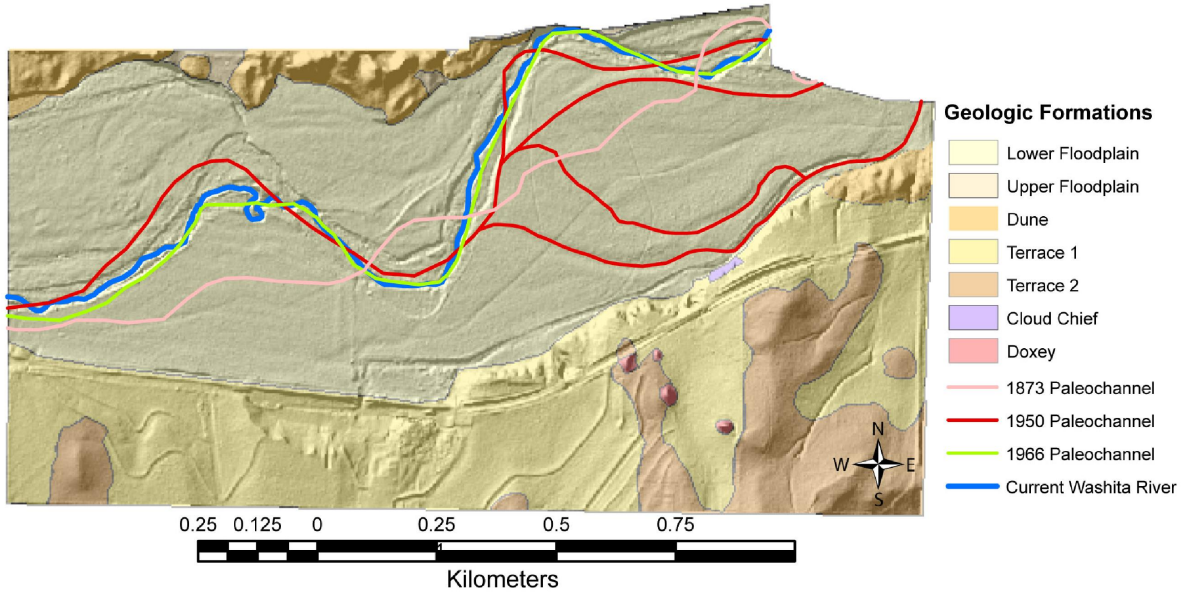
Plate 2c: Final map of WBNHS with geologic units draped over a LIDAR hillshade



Paleochannels derived from flow direction and slope (Plate 2 a-b).

Extracted from: (Stahl, 2012).

Plate 2d: Final map of WBNHS with geologic units draped over a LIDAR hillshade



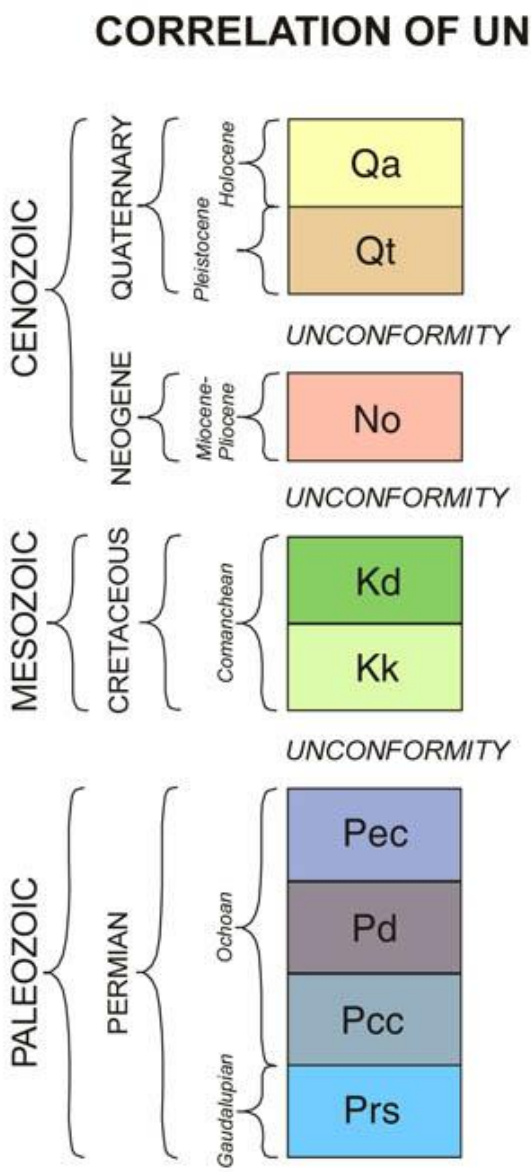
Paleochannels from historical aerial images.

Extracted from: (Stahl, 2012).

Oklahoma Geologic Quadrangle Map OGQ-78A

Fay, R.O., 2010, Preliminary Geologic Map of the Foss Reservoir 30' x 60' Quadrangle, Oklahoma, Oklahoma Geological Survey, Geologic Quadrangle Map, OGQ-78a, 1:100,000 scale. (*GRI Source Map ID 75552*).

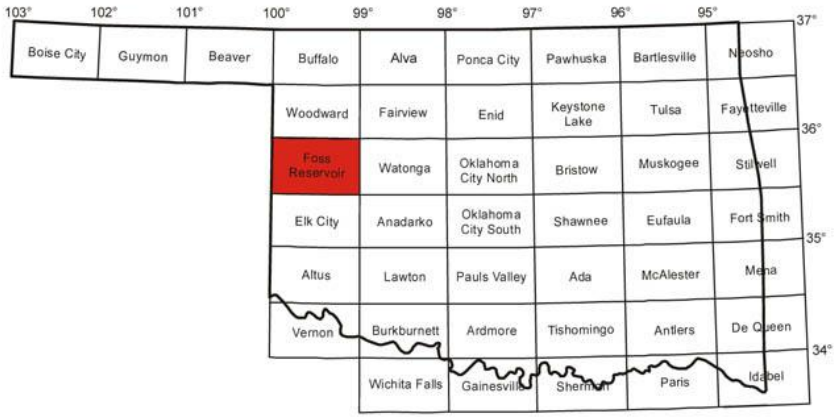
Correlation of Units



*** Only a subset of units presented in the above figure are actually within the extent of the GRI digital geologic-GIS map for Washita Battlefield National Historic Site.*

Extracted from: (OGQ-78A).

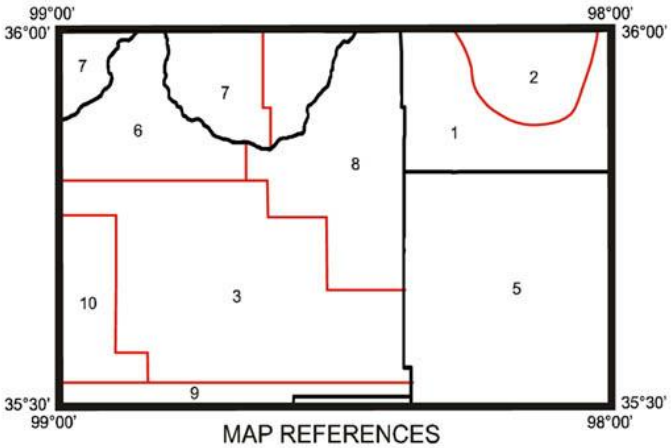
Quadrangle Location Map



Map of Oklahoma showing the locations of the 30′ X 60′ quadrangles. Red shaded quadrangle represents the current map

Extracted from: (OGQ-78A).

Map References



1. Alexander, W.B., 1965, Areal geology of southern Dewey County, Oklahoma: University of Oklahoma unpublished M.S. thesis, 42 p.
2. Birchum, J.M., 1963, Areal geology of northwestern Dewey County, Oklahoma: University of Oklahoma unpublished M.S. thesis, 33 p.
3. Bowers, J.R., 1967, Areal geology of the Cheyenne area, Roger Mills County, Oklahoma unpublished M.S. thesis, 62 p.
4. Carr, J.E. and Bergman, D.L., 1976, Reconnaissance of the water resources of the Clinton quadrangle, west-central Oklahoma, scale 1:250,000.
5. Fay, R.O., et al, 1978, Geology and mineral resources of Custer County, Oklahoma: Oklahoma Geological Survey Bulletin 114, 89 p., scale 1:62,500.
6. Kitts, D.B., 1959, Cenozoic geology of northern Roger Mills County, Oklahoma: Oklahoma Geological Survey Circular 48, 48 p.
7. Kitts, D.B., 1965, Geology of the Cenozoic rocks of Ellis County, Oklahoma: Oklahoma Geological Survey Circular 69, 30 p.
8. Lovett, F.D., 1960, Areal geology of the Quartermaster area, Roger Mills and Ellis Counties, Oklahoma: University of Oklahoma unpublished M.S. thesis, 81 p.
9. Meinert, J.G., 1961, Areal geology of the Starvation Creek area, Roger Mills and Beckham Counties, Oklahoma: University of Oklahoma unpublished M.S. thesis, 66 p.
10. Miser, H.D., et al, 1954, Geologic map of Oklahoma: U.S. Geological Survey, scale 1:500,000.

Extracted from: (OGQ-78A).

GRI Digital Data Credits

This document was developed and completed by Georgia Hybels (NPS GRD, Lakewood, Colorado) 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<GRI source maps, and intended to accompany the digital geologic-GIS maps and other digital data for Washita Battlefield National Historic Site, Oklahoma (WABA) developed by Georgia Hybels (NPS GRD, Lakewood, Colorado) (see the GRI Digital Maps and Source Map Citations section of this document for all sources used by the GRI in the completion of this document and related GRI digital geologic-GIS maps.

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).