# Geologic Resources Inventory Scoping Summary
# Washita Battlefield National Historic Site
# Oklahoma

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**Geologic Resources Division**
**National Park Service**
**U.S. Department of the Interior**

The Geologic Resources Inventory (GRI) Program, administered by the Geologic Resources Division (GRD), provides each of 270 identified natural area National Park System units with a geologic scoping meeting, a scoping summary, a digital geologic map, and a geologic resources inventory report. Geologic scoping meetings generate an evaluation of the adequacy of existing geologic maps for resource management. Scoping meetings also provide an opportunity to discuss park-specific geologic management issues, distinctive geologic features and processes, and potential monitoring and research needs. If possible, scoping meetings include a site visit with local experts.

The Geologic Resources Division held a GRI scoping meeting for Washita Battlefield National Historic Site on May 13, 2011, at the visitor center near Cheyenne, Oklahoma. Washita Battlefield National Historic Site and Black Kettle National Grassland share this facility, which serves as a USDA Forest Service district office and the National Park Service (NPS) headquarters building. Participants at the meeting included NPS staff and volunteers from the national historic site, Southern Plains Network, and the Geologic Resources Division; and cooperators from the Oklahoma Geological Survey and Colorado State University (see table 1, p. 19).

During the scoping meeting, Phil Reiker (Geologic Resources Division) facilitated the group's assessment of map coverage and needs, and Bruce Heise (Geologic Resources Division) led the discussion of geologic features, processes, and issues. Neil Suneson (Oklahoma Geological Survey) provided an overview of the geology of the national historic site and surrounding area.

During the site visit, participants stopped at the overlook area with its unobstructed view down to the river and the hills beyond. Participants walked along the designated trail from the overlook to the Washita River, inspecting the Permian (299 million to 251 million years ago) substrate of an unnamed knoll along the way (fig. 1).

The rocks underfoot and exposed in the knoll are the Cloud Chief Formation, which are the oldest rocks exposed at the national historic site. The Cloud Chief Formation was deposited in a shallow ocean setting, probably under arid conditions at the edge of an inland sea (Neil Suneson, geologist, Oklahoma Geological Survey, personal communication during scoping, May 13, 2011). The Cloud Chief Formation is variably referred to as "red clay," "red claystone," or "red shale." Claystone is hardened or consolidated clay, and has the texture and composition of shale, but lacks the fine laminations and fissility of shale. Because the Cloud Chief Formation is "pretty well stratified" (see fig. 1), Neil Suneson (Oklahoma Geological Survey) recommended that the Cloud Chief Formation be referred to as "shale."

In other parts of the state, the gypsum of the Cloud Chief Formation is massive, with thicknesses up to 30 m (100 ft). In such locations, the formation is mined. At the national historic site, however, the beds of gypsum are thin and interbedded with the red shale.

The knolls and bluffs surrounding the national historic site are made up of Doxey Formation (fig. 2). This formation, also shale, was deposited on a coastal mudflat, tens of feet above sea level (Neil Suneson, geologist, Oklahoma Geological Survey, personal communication during scoping, May 13, 2011). Although the Doxey Formation is more resistant than the Cloud Chief Formation, it is still prone to erosion, forming "badlands" topography.

Closer to the river, participants walked across fluvial terraces and alluvium (stream deposits) of the Quaternary Period (the last 2.6 million years). Fluvial deposits include fine-grained sediments, which participants noted as forming ripples in the river channel (fig. 3). Quaternary dune sand also occurs in the area, but has not been mapped within the boundaries of the national historic site to date (see "Geologic Mapping for Washita Battlefield National Historic Site").

**Figure 1. Permian red beds. Washita Battlefield National Historic Site is underlain by the Cloud Chief Formation, which in the area is made up of thin layers of gypsum and shale. The Cloud Chief Formation is exposed in the unnamed knoll along the trail to the Washita River, shown in the figure. Photo by Katie KellerLynn.**

**Figure 2. Bluffs and knolls in the Washita viewshed. The knoll in the middle ground of the figure is "Sugar Loaf Hill," where Custer's scouts overlooked Black Kettle's village. The knoll is made of the Cloud Chief Formation. The bluffs in the distance are made of Doxey Shale. Photo by Katie KellerLynn.**

**Figure 3. Ripple marks. Ripples are forming in the sediments of today's Washita River. Photo by Katie KellerLynn.**

## Park Setting

Washita Battlefield National Historic Site is located in Roger Mills County in western Oklahoma. The region is known as "red carpet country," and is part of the Western Red-Bed Plains physiographic province, which is characterized by gently rolling hills made of nearly flat-lying Permian (299 million to 251 million years ago) red sandstones and shale (Johnson and Luza 2008). The rock units in the area are the Cloud Chief Formation, Doxey Shale, and Elk City Sandstone. These marine, coastal, and fluvial units, respectively, record the withdrawal of a Permian sea from the area (Neil Suneson, geologist, Oklahoma Geological Survey, personal communication during scoping, May 13, 2011).

Structurally, the national historic site lies on the southern flank of the Anadarko Basin, a deep sedimentary basin that covers approximately 130,000 $km^2$ (50,000 $mi^2$) and contains over 12,190 m (40,000 ft) of sedimentary deposits. The basin subsided and filled with sediment while adjacent areas, such as the Amarillo-Wichita uplift, were folded and thrust upward. The "Amarillo uplift" is the portion of the uplift in Texas. The "Wichita uplift" is the portion in western Oklahoma. Most of the subsidence of the basin and uplift of adjacent strata occurred during the Pennsylvanian Period (318 million to 299 million years ago). There is a hint that uplift started in the latest Mississippian Period (328 million to 318 million years ago) and lasted through the earliest Permian Period (299 million to 270 million years ago), but 95% of the action was during the Pennsylvanian Period (Neil Suneson, geologist, Oklahoma Geological Survey, written communication, July 27, 2011).

The national historic site commemorates the site of the Southern Cheyenne village of Peace Chief Black Kettle, which was attacked just before dawn on November 27, 1868, by the 7th U.S. Cavalry under the command of Lieutenant Colonel George A. Custer. The national historic site contains the area that was the focus of the conflict, including Black Kettle's winter camp; the site where Black Kettle and his wife, Medicine Woman Later, were killed; and the pony kill site, where an estimated 800 Cheyenne horses were slaughtered by the 7th Cavalry. Areas covered by U.S. Cavalry military maneuvers are both within and outside the boundaries of the national historic site (see fig. 9). Included within the boundaries are a trail corridor between the overlook and the Washita River, and a contemplation area on the southern banks of the Washita River where it enters the national historic site.

In 1868, Black Kettle's winter camp was located on the floodplain of the Washita River—a single, low-gradient channel that meanders through the area (fig. 4). The Washita River is a tributary of the Red River, one of two drainage basins within the state; the other is the Arkansas River drainage to the north. About one-third of Oklahoma is within the Red River drainage basin. The water ultimately flows through Arkansas and Louisiana to the Atchafalaya River near the Mississippi River (Johnson and Luza 2008). The headwaters of the Washita River are in the northeastern part of the Texas Panhandle. The Washita River flows 80 km (50 mi) from its source before entering the national historic site, immediately upstream of Cheyenne, Oklahoma.

The event commemorated at Washita Battlefield National Historic Site is tied closely to two other National Park System units: Sand Creek Massacre National Historic Site in Colorado, where on November 29, 1964, U.S. soldiers attacked another peaceful encampment of Arapaho and Cheyenne people, including Black Kettle; and Little Bighorn Battlefield National Monument in Montana, which memorializes one of the last armed efforts of the Plains Indians to preserve their way of life.

During the Battle of the Little Bighorn in 1876, an allied force of several thousand Lakota, Arapaho, and Cheyenne warriors killed 263 soldiers and attached personnel of the U.S. Army, including Lieutenant Colonel George A. Custer and all of the men under his command. Scoping participants pointed out a singularly significant connection between the stories of Washita and Little Bighorn battlefields through Magpie, a Cheyenne youth, who survived the attack at Washita and eight years later fought at the Battle of the Little Bighorn.

**Figure 4. Washita River. From its headwaters in the Texas Panhandle, the Washita River meanders across the entire length of the national historic site, entering on the west after flowing 80 km (50 mi) from its source. Photo by Katie KellerLynn.**

## Geologic Mapping for Washita Battlefield National Historic Site

During the scoping meeting, Phil Reiker (Geologic Resources Division) presented 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, Federal Geographic Data Committee (FGDC)–compliant metadata, a help file that captures ancillary map data, and a map document that displays the map and provides a tool to directly access the help file.

When possible, the GRI Program provides large-scale (1:24,000) digital geologic map coverage for each unit's area of interest, which is generally composed of the 7.5' quadrangles that contain NPS-managed lands. In the lower 48 states, large-scale mapping is usually defined as "one inch to 2,000 feet" or quadrangles produced at a scale of 1:24,000 on a 7.5' × 7.5' base. There are thirty-two 7.5'

quadrangles on a 30' × 60' (scale 1:100,000) sheet. 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 resource management begins with the identification of existing geologic maps in the vicinity of the National Park System unit. Scoping participants then discuss mapping needs and select appropriate source maps for the digital geologic data or, if necessary, develop a plan to obtain new mapping.

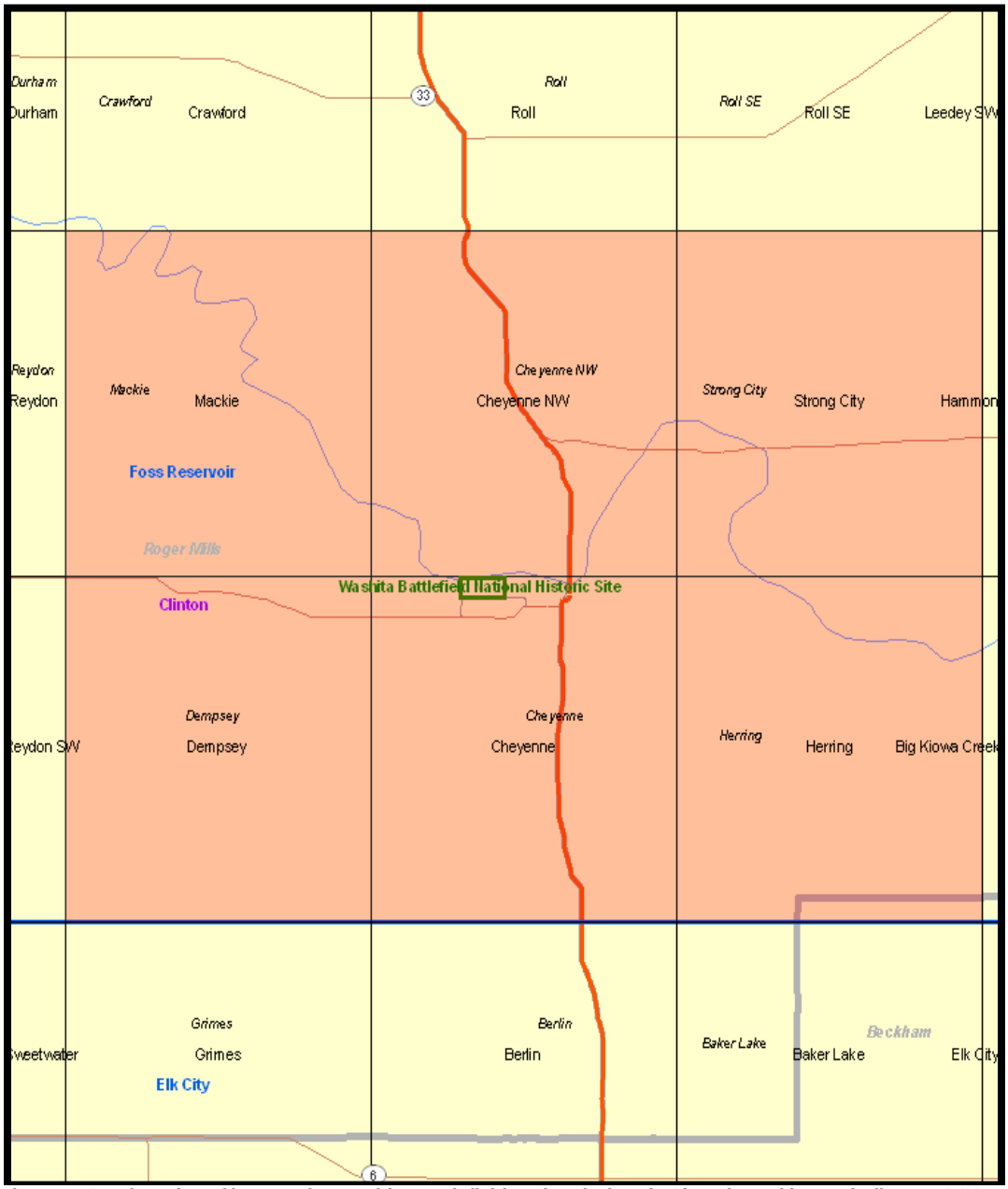


**Figure 5. Quadrangles of interest for Washita Battlefield National Historic Site. The red boxes indicate USGS 7.5' quadrangles of interest. GRI staff will digitize the geologic data of these quadrangles once the Oklahoma Geological Survey has completed mapping in the area. The 30' × 60' sheet for the area of interest is the Foss Reservoir (labeled in blue); the Elk City 30' × 60' sheet is immediately to the south.**

Prior to the scoping meeting, the National Park Service had identified six 7.5' quadrangles of interest for Washita Battlefield National Historic Site: Mackie, Cheyenne NW, Strong City, Dempsey, Cheyenne, and Herring (fig. 5). Scoping participants agreed that these quadrangles would provide adequate coverage for resource management at the national historic site. Unfortunately, no large-scale, geologic data are available for these quadrangles. However, Tom Stanley (Oklahoma Geological Survey) is currently working on the Foss Reservoir 30' × 60' sheet (scale 1:100,000), which covers these 7.5' quadrangles. Tom Stanley anticipates completing this project within the next two years. Scoping participants decided to wait for the completion of this map, which would then serve as the source for the digital geologic data for Washita Battlefield National Historic Site.

Significantly, at the 1:100,000 scale, the contact between the Cloud Chief and Doxey formations, which is often difficult to distinguish in this area, will be mapped. In addition, many of the Quaternary deposits in the Washita River corridor such as alluvium, various levels of terrace deposits, sand sheets, and sand dunes will be identified and mapped (see "Eolian Features and Processes" and "Fluvial Features and Processes"). Mapping terrace levels will show where the Washita River flowed in the past. Age dates of charcoal deposits on the terraces would also be useful in understanding the evolution of the landscape, in particular what the site looked like at the time of the battle. Scoping participants discussed the benefit of a partnership with the Oklahoma Archaeological Survey, possibly to map and study terraces along the Washita River. Such collaboration could provide a fuller, geoarchaeological context for changes to the landscape of the national historic site. Possible contacts for this information include Lee Bement of the Oklahoma Archaeological Survey (lbement@ou.edu) and Don Wyckoff of the University of Oklahoma, Department of Anthropology (xtrambler@ou.edu).

## Geologic Features, Processes, and Issues

The scoping meeting for Washita Battlefield National Historical Site provided an opportunity to discuss geologic features and processes, many of which have associated issues of management concern.

### Fluvial Features and Processes

The primary fluvial feature at Washita Battlefield National Historic Site is the Washita River, which is an integral component of both the natural and cultural landscape. The confluence with Sergeant Major Creek, located just downstream but not within the boundaries of the national historic site, also has significance for the battle. At this confluence, Major Joel Elliot and his men died at the hands of Arapaho and Cheyenne warriors. After entering the village with Custer, Elliot led a small detachment in pursuit of fleeing Indians; he and his troops were cut off and killed by warriors who had camped downstream from Black Kettle's village (National Park Service 2009).

In selecting the location for a winter camp, Black Kettle and his followers apparently chose this site because it was close to a water supply that was sufficient for the tribe and its horses: Black Kettle's camp included 51 lodges (Lees et al. 2001) and covered approximately 10 ha (25 ac) on the south side of the river (Marston and Halihan 2007). Black Kettle's camp was located upstream from Arapaho, Kiowa, and other Cheyenne camps, whose people and horses also needed water (see fig. 9). At the time of the attack, the riparian zone was enclosed by a canopy of cottonwood trees, which would have provided shelter and fuel for winter fires (Reber et al. 1999). Smaller, intermittent

drainages that led down to the Washita River were used by the Cheyenne for retreat and as hiding places during the attack. These same drainages also provided attack routes for pursuing U.S. troops.

At the time of the battle, the Washita River was a perennial, meandering stream that formed a series of horseshoe bends within and in the vicinity of the national historic site (Haecker 2000). Black Kettle's village was situated within one of these meander bends (Haecker 2000). The channel was 3 m (10 ft) to 4 m (13 ft) wide with steep banks exposed during low-flow conditions, for example, in November when the attack occurred (Barde 1900; Marston and Halihan 2007).

Because the Washita River is a naturally meandering river, the channel has migrated since 1868, potentially across the site of Black Kettle's camp. According to Marston and Halihan (2007)—a study of the geomorphic adjustment of the Washita River—the location of Black Kettle's village is now on the north side of the river as a result of natural meandering and artificial modifications. Between 1910 and 1930, land owners (farmers) created two artificial meander cutoffs to direct waters to irrigate crops. Scoping participants noted that there is a raised levee on the north side of the river, which was built as part of this water diversion project and also to provide flood control. In addition, disturbances during the Dust Bowl of the 1930s resulted in changes to the channel and flood regime; namely, poor agricultural practices led to excessive sediment supply and frequent floods (Cooke and Reeves 1976).

Changes also have occurred to Sergeant Major Creek. Since 1868, the creek has been straightened and channelized because it was impacting the railroad bridge, which was built in 1928–1929. The creek is now 6 m (20 ft) east of where it was at the time of the battle. According to scoping participants, the location of the former channel is apparent on images from Google Earth (fig. 6).


**Figure 6. Sergeant Major Creek. South of the confluence with the Washita River, Sergeant Major Creek has been diverted and channelized. Google Earth image (accessed July 14, 2011).**

Now controlled by a series of dams, flooding on the Washita River is not a serious issue for infrastructure at the national historic site. Under present conditions, the river channel is sometimes dry. In the past, both before and after the 1868 battle, flooding across the entire floodplain had been a natural and regular process of the Washita River (Marston and Halihan 2007). Scoping participants mentioned how the loss of flooding has resulted in the loss of seed banks for replenishing native vegetation such as cottonwood. Seasonal and periodic large-scale flooding events ended in the 1950s when the flood-control structures were placed on the Washita River and many of its tributaries. Notably, Roger Mills County was the first county in the state to host a large, flood-control system. Occasionally, flooding does still occur within the national historic site, but only when check dams upriver fail, for example, during wet spring periods. In spring 2007, under such conditions, 0.3-m- (1-ft-) deep floodwaters covered the floodplain at the national historic site, much to the pleasure of park biologists who were hoping for the replenishment of seed banks.

Significant fluvial features at the national historic site include terrace deposits. Terraces are former floodplains and mark the positions of earlier streams. Tom Stanley (Oklahoma Geological Survey) will identify the terraces in the area while mapping the Foss Reservoir 30' × 60' sheet (see "Geologic Mapping for Washita Battlefield National Historic Site"). Previous investigations identified three terrace levels above the present-day floodplain at Washita Battlefield National Historic Site. For instance, according to Lees et al. (2001), the highest and oldest terrace level is situated 6 m (20 ft) to 7 m (23 ft) above the riverbed. A younger terrace level, found primarily on the north side of the river, is approximately 3.5 m (11 ft) above the riverbed. The youngest terrace level is 2.5 m (8 ft) to 3 m (10 ft) above the riverbed. Haynes (1995), which provided an assessment of the geology at Washita Battlefield, proposed this youngest/lowest terrace level as the surface most likely for the location of Black Kettle's camp, but archaeological evidence has not confirmed this (Lees et al. 2001).

Scoping participants suggested that Alex Simms—an alumnus of Oklahoma State University and presently an assistant professor at the University of California in Santa Barbara—might be a resource for work already completed on the terraces along the rivers in Oklahoma. Post-scoping correspondence confirmed this. Simms is currently working on some fluvial terraces in the panhandle; he stated, "If you need anything else on the Washita, I love working at rivers in Oklahoma" (Alex Simms, assistant professor, University of California–Santa Barbara, e-mail communication, June 27, 2011). Currently, Simms has a student working on a Master's thesis who is mapping fluvial terraces throughout a small drainage basin—approximate 15 km (9 mi) long—that feeds into the Beaver River (North Canadian). This student is using sedimentary deposits to determine what types of depositional environments occurred along the drainage through time and how climate has affected the morphology of the river (Alex Simms, assistant professor, University of California–Santa Barbara, e-mail communication, June 27, 2011). Potential funding for a project within the national historic site could come from the Geoscientists-in-the-Parks (GIP) Program, administered by the Geologic Resources Division in collaboration with the Geological Society of America. Lisa Norby (Geologic Resources Division) is the contact for the GIP Program (lisa_norby@nps.gov or 303-969-2318).

Another fluvial feature of interest discussed during scoping is the Canadian River to the north of Washita Battlefield National Historic Site. The Canadian River serves as the boundary between Ellis and Roger Mills counties in Oklahoma. The headwaters of the Canadian River are in the

Sangre de Cristo Mountains of New Mexico, while the headwaters of the Washita River are in the panhandle of Texas. This geographic difference resulted in the terraces along the Canadian River having a glacial input of meltwater and material during the Pleistocene Epoch (2.6 million to 11,700 years ago), while no such input occurred for the terraces along the Washita River. Nevertheless, scoping participants suspected that numerous base-level changes have occurred along the Washita River as a result of past changes in climate.

### Disturbed Lands

In addition to changes in the fluvial system at Washita Battlefield, the land surface has also experienced change. As the area was homesteaded and population increased, the trees along the Washita were cut and used for timber, the soil was tilled, fences were erected, and terraces were cut into slopes to slow runoff during the drought years of the 1930s (National Park Service 2001). In addition, the Panhandle and Santa Fe Railroad constructed a line across the site in 1928–1929 (Cowley 1999). During construction, several small drainages were diverted or rerouted (Greco 2002). The railroad bed/grade altered the natural hydrology of the site by acting as a dam or constriction to local drainages (Greco 2002). The national historic site's general management plan proposes to remove the railroad bed, restoring a portion to the original grade and using other sections as part of the trail system. In 2001, staff at the national historic site contacted the Geologic Resources Division for technical assistance in removing the railroad bed. The resulting analysis and report provided information on site conditions, suggested the type and scale at which restoration might take place, identified factors that may enhance or limit the success of restoration activities, and included estimated costs for materials and equipment.

### Oil and Gas Development

Scoping participants stated that the national historic site is "surrounded by oil and gas development." Washita Battlefield National Historic Site is situated in the Anadarko Basin, which is one of the most prolific hydrocarbon producers in the continental United States (Ball et al. 1991). The sources of hydrocarbons are the Pennsylvanian (318 million to 299 million years ago) Atoka and Morrow shales (Neil Suneson, geologist, Oklahoma Geological Survey, written communication, July 27, 2011). The basin covers 25 counties in southwestern Kansas, 23 counties in northwestern Oklahoma, 13 counties in the northernmost part of the Texas Panhandle, and two counties in southeastern Colorado (Ball et al. 1991). Sediments from the Cambrian though Permian periods (542 million to 251 million years ago) are more than 12 km (8 mi) thick in the deepest part of the basin (Ham and Wilson 1967).

A primary issue for the protection of resources at Washita Battlefield National Historic Site is an active pipeline. The pipeline crosses the national historic site from the west side, just below the Washita River, to the north side, midway along the site's boundary. There also may be an abandoned pipeline within the site boundaries (Richard Zahm, park ranger, Washita Battlefield National Historic Site, telephone communication, June 28, 2011). In addition, preserving natural sounds and night skies in the midst of "oil and gas country" is a concern.

Recent oil and gas activities at the national historic site include a 3D seismic survey, conducted by ConocoPhillips in 2007. The survey was cable-only via foot traffic; that is, no trucks (McCoy 2007). The Geologic Resources Division provided comments to the "plan of operations" for this

project. The plan of operations is an operator's blueprint covering the scope of activities inside park boundaries including measures to protect park resources and values.

The national historic site's general management plan includes desired conditions and strategies related to oil and gas development. Moreover, Washita Battlefield National Historic Site and Roger Mills County have an emergency operations plan for handling hazardous spills (Richard Zahm, park ranger, Washita Battlefield National Historic Site, telephone communication, June 28, 2011). The National Park Service addresses nonfederal oil and gas development in parks under the Code of Federal Regulations (CFR), namely 36 CFR, Part 9, Subpart B ("9B regulations"), which covers minerals management. The regulations require a prospective operator to (1) demonstrate its right to the oil and gas, (2) submit and obtain NPS approval of a plan of operations, and (3) post a performance bond.

## Eolian Features and Processes

Turbines on Dempsey Ridge attest to the ubiquitous nature of the wind in western Oklahoma (fig. 7). There are currently 66 operating wind turbines. By the end of 2011, an additional 66 turbines are expected to be erected at this nearby wind farm. The primary concern with the development of wind energy in the vicinity of Washita Battlefield National Historic Site is preserving the site's viewshed: Washita is a place of contemplation where unobstructed views aid visitors in remembering and understanding the past. Thus far, managers at the national historic site have had good cooperation with wind-energy companies in preserving significant views. The Southern Plains Network is in the process of completing a conditions assessment for Washita Battlefield National Historic Site, which will address the development of wind energy (Rob Bennetts, program manager, Southern Plains Network, personal communication during scoping, May 13, 2011).

Geologic features also document the wind's handiwork on the landscape, including sand sheets and dunes. Although smaller scale maps—such as the geologic map for the state of Oklahoma (Heran et al. 2003; scale 1:250,000)—do not show dunes or other windblown deposits within the boundaries of Washita Battlefield National Historic Site, dune sand is mapped to the south and southeast. While mapping the Foss Reservoir 30' × 60' sheet (scale 1:100,000), Tom Stanley (Oklahoma Geological Survey) will break out the various types of eolian deposits (e.g., dune sand, sand sheets, and loess), some of which are likely to occur within the national historic site. Scoping participants suspected that nearby areas of sand sheets may be relicts of the Dust Bowl of the 1930s. Farther north, where the presence of dunes is prevalent, vegetation has stabilized many sand dunes.

A distinctive eolian feature across Oklahoma is windblown volcanic ash. Scoping participants knew of windblown ash occurring throughout the Miocene Ogallala Formation in Oklahoma. Participants pointed out a discrepancy: the ash occurs in Miocene (23 million to 5.3 million years ago) rocks, but the ash itself is documented as younger, that is, Pleistocene (2.5 million to 11,700 years ago) in age (see Izett and Wilcox 1982). Older ash beds have been found in the Panhandle region, but they are rare (e.g., Perkins 1998; Cepeda and Perkins 2006). Scoping participants suggested that Brian Carter, a soil scientist at Oklahoma State University, would be a resource for information about ashes in the area (brian.j.carter@okstate.edu or 405-744-9585). Carter has worked on floodplain reconstruction and geomorphic evolution of rivers using ash deposits in soils (see Carter et al. 1990; McQueen et al. 1993; Ward et al. 1993).

**Figure 7. Wind farm near Washita Battlefield National Historic Site. Wind turbines line Dempsey Ridge. Sixty-six additional turbines are slated to be constructed by the end of 2011. Photo by Katie KellerLynn.**

## Cave and Karst Features and Processes

No caves are known within Washita Battlefield National Historic Site. However, dissolution and collapse—processes related to the formation of caves and karst—are part of the landscape. The presence of collapsed strata results in unusual strikes and dips of what otherwise should be flat-lying strata in the area (Neil Suneson, geologist, Oklahoma Geological Survey, written communication, July 27, 2011).

Because evaporite rocks or "salts"—primarily halite but also gypsum—are components of the Permian red beds, sinkholes are known to form as a result of dissolution. Although sinkholes are not a notable geologic hazard at the national historic site, scoping participants warned of using fresh water when drilling into Permian strata. They discussed the "worst case scenario" of Wink Sink in Winkler County, Texas, where a huge sinkhole suddenly appeared on June 3, 1980. A second sinkhole, "Wink Sink 2," formed in May 2002. The Wink Sink brought nationwide publicity to Winkler County in the days and weeks that followed the collapse. The cause of collapse was dissolution of salt in the Permian Salado Formation (Baumgardner et al. 1982).

Salt dissolution results in the collapse of overlying strata into the collapse feature. Material that fills the collapse feature, called "collapse breccia," provides hints to the geologic history of the area that would have otherwise been eroded away. Often, collapse features become inverted topographic forms on the landscape, for instance, near the entrance of the national historic site (fig. 8). Erosion stripped away the sediments surrounding the collapse breccia, leaving a consolidated hillock above the ground surface.

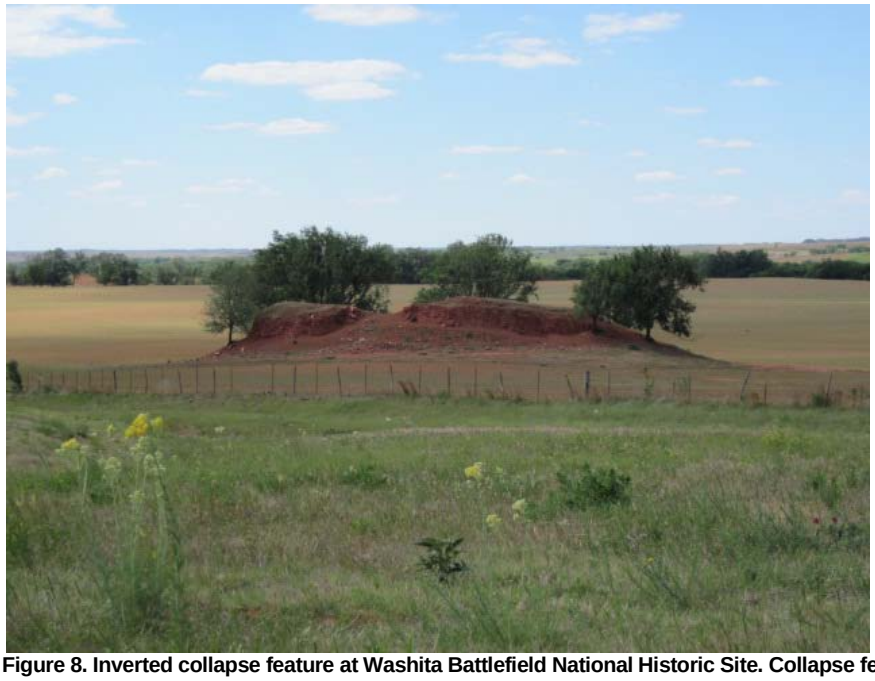

**Figure 8. Inverted collapse feature at Washita Battlefield National Historic Site. Collapse features form as a result of dissolution of salts in the Permian red beds. Collapse features are filled in by overlying sedimentary layers. Erosion removes the sediment surrounding the consolidated material of the collapse feature, leaving a mound in relief, such as this one near the entrance of the national historic site. Photo by Katie KellerLynn.**

## Lacustrine Features and Processes

There are many lakes in Oklahoma; most are artificial reservoirs, created by damming streams for flood control, water supply, recreation, and hydroelectric power (Johnson and Luza 2008). There are no lakes within Washita Battlefield National Historic Site. The closest lake is the Foss Reservoir, 50 km (30 mi) downstream. In addition, playa lakes occur to the north of the national historic site. Playa lakes are ephemeral and rarely persist year-round (Oklahoma Water Resources Board 1990). They form in shallow, saucer-like depressions scattered across the semiarid High Plains in northwestern Oklahoma and the panhandle (Johnson and Luza 2008).

## Paleontological and Archaeological Studies

Koch and Santucci (2003) completed an inventory of the paleontological resources for Washita Battlefield National Historic Site, documenting that no fossils have been found within the boundaries of the national historic site. However, Janet Brown, a GeoScientists-in-the-Parks (GIP) participant, discovered fossils from the Cloud Chief Formation just east of the boundary (Brown 2001). Findings included cup corals, coiled cephalopods, and trace fossils of worm trails. Moreover, scoping participants suggested that Pleistocene mammal fossils may occur in the alluvial deposits within the national historic site. Also, the Miocene Ogallala Formation occurs in the Antelope Hills and Twin Hills, which are within the viewshed of the national historic site. The Ogallala Formation is a well-known fossiliferous unit and contains a diverse fossil mammal fauna, including ancestors of antelope, camel, horse, elephant, leopard, and llama (Koch and Santucci 2003).

For related information about the paleontology, general geology, and archaeology of Washita Battlefield National Historic Site, scoping participants suggested work by Douglas Scott, now retired from the NPS Midwest Archaeological Center in Lincoln, Nebraska. Also, C. Vance Haynes, an archaeologist at the University of Arizona, conducted geomorphic investigations of the Washita

River valley in conjunction with an archaeological survey by Lees (1997). A multi-disciplinary approach studying the Quaternary sediments at Washita Battlefield National Historic Site may reveal significant finding about various resource types—geological, paleontological, and archaeological.

## Unique Geologic Features

For Washita Battlefield National Historic Site, "unique geologic features" are directly connected to the events that took place on November 27, 1868. These features are primarily topographic, or from a geologic perspective, they are landforms created through geomorphic processes.

The main geomorphic feature at the national historic site is fluvial, that is, the floodplain of the Washita River where Black Kettle and his people set up their winter camp (see "Fluvial Features and Processes"). Other significant landforms include ridgelines and knolls. During the conflict, U.S. Cavalry forces used the ridgelines in the area to their advantage, completely encircling Black Kettle's camp and effectively reducing escape routes. The low-lying position of Black Kettle's camp with its bordering alluvial terraces had apparently been selected to offer a modicum of protection from the winter winds prevalent on the Great Plains (Reber et al. 1999). However, the location became a deadly trap during hostile conditions (Cowley 1999). Furthermore, the cavalry used topographic highs as lookouts, for example, "Custer's Knoll," which served as the starting point for the attack. At dawn, Custer charged with the largest group of men straight into the village. Captain William Thompson circled his men far right to attack from the southwest. Captain Edward Myers led his men also to the right, but closer to the camp through a grove of trees. Major Joel Elliot and his men attacked from the southeast (fig. 9).

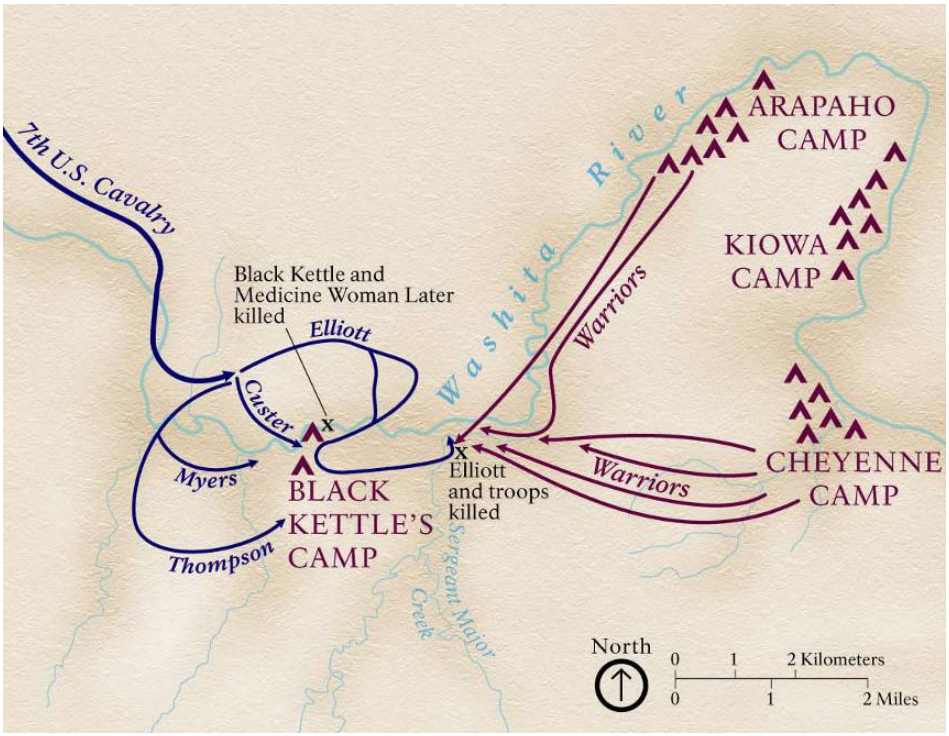


**Figure 9. The Battle of the Washita. On November 27, 1868, Lieutenant Colonel George A. Custer, commanding the 7th U.S. Cavalry, attacked Peace Chief Black Kettle's winter camp on the banks of the Washita River. Later, at the confluence with Sergeant Major Creek, warriors from other camps downstream attacked and killed Major Joel Elliott and a detachment of men who were pursing fleeing Indians from Black Kettle's camp. National Park Service graphic.**

Other “unique geologic features” are building stones used to commemorate the events that took place at Washita Battlefield National Historic Site. These stones are both historic and geologic resources. If mined locally, building stones can help to interpret the geologic setting of a National Park System unit. If mined elsewhere, the stones can contribute to a geologic understanding of regional, national, or even global settings, and also may help provide a “sense of place” for visitors to make connections.

During the site visit, participants noted several granite monuments at the overlook. The red granite memorial (fig. 10) was placed in 1932 and predates the national historic site, which was established in 1996. Participants suspected that the stone for the memorial was mined in Granite, Oklahoma, where Cambrian (542 million to 488 million years ago) granite is exposed at the surface as part of the Wichita uplift. Based on figure 10, Dr. David London (University of Oklahoma) confirmed this suspicion. He stated, “The red looks like ordinary Wichitas red granite to me. The small mafic enclaves are a familiar characteristic” (David London, professor, University of Oklahoma, e-mail communication to Neil Suneson, geologist, Oklahoma Geological Survey, July 18, 2011).


**Figure 10. Red granite memorial. Placed in 1932, this memorial commemorates the Battle of the Washita on November 27, 1868, and is most likely made of Cambrian granite from southern Oklahoma. Photo by Katie KellerLynn.**

The stone for the gray granite monument/interpretive sign (fig. 11) was prepared by Willis Granite Products in Granite, Oklahoma (see http://www.willisgranite.com; accessed July 14, 2011) (Richard Zahm, park ranger, Washita Battlefield National Historic Site, telephone communication, June 28, 2011). However, the gray color suggests that the granite was probably mined elsewhere (Neil Suneson, geologist, Oklahoma Geological Survey, telephone communication, July 18, 2011). Dr. London confirmed that the gray building stone does not look like Oklahoma rock, although some of the “autumn rose” building stone quarried in Troy, Oklahoma, is “pretty much gray” (David London, professor, University of Oklahoma, e-mail communication to Neil Suneson, geologist, Oklahoma Geological Survey, July 18, 2011). This memorial was placed in 1963. The National Historic Landmark marker (brass plate on granite base) was placed at the overlook in 1965 when the

site became a registered national historic landmark. Like the interpretive sign, the geologic origins of this gray building stone are unknown but probably not from Oklahoma.


**Figure 11. Gray granite interpretive sign. "The Battle of the Washita" interpretive sign was placed at the overlook in 1963. The stone was prepared in Granite, Oklahoma, though most likely not mined there. Photo by Katie KellerLynn.**

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