All-Day Field Trip: Minuteman Missile National Historic Site and Badlands National Park

An additional registration fee is required for this field trip.

The trip is limited to the first 50 registrants.

The trip is open to all professionals, honoraries, guests, and spouses.

Schedule:  
6:30 – 7:15 AM Breakfast: Pine Crest Ballroom C  
7:15 – 7:30 am Bus loading at main entrance to hotel  
7:30 AM Bus departure  
5:00 PM Return: The Lodge at Deadwood

The field trip begins with a 2-hour drive to Launch Facility Delta-09 which is part of the National Park Service’s Minuteman Missile National Historic Site. Here, a National Park Service Ranger will provide a brief presentation on the National Historic Site. Delta-09 was part of the Minuteman I and II missile systems that once dotted the landscapes of South Dakota, North Dakota, Missouri, Montana, Wyoming, Colorado, and Nebraska. Currently, Minuteman III missiles remain active in Wyoming, Montana, North Dakota, Colorado, and Nebraska. For nearly 30 years, these missiles and their facilities remained on continuous alert serving an important role in America’s triad of defense, including land-based ICBMs.

After visiting Launch Facility Delta-09, we will travel for another 19 miles to the northeast entrance of Badlands National Park. There, we will be joined by Dr. Rachael Benton, Park Paleontologist, and Dr. Emmett Evanoff, Assistant Professor of Geology at the University of Northern Colorado, who will lead the remainder of the trip through the Park. The Badlands of South Dakota is one of the most remarkable areas in North America, noted for its stark beauty, exceptional vertebrate fossils, and unique geologic history. This field trip will visit a portion of the 380 square mile park and provide access to experts on Park geology and spectacular views of White River Group stratigraphy, including some Tertiary-age faulting.

Very minimal walking will be required on this field trip as we will use the bus to travel from vista to vista. A box lunch will be provided at our stop at the Park’s Ben Reifel Visitor Center. There will be some time for browsing in the gift shop, viewing the exhibits, and watching activities in the fossil preparation lab. Our last stop in the Park will be followed by a 2-hour drive back to Deadwood.

What to wear: Casual dress; comfortable walking shoes or hiking boots; jacket; hat; sunglasses

What’s provided: Bottled water; box lunch (sandwich, chips, cookie, apple, soda)

June averages for Badlands National Park:  
High temperature: 83° F  
Low temperature: 56° F  
Precipitation: 3.12 inches

The field guide for this trip is provided below and will be given to all field trip participants on the bus.
Field Trip to the Minuteman Missile National Historic Site and Badlands National Park

June 9, 2013
MINUTEMAN MISSILE NATIONAL HISTORIC SITE

Launch Facility Delta-09, part of the Minuteman Missile National Historic Site, is located southeast of Wall, South Dakota, near Exit 116 on Interstate Highway 90 (fig. 1).

Figure 1. Location of Launch Facility Delta-09, Minuteman Missile National Historic Site.

The following information about the Minuteman Missile National Historic Site was taken from a National Park Service web site: http://www.nps.gov/mimi/index.htm.

Deterring War, Preserving Peace

The Cold War – an event lasting almost 50 years in human history that caused fear, panic, and distrust during the time of nuclear weapons development in the United States and Soviet Union. Minuteman missiles held the power to destroy civilization, but this destructive force also acted as a nuclear deterrent which maintained peace and prevented war.

Significance of Minuteman Missile National Historic Site

Delta-09 was part of the Minuteman I and II missile systems that once dotted the landscape of South Dakota, North Dakota, Missouri, Montana, Wyoming, Colorado, and Nebraska. Minuteman III missiles remain active in Wyoming, Montana, North Dakota, Colorado, and Nebraska. For nearly thirty years these missiles and their facilities remained on continuous alert and served an important role in America’s triad of defense, including land-based ICBMs.
Stop 1 – Launch Facility Delta-09, Minuteman National Historic Site. The National Park Service has preserved a piece of the country’s cold war history that will be explained by a National Park Service Ranger. Some photos of the site are provided in figure 2 and a schematic of the layout/cross section of the site is shown in figure 3.

![Launch Facility Delta-09 - Operational](http://nonplused.org/panos/minuteman/html/delta09.html)

![Launch Facility Delta-09 - Today](http://nonplused.org/panos/minuteman/html/delta09.html)

![Minuteman II training missile at Delta-09](http://nonplused.org/panos/minuteman/html/delta09.html)

![Personnel access hatch](http://nonplused.org/panos/minuteman/html/delta09.html)

Figure 2. Some photos of Launch Facility Delta-09.
From http://nonplused.org/panos/minuteman/html/delta09_axo.html

Figure 3. Site Plan for Delta-09.
Introduction

The Big Badlands of South Dakota is one of the most remarkable areas in North America, noted for its stark beauty, exceptional vertebrate fossils, and unique geologic history. The Park includes 243,302 acres (380 square miles; 985 square km) shown in figure 4. This field trip will visit a portion of the park and will stop at locations indicated on figure 5. This guide concerns the White River Group exposed in the North Unit of the Park. The name “Badlands” is essentially a translation of the Lakota name for the area, mako sica, and the French name mauvais terre a traverse. The name does not refer to anything evil about the area, but refers to how hard it is to cross the area by foot. One can hike along the Badlands Wall (the main ridge of badlands in the North Unit) for miles and not be able to find even a game trail that crosses the badlands. However, the badlands expose, over many miles, one of the most complete records of upper Eocene and lower Oligocene terrestrial rocks anywhere in North America and contains one of the world’s most abundant vertebrate fossil records for the late Eocene and early Oligocene. The Quaternary deposits of the North Unit have also been the subject of a Geological Society of America field guide by Burkhart and others (2008).

The White River Group is composed of abundant volcanioclastic mudstones, siltstones, and fine-grained sandstones, and less abundant claystones, conglomerates, limetstones, and tuffs (lithified volcanic ash). The White River Group was deposited during the late Eocene and early Oligocene, and represents a depositional pulse in the Great Plains resulting from a great influx of volcanic ash and dust from the west. The White River Group and its equivalents extend from western North Dakota to east-central Colorado and from western Wyoming to east-central Nebraska and South Dakota. This huge region was blanketed by volcanioclastic sediment that had an estimated volume of about 25,000 km³ (Larson and Evanoff, 1998). From regional studies of the distribution, mineralogy, geochemistry, paleomagnetism, and numeric ages of the tuffs in the White River sequence, Larson and Evanoff (1998) determined that most of the tuffs were derived from eruptive centers in the Great Basin of Nevada and Utah. However, the vast majority of silt-sized volcanic ash was deposited west of Badlands and was later blown to the area as dust or was washed into the area by streams. The White River rocks are now very rich in swelling smectitic clay derived from the weathering and diagenesis of small volcanic glass shards.
Figure 4. Map of Badlands National Park.
Figure 5. Map inset from figure 4 showing field trip stops in Badlands National Park.
The prominent banding seen throughout the Badlands is mainly the result of ancient soil formation. Following each depositional event, soil formation modified the sediments through various physical, chemical, and biological processes to produce soil profiles. Particular bands of color, since modified by diagenesis, represent distinct horizons within these ancient profiles. The types of horizons that formed represent an archive of paleoclimatic and paleoenvironmental conditions during the deposition of the Badlands. In addition to the vibrant striping, macroscopic evidence of ancient soil formation includes fossil roots, nodules and concretions, mottling, peds, and trace fossils. Based on analyses of paleosols from the bottom to the top of the Badlands, paleoclimates changed from humid to progressively arid conditions from the Eocene to Oligocene (Retallack, 1983).

The White River Group in the North Unit of Badlands National Park is divided into three formations, including the Chamberlain Pass, Chadron, and Brule Formations (fig. 6). The Chamberlain Pass Formation (Evans and Terry, 1994) is the basal unit of the White River Group and includes a series of intense red, highly pedogenically altered overbank deposits called the Interior Paleosol Series of Retallack (1983). Associated with this paleosol are unique silica-rich conglomerates and scattered, very white cross-bedded sandstone channels that are included in the Chamberlain Pass Formation. The few mammal fossils that occur in the Chamberlain Pass rocks (outside of the Park) are Duchesnian and early Chadronian in age (LaGarry and others, 1996). Below the Chamberlain Pass is a strong weathering zone, developed on Cretaceous rocks, called the Yellow Mounds paleosol. These Upper Cretaceous rocks include the Pierre Shale and Fox Hills Formation. The Pierre Shale is composed primarily of black shales and represents open marine deposition, while the Fox Hills, composed of alternating shale and sandstone beds, was the result of deltaic progradation into the retreating Western Interior Seaway. The Chadron Formation in most of the North Unit of the Park is composed of a thin sequence (typically 10 to 15 m thick) of gray claystone beds that weather into rounded gray hills. The fauna of the Chadron Formation is characterized by the remains of the huge, rhino-like brontotheres that characterize the Chadronian Land Mammal Age. The Brule Formation is divided into the Scenic and Poleslide Members. The Scenic Member is composed of alternating widespread mudstone layers and silty sandstone layers. The Poleslide Member is dominated by widespread thick siltstone layers interbedded with a few widespread silty sandstone intervals. Traditionally, the Scenic and Poleslide Members have been distinguished by their fauna, with the Scenic Member representing all of the rocks containing a fauna of the Orellan Land Mammal Age, and the Poleslide Member containing a fauna of the Whitneyan Land Mammal Age (fig. 7). The Orellan Land Mammal Age is characterized by abundant oreodonts (*Merycoidodon* ssp), tortoises (*Stylemys* ssp), and horses (*Mesohippus* ssp), and the lack of brontotheres. These Orellan taxa also occur in the Whitneyan, but Whitneyan faunas are dominated by the oreodont *Leptauchenia* ssp. However, the two members are now defined on the lithologic change from mudstone-dominated sequences to siltstone-dominated sequences that occurs high in the Orellan rocks. In the North Unit of the
Most of the units and thicknesses reflect the eastern half of the North Unit. However, Chadron paleovalleys are found in the west side of the Park.

Figure 6. A generalized stratigraphic column of the White River Group exposed in the North Unit of Badlands National Park.
The proposed nomenclature of the Brule Formation is based on lithologic changes (not biostratigraphic changes) and correlation with the type sections in the western part of the North Unit.

Figure 7. Ages, existing stratigraphic nomenclature, and proposed nomenclature for the rocks in the east side of the North Unit of Badlands National Park.
Park, the Brule Formation is capped by conglomeratic beds at the base of paleovalley fills of the **Sharps Formation**. These “Sharps Channels” are filled by sandy siltstone beds containing a distinct fauna of the Arikareean Land Mammal Age, including the huge entelodont *Daenodon* (Parris and Green, 1969) (fig. 8).

The information given in this field guide related to the Badlands is a result of new information gathered over the past decade. Starting in 2000, Dr. Rachel Benton, Paleontologist for Badlands National Park, organized two major research projects to make paleontologic and geologic inventories of parts of the North Unit, first in the Scenic Member (during the years 2000-2002; Benton and others, 2006) and later in the Poleslide Member (2003-2004; Benton and others, 2009). Dr. Benton worked with Carrie Herbel of the South Dakota School of Mines and Technology supervising large paleontologic survey crews documenting thousands of fossil sites in the North Unit. These paleontologic studies were made in conjunction with detailed paleosol analyses of the bone beds by Dr. Dennis Terry of Temple University in Philadelphia, Pennsylvania, and detailed regional stratigraphic studies of the Brule Formation by Dr. Emmett Evanoff, now at the University of Northern Colorado, Greeley, Colorado. Several new stratigraphic units are described in these studies, but currently remain as informal stratigraphic units. These unit names (such as the *Hay Butte marker*, *Saddle Pass marker*, and *disappointment limestone interval*) are italicized in the following discussion.

The new information on the White River Group given in this field guide updates the previous geologic and paleontologic studies that have been made in the area since the 1850s.

Please note that the **collecting of fossils, rocks and any other natural items is not permitted in the Park** – please leave what you find for the enjoyment and education of others.
Figure 8. Representative fossil mammals of the White River Group in Badlands National Park.

Illustrations in this figure are from O’Harra (1920), Peterson (1909), Scott (1940, 1941), Scott and Jepsen (1936), and Wood (1937, 1940).
Stop 2 – Door and Window Trailhead. The north entry to the parking area for the Door and Window Trailhead is 2.3 miles from the northeast entrance to Badlands National Park. Exposures here provide one of the best places in the park to see the rocks of the Poleslide Member. The overlook is situated in the middle Poleslide, between the lower and upper sandstone intervals. The wall to the east has numerous small gaps, or “windows” that overlook extensive badlands cut into the Scenic Member by Rake Creek, a tributary of the White River. The north side of the overlook has a walking trail that extends through a large gap, or “Door,” onto a bedrock bench supported by the lower Poleslide sandstone interval. To the south, the lower Poleslide tan siltstone beds are capped by the Cedar Pass white layer below the base of massive light gray siltstone beds of the upper Poleslide. The top of Millard Ridge to the south is capped by Sharps Channels. The lower Poleslide sequence along the Door and Window ridge is 49 m thick, the upper Poleslide is 32 m thick, and the Sharps Formation is 22 m thick.

Paleosols and sediments within the Poleslide Member at this locality reflect a combination of soil formation within vertically changing depositional environments (fluvial, lacustrine, and eolian), and relative periods of nondeposition and landscape stability versus vertical accretion of eolian volcaniclastic sediments (fig. 9). The thick siltstone unit at the base of the Poleslide was formed by the first widespread accumulation of loess over most of the North Unit. This siltstone unit is capped by a widespread silty sandstone sequence representing fluvial deposits. These in turn were overlain by sediments from a period characterized by wetter conditions as manifested by lacustrine deposits and laterally associated soils with hydromorphy and greater degrees of weathering. Loess deposits dominate the majority of the Poleslide above the brown mudstones, and appear as massive siltstone units punctuated with regionally extensive resistant bands which represent former long-term, stable landscapes. Fossils within aggrading eolian deposits appear to be randomly distributed, whereas fossils associated with periods of geomorphic stability are concentrated within resistant paleosol horizons. Paleosols associated with this environment are weak at best and show evidence of hydromorphy. From a facies/environmental perspective, these strata represent a period of landscape stability. Carbonate-dominated lakes form in response to low siliciclastic input. Based on the carbonate rich nature of these lakes, it is likely that they were spring-fed, similar to the lacustrine environments and tufas described from the lower part of the section within the Chamberlain Pass Formation and at the Chadron/Brule Formation boundary (Evans and Terry, 1994; Evans and Welzenbach, 1998; Evans, 1998, 1999).

The Door and Window Trailhead is one of the most heavily visited areas in the Park. This area was part of the 3-year study conducted by the National Park Service and three other cooperating institutions to study the Poleslide Member outcrops in the Park. The Door and Window Trailhead provided valuable information on the impact of heavy visitor use on fossil-rich deposits. The trail system is often the first stop for major tour busses travelling through the Park. The development of board walks along the Door and Window
trails has channeled visitor traffic to some degree, but due to the lack of signage and abundance of social trails, this area is still heavily impacted. Even though the Middle Poleslide Member outcrops throughout the Door and Window trail system, very few fossils were found in this area. As the survey participants traveled beyond the high traffic areas, fossils were found again in greater accumulations. Once the trail system was created many years ago, fossils were quickly picked clean from the area. This supports the concept that heavily traveled areas are significantly more susceptible to the theft of vertebrate fossils.

Figure 9. Common depositional environments, paleosols, and associated fossils within the Poleslide Member.
Turn left out of the parking lot for the Door and Window Trailhead. In 0.5 mile, State Highway 240 passes through vertical outcrops of the lower Poleslide Member. Shortly thereafter, Old Northeast Road joins the highway on the right. Old Northeast Road is along the area where Quaternary deposits were studied by Burkhart and others (2008) and was a major area of focus for the Poleslide Project of Benton and others (2009). Beyond this junction, the highway passes through Cedar Pass where the Cedar Pass white layer in the middle of the Poleslide Member is well exposed just above the road. On the left side of the highway at 1.5 miles from the Door and Window Trailhead parking lot is the parking area for the Cliff Shelf Nature Trail. The junipers in this area are growing on the hummocky upper surface of a major landslide involving primarily Poleslide rocks. The side-slope slump at Cedar Pass retains enough moisture to support the growth of trees and shrubs. Rocky Mountain Juniper (Juniperus scopulorum) is the most common evergreen tree in the park. Commonly referred to as “cedars,” their abundance here has given Cedar Pass its name.

Badlands National Park is within an area of transition between Rocky Mountain Juniper, which is the dominant species of juniper in the western United States, and Eastern Red Cedar (Juniperus virginiana), which is the most common juniper species in the eastern part of the country. The two species hybridize and characteristics of both can be found at Cedar Pass (Milton J. Haar, Ecologist, Badlands National Park, written communication, 26 January 2010). Continue driving on State Highway 240 for 0.6 mile to the Ben Reifel Visitor Center on the left.

Stop 3 – Ben Reifel Visitor Center. The spectacular ridge to the north and northeast of the visitor center (across the highway) is called Millard Ridge. It is capped by the sandstones of the Sharps Channels, and the Cedar Pass white layer is exposed as the ragged white band near the top of many of the spires. The highway just travelled descended this ridge from the gap called Cedar Pass where the Cedar Pass white layer occurred just above the road. The southern side of Millard Ridge also has many large landslides, several of which have caused problems in maintaining the highway just travelled.

The Park’s visitor center is situated just below the upper Scenic disappointment limestone interval that can be seen in detail just to the east of the building. The disappointment limestone interval contains thin, light gray, limestone stringers within brown to greenish-brown, clayey mudstones. The limestone beds contain angular granules of mudstone that weather away on the surface of the limestone, giving the limestone a pitted surface. The carbonate stringers, mottles and abundant fossil roots (rhizoliths) and clay skins in cracks in the mudstones all indicate that the interval is a thick cumulic soil sequence. The intense weathering to form the thick soil complex probably removed all but a few trace fossils from the interval. The limestone beds are not lacustrine because they do not contain fossils of freshwater organisms, such as freshwater snails, ostracodes, or algal structures. The limestone beds are better indurated than are thin carbonate stringers in modern soils, indicating an addition of carbonate from ground water long after the unit was buried. The Ben Reifel Visitor Center was remodeled in 2005 and has exhibits, a short
video tour, a gift shop with maps and literature about the park, picnic tables, and restrooms. During the summer months, a fossil preparation lab is in operation in the Ben Reifel Visitor Center Classroom.

**Turn left out of the parking area for the Ben Reifel Visitor Center.** Drive west on the Badlands Loop Road (Highway 240). In 7.9 miles (at the Big Foot picnic ground), the road will go through **Big Foot Pass.** Big Foot was the leader of a band of 55 Minneconjou Lakota from the Standing Rock Reservation that passed through this gap in the Wall in December of 1890 on their way to Pine Ridge. A few days later, Big Foot and his people were killed in the Wounded Knee Massacre. Panorama Point is 1.6 miles beyond Big Foot picnic ground on the left.

The **Panorama Point** overlook provides a view into a drainage that flows south from Big Foot Pass toward the White River. Despite the elevation, the observation deck is built upon middle Scenic rocks, just a few meters above the **Saddle Pass marker.** This position is relatively lower in the stratigraphic sequence from that at the Burns Basin overlook (which we will not stop at) because we are far up the northeast flank of the Burns Basin syncline (fig. 10) and because the Scenic Member increases its thickness. The total thickness of the Scenic Member below the top of the **Saddle Pass marker** in the basin below you is 49 m thick, as compared to the 25.6 m thickness of the same sequence in the Pinnacles (which is the last stop in the Park, Stop 6, before returning to Deadwood). The reason for the nearly doubling of thicknesses here is because we have entered an early Oligocene paleovalley. The highland that existed in the Pinnacles area extended to the southeast toward the buttes that you see to the southwest (far left) from the observation platform. Presumably, the paleovalley at Big Foot Pass also had a southeast trend that was parallel to the ancient ridge. However, the geometry of outcrops along the Badlands Wall exposes only a cross section through this paleovalley. The Scenic Member thicknesses remain high east from here.

This overlook was formerly called the Banded Basin overlook because of the prominent red stripes that occur in the light gray sandstones of the Middle Scenic. Except for the thick brown beds of the **Hay Butte** and **Saddle Pass markers,** these red bands are typically mudstone or claystone beds that can be traced laterally for typically only a kilometer or less. The red beds represent thin, muddy, overbank deposits in a remarkable sequence of sheet sandstone bodies. The color is derived partly from pedogenesis and partly from diagenetic alteration of iron silicate minerals to iron oxide minerals that accumulate in the mudrocks. The Hay Butte and Saddle Pass mudstone beds are unique, for they are very widespread and are not known to be cut by channel sandstones anywhere in the North Unit of the Park. Continue driving 8.4 miles past Panorama Point to the Conata Basin Overlook that will be on your left.
Stop 4 – Conata Basin Overlook – the Sage Creek Arch and White River Group Stratigraphy. At this stop you can see rocks of the White River Group exposed in the upper Conata Basin folded into an anticline, the Sage Creek Arch. The axis of the anticline runs essentially parallel to the ridge on the north end of the drainage basin, and crosses the wall on the far west side of the basin (fig. 11). The rocks you see on the southern flank of the arch dip 4 degrees to the southwest.

Below this overlook, the White River Group rests on an unconformity on top of the Cretaceous Fox Hills Formation. The Fox Hills is composed of alternating shales and thin sandstones that have been weathered to a yellowish brown color. Marine fossils and strontium isotopes indicate that the Fox Hills in the Park is Maestrictian in age (Chamberlain and others, 2001). A regionally extensive zone of soft sediment deformation and ejecta is preserved in the uppermost part of the Fox Hills at this locality. Based on biostratigraphic data, this impactite is dated to approximately 68 Ma (Jannett and Terry, 2008). A zone of ancient weathering, commonly referred to as the Interior Zone for exposures near Interior, overprints the Fox Hills in this area. The lower yellow zone is called the Yellow Mounds Paleosol Series, and is named for the yellow hills in this area (Retallack, 1983). A second paleosol complex overlies the Yellow Mounds, is intense red in color, and is called the Interior paleosol (Ward, 1922; Retallack, 1983). The Interior paleosol formed on the overbank deposits of a widespread nonmarine deposit, up to 11 m thick in places, referred to as the Chamberlain Pass Formation (Evans and
Based on vertebrate remains preserved in correlative deposits in Nebraska, this unit is *Duchesnean to Chadronian* in age (LaGarry and others, 1996). Both the Yellow Mounds and the overlying red Interior paleosol can be seen in the drainage directly below you.

The overlying Chadron Formation seen in the drainage below is a relatively thin sequence (about 5-10 m thick) of gray claystones that weather into rounded low hills capped by a strong popcorn surface. This “popcorn” is a result of the drying and contraction of the swelling clays in the Chadron. Vertebrates and radiometric dates of tuffs in the Chadron Formation (but not in the Park) indicate a late Eocene age for its deposition. On a regional scale, the Chadron can be divided into four separate members (Terry and LaGarry, 1998) of which the Peanut Peak Member is preserved in this part of the Park.

The upper formation of the White River Group is the Brule Formation that is divided into the Scenic and Poleslide Members. The Scenic Member is a series of alternating, widespread, thick, brown mudstone beds interbedded with thin, typically red, mudstone and claystone beds. The Poleslide Member is a series of interbedded tan...
siltstone and sandstone beds in its lower half and very light gray massive siltstone beds in its upper half. The shift from the mudstones and sandstones of the Scenic to the thick siltstone beds of the Poleslide reflects a shift in environments from mostly fluvial to mostly aeolian. The shift from river channels and overbank deposits to widespread blankets of silty loess reflects a climatic shift from subhumid to semiarid conditions. Fossil vertebrates tied into radiometric dates indicate an early Oligocene age for Brule deposition, again from stratigraphic studies made outside the Park.

In the outcrops below you, the Scenic Member starts with brown mudstones directly above the gray Chadron claystones and includes the white sandstone ledges exposed in the nearest small butte to the north of the overlook. There are eight subunits within the Scenic Member that can be correlated throughout the North Unit of the Park and are separated by marker beds. The most widespread and prominent marker beds in the Scenic are two thick, brown, mudstone units that are called the Hay Butte and Saddle Pass marker beds. The Hay Butte and Saddle Pass beds are distinct markers that extend for the entire 50 miles (80 km) along the Badlands Wall in the North Unit. The Hay Butte Marker occurs just below the overlook platform at this stop.

The Brule Formation was deposited on an erosional topography cut into the Chadron Formation through the North Unit of the Park. This is well demonstrated in the outcrops in the drainage basin below you. An isopach map of the Scenic rocks below the top contact of the Hay Butte marker (fig. 12) shows the geometry of the early Oligocene topography. The isopach map shows two south-flowing drainages cut into the Chadron Formation. A north-south trending ridge is directly in front of you at this stop, and this ridge was the east margin of a south draining valley (fig. 12). A cross section through the lower part of the Scenic along the west wall of the upper Conata Basin (fig. 13) indicates that the paleovalleys contain as much as 22.5 m of lower Scenic sediments, while laterally the lower Scenic is only 10 m thick on paleoridges. Sandstone beds in the paleovalleys thin and pinch out toward the margins of the paleovalleys. On highs there are no sandstone beds separating the lower Scenic mudstone sequence from the Hay Butte marker.

The highest buttes surrounding the upper Conata Basin are capped by conglomerate ledges of the Sharps Formation lying on the top of the Poleslide Member of the Brule. These conglomerate beds were deposited as channels at the base of paleovallies that were filled with massive silty sandstone beds above the basal conglomerate beds. These paleovalley fills have been traditionally called the “Sharps Channels” (Harksen, 1974). On the basis of faunal evidence, an unconformity separates the upper Poleslide Member from the Sharps Channels. The resistant Sharps Channels preserve the Poleslide Member from erosion, so the entire White River Group is preserved in isolated buttes along the Badlands Wall.

Turn left out of the parking area for the Conata Basin Overlook and drive 0.6 mile to the Yellow Mounds Overlook that will be on your left.

Stop 5 – Faults at the Yellow Mounds Overlook. A short walk along the top of the ridge to the west of the parking area provides a spectacular view of a high angle normal fault cutting the Yellow Mounds paleosol and the Chadron Formation. The Yellow Mounds is developed in the upper Cretaceous rocks that have been uplifted on the north side of the fault, and abuts the gray claystone of the Chadron Formation on the south side. Sixteen meters of displacement of units along this fault occurs in the Scenic Member in the bluffs to the
southeast of this overlook. The fault is exposed along the southern flank of the Sage Creek Anticline for 1.5 km to the east-southeast, and for 2.4 kilometers to the west-northwest where it crosses the west Wall of badlands (fig. 11). On this western side, the displacement of rock layers adjacent to the fault is only 3 m. The movement on this fault occurred after the deposition of the Scenic Member because the thicknesses between the individual units on either side of the fault are the same on the up-thrown and down-dropped blocks.

Figure 12. Isopach map of the lower part of the Scenic that reflects paleovalleys in the upper Conata Basin.
Turn left out of the parking area for the **Yellow Mounds overlook**. Follow the Badlands Loop Road (Highway 240) for 3.1 miles to the Pinnacles Overlook.

Just beyond the junction with the Conata Road (on your left) you will pass a tall butte on the west wall of the upper Conata Basin (fig. 14). This butte is the only place you can see the entire sequence of the White River Group in one vertical section along the Loop Road. The photograph of the east side of this butte (fig. 14) includes labels of all the stratigraphic units and marker beds. This photo was taken at the site marked by the small red square along the Loop Road in figure 12. These outcrops are best seen in the morning sunlight; in the afternoon, the outcrops are typically in shadow.

En route to the Pinnacles Overlook, the road will pass by the **Ancient Hunters Overlook**. The Ancient Hunters Overlook is situated on a large landslide that has rotated and down-dropped blocks of the Poleslide Member. The upper parts of the larger landslides have rotated blocks and hummocky topography that catches water and allows junipers to grow. Such juniper groves are prime habitat for deer and bighorn sheep. The overlook views over a basin in the headwaters of Whitewater Creek that flows northeast into the Bad River drainage with a ridge of the Badlands Wall on its south side. The road crosses this ridge and enters the headwaters of the Conata Basin that drains south into the White River. Retallack (1983) described and measured a detailed sequence of paleosols through the White River Group along a single transect starting in the drainages on
the left side of the highway and ending in the Pinnacles. Archeological sites have been documented in this area, including charcoal horizons and animal bone.

Stop 6 – Pinnacles Overlook. The last overlook on the Badlands Loop Road before exiting the Park has one of the most spectacular views in Badlands National Park. The overlook is on one of the highest places in the North Unit of the Park and the Pinnacles are the high spires due south of the overlook. To the west and southwest are many square miles of badlands that extend toward the horizon. The drainage basin directly below you is the headwaters of the east fork of Sage Creek that flows toward the northwest into the Cheyenne River. Below you is a wilderness area that contains the Park’s Bison herd. The grassy flats in the bottomland are the favorite resting and grazing spots for isolated buffalo bulls. The west edge of this drainage basin is the long table capped by two grassy flats called Hay Butte. To give you an idea of the size of this area, the butte is 3.4 miles (5.5 km) to the southwest of the overlook and the southeast end of the butte to the northwest end of the northern grassy top of the butte is 2.7 miles (4.3 km) long. To the left of the butte is the north side of the

Figure 14. View of the White River Group exposed on the ridge south of the Pinnacles, on the west wall of the upper Conata drainage basin.
Badlands Wall, a series of badlands ridges that separate the low prairies of the White River drainage to the south from the higher flats of the northern streams, such as Sage Creek. The Sage Creek valley is about 50 m higher than are the prairies on the south side of the Wall. To the right (northwest) of the overlook is the high grassy prairie that ends in badlands along the Sage Creek Rim. Drainages on the upper prairie flow toward the north-northwest along Bull Creek to the Cheyenne River. A well graded dirt road runs along the Sage Creek Rim that offers the best viewing places for Bison in the Park.

REFERENCES CITED


Wood, A.E., 1940, *The mammalian fauna of the White River Oligocene, Part III.*