# Late Cenozoic geology along the summit to museum hiking trail, Scotts Bluff National Monument, western Nebraska

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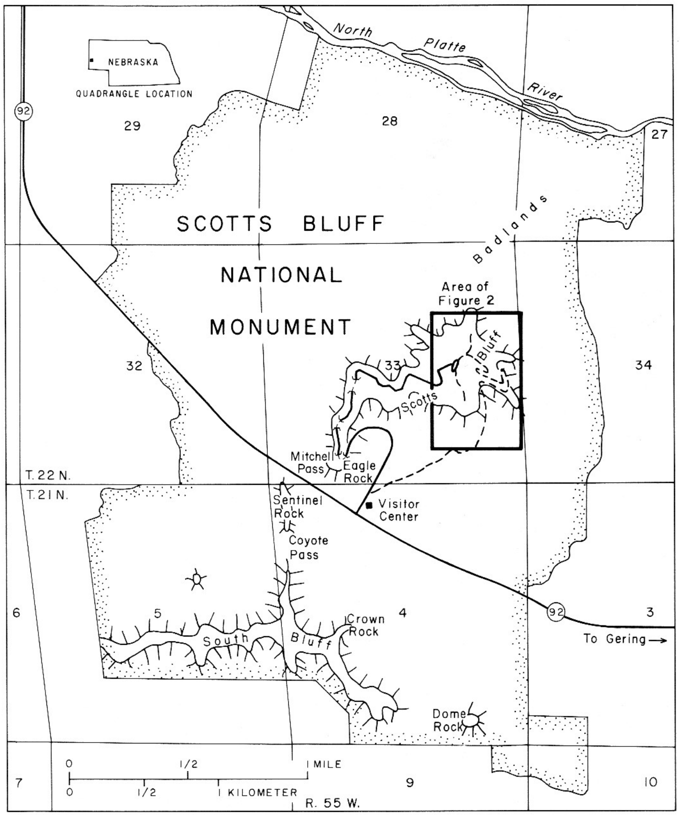


Figure 1. Location of Scotts Bluff National Monument. Base is from Scottsbluff South 7½-minute Quadrangle.

## LOCATION AND ACCESSIBILITY

Scotts Bluff National Monument is best reached by starting from the junction of Nebraska 71 and 92 in downtown Gering, Nebraska, and proceeding westward on Nebraska 92 for 2.4 mi (3.4 km) to the visitor center (Fig. 1). The monument is open from 8 A.M. to 8 P.M. Memorial Day to Labor Day, 8 A.M. to 6 P.M. Labor Day to October 1, and 8 A.M. to 5 P.M. October 1 to Memorial Day. Educational groups are not charged the nominal usage fee for admittance to the summit road and parking (Fig. 2). Please stay on the trails and note that collecting rocks or other items is prohibited without a permit from the National Park Service.

## SIGNIFICANCE OF LOCALITY

The exposures of the Arikaree and White River Groups (Figs. 3 and 4) along the summit to museum trail are certainly the most accessible of any in western Nebraska. A wide variety of sedimentary structures, diagenetic features, trace fossils, and volcaniclastic sediments is well displayed along the trail. In addition, an excellent panoramic view of the North Platte River valley is provided from the north overlook (Fig. 2).

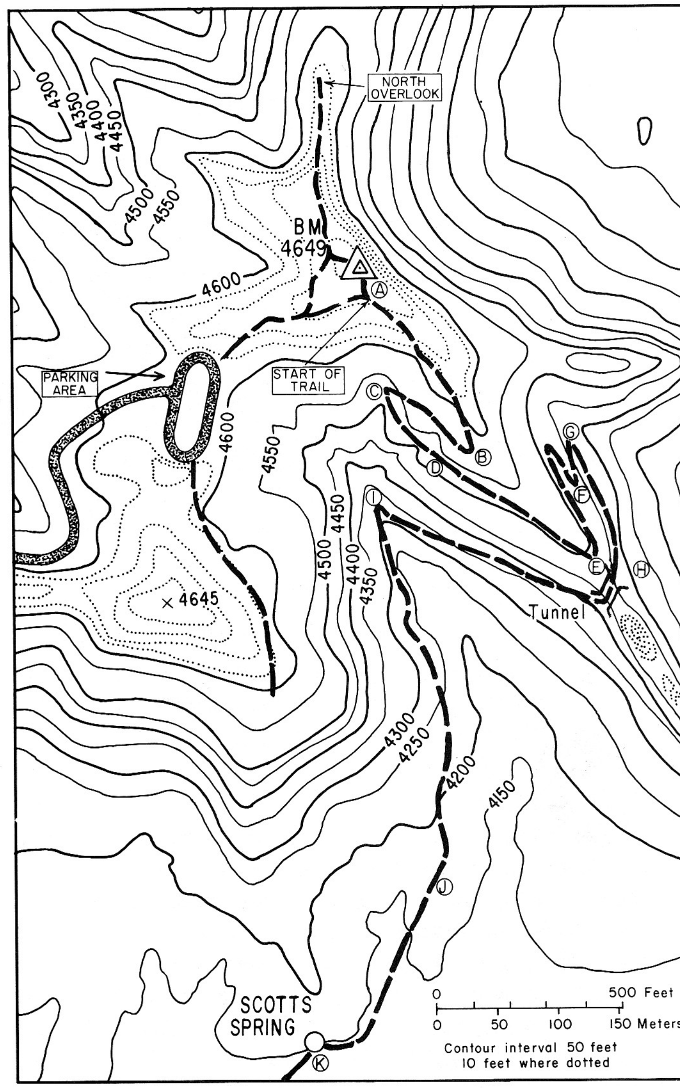


Figure 2. Topographic map of summit to museum hiking trail. Letters refer to stops along trail.

## SITE INFORMATION

The rocks exposed within the monument are Tertiary in age and are of nonmarine origin. They belong to four stratigraphic units (Orella; Whitney; Gering; Monroe Creek–Harrison) that

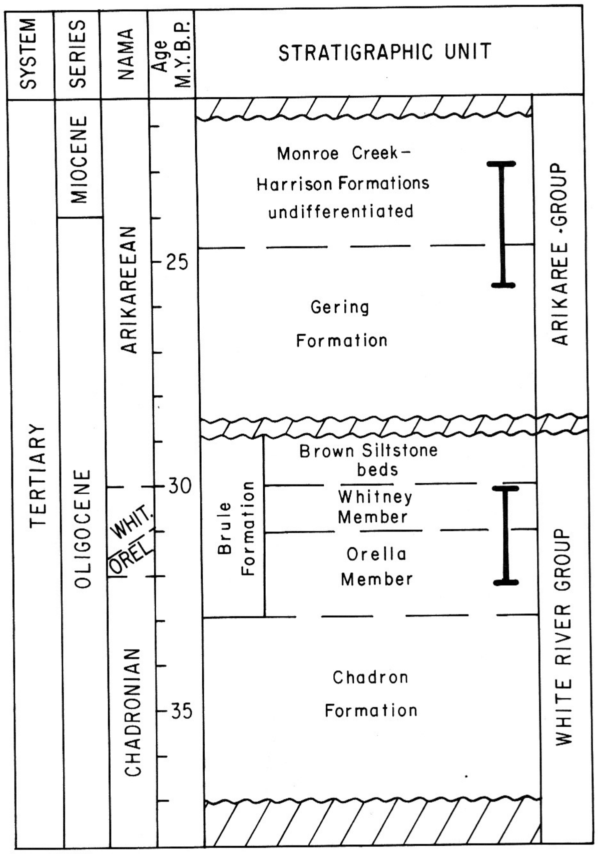


Figure 3. Time stratigraphic chart of a portion of the Cenozoic. Vertical bars indicate approximate stratigraphic intervals exposed within Scotts Bluff National Monument. NAMA refers to North American Mammal Ages (Whit. = Whitneyan; Orel. = Orellan).

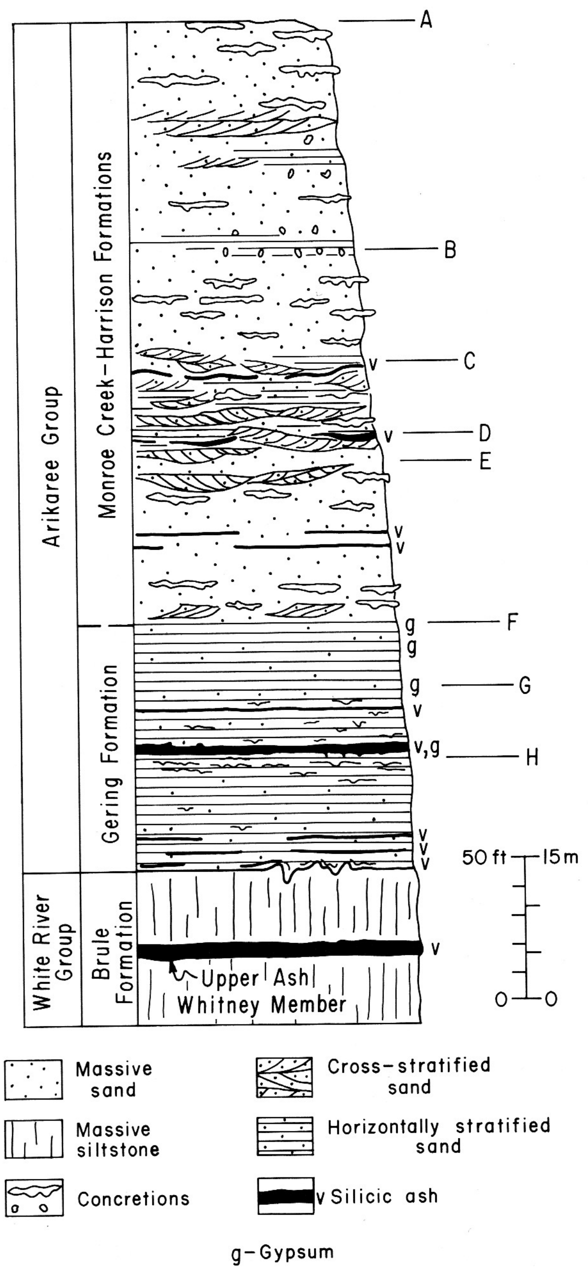


Figure 4. Diagrammatic geologic section along the upper part of the hiking trail. Letters refer to stops along the trail.

can be placed into two groups—the White River and overlying Arikaree (Figs. 3 and 4).

The Orella Member of the Brule Formation (not exposed on the trail) consists of siltstones and mudstones with interbedded thin lenticular sandstones and forms the small badlands area in the northeast part of the monument (Fig. 1). Subsurface information indicates that the base of the White River Group (underlain by Late Cretaceous Pierre Shale) is about 250 ft (75 m) below the lowest Orella exposures. The Whitney Member of the Brule Formation is a massive, pinkish-brown, volcaniclastic siltstone; it contains two vitric ash beds (Upper and Lower Ash) of regional extent. There is a 20-ft (6-m)-thick sequence of interbedded, fine-grained sandstone and siltstone below the Lower Ash on Sentinel and Eagle Rocks (Fig. 1). White River Group siltstones contain 40 to 70 percent silicic glass shards (Swinehart and others, 1985) and an additional 20 to 30 percent crystal and lithic pyroclastic detritus. The pyroclastic material was derived from western-source rhyolitic and volcanic centers, with those in Colorado the most probable sources (Swinehart and others, 1985).

The Gering Formation is about 88 ft (27 m) thick and consists of thin, horizontally stratified pale brown to gray brown, very fine to fine-grained, volcaniclastic sandstone (Fig. 4). It also contains a number of ash beds. Placement of an upper contact for the Gering is subject to some debate, as the contact is gradational at many localities. The horizontally stratified sequence is present at other sites in the region and appears to occur above the more typical fluvial cut and fill sequences of the Gering.

The overlying pale brown and light gray, silty, very fine to fine-grained sandstones are shown as a combined Monroe Creek-Harrison unit because the criteria for differentiating the two formations outside their type areas in northwest Nebraska have not proven consistent.

Figure 5. Sketch made from a photograph of eolian cross-stratified and horizontally stratified sandstone of the Arikaree Group at Stop D. Person is 6 ft (1.8 m) tall.

***North Overlook on Summit Trail***

The Orella badlands are visible from the North Overlook (Fig. 2). A large number of vertebrate fossils were collected from this area prior to 1910 when the area was incorporated into the monument and fossil collecting was prohibited.

The overlook is about 800 ft (244 m) above the North Platte River and provides a panoramic view of the fertile cropland in the North Platte Valley, which is about 6 mi (9.7 km) wide at this location. Upstream from this point, the North Platte River drains an area of 24,330 mi$^2$ (63,000 km$^2$) heading in the Rocky Mountains. Because reservoirs were built to retain spring snowmelt for irrigation during the summer, the flow of the river formerly was much more variable, and its channel was considerably wider than it is now. Regulation of the river's flow by means of reservoir releases, together with irrigation-seepage returns to the river, results in flow during all seasons. River discharge ranged from 449,000 to 1,700,000 acre-feet (0.55 km$^3$/yr to 2.10 km$^3$/yr), averaging 822,000 acre-feet (1.01 km$^3$/yr) during the 10-year period from 1967 to 1976. Most of the water used for irrigation within the North Platte Valley is obtained from canals that divert water from the North Platte River in Wyoming and Nebraska. A relatively small acreage is irrigated with groundwater.

***Summit to Museum Trail***

The trail begins between Summit Trail markers 12 and 13 and ends at the museum 1.6 mi (2.6 km) to the south. There are no permanent trail markers, so geologic points of interest are keyed to easily located sites on the trail (Figs. 2 and 4).

***Stop A*** (start of trail). The morphology of the calcite-cemented "pipy" concretions typical of the Arikaree Group is well displayed just north of the start of the trail. The concretions maintain a consistent northeast-southwest orientation over much of the southern Nebraska panhandle. Clasts of these concretions occur in a number of intraformational gully fills in western Nebraska and indicate that the concretions formed shortly after deposition of the host sand. Note the small diameter vertical tubules preserved in many of the concretions.

About 197 ft (60 m) down the trail is a 26-ft (8-m)-thick sequence of low-angle (7° to 15°), large-scale, cross-stratified sand (Fig. 4). This sequence is also well exposed at the south side of the summit parking lot (Fig. 2). A section of horizontally stratified sandstone with numerous small-diameter burrows is exposed another 98 ft (30 m) down the trail.

Both the massive and stratified sandstones of the Monroe Creek–Harrison contain 25 to 50 percent silicic glass shards and an additional 25 to 40 percent crystal and lithic pyroclastic detritus.

***Stop B*** (first switchback). Note the knobby "potato" concretions and the crudely stratified sandstone in this area.

***Stop C*** (second switchback). About 45 ft (14 m) down trail from the museum signpost is a thin, pinkish ash lentil with a meter or more of local relief. It can also be seen in the cliff face to the south. Note both the cross- and horizontally stratified sandstone above and below the ash (Fig. 4).

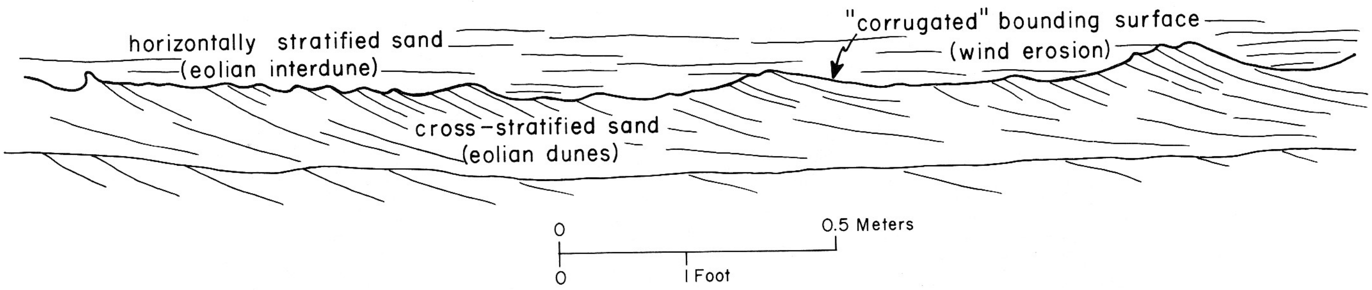


Figure 6. Sketch made from a photograph of a "corrugated" bounding surface exposed about 98 ft (30 m) downtrail from Stop D.

***Stop D*** (at concrete steps on trail, Fig. 5). The exposures between this stop and at Stop E (about 490 ft [150 m] southeast) are worth examining in some detail. The cross-stratification in these very fine to fine-grained sandstones is compound; large-scale wedge planar sets (Fig. 5) up to 5 ft (1.7 m) thick are themselves cross-laminated. These cross-laminated sets are laterally extensive, even and distinct. They contain small-scale foresets (up to a centimeter in length) with shallow dips that are typically nearly perpendicular to the dip of the large-scale foresets. The majority of the laminae are inversely graded. The relatively higher percentage of dark, heavy minerals in the coarse silt versus the very fine sand fraction allows relatively easy recognition of the inverse grading and cross-lamination, especially on surfaces oblique to the laminations. We interpret these structures as products of wind ripple migration (Hunter, 1977) on eolian dunes.

Horizontally stratified sandstones are also present in this sequence (Figs. 5 and 6); laminae in these rocks are typically inversely graded. This stratification was also produced by migration of wind ripples, but across flat interdune surfaces. In modern interdunes, a distinctive ridge and swale topography is produced by differential wind erosion of cohesive or lightly cemented, cross-stratified sand (Ahlbrandt and Fryberger, 1981, Figure 4c and 4d). When buried and viewed in vertical section, such erosional surfaces appear as irregular or "corrugated" bounding surfaces (Simpson and Loope, 1985). Such surfaces occur at several horizons visible from the trail (Fig. 5) between Stops D and E and seem best interpreted as features produced by wind erosion.

A lag deposit composed of evenly spaced, coarse sand to pebble-sized material is located at the base of the cross-stratified sandstones above the trail and can be traced laterally for hundreds of meters. A similar lag deposit in eolian sediments is illustrated by Ahlbrandt and Fryberger (1981, Figure 4a).

Further evidence of an eolian origin for the cross-stratified sandstones comes from flume and field studies, cited by Driese and Dott (1984, p. 583). For sands with grain sizes below 0.11 mm, subaqueous dunes and sand waves are not stable. The median grain size for the cross-stratified sandstone in the Monroe Creek-Harrison exposed here is less than 0.09 mm (Bart, 1974). This suggests that the cross-strata formed by the migration of eolian rather than fluvial bed forms.

About 75 ft (23 m) down the trail from the concrete steps (Fig. 5) is an exposure of a laminated volcanic ash lens up to 20 in (50 cm) thick. Excellent samples of a number of different types of invertebrate burrows are present in the ash and in adjacent sandstones. The burrows are cylindrical, smooth walled, massive or meniscate, and generally nonbranching. They were interpreted by Stanley and Fagerstrom (1974) to represent shelter burrows, deposit-feeding burrows, and vertical passageways made by insects, possibly beetles. Stanley and Fagerstrom (1974) interpreted the cross-stratified sands to have been deposited by migrating sandbars in a braided river system.

***Stop E*** (major bend in trail with museum signpost). Note the volcanic ash lens about 13 ft (4 m) above the trail. Compare the cross-stratified eolian sandstone with the massive sandstone. The mineralogy and grain size of these two units is very similar, and we suggest that the lack of depositional sedimentary structures is due to (1) a much slower sedimentation rate and intense bioturbation, and/or (2) trapping of sediment by vegetation so that laminations were never present.

***Stop F*** (second of three switchbacks along northeast-facing bluff). This stop is at the top of the horizontally stratified sandstone of the Gering Formation (Fig. 4). Here, "sand crystals" up to 1 in (2.5 cm) in diameter are developed at several horizons. The discoidal shape of these sand crystals clearly indicates that they were formed by the growth of gypsum which has since been replaced by calcite.

***Stop G*** (third switchback on northeast-facing bluff). There is at least one horizon of "sand crystals" here also. Note the uniform nature of the stratification in the Gering. Many individual strata can be traced for tens of meters. Small-scale cross-stratification occurs locally. About 200 ft (60 m) down the trail and 11 ft (3.3 m) above the white ash at Stop H, a 0.8-in (2-cm)-thick, gray volcanic ash bed is present and can be traced continuously for a minimum of 650 ft (200 m). A similar ash occurs in the same stratigraphic position above a white ash just north of the highest tunnel on the road approximately 0.6 mi (1 km) west of here.

***Stop H*** (at entrance to tunnel). The ash above the tunnel contains abundant calcite pseudomorphs after lenticular gypsum crystals. The evidence for precipitation of evaporites suggests an arid climatic setting. We interpret these horizontally stratified and

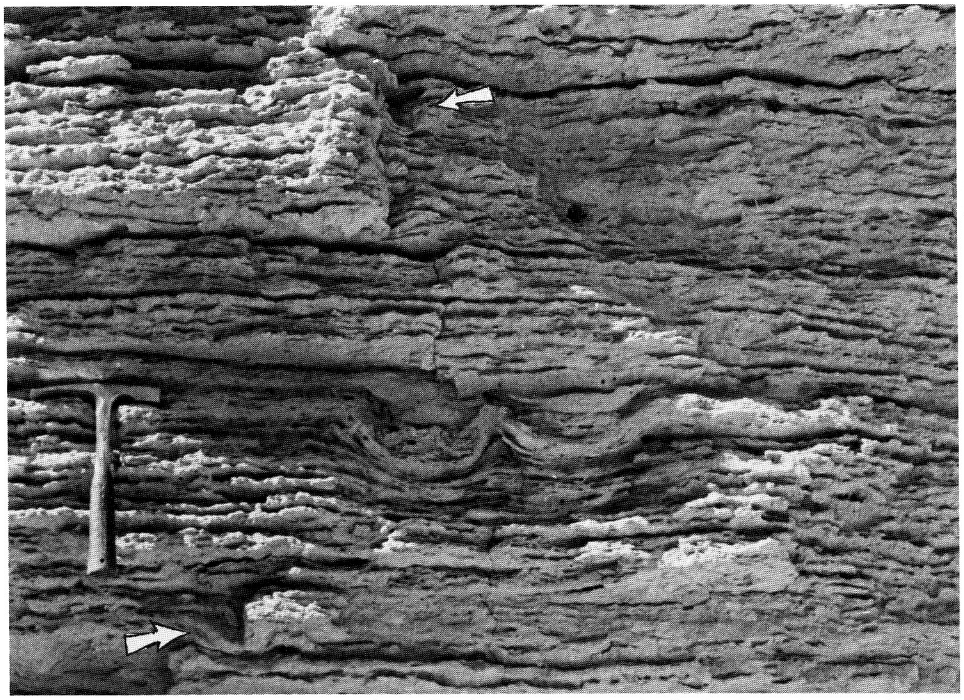

Figure 7. Photograph of concave-up deformation features interpreted to be fossil vertebrate tracks. Two tracks are easily visible near the center, and two others are indicated by arrows. The hammer is 11 in (28 cm) long.

small-scale, cross-laminated, very fine-grained sands as ephemeral stream deposits.

Beginning at the level of the thin gray ash described above, concave-up deformation structures are common (Figs. 4 and 7). Bart (1975) interpreted these and several other types of deformation at this locality as inorganically induced deformation structures. Due to their resemblance to features described by Laporte and Behrensmeyer (1980), we believe that many of these structures are tracks of vertebrates. The scale and bilobed nature of some structures indicate that some of the track-makers were large ungulates—probably entelodonts (Loope, 1986). Other potential track-makers known to have lived during this time include a variety of oreodonts, hyracodontid rhinos, tapirs, small horses, camels, and a variety of carnivores.

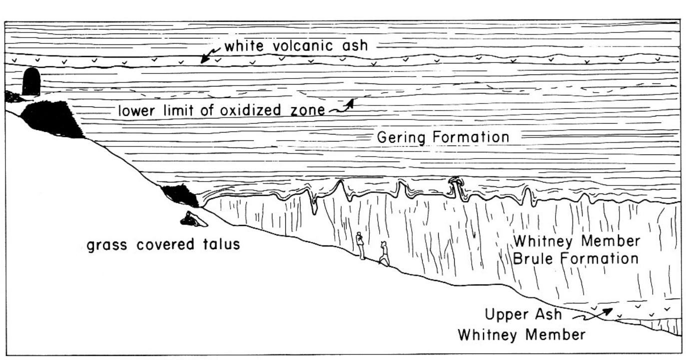


Figure 8. Sketch made from a photograph of the Gering-Whitney contact east of the trail tunnel (visible in the upper left corner). The two people standing on the talus slope are each 6 ft (1.8 m) tall.

***Stop I*** (at head-of-canyon switchback). Volcaniclastic siltstones of the Whitney Member of the Brule Formation are exposed here. The mineralogy, grain size, texture, and regional mantling nature of the Whitney all suggest that it represents slow accumulation of airfall pyroclastic material. The Upper Ash of the Whitney crops out about 30 ft (9 m) above the trail at this stop. Ash beds in the White River Group are much more continuous than those in the Arikaree Group and can be traced throughout much of the Nebraska panhandle (Swinehart and others, 1985).

***Stop J*** (700 ft [215 m] down the trail from Stop I). The highly irregular nature of the Whitney-Gering contact can be seen in the cliff face to the northeast (Fig. 8). At other exposures within the monument, this contact is flat and has very little relief. Bart (1974) and Stanley and Fagerstrom (1974) suggested that the deformation seen here is evidence against a major hiatus at the White River–Gering contact. However, stratigraphic evidence indicates that this contact represents a hiatus of up to 4 m.y. at the monument (Fig. 3).

The remains of a large rockfall that occurred in October 1974 can be seen on the talus slope below the end of the cliff face described above. Much of the erosion at Scotts Bluff occurs through such rock falls.

***Stop K*** (Scotts Spring). This spring issues from fractures in Whitney Member siltstones.

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