BANGS CANYON—A VALLEY OF BOULDERS

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Abstract

Large boulders of Dakota sandstone are strewn completely across a broad valley in Bangs Canyon in western Colorado. The boulders near the bases of the sandstone cliffs at the valley sides form talus. The rest of the boulder distribution may be remnants of a rapid process that carved the valley. Giant boulders scattered as far away as 800 m from the cliff face seem to provide a counterexample to other Colorado Plateau cliffs where the talus stops abruptly near the base. This region has additional geologic features, such as peneplain erosion of the Precambrian strata; salt, coal and uranium deposits; and the large range of aeolian, riverine, lacustrine, marine and igneous deposits, which will be of interest for future studies by creationists.

Introduction

Weathering processes are constantly eroding cliff faces wherever they are found throughout the world. Weathered debris ranges in size from material as small as the original mineral grains to large boulders of rock, known as talus, which accumulate below the cliff faces. Theoretically the talus boulders should weather to pebbles as the cliff face recedes. Debris eroded from the cliff face should therefore become smaller and more rounded with distance from the cliff face. The resulting sand grains could then be easily removed by wind and water.

In a previous paper, Holroyd (1987b) introduced the idea of "missing talus" at some cliff faces at Mesa Verde, the Book Cliffs, and Monument Valley. In a photograph showing the west side of Mesa Verde in Colorado, sandstone blocks had eroded from the cliff face and had fallen onto the very soft and steep shale slopes below. However, there were no decaying sandstone remnants visible across the pediment, the flatter region beneath or beyond the slopes. He suggested, based on a similarity of elevations, that some locations having this abrupt cessation of talus may be shorelines of extinct lakes. Wave action may have pulverized previous talus and swept it away as sand. The author believes that the talus we now see would have fallen since the demise of the lakes.

This article precedes a more detailed discussion on the "missing talus" phenomenon, which is widespread in the Colorado Plateau region. The author will discuss a valley in which large decaying boulders are strewn across a landscape below the cliff faces at the edge of Bangs Canyon. A later article will document "missing talus" at selected study sites. Another will explore possible extents of lakes on the Colorado Plateau, showing how the "missing talus" sites tend to be along the shorelines of such hypothesized lakes.

No absolute time scale is being offered in this series of articles. The author is appealing only to a relative scale related to the rate of weathering of the boulders. This rate must vary with rock composition and with the nature of the weathering process. The minimal weathering of talus at the sites listed in Holroyd (1990) indicates its relative youth. By "youth" and "recent" the author suggests an ice age or post-ice age time frame. That weathering observation in turn puts the demise of the lakes as "recent". The topographic analysis suggested in Holroyd (1987b) and illustrated in Holroyd (1990) required the "plugging" of the Grand Canyon in order to form lakes in the basins upstream. The Grand Canyon could not have coexisted with such lakes because it served to drain them. The author hopes to show through this series of articles that the carving of the Grand Canyon is also "recent."

Geology of the Uncompahgre Plateau

In describing the geology of the Uncompahgre Plateau region the author will use the standard geologic period names from stratigraphy. By this notation the author refers only to the depositional sequence and not to the evolutionary theory commonly associated with these period names.

Figure 1 shows a satellite view (north at the top) of the eastern part of the Colorado Plateau (western Colorado) with some geomorphic features identified. This is the region referred to throughout this and the next section of this article. The dark band (conifer trees) running diagonally across the lower part of the view is the Uncompahgre Plateau, capped with a narrow broken cover of snow. To the northeast a more extensive snow cover lies on the basalt cap of the Grand Mesa. The Colorado River flows from the northeast corner of the picture towards the southwest. Just west of the Grand Mesa it diverts around the north end of the Uncompahgre Plateau. Water is withdrawn from the river in this area to irrigate a broad section of the Grand Valley. South of the Grand Mesa the Gunnison River flows northwestward and joins the Colorado River at the city of Grand Junction. On the west side of the Uncompahgre Plateau are the Dolores and San Miguel Rivers.

The basement rocks of this region are Precambrian metamorphics and are believed to be remnants of a large mountain range oriented from northwest to southeast. Arkose rocks are found along both flanks. Arkose rocks are sandstones and conglomerates with at least 25 percent feldspar content. Feldspar can weather, unless rapidly buried, to clay minerals in the time available under normal uniformitarian deposition rates. Arkose rocks are therefore indicative of more rapid to catastrophic rates of deposition found, for example, in alluvial fans at the flanks of steep mountain ranges.

Weathering and erosion reduced the range to a peneplain, in a similar fashion as has been proposed for the Great Unconformity in the Grand Canyon. To the southeast of Figure 1 the unconformity contact outcrops in a small canyon on the west side of the village of Ouray, Colorado. There the Precambrian strata are

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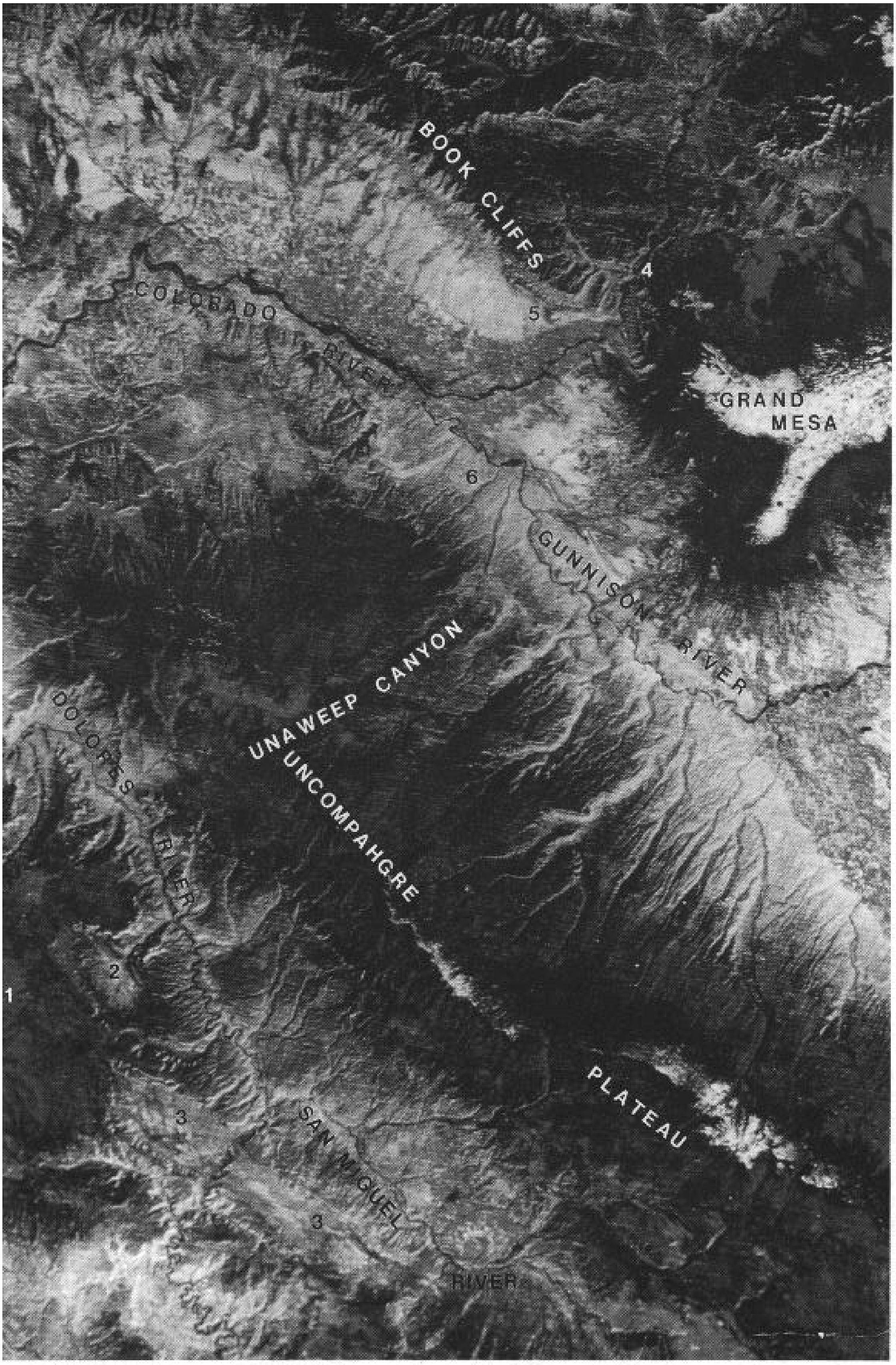

Figure 1. A Landsat satellite view of the Uncompahgre Plateau in western Colorado. Major features are labeled. Numbered features are identified in the text.

vertical in orientation, yet capped by a horizontal layer of Devonian and Mississippian limestones. Subsequent sedimentary layers visible from the road between Ouray and Ridgway include Triassic red beds, followed by Jurassic sandstones and shales, ending in the Jurassic Morrison Formation. The overlying layers, which line the eastern surface of the Uncompahgre Plateau, are of the Cretaceous Burro Canyon and Dakota Formations, composed mainly of durable sandstones, with some interbedded shales and Carboniferous layers. The Dakota formation is interpreted as the western shoreline of the westward-moving marine Zuni Sea. It is further postulated that the sea deposited up to a mile of the soft Mancos shale above the Dakota Formation. Its retreat brought the Mesa Verde Formation, "a series of thick, resistant, near-shore Cretaceous sandstones with many coal layers and carbonaceous shales" (Chronic, 1980). Holroyd (1992, Figure 5) illustrates some Dakota Formation plant fossils from the Uncompahgre plateau (sampled just to the east of the lower right corner of Figure 1) and discusses the rates of formation of the Morrison and Dakota strata in the Denver region.

Tertiary times brought the last widespread sedimentary layers, mostly to the fringes of the illustrated region. After the Laramide Orogeny they were capped or intruded by igneous rocks. The types of igneous rocks deposited include the volcanics of the San Juan and West Elk Mountains, basalt flows of the Grand Mesa and White River Plateaus, and laccoliths elsewhere.

Fault lines in the old Uncompahgre Mountain roots were reactivated under compressional folding during the Laramide orogeny and a subsequent regional uplift, and the present Uncompahgre Plateau was elevated. The layers above the hard Dakota sandstone have since been almost completely stripped of as much as two kilometers of overburden. Dendritic drainage channels on the eastern side of the plateau (Figure 1) have cut deep into the Precambrian rocks in places, exposing a colorful stratigraphic column. Colorado National Monument, at the north end of the Uncompahgre Plateau and southwest of Grand Junction, is a good place to view these strata. Many large dinosaur fossils are found where the Morrison Formation is exposed in these canyons. Additional information regarding the regional geology is found in Chronic (1980).

Other Regional Geologic Features

The region in and adjacent to that illustrated in Figure 1 has additional topics of interest. The geologic layering is relatively simple and needs further investigation from a creationist perspective. The initial erosion of this region could have been accomplished by the first part of the Flood. Deposition seems to have been initiated in the south and spread northward as the Flood period progressed. The last large depositional sequences and Tertiary orogenies are possibly from the end of the Flood through the subsequent ice age. The orogenies were followed by severe erosion to the present landforms.

In the lower left of Figure 1 the flanks of the La Salle Mountains are labeled with a white "1." The mountain core is a laccolith, a large igneous intrusion which lies unconformably above a region of salt anticlines. The two illustrated anticlines are Sinbad Valley (2) and Paradox Valley (3). Most rivers follow the axis of a deep valley. The Paradox Valley, however, acquired that name because the Dolores River cuts across its middle (between the 3s) perpendicular to the NW-SE valley axis. Recent drilling has found Pennsylvanian period salt (NaCl) layers squeezed into a vertical thickness of over 4 km near the valley center. These salt anticlines are some of the largest contributors to the salinity of the Colorado River. The author suggests the interpretation of these deposits as possibly being suddenly precipitated from an eruption of subterranean superheated brine ("fountains of the deep") during the early stages of the Flood.

Just upstream from the mouth of the San Miguel River was the village of Uravan, dismantled about 1987. The name derives from the mining of uranium and vanadium. Both the uranium and vanadium were precipitated as bright yellow carnotite from circulating subterranean waters by the organic carbon in the regional rocks. Some petrified logs nearly totally coated with carnotite have been found (Hurlbut, 1959). The easy mobility of uranium and related elements in these rocks prevents use of that radiometric series for age determination. Any mobility of elements into or out of the rocks resets the "clock?

The crushed polonium halos in coalified wood illustrated by Gentry (1986) came from nearby deposits on the Colorado Plateau. He interprets the halos as requiring a significant compression of the Triassic, Jurassic, and Eocene (Cenozoic) strata in less than a couple of decades. That range of strata is the entire geologic column above the Precambrian rocks in the study region.

From the top of the Uncompahgre Plateau all strata gently tilt downward towards the northeast (see cross section in Chronic, 1980, p. 141). The strata are generally parallel to the surface along the flanks of the plateau. They dip underground at the Gunnison River and extend deep below the Grand Mesa to the east. Under the west end of the Grand Mesa the lower half mile of exposed strata consists of Cretaceous Mancos Shale. The upper half mile consists of the Cretaceous Mesa Verde Formation, several Tertiary sedimentary layers and a basalt cap.

The Mesa Verde layers contain commercially valuable low-sulfur coal seams (Cameo mine at "4" in Figure 1 and other mines along the southeast side of the Grand Mesa). This coal may fit with the log mat formation theory proposed by Steve Austin and illustrated at Mount St. Helens (Austin, 1986). Vegetative debris may have floated near the shore as the Zuni Sea retreated. It became grounded or sunk to the bottom, was covered with sediment eroded from higher terrain to the west, and was converted to coal.

One of the last Tertiary sediments deposited on the Grand Mesa was a thin layer identified as the Green River Formation. Just to the north of the Grand Mesa, at and beyond the top of Figure 1, this layer contains thick deposits of oil shale. These oil shales are believed to be derived from the lake which existed in the former Piceance Basin. The Uncompahgre Plateau is along the approximate rim of the basin while the Grand Mesa is approximately the southern shore of the lake. These oil shale deposits might be interpreted as immediately post-Flood, when the geologic chaos was settling down.

The regional geologic history since the basalt flow has been entirely of erosion. The elevation drop from the western rim of the Grand Mesa to the rivers at Grand Junction is over a mile due to the removal of strata through the Mancos shale (white valley bottoms in Figure 1). Mesa Verde sandstone caps the Book Cliffs north of the Colorado River. The strata sequence there is the same as found at Mesa Verde. Just as in the photograph of Holroyd (1987b), sandstone boulders are falling from the cliffs near the 5 in Figure 1, forming talus which is limited in extent to the cliff base.

The specific region of interest in this article is Bangs Canyon, the minor valley just south of the 6 in Figure 1 and north of Unaweep Canyon. There are no roads in this region.

Canyon Formation

Cutting across the northwest end of the Uncompahgre Plateau is the large Unaweep Canyon, the Indian name meaning with two mouths. It looks like an abandoned river channel and now supports two small streams draining to the east and to the west. Lohman (1961) interprets the Canyon as an ancestral position of the Colorado and Gunnison Rivers. The valley presently has a flat bottom between vertical cliffs. Subsurface profiles, however, show the valley to be deeply V-shaped and filled with alluvium. Basalt rocks like those from the top of the Grand Mesa, east of the Plateau, have been found at the west end of the Canyon. As the Mancos shale eroded away from around the north end of the Plateau, a side tributary propagating southward from near the present city of Grand Junction eventually captured the Colorado and Gunnison Rivers and diverted them around the north end of the Plateau. The present streams draining Unaweep Canyon are not the cause of its formation.

With the removal of the Mancos shale from the east side of the Uncompahgre Plateau, streams, rills and gullies carved into the Dakota sandstone. These drainage features have cut deep into the surface of the Plateau. The water flowing through them seems insignificant compared to the sizes of the canyons. The author believes that precipitation was much more abundant in the past (see Oard, 1990), or perhaps the rocks were softer when the channels were started.

Another scenario came from a discussion among students in a geology course held in Montrose, Colorado, in Autumn 1985. The originator of this suggestion is unknown to the author, but it is worthy of consideration. The Morrison Formation was thought to have been made up of layers of multicolored shales and sandstones deposited in perhaps a Piedmont environment by various rivers and streams flowing eastwards from a high range of mountains. Some of the last stream beds may not have been solidly filled with firm material before the more durable Dakota sandstones began to be deposited. Ken Stoy has related to the author that his water well drilling is always slow in the hard Dakota sandstone. When he reaches the Morrison the drill digs much faster in the shales. In some spots, however, he passes through a siltstone between the Dakota and the Morrison (possibly related to the Burro Canyon Formation) which offers almost no resistance to the drill. Perhaps such siltstone was the last material to fill sluggish stream beds before the Dakota layers. Such siltstone would be a natural weakness, directing the channeling of water at the base of the Dakota aquifer. In some areas the Dakota could be undermined and slump into a vacated siltstone channel. The slump would attract surface waters as well. The end result would be that today's canyons on the eastern slopes of the Uncompahgre Plateau could have had their positions determined by the last river positions in the Morrison or Burro Canyon depositions. They could thereby be the retracings of fossil rivers.

Austin (1991) promotes a mechanism called sapping. Water-saturated sediments can slump catastrophically into lower basins. They can leave behind large valleys with steep walls, amphitheaters, or possibly dendritic canyons. Austin (1984, 1986) shows an excellent example of this in which a canyon was formed suddenly (on March 19, 1982) in the volcanic ash deposits north of Mount St. Helens. Neither the Toutle River nor the stream now occupying that canyon caused its formation.

The sapping scenario can work on the Uncompahgre Plateau. Morrison shales form unstable strata much like the Mancos shales. A slump in the Morrison would undermine the Dakota, and both layers would be flushed downstream.

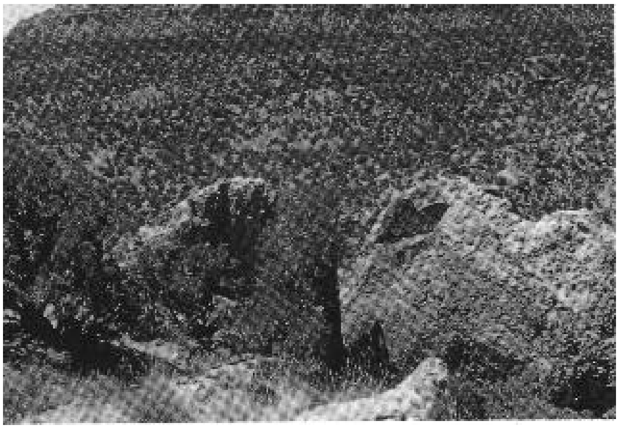

Figure 2. Some giant boulders in the east end of Unaweep Canyon dwarf the adjacent trees.

A Unaweep Inspection

Unaweep Canyon has a paved road through it, making access easy. Figure 2 shows some of the boulders at the eastern end of the canyon, looking north to the cliffs on the far side. The adjacent trees are pinyon pines and junipers perhaps about six meters tall. These boulders are well-rounded by weathering but are still giants. Their sizes are likely to be related to joint patterns in the undisturbed Dakota strata. However, no joint inspection was made in this study.

Figure 3 looks southeast at the nearby southern rim of the canyon. The landscape is covered with talus from the Dakota sandstone rim rocks. Looking north from the same spot is Figure 4. It shows rocks in the foreground resting on Morrison shales. The large boulders extend to the northern rim about a mile behind. They are not confined to the bases of the cliffs.

The orientations of the sandstone boulders were found to be seemingly random. Tumbling would be expected for the talus near the cliffs. Further erosional slumps and underminings in the Morrison shales appear to change boulder orientations and, to a lesser extent, their positions. A subsequent article will show an exam-

Figure 3. Talus from the southern rim at the east end of Unaweep Canyon.

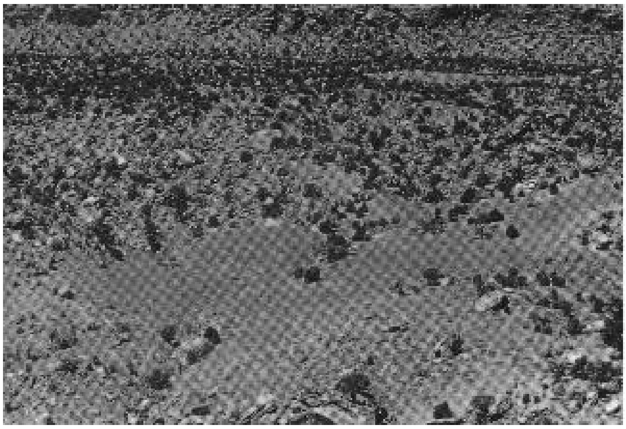

Figure 4. Large boulders extend from the foreground at the east end of the canyon, across the valley, and to the northern rim of Unaweep Canyon nearly a mile away.

ple of similar boulder movement in a Grand Canyon tributary as determined from rephotography after the passage of a century.

Many boulders far from the cliffs could not have rolled there recently from the canyon cliff faces because of deep intervening gullies. They may be near their original resting places after their removal from the receding cliff faces. Alternatively, boulders near the valley center could have been placed there from upstream sources by major floods, including debris flows. They could even have had subsequent movements as a result of later flood waters. However, any such floods which would move tree-sized boulders in directions other than downhill must be catastrophic. A detailed mapping of boulder sizes and locations in the Unaweep Valley and adjacent valleys could yield data relevant to the mechanisms of boulder placement.

Bangs Canyon Data Sources

About five miles north of Unaweep Canyon, on the northeast side of the Uncompahgre Plateau, is another watershed drained by Bangs Canyon. It exposes the same geology as Unaweep Canyon. It is undisturbed by any roads or dwellings, though trails (mostly from cattle) can be seen from the air. I noticed the canyon on an airline flight from Montrose to Grand Junction. I was watching the cliffs and talus patterns and then noticed that the distribution of large boulders stretched completely across this valley. This was a counterexample to the "missing talus" phenomena I was searching for. The valley is essentially inaccessible except on horse or on foot.

An opportunity for further study came when the Colorado Civil Air Patrol held an exercise at the Montrose airport. Members were given certain regions to fly over and "search" for a potential downed aircraft. I asked if a pilot could be given the Bangs Canyon region as a target and photograph the rocks there. This could simulate searching for and documenting a crashed plane and any survivors. First Lieutenant Carman W. Dunn of the Montrose Search and Rescue Squadron flew the mission in a Piper Cub using my 35 mm Nikon camera and 50 mm lens on June 14, 1987. He found the canyon and, as instructed, took pictures from various altitudes and orientations. Some show the general canyon. Many show the individual rocks and trees.

Most of the slides were scanned in color into computer files for later image processing. For those slides selected for analysis the computer resolution is 0.5 meters / pixel or better. (A pixel is the smallest dot in a computer image.) For additional referencing I acquired two 1:40,000 scale black and white aerial photographs from the National Aerial Photography Program (NAPP), frames 1096-94 and 1096-95 taken on September 5, 1988. The appropriate parts of the NAPP photographs were enlarged and scanned into computer files at 1.3 m / pixel. The Bangs Canyon part of the Island Mesa Quadrangle topographic map was scanned into a computer file at about 3 m / pixel. The topographic map portion was the basis for subsequent georeferencing, the attachment of geographic coordinates to an image, for all photography.

A view of this canyon as seen from another airline flight, looking upstream towards the Uncompahgre Plateau highlands, is shown in Figure 5.

Analysis Style

Most computer analyses were performed with the Map and Image Processing System (MIPS) software

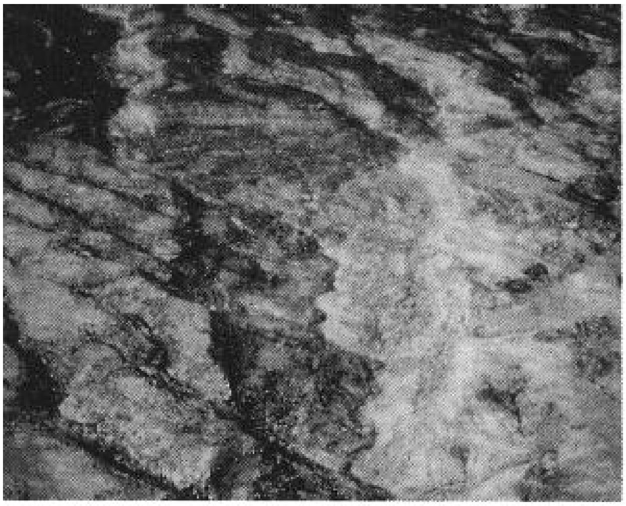

Figure 5. An aerial view of Bangs Canyon, looking upstream (southwest) towards the Uncompahgre Plateau highlands.

from MicroImages, Inc. (1991). The topographic map was georeferenced using latitudes and longitudes interpolated from the map. The NAPP photographs were then georeferenced by pairing numerous landmarks (stream bends and intersections, cliffs, clearings) identifiable in a split-screen view of both the aerial image and the map. Similarly, the 35 mm photographs were georeferenced by pairing the same features (and individual trees and rocks) visible in both the slides and NAPP photographs. Care was taken to minimize problems resulting from the viewing parallax in both types of aerial photographs, especially at cliffs.

All slides are assumed to be taken at non-vertical angles. The projection of individual slides onto a flat map would turn its rectangular area into a polygon and at best a trapezoid. The MIPS software was used to trace the slide outline and landmarks (streams, ridges, clearings) into a vector, or line, format. The resulting skeleton outline of the view was then warped (electronic rubber sheeting) to fit the NAPP view, according to the georeferencing. The interaction between the undulating topography and the viewing angles results in a mismatching between landmarks when the warped outlines from the slide are drawn on top of the NAPP image. By this process two slides were identified that had minimal warping and errors. They were taken nearly perpendicular to the sloping surface.

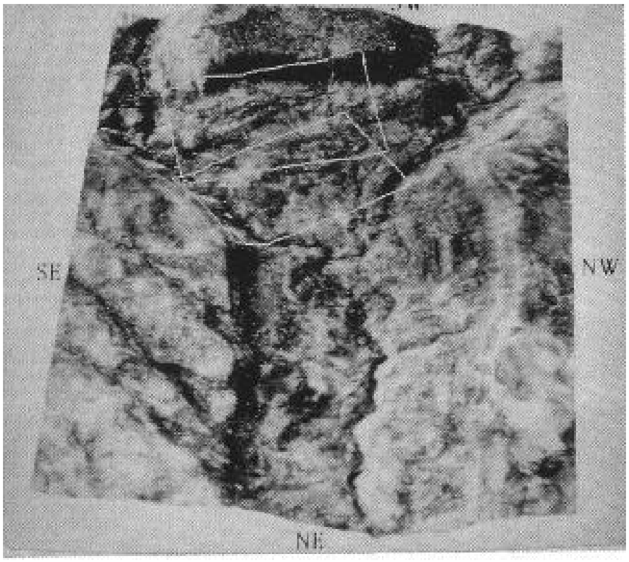

Figure 6. A computer generated 3D perspective view of Bangs Canyon from the northeast similar to Figure 5. The two white boxes outline the views of photographs used in this study.

The coverage of those two photographs is shown by the white surface-hugging boxes in the 3D perspective views of Figures 6, 7, and 8. To make these views the elevation contours of the topographic map were traced using the MIPS automatic line following routines. The software then converted the results to a digital elevation model (DEM), an array of numbers giving the elevation of the land at each pixel, at the 3 m/pixel horizontal resolution of the topographic map. An enlargement of a NAPP aerial photo was degraded to the same resolution. The MIPS software was then used to drape the aerial photo image over the DEM and look at it in 3D perspective from any position. Figure 6 is a view from the northeast similar to Figure 5 but from a steeper viewing angle. Figure 7 looks from the north, and Figure 8 is from the west. These computer generated images with natural shading should help one understand the valley structure near the study area.

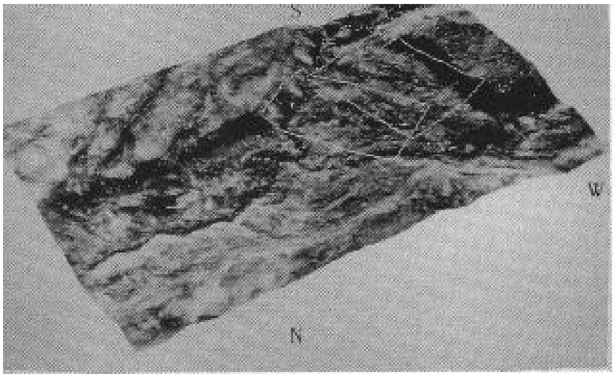

Figure 7. A 3D perspective view of Bangs Canyon from the north.

Figure 6 shows a pair of streams join to the right of the study area and then cut across a corner on the right. Similarly another pair join on the left and cut across the far left edge of the study area. The two resultant streams join just beyond the bottom of the study area and flow to the bottom of Figure 6. Those stream channels provide an effective barrier to keep modern talus from rolling into the study area from the northern and southern rims of the canyon. That leaves only the cliff to the southwest as a present source of talus.

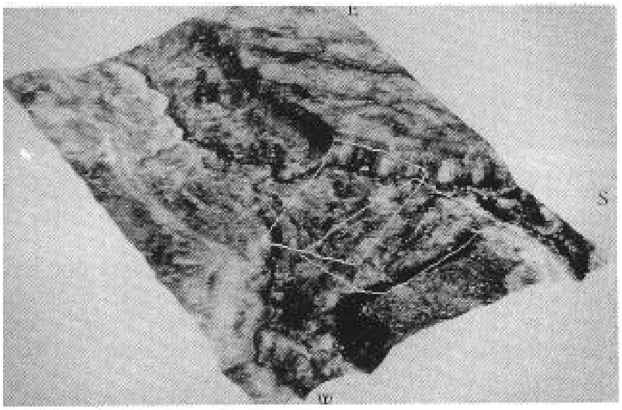

Figure 8. A 3D perspective view of Bangs Canyon from the west.

The computer images of the two slides were traced by moving a cursor around features in the viewing area. The perimeters of all visible boulders were drawn while confirming the identification by viewing the original slide photograph under a 10-40 power microscope. Many tree locations were marked with points (nodes). Streams, trails, ridges, and slide edges were marked with different classes of lines. This process is known as digitization, converting a picture into a series of points and lines. The boulder outlines are drawn in Figure 9 along with contour lines. The edges of each field of view of the individual photographic frames overlap in a trapezoid area near the figure center. In the overlap area the boulder outlines from the upper right picture were removed. Parallax errors of up to 10

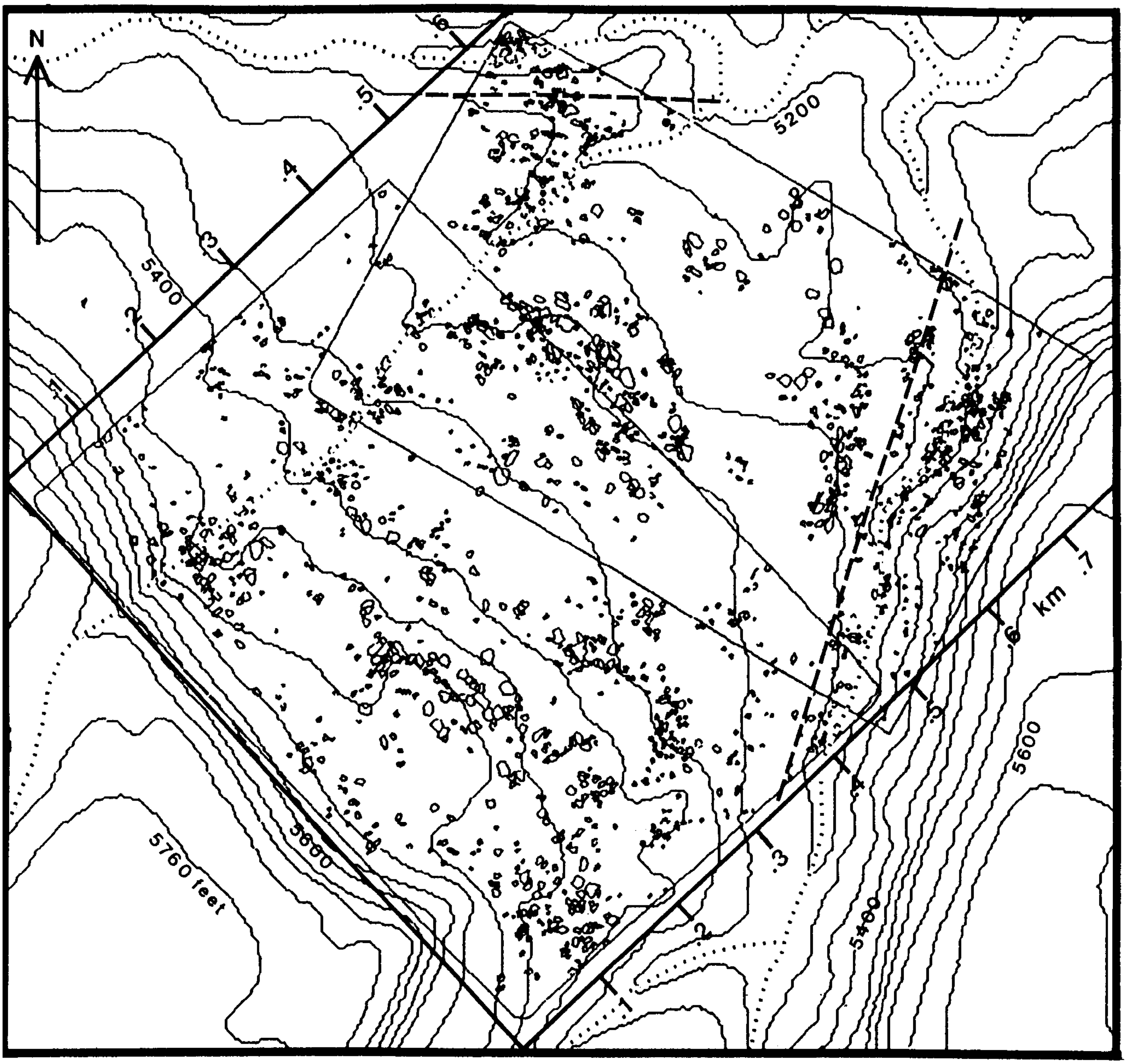

Figure 9. The boulder outlines in the study area and the coordinate system for position measurements. The dashed lines show where boulders were excluded from the study area to minimize possible contamination by talus from the cliffs to the north and east. The dotted lines are streams.

meters in position were found there, giving an indication of the size of errors in absolute accuracy caused by lens distortion, topography, and computer warping algorithms.

The MIPS software was then used to make a list of characteristics of every boulder, including its center geographic position (the Universal Transverse Mercator system was used to give a grid of meters north and east of a standard reference), maximum dimension (length), perimeter, cross sectional area, and roughness. The latter is the name MicroImages, Inc., gave to a parameter used by Holroyd (1987a) for identifying the shapes of snow particles. It is the product of the perimeter and the maximum dimension divided by the cross sectional area of an object. It starts at a theoretical 4 for a circle and increases as the perimeter or internal detail increases in complexity. Pointed or feathery snow particles can have a value exceeding 50. For rocks the roughness parameter should get smaller as a boulder weathers and becomes more rounded.

A computer program was written to sort the boulders with respect to distance from the southwestern cliff. The rotated coordinate system is shown in Figure 9. It is obvious that the zero distance position is not everywhere exactly at the cliff, but that should only blur the results slightly. A northern and a southeastern corner of the view were excluded to avoid possible talus from the other cliffs rolling up the far sides of the stream banks.

Boulder Distributions

The boulders that were mapped in the aerial photographs are buff colored (matching the Dakota Formation) and were lying on reddish soils (weathered shales of the Morrison Formation). Boulders less than 2 m across were not considered because of the 0.5 m / pixel resolution used in this study. The horizontal distribution of boulders in Figure 9 shows a scattered clustering and vacancy pattern littering the landscape. There is a major cluster on the east (right) that represents talus fallen from the cliff in that vicinity. That cluster was excluded from further analysis by allowing no boulders east of the nearby dashed line. The clusters nearest the southwestern cliff could be weathered outcroppings rather than remnants of the Dakota Formation. There are lenses of buff colored sandstone within the Morrison that resemble some of the Dakota layers above. Dinosaur fossils are sometimes found in such sandstone lenses. An expedition to this study area will be necessary to clarify the origin of the boulders in the clustered regions.

Elsewhere, apart from the clusters, the boulder distribution appears to have no obvious pattern. The rocks are certainly not clustered at the base of the cliff to the southwest, but are well represented nearly everywhere. That is the important point, contrasting with the distributions at other cliffs to be presented in the next article of this series.

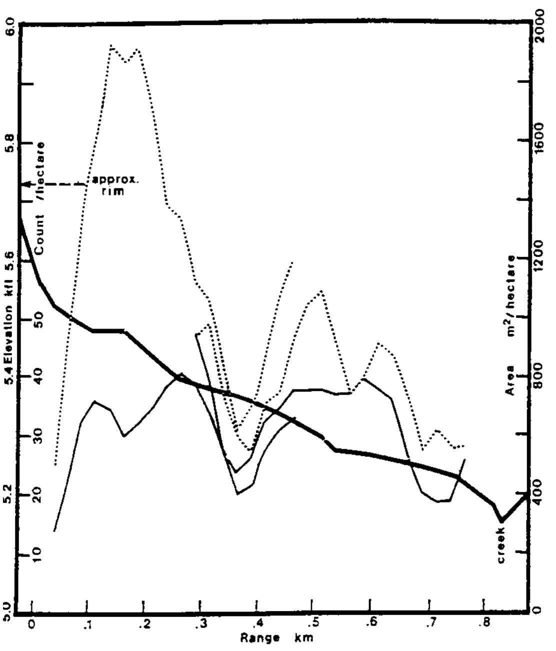

Figure 10. Distributions of Bangs Canyon boulders with respect to distance from the cliff: thick line—elevation, thin line-boulder count, dotted line-boulder area.

Figures 10 and 11 show the variation of several measurements with distance from the cliff. The thick line in Figure 10 gives the elevation of the land along the center of the study area. The rim is at an elevation of about 5725 feet. At the center of the view the rim is recessed from the origin of the coordinate system. The profile becomes level at ranges near 150 m. That is a location of a suspected outcrop of tan sandstone that interferes with this study. There may also be a minor outcrop near range 500 m. The stream is intercepted at 825 m. The elevation change from the rim to the stream is about 175 m (570 ft).

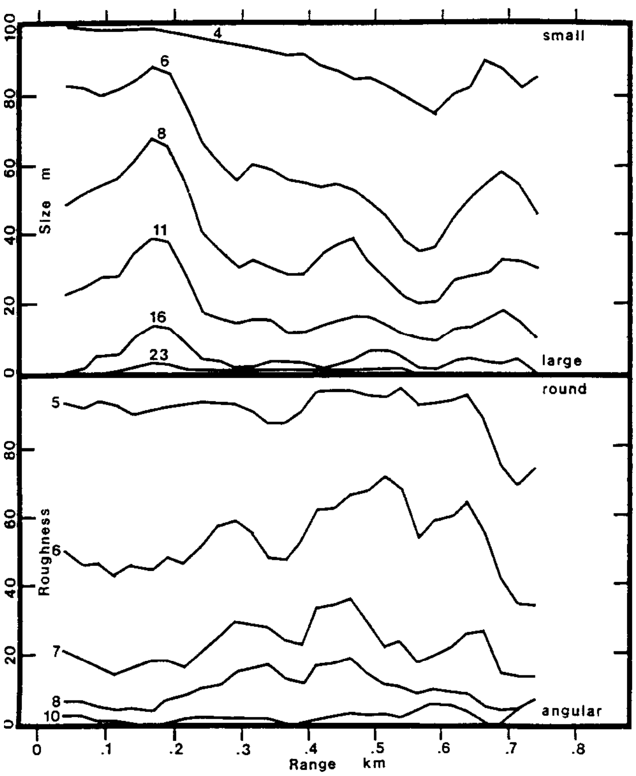

Figure 11. Distributions of Bangs Canyon boulders with respect to distance from the cliff: top—boulder size spectra, bottom—boulder roughness spectra.

The rest of the parameters in Figures 10 and 11 were calculated at a range resolution of 25 meters, smoothed with a running mean of three values, and plotted at the center range. The thin line curves of Figure 10 show the number of boulders per hectare as calculated for each photograph separately. In the overlap area the view closest to the cliff shows fewer boulders. This is because 1) the photographs look at somewhat different areas at the same ranges in the overlap region, 2) there are inaccuracies in the registration process from parallax on undulating terrain and lens distortions, and 3) some rocks may have been missed in each photograph. While there are large variations in this density of boulders, there appears to be no significant downward trend with distance.

The dotted lines of Figure 10 show the total area covered by boulders in square meters per hectare. The two photographs are again described separately. There is a major peak in coverage at the ranges near 150 m. This is the suspected outcrop region. Near 500 m is another possible outcrop region, though minor. There are differences again in the overlap region, but a minimum in boulder area at about 375 m is evident in both lines. There seems to be a weak trend of decreasing area covered by boulders with distance from the cliff. Considering only ranges beyond 250 m to avoid the major peak from the possible outcrop, the trend has a slope of -0.5 m^2/hectare per m of range, with only 15 percent of the variation explained by range.

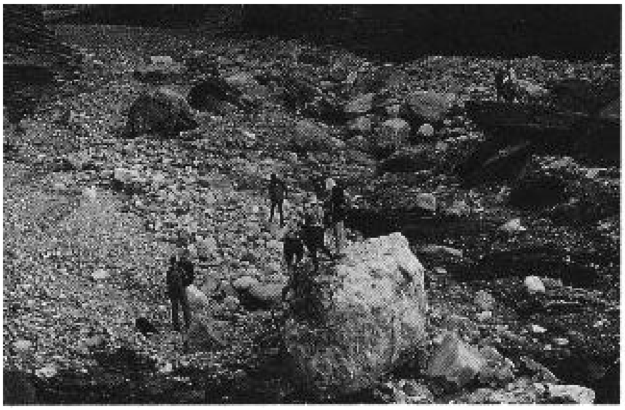

Figure 12. A large grounded boulder from a recent debris flow in the Grand Canyon at river mile 127.7 left.

In Figure 11 the two photographs are combined in the overlap region because the presentation is a spectral analysis. In both halves the ordinate is the cumulative percent of all boulders. The top half of Figure 11 shows the size spectrum. The thresholds are the maximum dimensions (approximate diameters) of the boulders in meters. These boulders are not small! At least some are larger than 16 meters in every range interval, and the small ones are near 3 meters across. The size series, though rounded to integers, is the set of powers of the square root of 2. (This is the same series known to photographers for the f-stops on a camera lens.) The reason for choosing a logarithmic size scale is because, to a first approximation, size distributions of natural "particles" tend to follow a log-normal distribution. The general trend in the figure is for the threshold lines to fall to lower values with distance from the cliff. This means that the boulders are decreasing in size. The peak at about 175 m is the suspected outcrop. This size trend is in agreement with the decreasing area curve of Figure 10. It is also in agreement with expectations that decaying rocks far from the cliff should be smaller than those more recently shed from the cliff edge. It is not in agreement with the observation that in an instantaneous fall of talus the larger boulders will tend to roll farther away from the cliff.

The cumulative size distribution of all 1545 boulders measured in this study (with a few duplicate entries in the overlap area) was plotted on log-probability graph paper. The data points nearly followed a straight line, confirming the approximate log-normal distribution of the sample. The line was compared to those of a perfect log-normal distribution and to distributions intentionally truncated at their small end. The comparison suggested that perhaps ten percent of the boulder distribution was smaller than the 2 m threshold. The size distribution of the top of Figure 10 is therefore not greatly affected by the truncation at 2 m.

The bottom half of Figure 11 shows the spectrum of roughness values. Only boulders at least 6 m in size are considered in this part because the computer digitization technique introduces artificial angularity to smaller boulders. The round boulders are plotted at the top and the angular at the bottom. There are some fluctuations in the spectrum but no general trend with distance. This result is contrary to what is expected for talus resulting from steady state cliff erosion. One would expect boulders far from the cliff to be more rounded and thus have lower roughness values.

Discussion

This article on Bangs Canyon boulders has presented an analysis of a valley in which large boulders litter the entire landscape. They are not confined to the bases of the cliffs lining the valley. The cliffs still appear to be shedding talus which accumulates at their bases. In an article to follow there will be several sites described at which the coverage of talus ceases abruptly near the cliff base. Bangs Canyon therefore seems to present an interesting counterexample to the "missing talus" phenomenon. The obvious question, therefore, is "Why is this valley so different?'

A study region was defined in which there was good photographic coverage at high resolution with a minimum of distortion. Study boundaries were set so that talus from other cliffs would be unlikely to have rolled into the study area. The most unusual feature of the boulders in the study area is that they extend to about 800 m from the cliff face. In the "missing talus" study areas the boulders range to only a few hundred meters away.

A major structural difference between Bangs Canyon and the "missing talus" sites is the direction of the slope of the strata with respect to the cliff edge. At Bangs Canyon water from an extensive upslope watershed should flow towards the cliff edge and exit there. The seepage should accelerate the erosion of the soft shales and siltstones, undermining the Dakota sandstones. At the "missing talus" sites at Mesa Verde, illustrated by Holroyd (1987b), and at the Book Cliffs north of Grand Junction, Colorado, the strata slope away from the cliff edge. Ground water there flows away from the cliff edge and does not contribute to cliff recession. At Monument Valley the slope is insignificant and there is minimal watershed at the higher elevations. Ground water seepage there is minor.

The Dakota sandstones of the Uncompahgre Plateau are a major aquifer. They collect an abundance of ground water from the snow pack and rainfall at the crest of the plateau and channel it to lower elevations. This process creates artesian well conditions in the valley east of the plateau. A 200 foot deep well drilled by Ken Stoy on my former property near Montrose found two different levels of pressurized water, including one at the boundary between the Dakota and Morrison Formations. The well had to be capped to prevent water from flowing out naturally. Such pressurized water would exploit rock weaknesses, such as fossil stream channels filled with only siltstone, and accelerate the undermining of cliffs in the region, particularly at such weaknesses. That tends to support the theory that the present valleys of the Uncompahgre Plateau are retracing fossil streams at the top of the Morrison Formation.

The pressurized water in the Dakota Formation also supports Austin's sapping hypothesis. It would cause catastrophic slumping of the landscape, leaving behind sharp cliffs at the site of the structural failures.

The two parts of Figure 11 may both be explained by the sapping hypothesis. In a catastrophic slumping of the land it is possible that the largest boulders would settle out of a moving slurry first while the smaller ones continue farther with the flow. This is the opposite from an instantaneous fall of talus from a cliff, in which the largest boulders tend to roll farthest while the smallest fragments are stopped more rapidly by frictional sliding. The size spectrum of Figure 11 shows the larger boulders closer to the cliff edge.

The roughness spectrum of Figure 11 is perhaps more revealing. The hypothesis on roughness is that boulders become more rounded with aging and thus tend towards smaller roughness numbers. The spectrum showed no significant trend of roughness with distance from the cliff edge. This speaks against a steady state erosion of the cliff edge. It is, however, in good agreement with a catastrophic formation of the canyon. All of the boulders in the center of the valley would be of similar age in a catastrophic failure and therefore have comparable roughness values.

A catastrophic sapping would create a slurry or debris flow that would prograde across the valley floor, which consists of the top layers of the Morrison Formation. Boulders within the debris flow could be of any orientation. Sandstone lenses in the Morrison would be resistant to erosion by the slurry and would become outcroppings, such as may be found near range 150 m. Subsequent erosion of the exposed Morrison shales would undermine the grounded Dakota sandstone boulders and let them tilt further to a wide variety of orientations, just as is found.

The debris flow mechanism is presently an important means of erosion, transport, and deposition within the Grand Canyon (Webb et al., 1988, 1989). This author was invited by Webb to examine on 14 April 1991 a recent debris flow at a minor side canyon at about mile 127.7 left. It started in the shales above the Redwall cliffs and plunged into the rubble at the cliff base 1.3 km upstream from the Colorado River. An intense rainfall may have wetted and softened the red clay binding that rubble. Presumably a second or continuing intense rainfall shortly thereafter provided the lubrication to flush the mass of rock and clay downstream in a catastrophic debris flow. The flow scoured many parts of this side canyon. Most of the material was ejected from the hanging valley into the Colorado River channel, where it created a new rapid and beach. Some of the debris grounded itself before falling over the lower cliff to the river. Figure 12 illustrates one of the giant boulders moved in the debris flow. The people standing on it provide a scale. The lighter colored rocks are unweathered debris from this recent debris flow. The canyon walls are of brown Tapeats sandstone and the canyon floor is of black Vishnu amphibolite. The size of the giant boulders here and elsewhere in the debris flow are comparable to those in Bangs Canyon.

One reviewer rightly observed that the bulk of this analysis assumes that the large boulders are near the locations of their original deposition after being removed from the cliff face. The subsequent sliding and tilting from further erosion of the Morrison was presumed to be minor. No consideration was given to the possibility that the boulders might have been redistributed by later floods. Floods can indeed move giant boulders of the size (6 m median) measured in this study. However, such floods must be catastrophic in magnitude. Such a possibility has no major effect on the conclusion that the boulder distribution results from catastrophic processes. Debris flows in this part of Bangs Canyon would follow near the main channels, found to the north and east of the study area shown in Figure 9. Debris flows could leave trails of boulders paralleling the channel, like a glacial lateral moraine. The banding in boulder locations in most of Figure 9 instead parallels the cliff face to the southwest. There is one band just west of the dashed line defining the eastern boundary of the study area. That band could indeed be a debris flow remnant along the east channel. Therefore there appears to be merit in a further study of Bangs, Unaweep, and other canyons of the Uncompahgre Plateau. The full extent of boulder distributions over the entire canyon systems could be mapped to try to distinguish between primary boulder positions and subsequent redistributions from debris flows, either of which would be evidences for catastrophic processes.

The evidence of Bangs Canyon seems to present an example of catastrophic canyon formation by sapping. Pressurized groundwater, possibly aided by an abundance of surface melt water and / or precipitation, undermined the resistant sandstones at weaknesses in or just above the Morrison Formation. The debris left the canyon as a slurry or debris flow. A trail of boulders grounded out of the slurry and still litter the landscape today.

Boulders then began to fall from the remaining cliff edges. The exposed shales in the valley center eroded more rapidly thereafter, deepening the valley and rearranging the large boulders. The author believes that the canyon formation is geologically recent because the remnant boulders in the valley center have not eroded away by normal weathering processes.

Looking ahead to a future article, the “missing talus” sites are consistent with a large lakeshore at an elevation somewhere between 5000 and 6000 feet. Bangs Canyon is in that range. Elsewhere it is thought that wave action along the shoreline may have pulverized previous talus material. If the shoreline extended into Bangs Canyon, the water may have helped erode exposed shales and boulders. The narrowness of Bangs Canyon and its orientation to the northeast may have limited the power of storm-driven waves within it. On the other hand, a lake in the region may have left water-saturated terrain that would be more prone to have a catastrophic failure after a sudden demise of the lake. The timing of the formation of Bangs Canyon with respect to the lake system is left unresolved in this article. A proper study for that purpose will require a more extensive aerial mapping of the boulders in Bangs and adjacent canyons, showing the highest and lowest elevations at which these giant boulders are found.

At the start of this study of Bangs Canyon it was thought that the boulders littering the landscape were the result of talus formation. The unusually large range of boulders from the cliff edge seemed to be an interesting counterexample to the “missing talus” phenomenon. Now, however, the sapping hypothesis of Austin and debris flow mechanism of Webb et al. seem to be a more reasonable explanation for the boulders across the valley floor. Talus resulting from slow cliff recession is probably located at the valley edges only, beneath the cliffs. That talus material is not abundant enough to have affected the distributions presented in this article. Such minimal talus deposits is another indicator of the geologic youth of Bangs Canyon. Bangs Canyon therefore seems to be worthy of further study, both from aerial photography and on the ground. Perhaps some way can be found to distinguish between boulders that are sapping or debris flow remnants and those that are from more recent falls of talus.

Acknowledgments

This is a remote sensing study of a nearly inaccessible canyon that the author has seen only from the air. The study could not have been done without the photographs taken by Carman W. Dunn on a Civil Air Patrol practice mission. Scanning of the slides was provided by MicroImages, Inc., Lincoln, Nebraska. Several of the features in the MIPS software were written by MicroImages in response to the needs of this study. The MIPS software used in this study was provided jointly by MicroImages and a grant from the interest on the Creation Research Society Laboratory Fund. The author greatly appreciates the contributions of the donors to this fund and the donations of expertise from MicroImages, Inc. The debris flow expedition in the Grand Canyon was provided by Department of the Interior agencies through the invitation of Bob Webb.

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THE 1993 MIDWEST FLOODS AND RAPID CANYON FORMATION

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Abstract

The processes which creationists postulate may be responsible for rapid canyon formation were vividly demonstrated during the floods which occurred in the Midwest during the summer of 1993. Erosion damage to spillways at three sites is described: Tuttle Creek Lake on the Big Blue River at Manhattan, Kansas; Coralville Lake on the Iowa River at Coralville/Iowa City, Iowa; and Milford Lake on the Republican River near Junction City, Kansas. Each location involved not only the removal of overburden, but also rapid erosion of the underlying strata. Details of duration, water volume, and water flow rates are presented and, where possible, these data are compared to those of prehistoric flood catastrophes. It is shown that extensive erosion in a short period of time is possible even in relatively well-consolidated and lithified strata, and that the pattern of erosion sometimes is remarkably similar to certain features found in the Grand Canyon. Additionally, brief descriptions of strata and fossils are provided.

Introduction

The Creation Research Society has an ongoing project to investigate instances of rapid erosion and to further develop a creationist model for canyon formation. Creationist thinking on the potential for rapid canyon formation has been recently chronicled in this journal (Williams, 1991; Williams, Meyer, and Wolfrom, 1991, pp. 93-97; Williams, 1993). A decade ago Austin (1984) chronicled rapid erosion and canyon formation on Mount St. Helens following the 1980 volcanic eruption. In this paper three examples will be presented showing the erosive power of vast quantities of turbulent water, moving swiftly under pressure, and laden with sediment: Tuttle Creek Lake on the Big Blue River at Manhattan, Kansas; Coralville Lake on the Iowa River at Coralville/Iowa City, Iowa; and Milford Lake on the Republican River near Junction City, Kansas. The Tuttle Creek area will be discussed in some detail later in the paper, but first the two other locations will be briefly surveyed. All three cases provide exceptional opportunities to observe firsthand the conditions which creationists postulate are capable of rapid canyon formation, even in limestone bedrock.

Milford Lake

On 20 July 1993, water began flowing through the emergency spillway of Milford Lake. Three days later the earthen spillway dam and the road atop it (Kansas State Highway 244 Spur) were breached, producing extensive erosional damage as a result of the rushing flood waters (Figure 1). Water flowed through the

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