



The Proceedings of the International Conference on Creationism

Volume 2
Print Reference: Volume 2:II, Pages 115-128

Article 46

1990

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Recommended Citation

Holroyd, Edmond W. (1990) "Missing Talus on the Colorado Plateau," *The Proceedings of the International Conference on Creationism*: Vol. 2 , Article 46.

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MISSING TALUS ON THE COLORADO PLATEAU

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ABSTRACT

A photogrammetric examination of the size distributions and degrees of aging of talus boulders at several locations in western Colorado, northwestern New Mexico and northern Arizona indicates that steady-state cliff erosion and talus formation has not been continuous. The recent removal of earlier talus by the shoreline waves of large extinct lakes is suggested.

INTRODUCTION

The erosion patterns of the Colorado Plateau, including the Grand Canyon, the mesas and buttes of Monument Valley, and the arches in the national monuments, are commonly thought to be indicative of many tens of thousands to millions of years of natural sculpturing processes. However, the lack of aged talus beyond the bases of numerous cliffs in the area appears to be testimony of the removal of previous rocks by wave action at the shorelines of extinct lakes. The angular nature of the present talus indicates a relatively recent demise of those lakes, which could not have coexisted with the Grand Canyon. This is an indication that the Grand Canyon is post-Flood and was carved recently.

Such a scenario was mentioned in a short note by Holroyd (1) along with a photograph of talus falling from the western cliffs of Mesa Verde. The note pointed out the lack of aged talus on the flat plains (pediments) away from the cliffs. At similar locations, previous rock strata continuity for hard rocks over soft rocks can be assumed across the valleys of dissected plateaus; the valley is the vacated volume caused by previous erosion. One would therefore expect to find a trail of decaying talus left on the pediments by the receding cliffs. But such a trail is not always present.

Several explanations for such "missing talus" were offered. A more rapid decomposition of the hard sandstone talus than the soft shale and mud on which the talus fell seems unlikely; hard rocks should last longer than soft rocks. Rock removal by a river is not appropriate at that location because of the lack of a river in the region. A general regional scouring of the landscape by some unknown broad sheet of flowing water might have caused the widespread removal of the softer strata and the gross carving of the cliff edges. But a lake shore erosion scenario appeared to be the simplest solution for cleaning the cliff bases of old talus. The note recommended that careful field observations be made to refine hypotheses about possible missing talus.

A preliminary photographic survey was made on 35 mm film of talus at the several locations in the Colorado Plateau listed in Table 1. Cliffs with basalt and similar igneous rock caps were excluded from consideration because prior existence of extensive beds of such hard strata above the present pediments could not be assured. Some photogrammetric analyses have been completed to characterize the size, location, and shape characteristics of the talus at some of the sites. The resulting distributions at one site were "aged" to examine what a steady state distribution of talus away from the cliff might look like. The Bangs Canyon site was photographed, but not yet analyzed, to serve as an counterexample of a broad valley in which talus can be found strewn across its entire 0.8 km width.

The existence of large glacial and post-glacial lakes is generally accepted in geological literature. Lake Bonneville is named as such a predecessor for the Great Salt Lake on the basis of raised beaches throughout the basin, as summarized by Hintze (2). Many other lakes are named by Whitcomb and Morris (3). Numerous biblical creationists, such as Oard (4) and Northrup (5), recognize a glacial period, giving it a setting well after Noah and probably

during the lifetime of Job. Burdick (6) and Northrup (7) point to the rapid draining of such a post-glacial lake as the mechanism for the carving of the Grand Canyon.

To examine the lake shore hypothesis, digital elevation data for the Colorado River basin were examined. The Grand Canyon was "plugged" up to the level at which the water would flow through a different spillway around the Kaibab uplift. The extent of the resulting "lake" was thereby mapped. A more recent lake, created by the damming of the Colorado River by lava from Vulcan's Throne, was mapped in a similar manner. The shorelines of these "lakes" were nearly coincident with the "missing talus" sites under examination.

Table 1. The locations and rock strata of sites photographed for this study.

<u>Site no., name</u>	<u>approx. location</u>		<u>base elev. m</u>		<u>hard strata</u>	<u>soft strata</u>	<u>period</u>
near Towaoc, Colorado:							
1. Mesa Verde	37° 12.5'N	108° 40'E	1770		Mesa Verde ss.	Mancos shale	Cretaceous
2. Flat Top Rock	36 58.5	108 44	1610		Mesa Verde ss.	Mancos shale	Cretaceous
near Grand Junction, Colorado:							
3. Book Cliffs	39 7.5	108 22	1460		Mesa Verde ss.	Mancos shale	Cretaceous
4. Bangs Canyon	38 57.5	108 31	1580		Dakota ss.	Morrison shale	Cret./Juras.
near Marble Canyon, Arizona:							
5. Marble Canyon	36 49	111 38.5	1120		Shinarump cong.	Moenkopi silts.	Triassic
6. rd. to Lees Ferry	36 50.5	111 38	1070		Shinarump cong.	Moenkopi silts.	Triassic
in Monument Valley, Arizona:							
7. Rain God Mesa	36 57	110 5	1580		De Chelly ss.	Cutler shale	Permian
8. Spearhead Mesa	36 56.5	110 3.5	1580		De Chelly ss.	Cutler shale	Permian

THE TALUS OF FLAT TOP ROCK

Several kilometers to the south of the photo of Holroyd (1), just across the border into New Mexico, the road passes about 550 m to the west of a mesa named Flat Top Rock. It is a smaller cliff with the same strata of hard Mesa Verde sandstone lying on soft Mancos shale. Its top is about 100 m above the immediately surrounding plains. Most talus traveled no farther than the 100 m horizontally to the base of the shale slopes, though a few rolling boulders made it to almost 150 m from the cliff edge.

A pair of photos were exposed from the road according to the geometry illustrated in Figure 1. Thin vertical and horizontal lines form squares of 1 km in the Universal Transverse Mercator grid system. The northernmost, part of which is shown in Figure 2, was taken from a range of about 1070 m from the facing slopes. The other photo was taken at a range of about 550 m from the facing slopes and is shown in Figure 3.

The focal length of the nominal 50 mm lens was calculated from photographs of stars to be actually 51.3 mm. The base line between the photos was about 990 m based on the positions of other mesas in the backgrounds. The photo in Figure 2 was aimed at azimuth 126.6° with an elevation angle of 7.0°. The photo in Figure 3 was aimed at azimuth 70.5° with an elevation angle of 10.9°. The large angle of about 56° between the two photos made it relatively easy to determine the 3-dimensional position of any point visible in both photos.

The original slide photos were scanned in color at 2000 pixels per inch for use in an image processing microcomputer system. The software used for the analysis was the Map and Image Processing System (MIPS) from MicroImages, Inc. (8). Equations were derived relating pixel positions (lines and columns) to angles and then to distances. Horizontal locations were measured in the photo of Figure 2. Both horizontal and vertical locations were measured in the photo of Figure 3. These three numbers (pixel positions) were entered into an HP-67 programmable calculator to derive the horizontal coordinates (meters east and south of photo site for Figure 2), range from photo site of Figure 3, and elevation (meters above sea level).

A map was thereby derived which showed the locations of the largest rocks seen in both photos and the approximate elevation contours. At the north and south ends of the map the rocks in the drainage channels were hidden from view of one camera by adjacent ridges. Contours away from major rocks were not analyzed. It had been hoped to accurately locate the positions of all rocks at the base of the cliff. But the leveling of the terrain of the foreground pediment caused many rocks to be behind foreground rocks in at least one of the photos and thus impossible to correctly identify as being the same rock in both photos. Aerial photography from a low enough altitude to resolve the rocks would greatly improve future studies of talus locations.

The analysis provided the measurement that beyond about 100 m from the cliff edge there were almost no boulders of any size. There were only a few of similar aging that happened to have

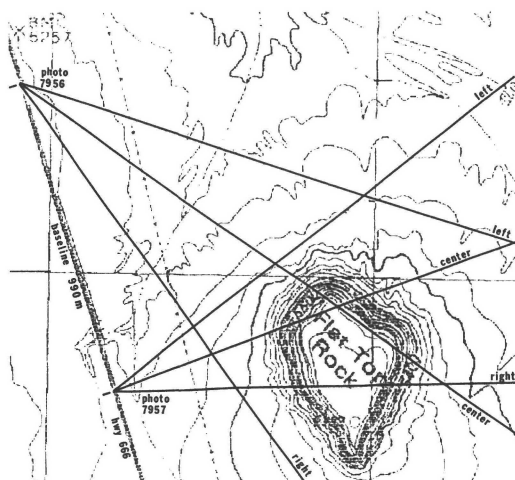


Figure 1. A topographic map of the vicinity of Flat Top Rock showing the fields of view of the two photos analyzed.

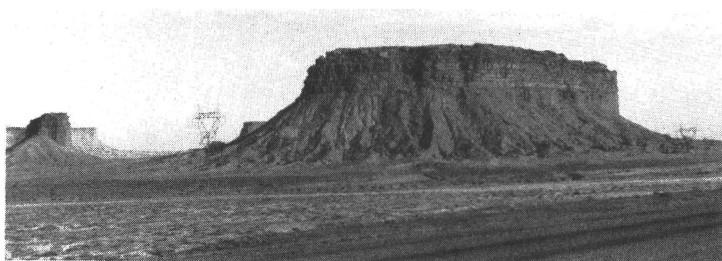


Figure 2. Flat Top Rock as seen from the northwest.



Figure 3. The northwest side of Flat Top Rock.

rolled farther. It also showed that the slopes of the shale surface ranged from about 36° at the north to about 30° at the south end of the study area.

The photo of Figure 2 was used for a size spectrum. All rocks analyzed were assumed to be at a range of 1070 m. This created size errors of up to 5 percent. Using a constant range for talus in the photo of Figure 3 would have created errors of up to 27 percent or else laborious corrections.

The rock sizes were measured with the MIPS software. It was assumed that the rock orientation with respect to the plane of the photo was mostly random and so the maximum extent of the rock, as viewed, was a sufficient measurement for a size distribution of many rocks. The cursor was therefore placed at the maximum extremities of each rock. The software automatically converted that distance into meters. A label indicating the pixel coordinates of the bottom of each rock was typed into the computer and then stored in a file with the rock size. Rocks smaller than 1.5 m were often measured but were ignored in compiling the size spectra.

Using the coded labels, the rocks were then sorted by altitude and partitioned into distance groups at 10 m intervals from the cliff edge, and into size groups at 0.5 m resolution. The number of rocks in each distance bin is shown as the lower line in Figure 4a. It is seen that the number of rocks increases with distance from the cliff and then drops abruptly beyond the 100 m position marking the approximate bottom of the slope. The size spectrum is shown in Figure 4b in terms of cumulative percent of all rocks in the distance interval. Though the size spectrum is noisy for this number of rocks, the general trend is for larger sizes to be near the base of the slope. There is no transition back to small, decaying sizes for increasing distances from the cliff across the pediment.

This should be an expected result for a fresh fall of rocks from the cliff. The largest rocks would have the largest momentum and energy and should travel the farthest. However, at the base of the cliff the terrain flattens and provides little further gravitational assistance to the movement of the rocks. They therefore quickly come to a stop. Rain and frost heaves will not provide much more horizontal movement of the larger rocks thereafter. Their geographic location should remain close to where they fell from the cliff until they decay to a more mobile sand.

ESTIMATES OF SPECTRA OF AGING TALUS

This irregular size and location spectrum was then used as a basis for estimating what a spectrum of decaying rock might look like. The present spectrum, by its abrupt cutoff at the base of the slope, appears to be similar to a relatively fresh fall of talus with little aging. The rocks at the bottom are still angular with limited rounding due to decay. It is therefore assumed that talus falls in the past would produce the same size and location distributions, with respect to the cliff edge, as the present data set.

An "aged" spectrum was assembled in each location bin of 10 m horizontal width. Into each bin went all of the present rocks for that location. Then the additions were the present spectrum offset at successive 10 m intervals (to represent contributions from each step in the recession of the cliff edge) but successively shrunk as well by moving all rocks a set number, n , of 0.5 m size bins to a smaller size. The process was repeated, shifting 10 more meters and shrinking the previously shrunk spectrum n more size bins, until no more rocks remained. Rocks becoming smaller than the 1.5 m limit of the original spectrum vanished from consideration.

Four shrinkage rates were considered for this simulation. The rocks were decreased in size at 5, 2.5, 1, and 0.5 m for each 10 m shift in horizontal location. These rates represent a loss of material from each end of a rock of half of those numbers. The shale, however, presents only one surface for erosion. It is therefore more appropriate to compare the 10 m recession rate of the shale and cliff with the one-sided talus shrinkage rates of 2.5, 1.25, 0.5, and 0.25 m. The ratio of such rates are then 4, 8, 20, and 40 meters of shale per meter of sandstone. The simulations are labeled with these latter numbers representing the relative erosion rates of the two rock types.

Figure 4a shows total rock counts in each distance bin for the original count and those for three of the four aging rates. The 4:1 rate is so fast as to hardly change the rock counts. The rates of 20:1 and 40:1 have appreciable tails of decaying talus on the pediment.

The size spectrum for the relative decay rate ratio of 40:1 is presented in Figure 4c for comparison with the original spectrum in Figure 4b. The spectrum on the shale slope is similar to the original, but the shrinking effects of the decay are obvious farther out. The spectra for the faster decay rates are intermediate.

TALUS ON PEDESTALS

In some locations the boulders have shielded the underlying shale from erosion, resulting in the boulders sitting on pedestals of shale. Figure 5, taken along the road from Marble Canyon to Lees Ferry, Arizona, illustrates an extreme example of such pedestals. The ages of my children at the time ranged from 5 to 13; their presence under the rock provides a scale. Such pedestals confirm that there is a great difference in erosion rates for the two rock types.

The pedestal thickness can be used together with the slope of the surrounding surface to compute a horizontal recession distance of the softer strata since the boulder arrived at the site. Photos at the same site taken parallel to the surface elevation contours suggest a slope of about 1:10 where most of the large talus is located. The pedestal in Figure 5 is about 3 m tall, giving a horizontal shale recession distance of about 30 m. If the boulder has lost 2 to 3 m of material from all sides since landing, then a relative decay rate ratio of 15:1 to 10:1 can be roughly estimated.

Most of the adjacent boulders do not sit on tall pedestals, so such a decay rate ratio calculation should not be considered final. Yet it is in the range by which Figure 4a suggests that there should be some detectable trail of decaying talus remnants across the pediment. Photos to the right and left of Figure 5 show an abrupt cessation of talus at large sizes, just like at Flat Top Rock.

AN AGING TALUS INDICATOR NUMBER

An index, designed for images made up of pixels, is introduced by Holroyd (9) for classifying the shapes of snow particles. It is calculated as $F = P \cdot D / A$, where P is the perimeter of the image (including internal perimeter for interlocking branches), D the maximum dimension, and A the cross sectional area (holes subtracted). The smallest this index can be is 4.0 for a solid circle. It is 6.55 for a semicircle, 5.66 for a square, and 6.71 for a rectangle of sides with a ratio of 1:2. For needles and stellar shaped ice crystals the ratio can approach about 50. It is a good classifier for the amount of fine structure in the image. It is also independent of particle size.

This number could be highly useful for giving a relative index for rock aging. Fresh talus should be highly angular, giving a relatively large number. As the rock ages, its corners should round and the shape should tend towards spherical or hemispherical, thereby achieving a lower index number. MicroImages, Inc. (8), added this index to their MIPS software for use in this project, calling the index "roughness".

The rocks at the far lower left and the lower right of center of Figure 3 were analyzed for roughness. Using the MIPS software the boulders were carefully outlined. Because the ratio is independent of scale, the range of the rocks did not matter. The outlines of the rocks were then extracted from the image and the roughness was calculated for each. The results for 60 of the rocks in Figure 3 are presented in Figure 4d as the dotted line in a cumulative percentage curve. In this particular sample of rocks there was a slight tendency for an increase in the roughness with size, but the correlation coefficient was small.

For comparison the "roughness" ratio was calculated for talus in Monument Valley, Arizona. One site, No. 7, of relatively old talus was photographed at the northwestern corner of Rain God Mesa. An aerial view of the same location, but from farther away, is given by Baars (10), with the site being the near corner of the mesa in the center of the view. The talus ends abruptly at the base of the shale slope, as confirmed by that aerial photo.

The other site, No. 8, was the southwest corner of Spearhead Mesa, which lies east of Rain God Mesa. The talus here is more angular and presumably fresher than at the other sites examined, but some of the boulders are on short pedestals. Four photos were combined for a large sample of the rocks at this mesa corner. Those photos which included a view of the pediment showed the typical abrupt cessation of the talus and at large sizes.

The cumulative distributions of the roughness index for the two Monument Valley sites are shown in Figure 4d as solid lines. The Rain God Mesa distribution, 7, shows smaller numbers and therefore more rounding than the Flat Top Rock distribution. The Spearhead Mesa distribution, 8, shows larger numbers, in keeping with the angular nature of those rocks.

In general, roughness distributions for differing geologic formations should not be compared for the purposes of determining relative age. While the Rain God Mesa talus can be judged to have been aged longer than the talus examined at Spearhead Mesa (both are of De Chelly sandstone), it is not appropriate to conclude that the Flat Top Rock talus is intermediate in age. The Mesa Verde sandstone most likely has a different rate of decomposition from the De

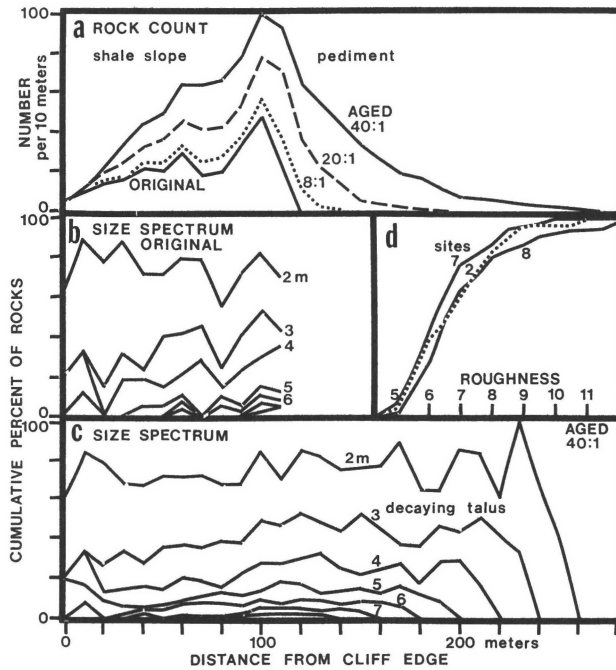


Figure 4. The original and "aged" number (a) and size (b,c) spectra of talus with distance from the cliff edge. The ratio of the relative single direction decay rates for the shale and sandstone are 8, 20, and 40:1 as labeled for the "aged" distributions. In (d) is the cumulative percent distribution of the "roughness" index for talus at three locations identified by number from Table 1.



Figure 5. Conglomerate talus sitting on siltstone pedestals along the road from Marble Canyon to Lees Ferry, Arizona. The children provide a scale for this extreme example, suggesting a pedestal height of about 3 meters.

Chelly sandstone. Talus at the site of Figure 5 appears more rounded, but the roughness distribution has not yet been measured.

POTENTIAL POST-GLACIAL LAKES

One of the explanations offered for the "missing talus" was wave destruction of previous talus at the shorelines of recently extinct lakes. To examine this hypothesis digital elevation data for the Colorado River Basin were examined to determine the extent of possible lakes that might have been present if the Colorado drainage was blocked. The data have a horizontal resolution of 30 seconds of latitude and longitude and 20 ft elevation. They were derived from 1:250,000 scale topographic maps of typically 200 ft elevation resolution. The numbers in this data set tend to cluster near the even 200 ft elevations.

As indicated in Holroyd (1), plugging the Grand Canyon at about 1700 m elevation (5600 ft) would cause the Colorado River to be diverted to the north of the Kaibab uplift, near the Arizona-Utah border. It would also cause the formation of a series of large lakes. Those possible lakes for a 1700 m surface are shaded with the MIPS software in Figure 6 using present topography. It is recognized that surface topography is always changing by erosion and deposition, by uplift and subsidence, and by igneous activity. In this study the topography of the recent past is assumed to be nearly the same as that of today, but only to get a general idea of the possible locations, areas, and volumes of recently extinct lakes.

The southern basin of that series of possible lakes fills the present Painted Desert of Arizona. Geologists (11-14) recognize the recent (Pliocene) presence of a Lake Bidahochi in that location on the basis of the lacustrine Bidahochi formation in northeastern Arizona. The top of that formation is above 1850 m (6070 ft), indicating a lake surface higher than that considered in Figure 6. But none of the references illustrate a possible extent of Lake Bidahochi. It would have been larger than that shown here.

Geologists (13-16) also point out that lava has plugged the Grand Canyon several times at Vulcan's Throne. The much smaller lake that would be formed if the lava from Vulcan's Throne plugged the river to the top of the canyon at that location (1160 m, 3800 ft) is shown as an inner solid black in Figure 6. Nations and Stump (15) indicate that the oldest remnant of lava in the canyon has a top elevation of about 925 m (3035 ft). Baars (16) mentions a plug whose top would be at about 670 m (2200 ft) for the most recent flows of lava.

The talus site numbers from Table 1 are plotted in Figure 6. It is seen that the Kaibab plug produces a "lake" whose shores would be near most of those sites. The Vulcan's Throne plug produces a possible shoreline at the Marble Canyon site. This provides circumstantial evidence that shoreline cleansing of the slopes of previous talus might have been possible.

The software of Jensen and Domingue (17) was used to determine the basin upstream from the junction of the Colorado River and Bright Angel Creek in the Grand Canyon. A program was then written to convert the elevation data within that basin outline to a table of areas and cumulative "lake" volumes within each elevation contour. The calculated areas and volumes behind the Kaibab plug would be about 69,000 km² and 12,600 km³. For comparison, Hutchinson (18) gives the area and volume of Lake Superior as 83,300 km² and 12,000 km³. So the series of lakes that might have existed behind a Kaibab plug would sum to a lesser surface area but a similar volume to the world's largest fresh water lake.

SUMMARY AND DISCUSSION

This study has amplified on a previous note that raised the question of possible "missing talus" on the Colorado Plateau. Photogrammetry was used to examine the talus at several widely separated locations as a part of a continuing analysis. Size, location, and roughness distributions were measured for the talus at Flat Top Rock. They showed that the largest boulders tend to be found at the base of the shale slopes, where there also are the greatest numbers of rocks. But the presence of talus abruptly ceases a short distance away across the flatter surfaces of the pediment. There is no trail of decaying talus beyond the large talus boulders. This pattern is repeated at Monument Valley, Marble Canyon, and presumably at many more sites not yet examined.

The present talus size and distance spectrum was "aged" in a numerical experiment. Size and distance spectra were calculated for four different relative rates of decay for the shale and sandstone rocks. If the rates do not differ by more than about 10:1, then it will be difficult to detect the trail of decaying talus because it would be hidden amongst the more recently fallen boulders. But if the rates of decay differ by more than 20:1, then there should be a very obvious distribution of shrinking talus with distance out onto the pediment. Those decaying rocks are not present at most of the sites, indicating that previous talus has

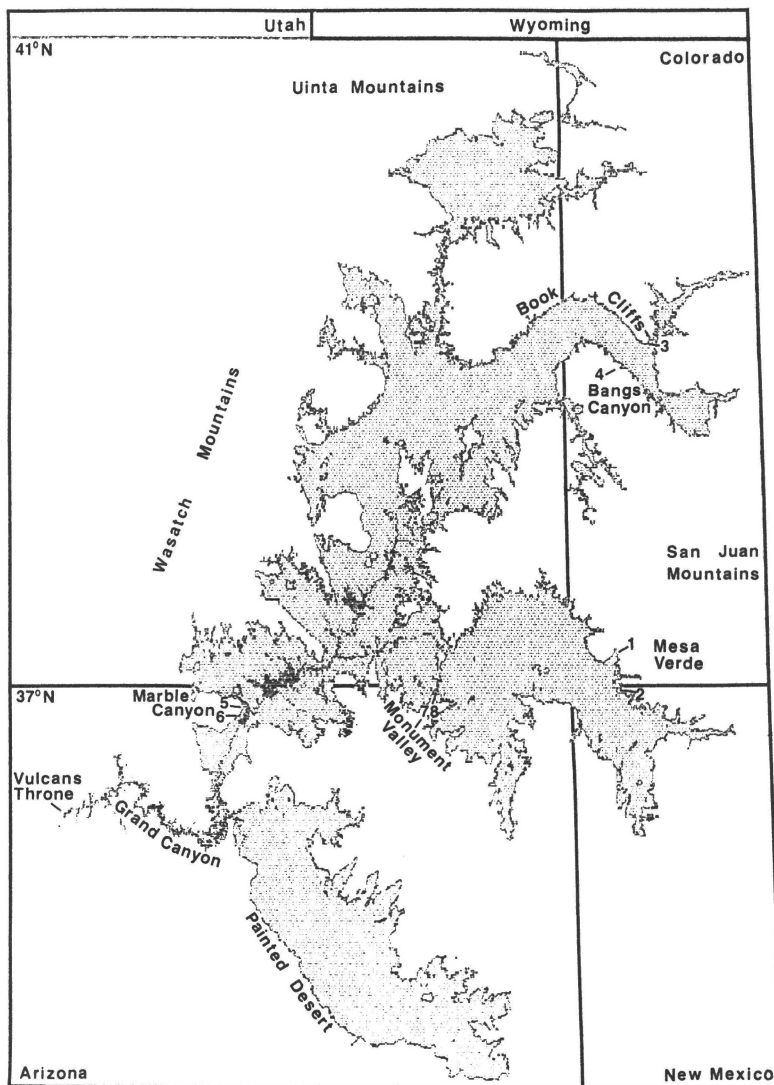


Figure 6. The outlines of "lakes" formed on present topography if the Colorado River was plugged at the Kaibab Uplift (shaded) and at Vulcan's Throne (inner black). The talus study sites listed in Table 1 are identified by number.

been removed by some process and that the elapsed time since the cessation of that process has only been sufficient to erode the cliffs back several tens of meters.

A crude estimate of relative decay rate was made on the basis of a pedestal under a giant boulder near Marble Canyon. The result was in the range that would require expectation of a short trail of decaying talus. But there is a need for a large number of measurements of the relative decay rates for different rock formations. This is a critical number for determining that talus might be missing.

The presence of large lake bodies which have since become extinct is a reasonable concept in terms of post-glacial lakes. Many other former lakes are already recognized by geologists. The outline was derived for a lake that might have existed before the carving of the Grand Canyon. It had an area and volume comparable to Lake Superior. Also sketched was a much smaller and more recent lake caused by the plugging of the Colorado River at Vulcan's Throne by lava pouring into the canyon. All or parts of both lakes are recognized by many geologists. The shorelines of those lakes are near the sites of the talus studies.

These studies are preliminary and there is much more that can be done. Additional cliffs could be examined by low level aerial photography or video to better map the extent of the talus with respect to the cliff edges. Other studies need to establish the relative rates of decay of the hard and soft rocks. Numerous small cliffs on the Colorado Plateau might be examined for possible shoreline etchings.

To date these preliminary studies suggest a link between "missing talus" and extinct shorelines. The present talus is decaying and the cliffs are receding. The "missing talus" phenomena indicate that the demise of those lakes was relatively recent. The cliffs have receded only tens of meters since then. In fact, perhaps half of the shale slopes at Monument Valley have not yet had a subsequent fall of talus. Yet the lakes that would have washed the slopes of Monument Valley and Mesa Verde could not have coexisted with the Grand Canyon. Therefore, because the demise of those lakes appears to have been recent, the carving of the Grand Canyon must also have been recent.

ACKNOWLEDGMENTS

Parts of this study were funded by the interest of the Creation Research Society Laboratory Fund. MicroImages, Inc., of Lincoln, Nebr., provided the Map and Image Processing System software and the scanning of the 35 mm slides. Dr. Tom Huber of the University of Colorado-Colorado Springs provided the scanning of the topographic maps.

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NOTE

Flat Top Rock (Site 2) and Monument Valley (Sites 7, 8) are within the Navajo Reservation. Therefore a Field Investigation Permit was required for the research reported in this paper. Individuals or organizations desiring to conduct geological, paleontological or other related scientific investigations on the Navajo Reservation must first apply for and receive a permit from the Navajo Nation Minerals Department, P.O. Box 146, Window Rock, Arizona, 86515. The permit application fee of \$100.00, a map detailing the area of the proposed investigations, and a complete description of all proposed activities are required for processing the application.

The Navajo Nation Minerals Department in no way condones or supports this research. The issuance of a permit does not indicate approval or disapproval of the conclusions of the report by the Navajo Nation.

DISCUSSION

Dr. Holroyd has provided valuable observations concerning the deficiency of expected talus deposits in an important geologic area. Uniformitarian geologists would suppose significant foot-slope deposits if landscapes of the Colorado Plateau have been backwearing slowly during millions of years. These, as the author points out, are not found. I have personally inspected the slope near Lees Ferry (Figure 15) and can attest to the fact that it is a remarkable contradiction to uniformitarian orthodoxy.

Dr. Holroyd proposes that many slopes on the Colorado Plateau have been affected by shoreline wave erosion from high elevation lakes. I agree. Not mentioned by the author are important recent studies on the Colorado Plateau showing the importance of sapping, the failure of foot-slopes by outflow of water from the strata. Sapping process would be an extremely important cause of slope failure following catastrophic drainage of lakes. Catastrophist geomorphology is alive and well on the Colorado Plateau!

Steven A. Austin, Ph.D.
Santee, California

If as Dr. Holroyd states in this paper that there are practically no boulders more than 100 meters from the base of the cliffs, then this is truly a remarkable piece of information.

- 1) Is it possible that including boulders smaller than 1.5 meters would alter his conclusions?
- 2) Is it possible that many of the older boulders have been buried by clay washed down from higher on the slope and are thus hidden from view? Did Dr. Holroyd investigate this possibility?

Glenn R. Morton, M.S.
Dallas, Texas

Dr. Holroyd misunderstands Burdick's explanation of the carving of the Grand Canyon. Burdick had explained it by means of dammed up Noahic flood waters during the retreat of the Noahic flood. In no way does Burdick's explanation relate to an erosion of the canyon by trapped glacial melt waters from a post Noahic flood ice age several centuries after the flood as I had first proposed in 1968.

Dr. Holroyd's idea of mapping the beaches of the ice age lakes which I had proposed as the instrument that abruptly eroded the Grand Canyon was excellent. Nevertheless, it is handicapped by the uniformitarian assumption that the Kaibab/Coconino plateaus and the 5,600 ft. level imposed by his computer simulation based upon present elevation configurations. Of course these fossil beaches also may be testimonies of the uneasy profile of the continent during the centuries of major continental division in the post-flood era. Indeed, they probably are just that.

The order of events at the Canyon can be reconstructed from the present scene.

- 1) The Mesozoic Navajo, Kayenta, Chinle, Shinarump and Moenkopi Formations (which survive in the Vermillion and Echo cliffs) overlaid the area of the Colorado Plateau.
- 2) These, clearly preserved in the Vermillion and Echo Cliffs, were removed, almost without trace, from the Kaibab formation in the Kaibab/Coconino Plateaus by moving waters that carried them into the great estuary of the sea which then lay to the west. The erosion of the Grand Canyon had begun.
- 3) Powerfully moving ice age melt waters from the north now found the great crisscross faults which had fractured the well indurated Noahic flood formations of the upper Grand Canyon layers were now exposed. These had resulted from major continental movement and the resulting uplifts several centuries after the flood. The racing glacial melt waters ripped blocks as large as a football stadium from the formation, using them as erosive tools as the Canyon and its abrupt, fault-structured side canyons abruptly were carved. (The Colorado River today meekly follows the course of its violent, catastrophic path through the resulting canyon).
- 4) The present surface of the plateau, the Kaibab formation, then was upwarped between 7,000 and 8,000 ft. along the Kaibab Plateau.

- 5) Probably it was the same violent adjustment that downwarped other parts of the Kaibab formation to lie at less than 5,000 ft. near Fredonia, east of the Grand View fault toward Cameron and also near the Mesa Butte fault near the San Francisco Peaks. Careful study will demonstrate that the original Paleozoic deposits in the Canyon's walls strongly suggest repeated major sea intrusion and retreat during their deposition at near sea level. The continuation of this crustal disturbance conceivable be preserved for us in the continued elevation of fossil lake bed beaches to the north, east and northeast of the Canyon.

As a result, it is highly probable that we cannot estimate the original elevation of the present 5,600 ft. saddle north of the Kaibab uplift at the time of the Canyon's erosion. Neither can we know for certain the elevation of the upper layers of the near 2,000 feet of Post-Flood Mesozoic alluvial sand deposits which initially were stripped off of the Kaibab/Coconino Plateaus before the waters carved their way through the massive crisscross fault structures in indurated Kaibab and underlying structures to form the Grand Canyon. Only by comparison of the present fossil beach levels in different parts of the great lake system which once existed above the Grand Canyon can we even estimate the elevation of the Kaibab/Coconino plateau when that erosion began. The actual erosion took place when the trapped post-flood ice age waters broke through the dam which had impounded them, allowing the catastrophically abrupt erosion of the Grand Canyon. I originally had proposed that the Kaibab/Coconino uplift itself had been that temporary dam. However, presently I think that Walter Brown is correct in proposing that the Vermilion Cliff/Echo Cliff uplift was the barrier behind which the ice waters impounded.

Whether it is true that the Kaibab/Coconino Plateau has continued elevation after erosion or the proposed depression of the saddle to the north is the problem or perhaps both remains for researchers to discover. The question needs far more careful study by creationists who are physical geologists who also recognize a valid working model for the catastrophic post-Noahic flood centuries. My own discovery of man's firepits on the ancient shores of fossil Lake Uinta east of the Vernal, Utah, (a lake that contributed to the erosion of the Grand Canyon), is suggestive of the kind of a time frame needed to establish the approximate time when these glacial waters from Wyoming, Montana, Colorado, Arizona and New Mexico carved the Grand Canyon. This indicates that it was well after the tower of Babel which forced man to flee onto that which became major continental blocks in the following centuries.

Dr. Holroyd also would do well to examine the giant deltas found at the mouths of deep canyons in the Roan and Book cliffs to the northeast of Arches National Monument. These appear to have been deposited while Fossil Lake Kapiowitz had backed up the present Green River Drainage to the very foot of the Uinta Mountains into Fossil Lake Uinta. Apparently the great Green River Basin of southern Wyoming succeeded in working its way across the eastern end of the young Uintas to form the great Green River Gorge and join the Fossil Lake Uinta extension of Fossil Lake Kapiowitz even as the Uintas were still rising. It was geologically a very unstable period of Biblical history, a factor which the author has neglected in his computer mapping of the fossil lakes which carved the great Grand Canyon Gorge.

Bernard E. Northrup, Th.D.
Redding, California

CLOSURE

Reply to Dr. Steven Austin

I have not yet addressed the sapping process in this "missing talus" study. Sapping does not appear to be a present process at most of the sites used in this study. Site 4, Bangs Canyon, is the exception. At all the other sites the strata are nearly perfectly horizontal or else such that water would drain inwardly, from the cliff edge towards the interior of the mesa. There are no springs at the bases of these cliffs.

At Bangs Canyon, to be addressed in a subsequent study, the talus formation appears to be the result of sapping. A photograph of talus strewn across its entire 0.8 km width was shown in the oral presentation at the ICC. A local water well driller has frequently found a layer of very soft mudstone separating the water-bearing Dakota sandstone above and the more impervious Morrison shales below. The highlands of the Uncompahgre Plateau capture more precipitation than the neighboring lowlands. That water drains downhill through the Dakota strata, sometimes resulting in artesian wells at lower elevations. Where erosion has cut through the sandstone there appears to be a rapid widening of the resulting valleys. It is hypothesized that at such exposures of the strata the mudstone, above which the water had been flowing, was rapidly flushed out, undermining the sandstone blocks. Surface waters then poured into the resulting depressions and were able to erode the Morrison shales as well. The durable sandstone blocks were left littering the surface.

The rocks in Bangs Canyon were photographed from the air several years ago. Similar rocks in the neighboring and more accessible Unaweep Valley were visited and photographed to aid in the analyses.

Dr. Austin makes an important point about possible sapping following the catastrophic drainage of lakes. He has documented the rapid formation of a canyon system north of Mt. St. Helens following the major eruption. Part of the water-saturated new strata turned into a mud flow and left cliffs similar to those in this study. (See his paper in Volume 1 of the 1986 ICC Proceedings, p.5.) Though sapping does not appear to be presently happening at most of the "missing talus" study sites, sapping associated with the catastrophic demise of large lakes could have been the agent to form the cliff edges in the first place. Sapping would have been even more effective in the early years following the Flood because the strata would still have been water saturated and poorly consolidated. This is certainly a good topic for further research.

Reply to Mr. Glenn Morton:

During the past year I have obtained a copy of NAPP aerial photograph number 1106-66 to refine my analyses of Flat Top Rock. The 1:44420 measured scale of the image permits only resolution of large talus, about 4 m and larger, depending on illumination. Matching individual boulders from Figure 2 with those visible in the aerial photograph allowed a better definition of the slope at the base of the mesa. The range of the farthest boulder was revised from 150 m to 175 m. Yet 63 percent of the boulders were still within 100 m from the cliff edge. On the far side of the mesa the farthest boulder was found at a range of 220 m. Such a revision of distances, however, does not change the conclusions.

Including boulders smaller than 1.5 meters also would not alter the conclusions. Such smaller sizes were visible in the roadside photographs, especially Figure 3. Any that might have been farther away from the cliff edge would have been closer to the camera and therefore even more visible. The median size of the farthest-out boulders was about 4 m, with none smaller than 2 m. It is the total absence of the smallest sizes at the farthest ranges that is so remarkable at all of the study sites. Small decayed talus remnants are definitely missing.

Some talus boulders right at the change in slopes at the cliff base can be found to be partly buried in clay and smaller fragments. However, farther out on the pediment there have been no indications of significant burial. The tendency there is more towards pedestal formation, as in Figure 5, than burial. The pediment is often of undisturbed shale strata with only a thin layer of dirt and clay on top, removing the need for excavations to find buried boulders.

This is a preliminary study, to introduce a new topic for research. A next logical step would be to measure sizes, roughnesses, burials, and pedestals more precisely at these and other sites. The findings of this present research hopefully justify such confirmatory studies.

Reply to Dr. Bernard Northrup

I included references to the works of Burdick and Northrup because I was influenced by their writings more than a decade ago, perhaps in the Bible-Science Newsletter. I could not, however, identify the source of that influence for this paper, nor correctly summarize the contents. I am therefore highly pleased with Dr. Northrup's explanation presented here. It is the best that I have seen.

I recognize the limitations of my uniformitarian assumption of former surface elevations similar to those of today. I state this in my text and did so even more in my oral presentation. The latter presented new analyses of the elevations of cliffs throughout part of the region, particularly the Defiance Plateau-Chuska Mountain area. The cliff bases were at varying altitudes, possibly requiring a Defiance uplift after the demise of the shoreline-cutting lake. I therefore do not require any elevations to have remained constant during and after the proposed processes. This study has used modern elevations to show the reasonableness of a scenario. I am sure that further investigations will give evidence to define the shorelines better.

Dr. Northrup has nominated additional locations for study. It would be helpful to receive a more precise listing of all suspected shoreline locations, giving latitude, longitude, and elevation coordinates, as I have in Table 1, both from Northrup and from any others who think they may have found something. The Colorado Plateau is a large area, and I do not expect to visit even most of it personally. I can, however, use remote sensing techniques, satellite images, aerial photography, geological maps, and elevation data to examine pro-posed shoreline locations. The many shorelines of former Lake Bonneville are slightly tilted because of the subsequent rebound of the land. I would expect similarly varying shoreline elevations for the

proposed lakes in my study. A finding of consistent tiltings could be of benefit to the scenario.

Suggestions of other sites should not just be limited to positive evidence of shoreline action. The absence of such etchings may also be informative. The slopes of Navajo Mountain should certainly be examined. I have yet to notice any shoreline etchings in my remote views of the mountain, the photographs of others, or in topo-graphic maps. If there are no shoreline etchings in strata capable of preserving them, then perhaps my hypothesis fails, or else the Navajo Mountain laccolith was formed after the demise of the lake.

Travelers through the Colorado Plateau region should remain alert to phenomena related to this issue. I am highlighting the testimony of "missing talus" and possible shorelines. It is highly likely that further contributions from other observers will refine or refute this scenario. The rocks have a story to tell us.

Edmond W. Holroyd, III, Ph.D.