A REMOTE SENSING SEARCH FOR EXTINCT LAKE SHORE LINES ON THE COLORADO PLATEAU

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ABSTRACT

The breached-dam hypothesis for the formation of the Grand Canyon needs physical evidence for the justification of extinct lakes. Digital elevation data were used for basin and proposed lake shore mapping and for cliff identification on the Colorado Plateau upstream from the Grand Canyon. Satellite images, aerial photographs, and visual searches from aircraft were used to confirm cliff locations in a search for shore line cliffs that might exhibit the missing talus phenomenon. The distributions of mapped Pliocene and Pleistocene sediments show that some may be related to the hypothesized extinct lakes. Although not proving the case for such lakes, the findings are consistent with the hypothesis.

INTRODUCTION

Inspired in part by other writers, most likely in some issue of the Bible Science Newsletter in the late 1970's, and by the basin-like appearance of the Painted Desert of Arizona in manipulations of digital elevation data, I produced a hypothetical map in December 1986 outlining a possible series of lakes that would be impounded by a plugging of the Grand Canyon. Those lakes at a surface elevation of 1700 meters above sea level were mentioned by Holroyd [8], included by Austin [1, p.78], presented by Holroyd [9, p.122], and shown in their original color and videotaped during the oral presentation of Holroyd [9] at the Second International Conference on Creationism. A different outline was independently produced and published by Brown [3, p.83] for an elevation of 5700 feet. The Austin [1] version was redrawn in Oard [10, p.41]. The suggestion has been that catastrophic breaching allowed the water from such lakes to carve most of the Grand Canyon, a hypothesis summarized by Austin [3, pp. 92-107] in a catastrophic breach.

There is little basis at this time for choosing between 1700 meters (5577 feet) and 5700 feet (1737 meters), so in this report I will illustrate the latter. The number is related to the present elevation of the pour point (PP) of the lakes at the north end of the Kaibab Plateau, near the Arizona/Utah border. The pour point is the location of the lowest elevation (apart from the Grand Canyon) through which water could spill out of the basin. That saddle is presently dry and without obvious indications of a previous stream channel. The soil is the decayed remnants of the soft, red Moenkopi siltstone. The land there could easily have been lowered by erosion since the demise of the proposed lakes. Furthermore, isostatic rebound of the regional ground after the removal of the water burden would alter former elevations.

A new illustration of the hypothetical lakes is presented in Figure 1. It differs from other versions by having the Grand Canyon (GC) artificially filled rim to rim from about the junction of the Little Colorado River to the position of Lake Mead. The terrain was then highlighted by artificial solar shading. The difference between the 1700 meter lakes and the 5700 foot lakes is shown in the white shading.

A series of articles by Williams et al. [15, 16, 17] provided an excellent review of past hypotheses on the formation of the Grand Canyon, including antecedent rivers, river capture, piping, and the breaching of dams releasing the waters of upstream lakes. Oard [10] produced studies supporting possible lakes during the Ice

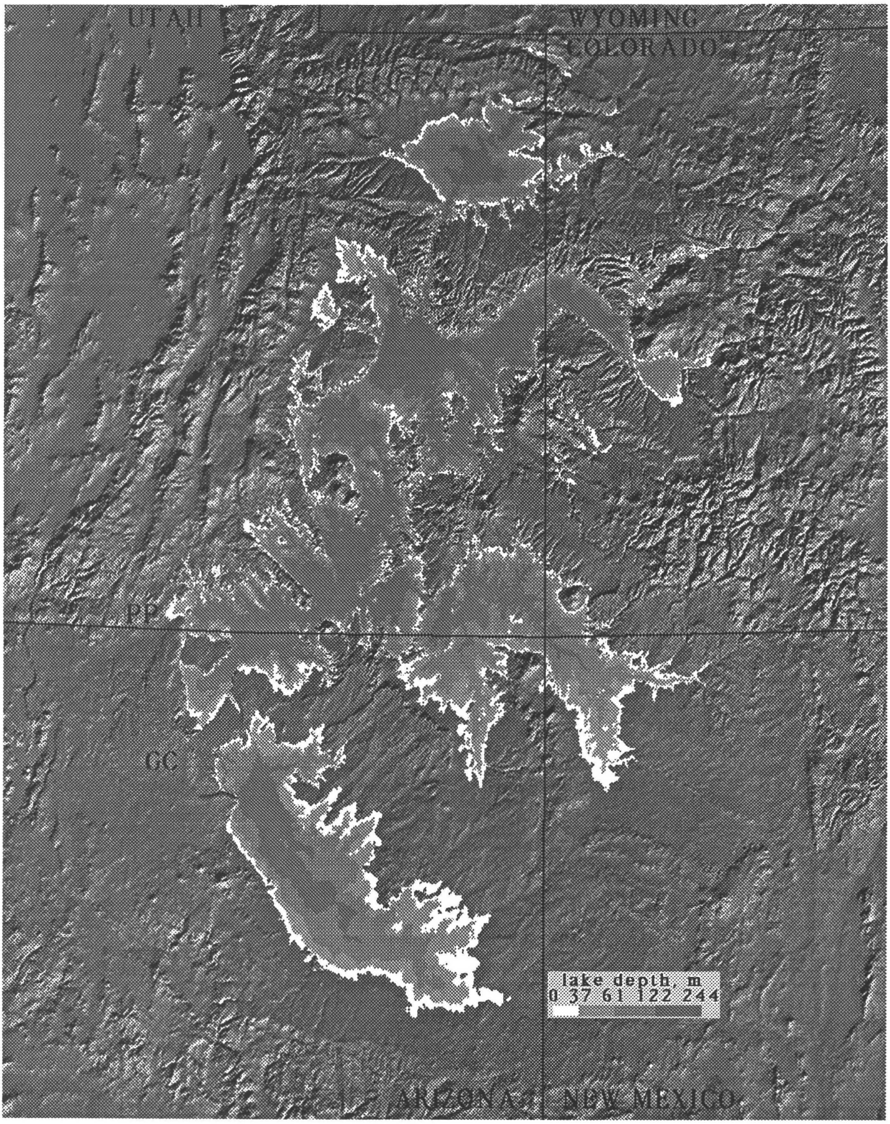

Figure 1. A view of the 5700 foot lakes that might have been impounded behind the Kaibab Uplift. The Grand Canyon has been filled in and the terrain given solar shading.

Age, but cautioned that other evidence might lead to problems with the dam-breach theory. The study that follows examined several data sources related to the dam-breach theory.

Holroyd [8, 9] suggested that the missing talus phenomenon at the bases of regional escarpments might be an indicator of shore lines of extinct lakes. The wave action at such shore line cliffs would pulverize previous talus. The present talus would have fallen since the demise of the lakes. Some of the study sites [9, Table 1] were near the pour point elevation of 1700 meters above sea level. The area and volume of a series of lakes at the 1700 meter level would be equivalent to Lake Superior. Such a possible series of lakes impounded behind the Kaibab Plateau is of importance to creationist studies. The lakes cannot coexist with the Grand Canyon. The relative youth of the angular talus boulders indicates a recent period for the demise of the lakes. If true, then the carving of the Grand Canyon must also be recent. An exact match of elevations should not be expected because of probable tectonic changes after the removal of the water overburden.

AVHRR SATELLITE VIEW

The oral presentation of Holroyd [9] included a view of the Colorado Plateau as seen in a mosaic of satellite images from the NOAA AVHRR polar-orbiting weather satellite. Figure 2 shows the AVHRR view with the 5700 foot lake shore lines superimposed. It is readily seen that the "lake" outlines surround naturally bright regions of the Colorado Plateau. The exception is along the southwest side of the southern lake where the ground is covered by black lava flows. This white enclosure is more than just a coincidence. The bright regions are low desert basins and most of the dark regions are vegetated highlands. The shading is strongly related to present elevation-controlled climate. The lowlands experience the drying effects of air subsiding from the highlands and undergoing compressional warming and relative humidity reduction. This results in much less precipitation reaching the ground in the lowlands and a higher evaporation rate there. The vegetation in the lowlands is therefore sparse. As a result the shading follows the elevations. The elevations were used to derive the "lakes" of Figure 1. This relationship does not prove that the lakes ever existed but only offers circumstantial evidence. The climatological shading and the fillable basins are both strongly related to the same elevation distributions.

AERIAL RECONNAISSANCE

Since the development of the lake hypothesis I have searched the Little Colorado and San Juan River Basins and the Uinta Basin both visually and photographically, from commercial aircraft flights and somewhat on the ground, for any shore line indications. In a similar way some Landsat satellite images of the region have been examined. While numerous suggestions have been found over several years of studies, none were clear indicators of ancient shore lines. Lake Bonneville and other lakes have left multiple and distinct strand lines (shore line carvings in hillsides) in Utah and Nevada. It is therefore of great concern for the breached-dam hypothesis that similar strand lines are not obvious throughout the Colorado Plateau.

Moderate to major cliffs are visible from high altitude. Lesser abandoned sandy beach ridges are less likely to be noticed. The Colorado Plateau has an abundance of cliffs but most seem to have little possibility of being shore line etchings. Their shapes suggest other causes for their sculpture. If lake shore lines lay against many of these cliffs, it seems only fortuitous.

Flights at low sun angle show the highlighted surface texture of the land. I noticed that there was a general tendency for the broad lowlands (basins) to have smooth surfaces while higher terrain showed erosional sculpturing. I do not have any data set whereby I can test if the demarcation between rugged and smooth terrain texture is related to the "lake" elevations, but it would be an interesting study.

The south side of the Painted Desert (Little Colorado Basin) has no shore line escarpments. The surface is the hard Kaibab limestone with sometimes a red remnant of the soft Moenkopi siltstone that was washed off elsewhere Several streams have become entrenched in the limestone. The north side of the basin is covered by Moenkopi siltstone and Chinle shales which are not capable of supporting tall cliffs. The basaltic caps on the Hopi Buttes and some exposures of the Bidahochi Formation (lacustrine and volcanic ash) do exhibit cliffs at elevations near to above the "lake" elevations being considered.

There are some cliffs within the San Juan River Basin but mostly near the highland periphery. There were no continuous topographic features that could be interpreted as a major shore line from an aerial viewpoint. The missing talus sites of Mesa Verde and Monument Valley seem like isolated occurrences compared to the rest of the basin. There are interesting escarpments on the flanks of the Chuska Mountain plateau and surrounding Defiance Uplift region but they are seemingly bent upwards with the higher terrain. Interpreting them as the sides of landslide source regions may be more reasonable.

The Uinta Basin shows some escarpments but they seem to be related more to sediment plumes from the Uinta Mountains. No good shore line remnants were noticed from the air even though the basin is filled with lacustrine deposits.

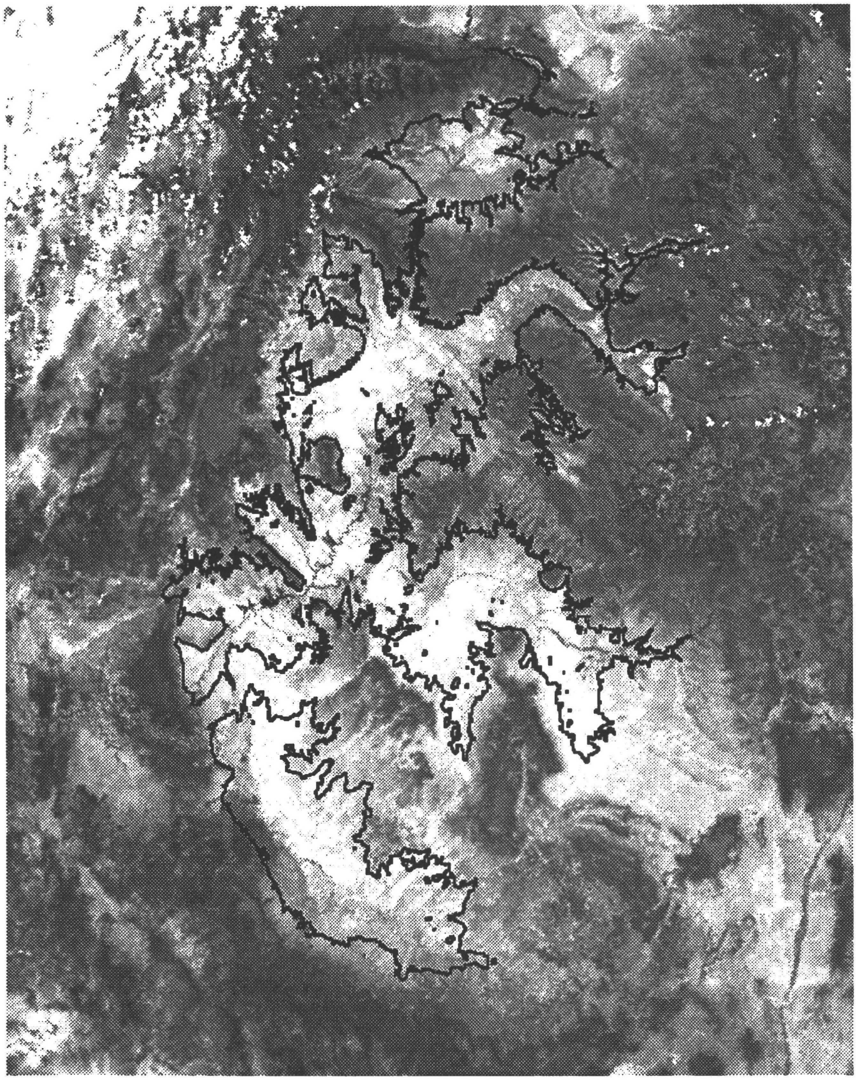

Figure 2. A view of the Colorado Plateau from the NOAA AVHRR weather satellite system. The 5700 foot "shore lines" are superimposed.

CLIFFS FROM DIGITAL ELEVATION DATA

A careful examination of some 7.5' topographic maps containing known strand lines of Lake Bonneville suggests that computer analysis of digital elevations (DEM) derived from such maps at 30 meter horizontal resolution should be able to detect the presence of those strand lines. A computer program trained on Lake Bonneville data could then be used to search the Colorado Plateau region for similar strand lines. Unfortunately, DEM data for major portions of the Colorado Plateau region (especially Arizona) are not yet available. When they are available in perhaps a decade from now, the necessary data set will cost many thousands of dollars. The present price is $7 per quadrangle, of which there are 64 in a 1-degree latitude/longitude square.

Until those data sets are available we need to use the standard topographic sets that have been available for over a decade. The data source for such elevations is the Defense Mapping Agency (DMA) analyses of 1:250,000 scale topographic maps. The data are not of the highest quality, but are complete for the entire continental United States and adjacent Mexico and Canada. They are available from a number of sources, government and commercial. Data accuracy is restricted by the contour interval of the original maps, typically 200 feet in mountainous areas. The histograms of the elevation data are full of spikes, typically at whole contour levels on the original maps. Other blemishes are discontinuities at the 1-degree latitude or longitude original map boundaries and sometimes positional errors of about a kilometer. Some parts of the data set have pits and corrugations where none exist in reality.

Following image processing notation, each location of an elevation value is called a pixel, the smallest element making up an image. The DMA data set is available in two resolutions. In the coarse set the pixel size is 30 seconds of arc, and in the fine set it is 3 seconds of arc, in both latitude and longitude. Whereas the north-south scale of each pixel is constant, there are fewer east-west meters for the northern pixels compared to the southern. The crude 30-second data set was used for Figure 1.

The missing talus phenomenon was found at cliffs that were hundreds of feet tall, at which softer shales were capped by harder sandstones. It therefore seemed appropriate to search the Colorado Plateau region for all cliffs to see if they presented any pattern, horizontally or vertically, that might be related to the hypothesized lake shore lines. No particular elevations were sought in this part of the study. The desire was to let the data nominate special elevations, if any. Digital elevation data for the entire region were examined at a resolution (3 seconds of arc) ten times finer than that used for the original lake boundary mapping.

Known regional cliffs were found from the digital terrain by computer algorithms that identified all slopes of at least 20 degrees. The value of 20 degrees obviously does not represent a real cliff. The data itself has a horizontal resolution of only about 85 meters. The vertical resolution on the maps from which the data were derived is only 61 meters (200 feet), though intermediate elevations are present in the data set. The 20 degree slope was found to be a good indicator in this data set for real cliffs that had much steeper slopes. A better computer search will be possible in the future when the 30-meter data set is complete.

The elevations, rounded to 20 meter resolution, at which such slopes were found were then recorded. River channel canyons (facing pairs of cliffs) up to a few kilometers wide that were identified by that criterion were edited out of the data set. Mountain slopes, being at much higher elevations than the potential lake shore lines, were retained but otherwise ignored. The remaining data set of steep slopes generally contained all the significant regional cliffs identified by the visual, photographic, and satellite searches.

CLIFF ANALYSES

Because the elevation data had histogram spikes at preferred values, typically 200 foot contours, ratios were made of the number of "cliff" pixels at a particular level to the total number of elevation pixels in the region of interest. Furthermore, a running mean over every three adjacent levels (20-meter) was performed to minimize the 200 foot data problem. The goal was to see if the spectrum of the ratios, plotted against elevation, would show some preferred elevations. Consistency of preferred cliff elevations could be indicative of shore line cliffs.

For convenience the watersheds upstream from the Grand Canyon were divided into five regional units (see Figure 4). They are the Little Colorado River (LC), San Juan River (SJ), Uinta Basin (UB), Upper Green River (UG), and the rest of the Green and Colorado River (CO) watersheds. Divisions were made along major basin crest lines. A watershed analysis program was used on the 30 arc-second digital elevation data to outline the sub-basins. Its only major error was in assigning the upper part of the Dolores River to the San Juan watershed. Those digital elevation data lacked the resolution to show the river passing through a major ridge northwest of Cortez, Colorado. The regional subsections were made only for summary purposes and no harm is caused by this blemish.

Figure 3 shows part of a graph of the fraction of slopes at or greater than 20 degrees (edited), detected at each elevation, and smoothed by a 20 meter running mean. The region generally has smooth flat lowlands in which cliffs are rare. The highlands have an abundance of steep mountain slopes. In between, some of the curves for each of the five regions have irregularities showing an enhanced frequency of steep slopes (cliffs) near some set of elevations.

In general, the graph shows two particular elevation bands (1.7 and 1.9 km, shaded in Figure 3) of occurrences of special elevations. The upper band is significantly higher than the 1700 meter elevation being considered in this study. An exploration of other possible lake levels showed that with the blockage of both the Grand Canyon and the pour point to the north of the Kaibab Plateau, the next pour points (three of them) would all be at about 2000 meters (6600 feet). Higher lake levels cannot be achieved with the present terrain. The 1.9 km level is appropriate to the lacustrine deposits of the Bidahochi Formation near the Arizona/New Mexico border and to erosion patterns (presented below) at Navajo Mountain. That level is found mostly in the southeastern parts (SJ) of this study. If these 20-degree "cliffs" are related to shore lines, they may indeed represent a second, higher lake level prior to the one illustrated in Figure 1.

The LC basin has a questionable ripple at 1.9 km because of the smoothness of the terrain in that basin, but that is the approximate level of the lacustrine Bidahochi Formation. The UG and CO had the largest offsets (at about the 1.7 km level) from the general curves. The 1.2 km peak on the CO curve is from Marble Canyon and may be related to the extinct Prospect Lake, dammed at Vulcans Throne after the carving of the Grand Canyon. The UB fluctuation at 1.9 km is the striped shading on the dotted curve. It overlaps the SJ curve shading.

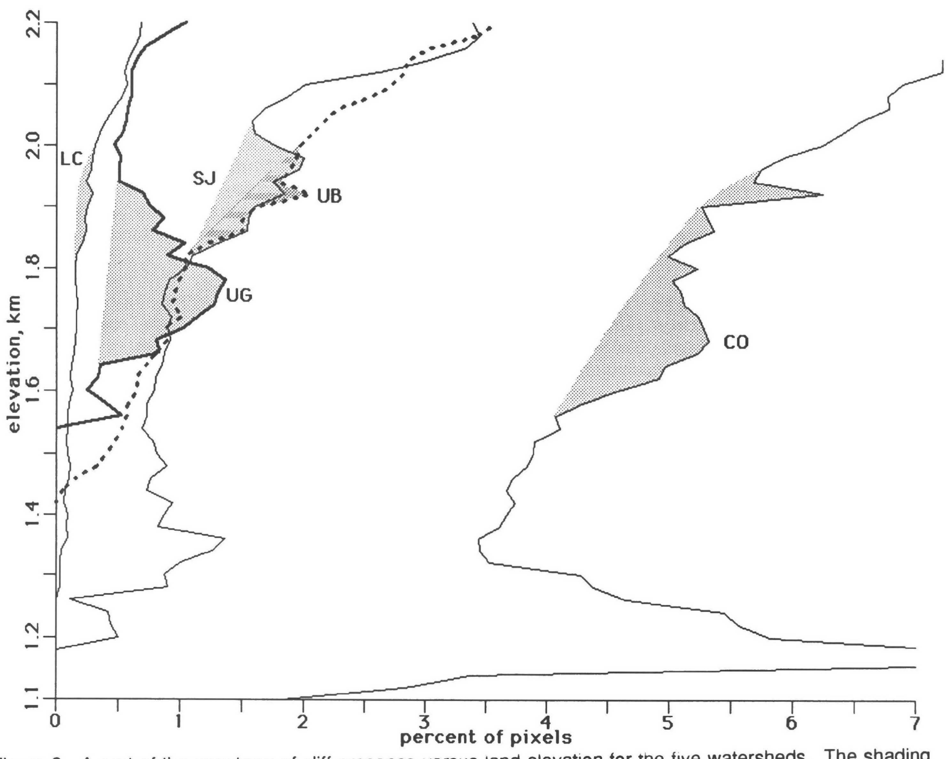

Figure 3. A part of the spectrum of cliff presence versus land elevation for the five watersheds. The shading indicates a possible enhanced presence of cliffs.

The elevations shaded in each basin were isolated from the 20-degree slope ("cliff") data. A count of the number of surviving pixels in each 10x10 pixel square provided a percentage of cliff presence at a resolution of 30" of arc, like that used for the "lake" outlines. In Figure 4 are shown the outlines of the basins used (black lines), 5700 foot lakes (gray shade), and locations having at least 5 percent cliff presence (black dots) within the special elevation bands of Figure 3.

As expected, the LC basin (south) has only a tiny scattering of special locations. The line of black dots at the northwest shore line near the GC is a fault escarpment. Except for Mesa Verde, the SJ cliffs are at the higher elevation of about 1.9 km. The CO region has a very high incidence of cliffs, especially near the shore line.

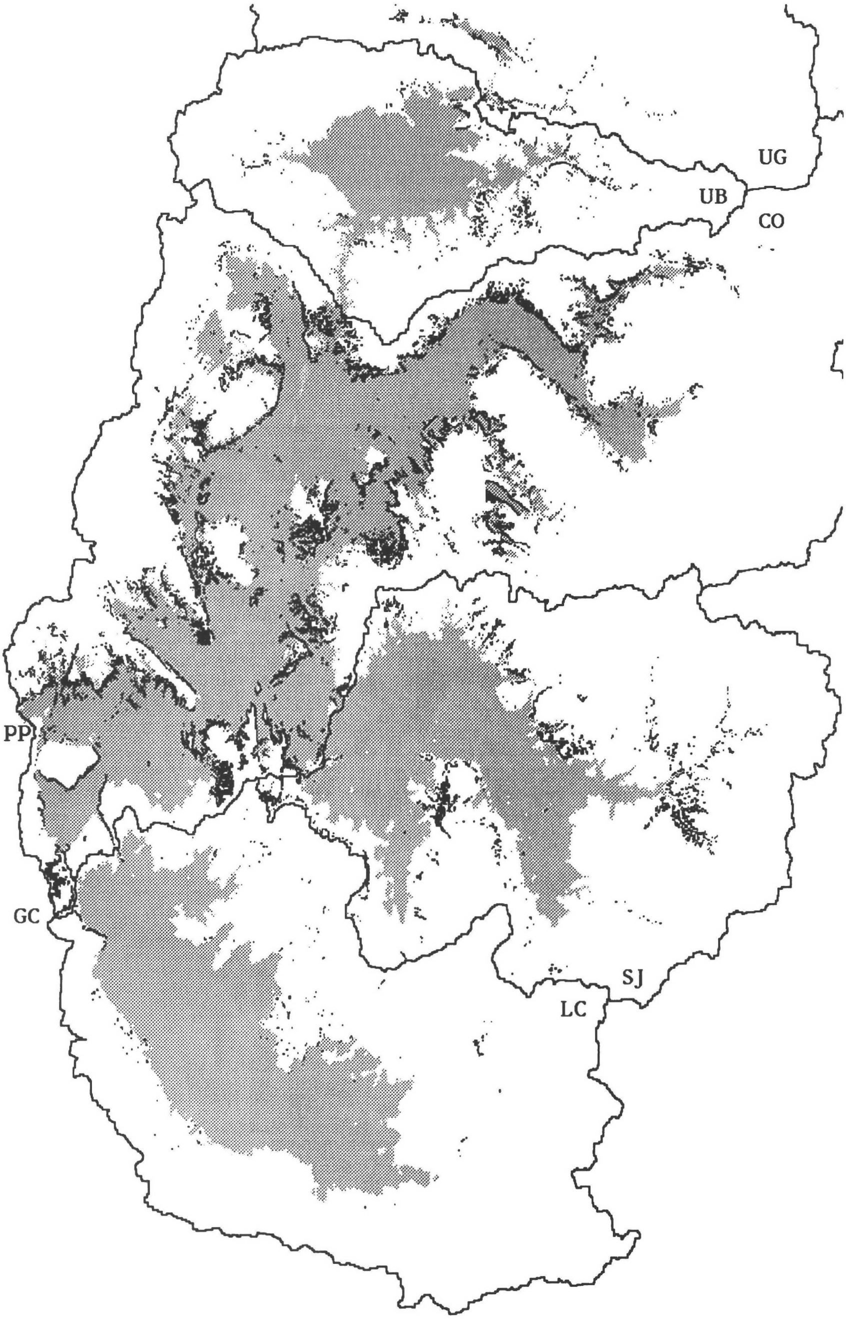

Figure 4. The locations of at least 5 percent presence of cliffs (black dots) within the shaded elevation bands of Figure 3. The basin outlines and labels are also in black and the 5700 foot lakes in gray.

Most of this is just caused by the general offset of the curve to higher values in Figure 3. But there are numerous regions with a clear shore line matching. The Book Cliffs at the eastern end of the northern CO shore line extend westward from Grand Junction, Colorado, to Price, Utah. In the latter region they are still present but at above 2000 meters, as if the region has been tectonically lifted. The UB region is mostly smooth, but there are some linear collections of dots in the east and west and in the north at Dinosaur National Monument (DNM). The UG cliffs are all in the DNM region and Flaming Gorge. All of the higher missing talus sites of Holroyd [9] received black marks in Figure 4. It appears that there is an abundance of other regional cliffs worth investigating with respect to the proposed shore lines.

These two digital elevation studies, presented in Figures 3 and 4 for vertical and horizontal positions, respectively, are not proof by themselves of extinct lakes. Figure 3 unexpectedly indicated two elevations to be considered. While many of the cliff positions in Figure 4 may be only coincidentally related to the possible shore line positions, some of those cliff positions should have field checks to see if there are additional indicators of strand lines.

NAVAJO MOUNTAIN

Throughout the Colorado River Basin are tall laccolith mountains that rise to above the possible lake levels being considered. It seems reasonable that if the mountains were present at the time of the lakes, then they should have remnants of a strand line in the form of cliff etchings caused by shore line wave erosion and/or small deltaic deposits at the water line. Digital elevation data at the superior 30 meter resolution were acquired for Navajo Mountain, strategically located next to the present Lake Powell and Colorado River. The data were given a "solar shading" in Figure 5 from an impossible northeast point to bring out topographic detail.

A possible shore line etching can be seen along the south side where there is a bolder pattern of alternating blacks and whites. The mountain does not flare continuously out onto the flat terrain. This is also visible in Landsat satellite image data. An oblique aerial photograph by Shelton [13] shows that there are indeed cliffs of Navajo sandstone ringing the southern base of Navajo Mountain. In that higher photographic resolution they look like sea coast promontories. The feature is more difficult to observe around the northern side of the mountain because mass wasting has destroyed most of the features at the mountain base level. The elevation of the cutting is just below 2000 meters (about 6500 feet on the 7.5' topographic map), in agreement with the 1.9 km level highlighted in Figure 3.

An examination of geologic maps of Navajo Mountain shows that Morrison strata cap the summit. Except for fluvial cuts, only older Navajo strata ring the base at about the 2000 meter level. To the west of Navajo Mountain (left side of Figure 5) an unnamed plateau is also capped by Morrison strata but at elevations almost

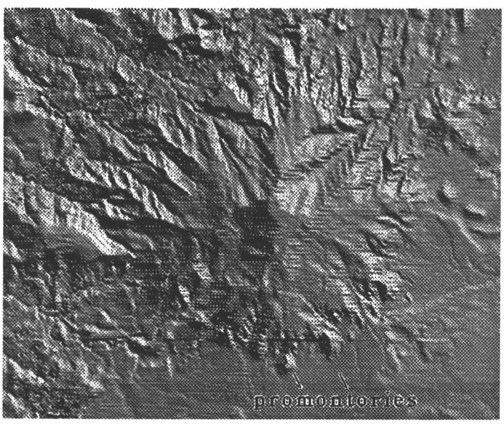

Figure 5. An artificial shading of high resolution elevation data for Navajo Mountain may indicate a shore line etching along the southern side.

entirely below the 2000 meter level. Similar but smaller Morrison remnants exist to the north in several locations and also below the 2000 meter level. The cutting away of the Morrison, Entrada, and Carmel Formations and into the more resistant Navajo Formation, completely around the mountain, is consistent with the mountain being an island in a body of water with a surface elevation lower than about 2000 meters. The Morrison remnants beyond the mountain base would have been under water and sheltered from wave action. The Morrison and intermediate strata near the mountain summit would have been higher than any wave action and also protected. The Navajo Formation would be carved by the waves into the cliffs and promontories we can still see today. The shore line evidences would then be raised nearly a few hundred feet by isostatic rebound after the demise of the lake.

Other laccoliths have not yet been examined in detail for strand lines.

SEDIMENTS

One of the difficulties of the breached dam hypothesis noted by Oard [10] was that if the lakes existed in a region of the abundant precipitation needed to keep them from simply evaporating, then there should be a variety of sediments resulting from turbid rivers entering the edges of the lakes. Such deposits have not seemed obvious to other observers. Lake Bonneville has left sediments throughout its former extent, as indicated on the geologic map of Utah [6].

The 1:500,000 scale geologic maps of Arizona, Colorado, New Mexico, and Utah [18, 14, 4, 6] and 1:1,000,000 scale geologic map of Arizona [11] were examined. Conventional geologists assign the carving of the Grand Canyon to Pliocene and Pleistocene (late Tertiary and Quaternary) times. The outlines of all Pliocene and Pleistocene sedimentary strata delineated on maps (omitting the most recent Quaternary alluvium and aeolian deposits) were transferred into the computer for comparison with the elevation data.

The elevations of all such strata are plotted in Figure 6 as cumulative curves. The figure is split into two parts for readability. The formation map notations and state abbreviations are indicated in the figures. At this writing it is not necessary to further describe their characteristics and names. Those formations that have the greater presences are in thicker lines. For comparison, the cumulative curve for regional elevation is the dotted line. Formations that exist only in a narrow elevation band are steep, such as some of those in the lower half of the figure. Those at distinct multiple elevations have some horizontal segments. Some of these recent sedimentary deposits are above the 2 km limit being considered for any lake phenomena. Some formations have a continuous distribution through that level. The best candidates for lake deposits are those whose curves are steeply climbing at elevations under 2 km. The horizontal positions of all formations having at least 10 percent presence at elevations under 2 km are plotted in Figure 7, but only up to the 2 km level.

At the south, the Bidahochi (Tsy and Tu) Formation (known to contain lacustrine components [12]) rings the eastern end of the "lake". More modern Qo (older alluvium) sediments occupy the bottom of the basin. There are a few river channel deposits in the San Juan lobe (east center) and only a few mountain-generated deposits elsewhere. The Uinta Basin (near top) is filled with recent deposits, some of which are obscured by alluvium and therefore not plotted here. A solid band of sediments seemingly unrelated to any proposed lake is at the very top of the figure. Elsewhere, within the main CO portion of the study area, there is an abundance of patchy deposits draining from the higher terrain into the periphery of the proposed "lake". They resemble deltaic deposits of small streams entering a lake but could also be alluvial fans and debris flows unrelated to any lakes. Geologic study of these sediments are needed. Figure 7 shows an abundance of deposits that are candidates for further study with respect to the lake hypothesis. Many will be shown to be unrelated to lake deposits, but some may, with further study, support the previous existence of giant lakes on the Colorado Plateau.

None of these deposits is solidly filling the basin bottoms like the Lake Bonneville sediments, with the possible exception of the Uinta Basin. The pattern elsewhere suggests that the duration of the "lake" was brief. Additional sediments, if they ever existed, were probably unconsolidated and vulnerable to sapping and a sweeping away during a catastrophic lake demise and subsequent erosion under higher precipitation rates (Oard, [10]) than today.

CONCLUSION

This study has investigated several types of data relating to the breached-dam hypothesis of the Grand Canyon. The regional topography, with its natural but dry basins, suggests the possibility of filling them with water. The missing talus phenomenon is still there to be explained, and a lake shore hypothesis is attractive. The region apparently has an abundance of cliffs at similar elevations that could also have "missing talus". Such cliffs are sometimes consistently near the proposed shore lines. There are indeed some relatively recent sediments of the same geologic age as the assumed carving of the Grand Canyon. A few of these formations are admittedly lacustrine [12]. Whether or not the rest can be related to the proposed lakes needs further study.

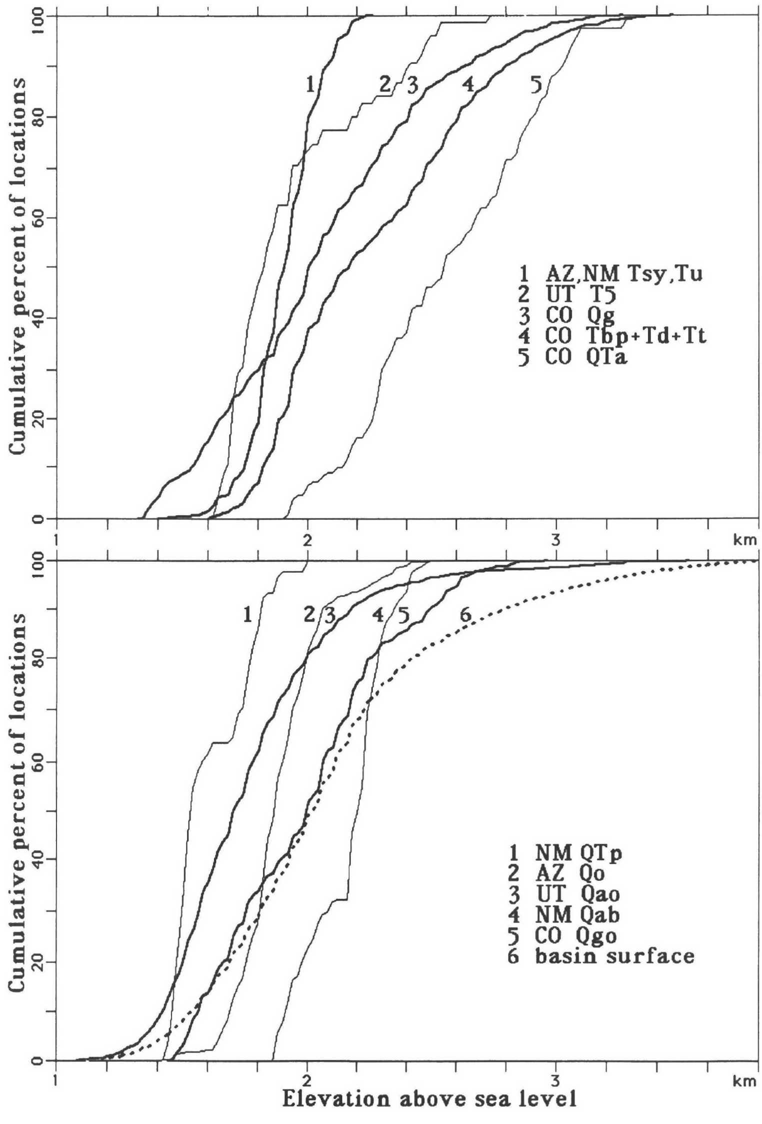

Figure 6. Cumulative distributions, against elevation, of Pliocene and Pleistocene sedimentary formations upstream from the Grand Canyon.

The major cliffs and the recent sediments are not, by themselves, indicators of extinct shore lines. The data presented here are only circumstantial evidence for the extinct lakes. More study is needed, particularly literature searches and field examinations. The slope study, at the resolution used, would not have readily seen the established extinct shore lines of Lake Bonneville. That basin was different from the Colorado Basin in that the sediments never had a possibility of being swept out of the basin, and so they still cover the lowlands today. The sparseness of the recent sediments in the Colorado Basin may actually by indicative of subsequent removal rather than a negation of the lake hypothesis.

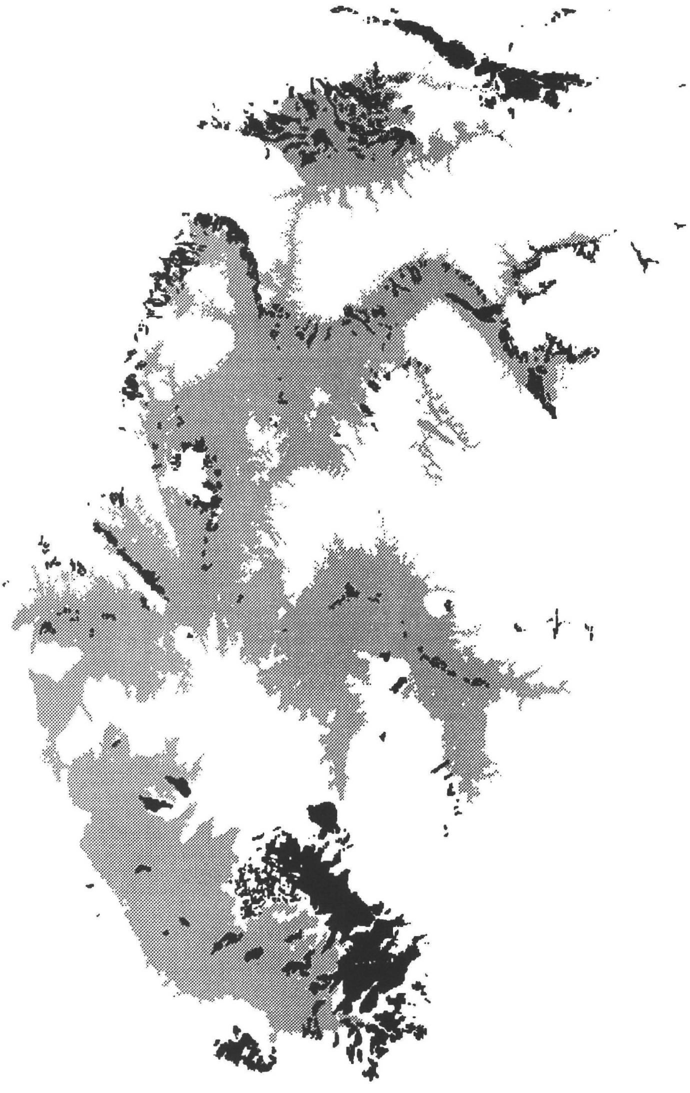

Figure 7. The locations (black) of Pliocene and Pleistocene sedimentary formations at elevations up to 2000 meters. The 5700 foot "lakes" are shaded.

ACKNOWLEDGMENTS

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