ANALYSIS AND DATING OF COMPOSITE PALEOLANDSLIDES IN THE GRAND CANYON REGION, ARIZONA

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ABSTRACT

The Grand Canyon and surrounding Colorado Plateau contain spectacular examples of ancient landsliding, most of which is believed to have occurred during Pleistocene time (1.8 million to 8 thousand years before present). This region has experienced relatively rapid tectonic uplift and thus accelerated erosion and down cutting by the rivers and streams. The resulting high topographic relief combined with geologic weaknesses have contributed to a large number of landslides in the Colorado Plateau.

Some of the landslides in question have been analyzed using slope stability models and should not have failed based on present day conditions. Several large volcanic eruptions during the Pleistocene poured lava into the Grand Canyon, damming the Colorado River and creating several large lakes, with the largest being approximately 2,800 feet deep. These lava dams were eventually overtopped and washed out, sometimes catastrophically, by the Colorado River. The saturation of adjacent slopes and subsequent failure of the lava dams would have created a rapid drawdown condition, possibly leading to slope instability. Other factors may have influenced the formation of these landslides including the strain softening of the slope material due to gravity faulting and seismic activity. The Colorado River and some of its tributaries were dammed at least four times by landslide activity.

We propose to sample and analysis of the rock units responsible for the failure of the landslides. They will be tested under various states of saturation and confinement to see what may have been the mechanism responsible for the landsliding.

Various methods have been proposed to date these large landslides. Each of the methods have inherent strengths and weaknesses. We are proposing to age date sediments deposited in lakes behind these ancient landslides using palynology, or the analysis of pollens. Certain species of vegetation lived for only certain times throughout geologic time and the identification of pollens trapped in sediments could give a narrow range as to when and thus possibly why the landslides occurred.

The Thunder River Slide – Grand Canyon, AZ

The Thunder River Slide occurred in Surprise Valley, an area in the Grand Canyon adjacent to Thunder River, a large spring feeding Tapeats Creek, a tributary of the Colorado River. The spring, seen to the right in this picture, may or may not have played an important role in the formation of this landslide.

Image showing the exposed landslide slip plane of the Thunder River Landslide (marked in red) below Surprise Valley. The slip surface is located in the Bright Angel Shale and is shown here between the three pairs of red lines. This is a proposed sampling location to analyze the strength of the shale under various states of saturation and confinement.

These reddish lacustrine (lake) sediments that were trapped in the graben, or downdropped portion of the Surprise Valley Slide may be the key to dating this landslide. Pollens specific to certain geologic times may be preserved at this site, making this a proposed sampling location.

Shaded relief map showing an overview of the Surprise Valley Area – This map was created by overlaying a topographic map of the area on top of a hill shade derived from a digital elevation model (DEM). These are also very useful for identifying landslides or any other geologic anomaly affecting topography such as a fault.

(Lower Right) This three dimensional render of the landslide filled Surprise Valley Region was created using a digital elevation model (DEM) and Terragen, a computer modeling application. Airplane flight is currently prohibited at low levels over the Grand Canyon, making this an excellent tool for identifying landslides.
These three bedrock landslides are part of the much larger Surprise Valley Landslide complex. They slid along a curvilinear slip surface, resulting in their strata dipping back into the main escarpment. This type of landslide occurs throughout the world but was first studied near the town of Toreva, AZ, giving it the name Toreva Block.

DEMs can also be used to generate photorealistic images of areas inaccessible to people. There is some error, such as the absence of the Colorado River, in this image of the Grand Canyon but such images can serve to help in the study of inaccessible and remote areas.

The Deer Creek Slide – Grand Canyon, AZ

The Deer Creek Slide is a massive composite landslide alongside Deer Creek, a tributary of the Colorado River. When this slide moved, it managed to dam both the Colorado River and Deer Creek. The Colorado overtopped the dam and returned to its prior channel while Deer Creek was diverted and is currently cutting a new channel. This landslide appears to be relatively young geologically speaking.

(Below) Shaded relief map showing an overview of the Deer Creek and Cogswell Butte – The Deer Creek Slide occupies most of the SW corner of the map.

The Deer Creek Slide as viewed from above.

The old channel of Deer Creek is visible (contact marked in red) buried by the slide. Deer Creek is currently excavating a narrow canyon as it downcuts and attempts to re-establish local base level with the Colorado River.

Deer Creek was rerouted by the slide and has excavated a scenic canyon.

(Right) A large slide originating on the west side of Cogswell Butte dammed and diverted the Colorado River to a new channel. The new channel through the Granite Narrows is the narrowest point in the Grand Canyon. The old river channel (outline marked in red) is visible up and to the left of the river.

Deer Creek drops over Deer Creek Falls just before joining the Colorado River. These falls are also a product of the landslide.
The Vermillion and Echo Cliffs, AZ

The Vermillion and Echo Cliffs are located along the Colorado River upstream from the Grand Canyon and downstream of Glen Canyon Dam, in easy access of U.S. Highway 89A. The base of these reddish colored cliffs are covered with prehistoric landslides. The echo cliffs are shown here, photographed from Hwy 89A heading southeast.

The Vermillion and Echo Cliffs are the site of countless landslides that may have allowed potentially datable sediments to be deposited soon after their formation. Streams in the area may have also cut through landslide slip planes. One can see the strata of these Toreva Blocks dipping back into the parent slope.

The Vermillion Cliffs may be viewed from above as Hwy 89A winds its way up the Kaibab Uplift and towards the north rim of the Grand Canyon. Several sets of landslides are visible behind the author along the cliff face.

Typical stratigraphy of the Vermillion and Echo Cliffs – The landslides initiate in the Chinite Shale and propagate upwards through more resistant sandstone layers. These cliffs rise in elevation as one heads west towards the Kaibab Uplift. Their base starts at around 3,800' near Lee’s Ferry to 5,600 near House Rock Wash. Their maximum height is around 3,000' tall. It is likely that a wetter climate and lava dams farther down the Colorado during the Pleistocene contributed to the sliding. Few large slides appear to have occurred in recent times.

The Colorado River flows between the Vermillion and Echo Cliffs here at Navajo Bridge over Marble Canyon. Several landslides may be viewed in the background along both sets of cliffs.

The large landslides along the Vermillion and Echo Cliffs are clearly visible from Hwy 89A. Many are on publicly land owned by the Bureau of Land Management. This ownership along with the close proximity to the highway make this an ideal study site.

(Left) This aerial photo of the Vermillion Cliffs near Navajo Bridge shows smoothing of the topography due to inundation by Pleistocene lakes. The line dividing the rough textured area near the top of the promontories from the smoother surface below is the old water level.