Introduction to Megalandslides In The Grand Canyon Region

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The Grand Canyon is one of the world's greatest geologic and scenic wonders, created as the Colorado River sliced through the Kaibab Plateau. Deeper parts of the canyon have exposed portions of the geologic record dating back to 1.7 billion years, providing an extensive rock record for geologists to study. Landsliding is just one of several important mechanisms which have helped to shape the canyon throughout the ages. These events range from small rockfalls and topples, seen throughout the entire canyon, to massive complexes of composite megalandslides, the largest of which are over 2,000 feet tall and consist of over 1 cubic mile of displaced material. Our work seeks to identify, analyze and date some of the larger bedrock megalandslides (those which have displaced 10 million cubic meters or more of earth) present in the Grand Canyon region of the Colorado Plateau. Besides the Grand Canyon proper, we are researching landslides mantling the Vermilion Cliffs, Echo Cliffs, and Second Mesa near Toreva, AZ.

The canyons of the Colorado Plateau are home to a large number of landslides, some of which have created spectacular features. The Vermilion Cliffs, a 30 mile escarpment running directly behind the Hatch River Expeditions office between House Rock and Lee's Ferry, AZ, is mantled with landslides wherever the weak Petrified Forest Member of the Chinle Formation is exposed. This formation is composed of a montmorillonite rich shale that loses significant strength when wetted.

As river running boats are put in the river at Lee's Ferry, one can look across at the Echo Cliffs and upstream towards the lower portion of Glen Canyon. Although the Echo Cliffs are composed of the same formations as at the Vermilion Cliffs, its landslides are not nearly as large or in the quantity seen along the Vermilion Cliffs. This almost certainly due to the fact that the rock strata of the Echo Cliffs dip back into the slopes, serving to help self-stabilize the cliffs. Some of the largest landslides along the Echo Cliffs are just across from Lee's Ferry and are clearly visible from the boat launch.

Many of these slides and others within Grand Canyon may be attributable to tallest three of a dozen or more gigantic lakes impounded by lava dams in the western Grand Canyon within the past 2 million years. Over 150 lava flows have poured over the side of Grand Canyon and evidence of these is clearly seen in the form of black basalt from river miles 178 to 246. The highest dam, estimated to have been around 2,300 feet tall, was at the site of Prospect Canyon. When this lake was full, it likely extended upstream through Utah, almost to the Colorado border and placed Lee's Ferry under approximately 1,000 feet of water. This would have saturated the base of the nearby Vermilion and Echo Cliffs approximately 10 miles in each direction of Lee's Ferry possibly leading to instability of the slopes. Slopes above the old hypothesized waterline have also experienced sliding but the landslides are of a drastically different form.

Once on the Colorado, one quickly descends into Marble Canyon and begins to see evidence of rockfalls on the canyon walls. These falls are caused by the weathering and spalling of rock, often along pre-existing fractures. The gigantic megalandslides do not begin until the Cambrian-age Bright Angel Formation, mostly shale, begins about 50 miles downstream of Lee's Ferry. Landsliding is also present where weak Precambrian-age shales are exposed. Although landsliding is present in this area, it is mostly confined to side canyons and away from the river. The Bright Angel Shale is also sandier here, giving it a greater strength and thus higher resistance to sliding than downstream. It is not until around mile 130 that large landslides are present along the river. An ancient eroded landslide is present high above the river on the south side of the canyon at mile 131 and is the only large landslide on the south side in central Grand Canyon. This appears to have dammed the Colorado River but has received very little study due to its relatively inaccessible location.

Tapeats Creek flows in from the north near mile 134. One begins to notice two landslide related features at this point. The spectacular Granite Narrows, cut through the Zoroaster Granite, were formed when the Colorado River was dammed by a large landslide from off nearby Cogswell Butte at river mile 135. An old buried channel of the Colorado River is visible about 250 feet above present day river level on the north side just before entering the Granite Narrows. The high elevation of the old channel relative to modern river level indicates this slide is quite old. The Colorado River was dammed for a period before it rerouted itself to the south, bypassing the old landslide dam. The river had to cut rapidly (in geologic times) though the hard granite to re-establish equilibrium. Most of the cutting was downward and the river passes through the narrowest point (76 feet) in the Grand Canyon at these narrows.

Fluffy fine-grained sediments are present all along the south side of the river. These are thought to have accumulated in an old lake formed behind the Deer Creek Landslide Dam, which is a younger landslide on the north side beginning at around Mile 136. The Deer Creek Landslide dammed both Deer Creek and the Colorado River. As with the Cogswell Butte slide The Colorado River, the river was rerouted to the south and an old buried channel is present. The channel form is in the Tapeats Sandstone and is best seen looking upstream from below the obstruction. It is at nearly present day river level, indicating that this slide is relatively young. A dry lake bed known as Anasazi Stadium west of Deer Creek was created when a graben, or pull-apart structure, formed atop the landslide and created a closed depression. Sediment may fill this closed basin to a depth of over 300 feet.

Deer Creek is still cutting a new gorge as it bypasses the landslide blockage. This has led to the formation of the scenic Deer Creek Narrows and Falls. The old buried creek channel is visible from two locations within the narrows and along the Colorado River where seepage water continues to flow and support a large patch of vegetation on the slope downstream of the waterfall. Deer Creek was once dammed in the past by a much older landslide from the western side of Cogswell Butte. This ancient slide and has been eroded to its inner core, exposing bizarre folds in the rock which are easily viewed from the trail along the river between Tapeats and Deer Creeks.

Several prior researchers have identified what Professor Dr. John Warme of the Colorado School of Mines has recently named Poncho's Radical Run-ups after Poncho's Camp, a riverside camp just below the features. It appears that these highly fractured and eroded rock formations are part of an even older landslide that once dammed the river in the vicinity of Deer Creek and ran far up the opposing slope. These remnants appear as slabs of rock angling up the south slope of the canyon up to 900 feet above the present day river level. These features were created when formations from the north side of the canyon were pushed across the river and far up the opposing slope by what must have been an enormous landslide measuring over 2000 feet thick. Based on trapped river gravels, it is suspected that the river was over 200 feet higher than its present elevation at the time of this slide. This puts the landslide run-up at around 700 feet, making this the highest recognized landslide run-up in the U.S.

Surprise Valley, which runs between Tapeats and Deer Creek to the north Cogswell Butte, is filled with landslide debris of varying age. The Surprise Valley Landslide Complex is the largest in Grand Canyon and may contain over 1 cubic mile of displaced debris. Those who day hike between Thunder River and Deer Creek climb atop this mass of debris when ascending the slope above Thunder River and pass tilted and broken masses of rock which are all portions of this gigantic complex. A graben once formed a closed depression in central Surprise Valley but this has been breached by Bonita Creek, exposing accumulated reddish layered sediments. This slide complex dammed Tapeats Creek on several occasions and some of the old buried channels are visible high on the west wall of Tapeats Canyon downstream of Thunder River. Other landslide complexes are located far up Tapeats Creek and Tapeats Cave Canyon. Tapeats Cave Canyon is home to Tapeats Cave and Spring, which is largest spring discharging from the north side of Grand Canyon (48 mgd).

Fishtail Canyon, at around river mile 140, is home to one of the more recently recognized landslide dams in central Grand Canyon. This huge landslide and its dam were discovered in the summer of 2004 by the authors. The slide was over 2,000 feet tall and it is estimated to be approximately 445 million cubic yards (340 million cubic meters) in volume. Thick sequences of sediments are deposited upstream of the landslide dam in Fishtail Canyon and another buried channel is present, showing that the creek was diverted to the west. This slide also seems to have dammed the Colorado River but like the others upstream, the dam is completely eroded away. It is hypothesized that this landslide is older than the Deer Creek Slide but younger than Poncho's, Cogswell Butte Slide, Mile 131, and Surprise Valley Slides.

Most of the landslides in this region come from the north side of the river. Rock strata dips to the south, or away from the north slopes, which helps stabilize the southern slopes. This encourages sliding along the north side of the river and one will notice that much of the Grand Canyon is wider on the north side due to this phenomenon.

Not far downstream of Fishtail Creek, the Bright Angel Shale dips below river level and the massive landsliding ceases for a while. River anticlines, or features where rock strata bend upward on each side of the river, are hypothesized to be incipient landslides forming as the underlying bright Angel Shale creeps under the load of the overlying rock strata. This is most noticeable in the vicinity of Kanab and Havasu Creeks. Once the river cuts into the underlying shales, landslides will likely form in this area.

As one proceeds farther downstream, the Bright Angel Shale re-emerges and large scale sliding resumes up to and including the Grand Wash Cliffs, which are the official downstream end of the Grand Canyon. Although these slides have not been studied in as much detail, they are no less significant than those between Tapeats and Fishtail Creeks. The lower portion of the canyon has experienced extensive faulting along the Toroweap, Hurricane, and numerous other faults. There have also been earthquakes and volcanism in this region, which may have helped trigger many of the numerous large slides in this area. There is also evidence of landslide damming along several portions of the Colorado in this area. Landslides also occur well below the area influenced by the lava dams, indicating some other cause such as a wetter past climate, or the causes mentioned above, are involved in their formation. Most of the large scale landsliding common throughout the Colorado Plateau appears to have taken place during the Pleistocene and this activity seems to have been relatively infrequent during Holocene (11,000 years ago to present) times.

Our research seeks to evaluate complex bedrock landslides defying explanation by conventional slope stability models, which are often designed more for soil and not as much for rock. The analysis will include the study of landslide dams, which have failed in historic times with catastrophic consequences comparable to the Dec 2004 tsunami in SE Asia. High devices relying on GPS units and computer based mapping are being used to identify and map the landslides. We are also attempting to date these landslides by collecting sediments from behind landslide dams and within landslide headscarp grabens. These sediments will be studied using palynology (analysis of pollens), optically stimulated luminescence (OSL) dating, and radiometric dating based on the decay of naturally occurring radioactive isotopes. Such a combination of data can help analyze long-term climate changes and possibly correlate landslide events to periods of a wetter climate and/or the formation of lava dams in the canyon.

Reading/References List:

For more detailed information on our research, please visit http://web.umr.edu/~rogersda/cp_megalandslides online. I will discuss other geologic wonders in the Grand Canyon throughout the river trip as there is simply too much to fit onto two pages.

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