Landsliding and Mass Movements in Grand Canyon and Their Implications for Canyon Evolution

Jesse Robertson, Karl Karlstrom, Peter Huntoon, John Warme, Ryan Crow, Andy Darling, Laura Crossey

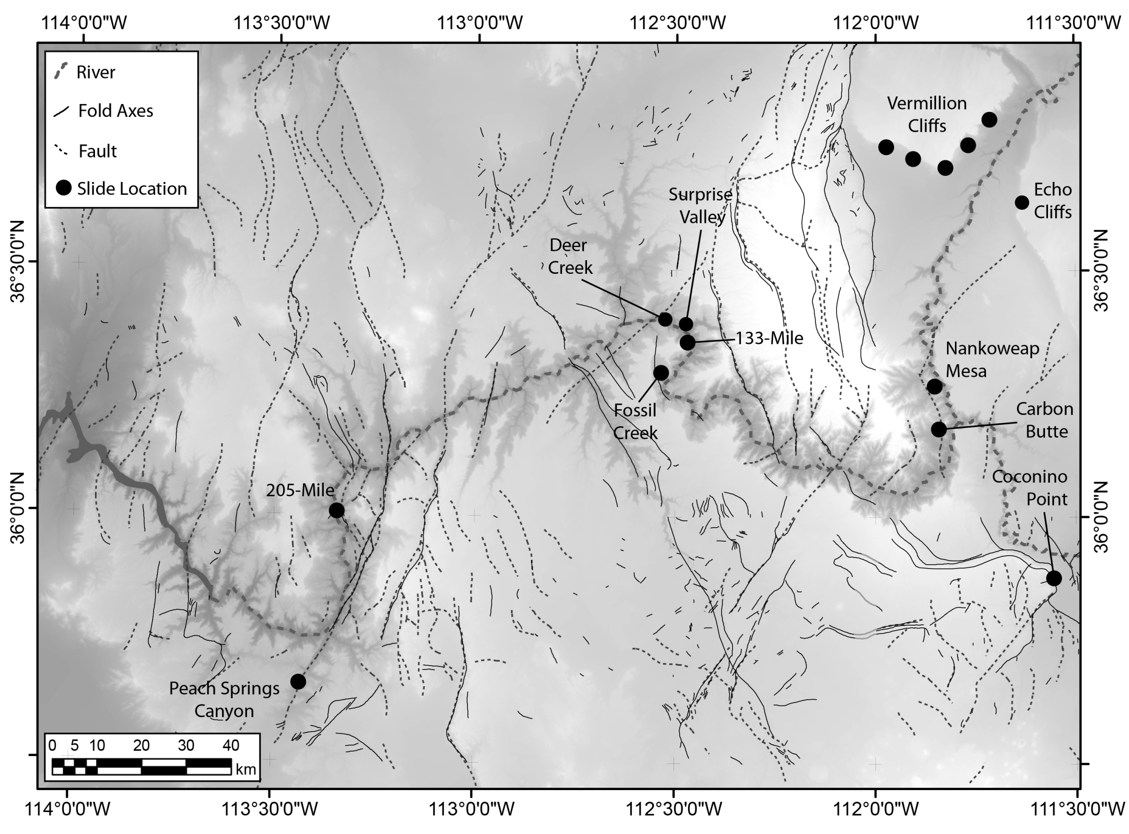
What can landslides tell us about bedrock canyon evolution? To answer this question, we need to understand where, when, and how landslides occur as well as the effect of landslide dams on major rivers and canyon widening. Response of continental-scale river systems to landslide dams depends on stream power, channel shape, landslide volume, frequency, composition, and mechanism(s) of emplacement. New field and geochronology studies of landslide deposits in Grand Canyon are beginning to provide some answers.

Well-known Toreva-style bedrock slumps and slides are preserved in and around Grand Canyon. Some examples near Grand Canyon include those at the Vermillion and Echo Cliffs (including the reactivation of an older landslide on February 20, 2013 that affected Highway 89) and Coconino Point at Gray Mountain. In Grand Canyon, notable landslides include Carbon Butte in eastern Grand Canyon, 133-Mile, Surprise Valley, Deer Creek, 205-Mile, and Peach Springs Canyon in western Grand Canyon (see figure). Other less well-known deposits cap Nankoweap Butte in eastern Grand Canyon and Fossil Creek in central Grand Canyon. In nearly all cases, failure occurred on weak shale horizons like the Bright Angel or Hermit shales. Paradoxically, Toreva-style landslides do not occur everywhere these lithologies are exposed, which suggests additional controls. Landslides between river miles (RM) 130-140 (including Surprise Valley) are the dominant landslides in Grand Canyon. They represent the largest volume of landsliding that records multiple generations of events in a single area. Our hypothesis is that 1) failures are first localized in the Bright Angel Shale or other weak horizons caused by either a) seismic triggering from nearby faults or b) increased pore fluid pressure, and that 2) in general, major catastrophic slides lead to subsequent smaller yet significant river damming slumps and slides (similar to recent Echo Cliffs event). The goal of my Master's research is to examine the interplay between these multiple processes that may have operated within the study area to explain the localization of landslides, pre-and post-slide river incision rates and processes, and landslide dam removal.

Landslides between RM 130-140 consist of several distinct slides of diverse age and character, some of which dammed the Colorado River. The major slides include 1) 133-Mile, 2) Surprise Valley, Cogswell Butte, and subsequent slides, 3) Pancho's Radical Runup, and 4) younger reactivated slides off Cogswell Butte and Deer Creek. 133-Mile slide detached from the south rim, includes Tapeats through Redwall strata, and dammed the Colorado River as evidenced by gravels both above and below slide deposits. Surprise Valley (including multiple Toreva blocks north of the intersection of the Thunder River and Deer Creek Trails) formed when Cogswell Butte slightly back rotated and translated along a detachment that underlies it all. This detachment is beautifully exposed near Thunder Spring. Piano slide, a smaller slump off the over-steepened south face of Cogswell Butte, filled a Colorado River paleo-channel near the Granite Narrows (RM 135R). Another slump (Cogswell West) fills the oldest preserved Deer Creek paleo-channel and can be readily observed along the popular route between Tapeats and Deer Creeks. Pancho's Radical Runup, preserved directly across from Deer Creek Falls, involved thrust-style emplacement of a >1.5 km-wide, >5 m-thick slab of Muav through Redwall Limestones. Riding on a 1-3 m cushion of slope debris, river cobbles, and brecciated material, landslide debris traveled across the river and >200 m up the south side. This event dammed the river below Deer Creek and may or may not have been driven by the main Surprise Valley/Cogswell Butte landslide. The Deer Creek slide mass on river-right below Deer Creek Falls appears to be a younger, smaller reactivation of this initial catastrophic slide. This event diverted the Colorado River to the south – a paleo-river channel filled with Deer Creek slide debris is preserved a few meters above river level at RM 137.2R. This event diverted

Deer Creek to its modern location, where it then incised into the Tapeats Sandstone, carving the Deer Creek Narrows and forming Deer Creek Falls.

Field relationships and existing geochronology suggest saturation of shales to be the main driver of landsliding in the Surprise Valley area. Different heights of river gravels buried beneath the different slides (133-Mile, Surprise Valley, Deer Creek), inset relationships of younger slides within older ones, and no evidence for alignment along a fault, all argue against the seismic initiation hypothesis. The modern presence of high-volume springs near Surprise Valley (i.e. Dutton, Thunder, and Tapeats Springs) suggests groundwater may have played a role in weakening the shales and promoted sliding. Additional geochronology is underway to test these hypotheses; however, preliminary cosmogenic burial age dates recording the time Colorado River gravels became buried beneath landslide debris in paleo-channels 70 and 61 m above river level give ages of 940 ± 240 ka (1σ) and 978 ± 287 ka (1σ), respectively. These ages provide the most direct geochronology to date on the Surprise Valley- and Pancho's Radical Runup-related landslides. The agreement of the two dates in different locations at about the same height above river level is interpreted to give the approximate age of both the main Surprise Valley (Cogswell Butte) detachment and Pancho's Radical Runup. The Deer Creek slides may be as young as the ~21 ka age on proposed landslide dam lake deposits at RM 134.5L (Webb et al., 2005).



Digital elevation model showing locations of notable landslides in and around Grand Canyon. In general, landslides occurred along the river corridor as well as near major faults and folds. Multiple events together representing the largest landslide volume in Grand Canyon occurred near Surprise Valley.