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Rates of river incision and scarp retreat in eastern and central Grand Canyon over the past half million years: Evidence for passage of a transient knickzone: COMMENT

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Abbott et al. (2015) and Crow et al. (2014), two Grand Canyon incision studies, come to very different conclusions despite apparent methodological similarities. Crow et al. (2014) used U-Th, Ar-Ar, and cosmogenic burial dating of material associated with Colorado River (CR) strath terrace sequences at 6 sites throughout Grand Canyon and concluded that average bedrock incision rates have been temporally steady at each site over at least the last 650 ka, but vary spatially from 100 to 160 m/Ma due to differential mantle-driven uplift. Abbott et al. (2015) used our unpublished Ar-Ar dating on a dike in western Grand Canyon, near river mile 159, plus U-Th dating of travertine-cement in sidestream alluvium, near Hermit Rapid, to suggest that incision rates were 1–4 km/Ma from 500 to 400 ka and <200 m/Ma after 400 ka, a difference they ascribe to a migrating knickpoint. The conclusions of these studies are contradictory.

The simplest criticism of the Abbott et al. (2015) interpretation is that neither of their sites contains unequivocal CR deposits. We visited both sites repeatedly but rejected them as CR incision points because datable materials could not be unambiguously related to the paleoposition of the CR. The ca. 520 ka, 159-mile dikes intrude bedrock, along en echelon joints, on both sides of the river to near a height of 400–450 m, where welded pyroclastic tuff is found (Wenrich et al., 1997). The paleo-position of the CR at the time of dike propagation is unknown because the dikes could have intruded into an extant canyon or one filled with lacustrine deposits. Abbott et al.'s argument that the canyon would act as a "stress concentrator" is complicated by joint control that created preexisting anisotropy for magma movement. Numerous modern examples show that dikes can propagate across significant relief without concentrating eruptions at the lowest point (or in some cases, even breaking out there). For example, during the 1973 Mauna Ulu eruption, en echelon dikes crossed the 100-m-deep Pauahi Crater with significant fissure eruptions on the flanks and rims of the crater but not at its bottom (Tilling, 1987). Thus, we reject the 159-mile dikes as a robust incision constraint for the CR.

At the Hermit site, travertines cemented a ~70-m-thick aggradational sequence of sidestream and colluvial deposits on the Tonto platform, interpreted by Abbott et al. (2015) as a tributary fan that was at the same elevation as the CR. However, the lack of verified CR gravels suggests the CR could have been much lower. Additionally, the age of the deposits is uncertain, as only 30% of the analyzed samples gave U-Th ages. The rest of the samples show evidence for open-system behavior, are plausibly outside of U-Th dating range (>600–700 ka), and would give ^{234}U model ages of up to ca. 1.6 Ma. Their successful ca. 500 ka U-Th ages come from the base of deposits and are plausibly younger infillings, similar to well-documented examples throughout Grand Canyon (Crow et al., 2014). Such infillings are expected at a deposit's base where carbonic groundwater can migrate through permeable hill-slope deposits. Careful dating of both travertine clasts and infillings (Crow et al., 2014) is needed to bracket the age of gravel deposition.

We suggest two possible models that could explain all existing data. 1) The ~500 ka U-Th ages reported by Abbott et al. (2015) may be secondary travertine infillings, and gravel deposition took place at ca. 2 Ma. 2) The deposits at the Hermit site are due to sidestream aggradation with local base level controlled by the Tapeats sandstone lithologic bench or a lake behind a ca. 500 ka downstream lava dams (Crow et al., 2015). As an analog for the lake possibility, the Spencer Canyon sidestream debris fan has aggraded ~30 m since the 1930s due to construction of Hoover Dam. Like the Hermit location, it is dominated by sidestream alluvium, it largely lacks CR gravel or appreciable lake deposits except directly at its confluence with the CR/Lake Mead, respectively, and its elevation is well above the bedrock channel.

Figure 1 shows CR paleoprofiles with a transient knickpoint as suggested by Abbott et al. (2015) as well as our CR gravel-constrained incision rates (Crow et al., 2014; Karlstrom et al., 2007). Most of our data would have to be wrong for their model to work. In contrast, the alternate models of their data presented above honor the abundant CR gravel-constrained incision rates, postulate subparallel CR paleoprofiles (Fig. 1), and do not require 1000–4000 m/Ma incision rates that are 2–8 times greater than the highest knickpoint-controlled rates known for bedrock incision in the southwestern U.S. (Donahue et al., 2013).

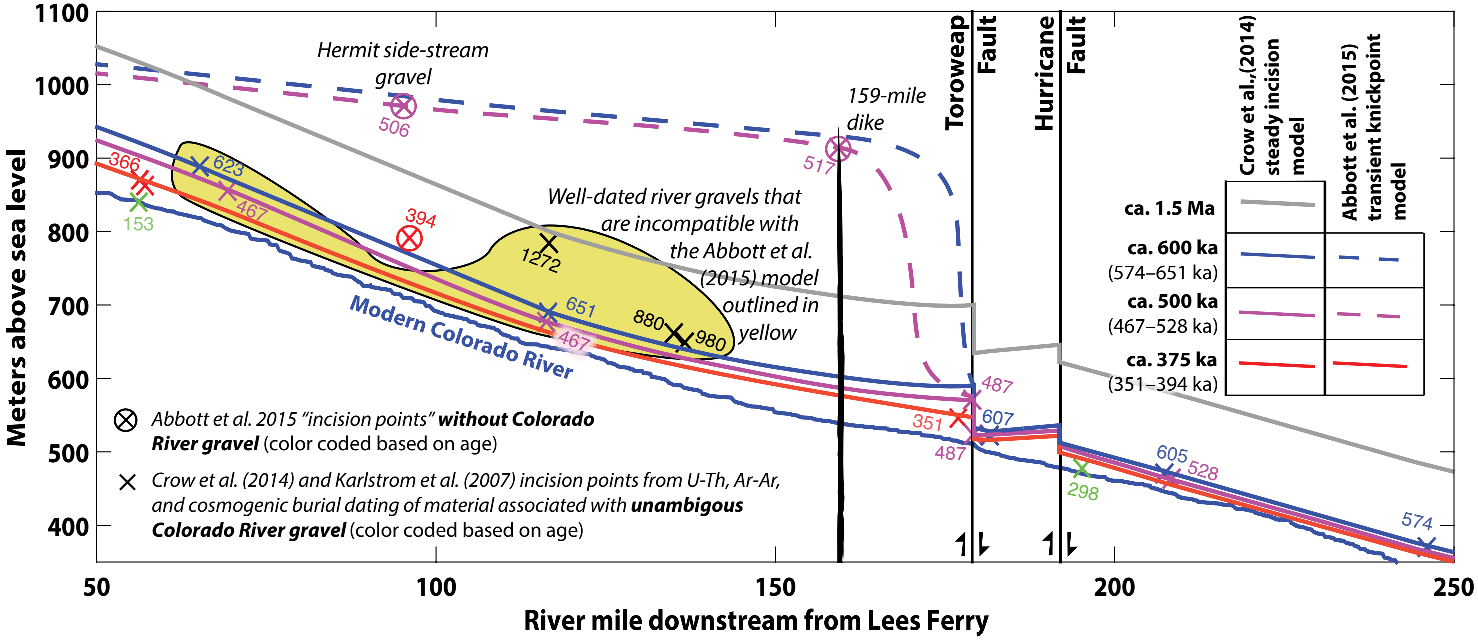

Figure 1. Longitudinal Colorado River profile showing paleo profiles implied by Abbott et al. (2015) and those suggested by Karlstrom et al. (2007) and Crow et al. (2014). Our preferred profiles honor incision points constrained by unambiguous mainstream-river-gravel and do not support a ~400 m high knickpoint, which we consider unreasonable. Data from Crow et al. (2014), Karlstrom et al. (2007), and Abbott et al. (2015). Numbers next to incision points are mean ages in ka.

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