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Comment on "Age and Evolution of the Grand Canyon Revealed by U-Pb Dating of Water Table Type Speleothems"

Joel Pederson, *et al.*

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Comment on "Age and Evolution of the Grand Canyon Revealed by U-Pb Dating of Water Table–Type Speleothems"

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Polyak *et al*. (Reports, 7 March 2008, p. 1377) reported speleothem data leading to their inference that the western Grand Canyon incised much earlier than previously thought. This contradicts several lines of published geological knowledge in the region, hinges upon unjustified hydrogeological assumptions, and is based on two anomalous data points for which we offer alternative explanations.

The highly publicized conclusion of Polyak *et al*. (*1*) that the western end of the Grand Canyon is more than 10 million years older than previously thought ignores and contradicts long-established regional geologic knowledge. We ask that the authors provide a rigorous justification of both their assumptions and their interpretations, specifically in the context of the well-published geology of the region. Considering this, we propose alternative interpretations of their two anomalous western Grand Canyon data points.

The initial speleothem and geochronology results reported by Polyak *et al*. are potentially valuable, inasmuch as they approximate, to within tens of meters, the past groundwater table. However, the authors make two fundamental assumptions in the large step from their nine basic data points across the region to their interpretations about the region's topographic evolution. As stated in (*1*), they assume that apparent groundwater table lowering is a direct proxy for, or "equivalent" to, the depth of canyon incision by an axial river some distance away. In addition, they assume that this paleo-groundwater table was "flat," such that, lacking a gradient head, this groundwater would not flow or relate to topography at all. Both of these conditions are impossible in landscapes of high relief such as this. These assumptions are erroneous even in the broadest sense, considering the complicated spatial relation of the variably perched or confined modern groundwater table to today's diverse Grand Canyon geology and topography (*2*). We ask the authors to justify these key assumptions and explore more rigorously the resultant uncertainties in their data.

In terms of interpretations, we are particularly concerned that the primary conclusions of Polyak *et al*. rely on two anomalously old and anomalously positioned data points [sample sites 1 and 4 of figure 2 and table 1 in (*1*)]. These sites are situated 30 to 40 km away from the modern Colorado River and are similar to each other in height above it, but one is dated at ~7.6 million years ago (Ma) and the other is more than twice as old, at ~17 Ma. On the basis of these two data points, the authors conclude that by ~17 Ma, the western Grand Canyon had been substantially cut by a precursor drainage flowing to the west. This older western drainage hypothetically captured the upper Colorado River near where most people visit the national park today in the eastern Grand Canyon. Thus, Polyak *et al*. envision a major regional drainage, excavating a canyon on the scale of at least several hundred cubic kilometers.

First, the presence of such a precursor western canyon contradicts Lucchitta and Jeanne's study exploring this issue with dated basalt flows recording paleotopography in this area (*3*). Second, such an excavated mass of rock must go somewhere downstream, but this runs into the classic "Muddy Creek" problem of Grand Canyon geologic history (*4*–*7*). Their inferred early incision would have delivered an overwhelming volume of clastic sediment to the internally drained Grand Wash Trough basin between 17 and 9 Ma, with this basin itself incised by 7.6 Ma. These interpretations directly contradict our geologic knowledge of the sources of sediment and the timing of deposition and erosion in these places. The geology of the beautifully exposed and well-dated sedimentary basins of the southeastern Lake Mead region has been well published and reconfirmed over nearly 80 years of study, and we know that their clastic fill was locally sourced and then incised soon after, ~6 Ma (*4*–*8*). In fact, the evidence for no substantial drainage or canyon cutting feeding the basins of this area is the seminal recognition that jump-started scientific debate about the region's landscape evolution decades ago (*5*, *9*). Similarly, it is also well known that the Colorado River did not finally integrate through those downstream basins and deliver Plateau-derived sediment to the lower Colorado River region until between 6 and 5 Ma (*10*–*12*). Third, Polyak *et al*. seem to ignore the well-researched system of deep, gravel-filled Paleogene paleocanyons on the southwestern plateau that dominated local topography through Miocene time (*13*, *14*). These Eocene paleocanyons contain a direct and dated record of subsequent aggradation by northeast-flowing drainages from late Eocene until middle Miocene time or later, again contradicting Polyak *et al*.'s claims of a west-draining western Grand Canyon at this same time. In fact, one of these paleocanyons lies directly between their 17 Ma data point and the Grand Canyon, and it extends below the elevation of their sample, assuring that a distant western Grand Canyon is not being detected in their data. The conclusions of Polyak *et al*. therefore need to be reconciled with existing knowledge of the region.

We argue that there are better interpretations of the two anomalous western Grand Canyon data points described in (*1*). Three to five kilometers of vertical slip along the Grand Wash fault is well documented between 16.5 and 8 Ma (and not before this time, as Polyak *et al*. state), forming the Grand Wash Trough and up to 1.6 km of topographic relief along the southwest edge of the Colorado Plateau (*6*, *8*). For the 7.6-Ma data point, which is much closer to the Grand Wash fault escarpment than to the modern canyon, this preceding and contemporaneous faulting suggests a groundwater connection from the plateau to adjacent springs in this lowering basin, not a topographic canyon off to the south (*7*, *15*). The older 17-Ma data point 30 km south of the Grand Canyon could be simply related to broad denudation and escarpment retreat in that area or, even more likely, to those closer, northeast-flowing paleocanyons mentioned above that predate the western Grand Canyon we see today.

The famous landscape of the Grand Canyon lies along the front lines of competing scientific and nonscientific views of Earth's antiquity and evolution. Regional geological knowledge of the Grand Canyon is especially rich and detailed, but it is already prone to unnecessary controversy and is frustratingly difficult to synthesize and communicate to the public. The report by Polyak *et al*. adds to the confusion rather than building upon previous science, and it therefore makes relating Grand Canyon science to the public even more challenging.

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