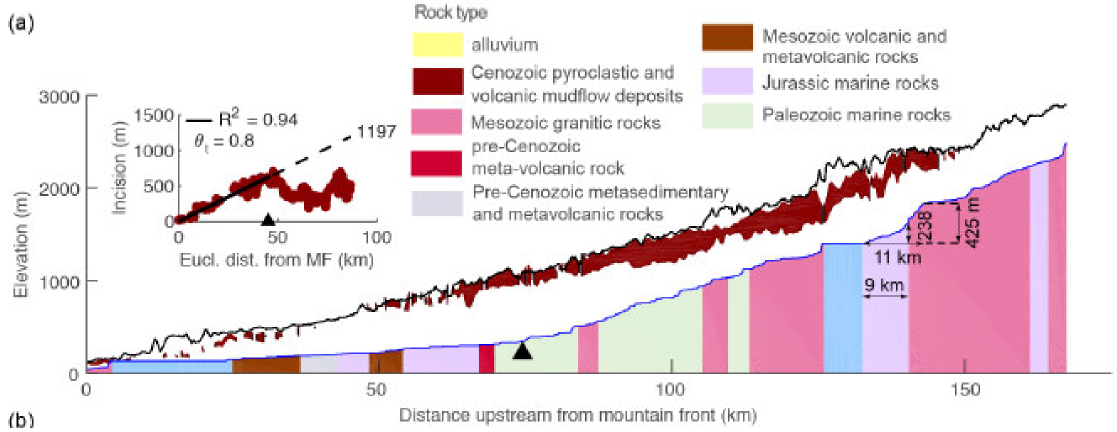
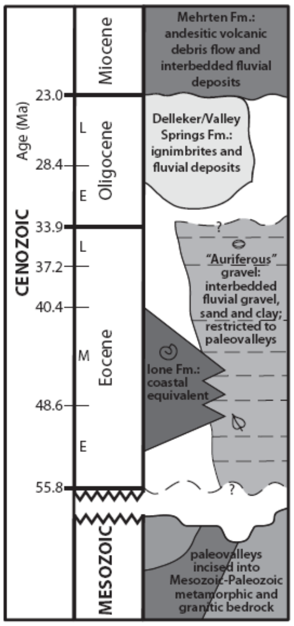
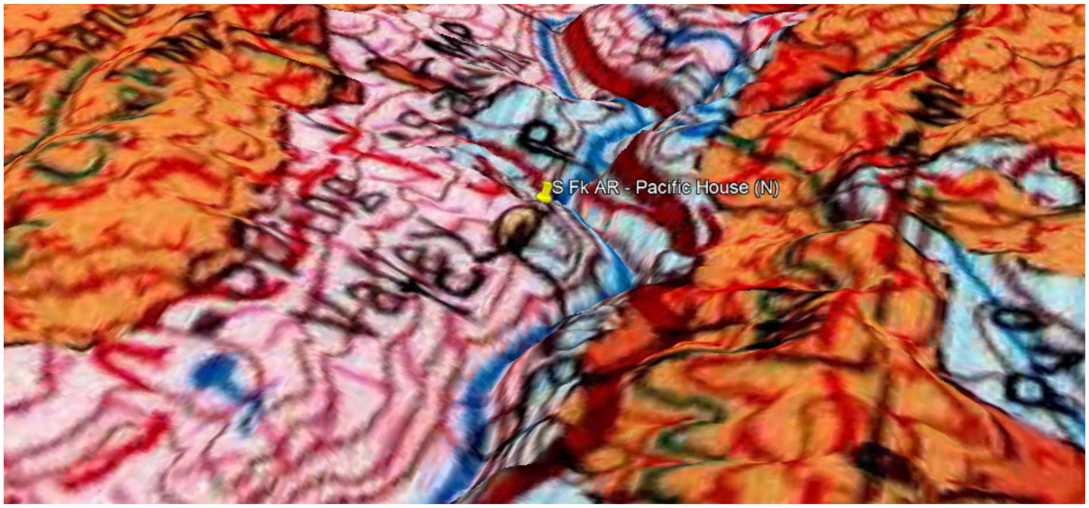
Northern Sierra Nevada: Canyon Incision

To calculate their tilt estimate, the authors have assumed that the canyons in the northern Sierra Nevada were deepened beneath the lowest level of the volcanic rocks only in the past 5 Ma. In other words, they assume that the bedrock river bed was at the same elevation as the lowest volcanic outcrop 5 Ma and, since then, has incised through bedrock down to its present elevation. This assumption is critical to their tilt estimate, as represented in the inset to their Figure 10a:

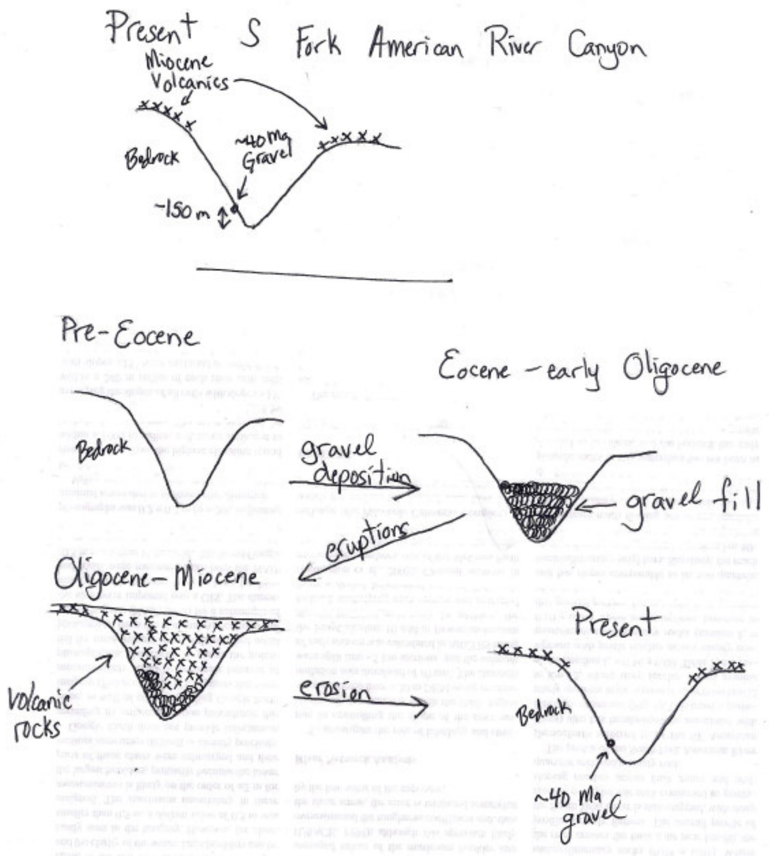


However, as shown in the figure below (right), much older sediment can be found deep within these canyons.

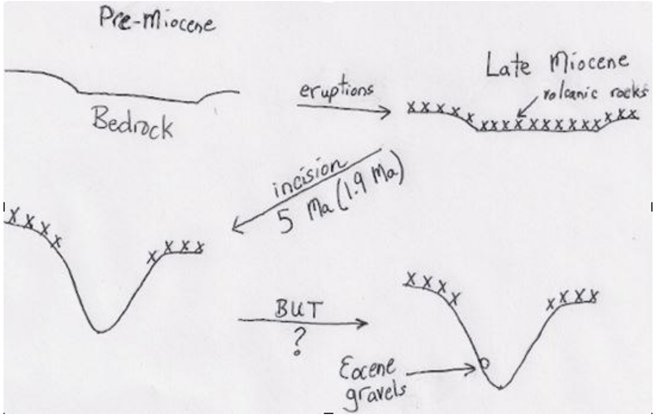




This is a view of the South Fork American River. The Miocene volcanic Mehrten Formation is shown in orange; the small patch of Eocene – early Oligocene auriferous gravels are shown with the yellow pin on the map (the small tan oval); the granitic bedrock is pink. To the left, I show the stratigraphic relationship of these sediments. This means that the fundamental assumption used by the authors for their tilt estimate is unequivocally refuted. The elevations of the volcanic rocks do not represent late Cenozoic bedrock channel elevations and, therefore, the points shown in the inset of Figure 10a are not bedrock incision depths; they are simply reflecting the fact that valley relief increases as you go into the mountains. The canyon’s present topography and its distribution of sediments is explained by the sketch below.



The authors have assumed, however, that all the bedrock below the Late Miocene volcanics in the first sketch (ie. “Present S Fork”) was incised since 5 Ma. Here is a cartoon illustrating their conclusion regarding the timing of canyon incision.



Clearly, significant post-Miocene bedrock incision is contradicted by the presence of the Eocene gravels near the bottom of the canyon and this represents a fundamental problem in their analyses. (I should emphasize that nothing that I'm presenting here is new: these stratigraphic relationships and Eocene deposits have been known since at least 1880.) This problem impairs two of their approaches regarding uplift of the northern Sierras. In Sections 4.1.1 and 6.1, tributary knickzones are used to estimate the timing of tilt; since these large knickzones date back to at least the Eocene, they cannot provide much information regarding recent uplift. In Section 4.4.2 and 6.2, tributary knickzone drop heights and incision depths are used to estimate tilt magnitude but, these incision depths are a product of a much older period of incision and won't provide information regarding recent incision. Since the Eocene, there has been only a maximum of 100-200 m of net bedrock channel incision, all of which can be attributed to the response to uplift during the Mesozoic. As I mentioned elsewhere, the northern Sierra was buried by gravel and volcanic rocks during much of the Cenozoic and the rivers have only recently have had access again to their bedrock beds.

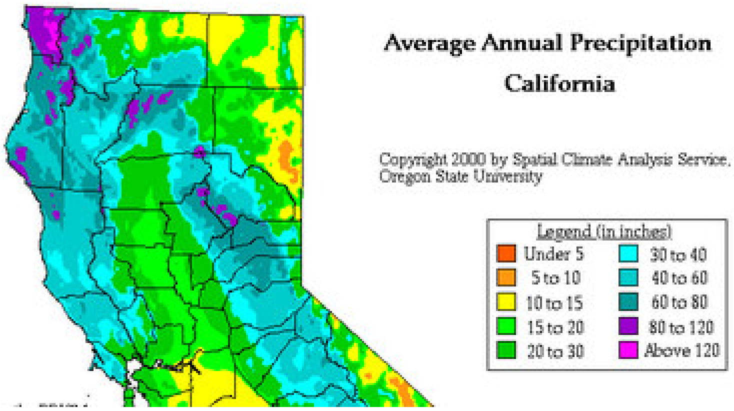
Northern Sierra Nevada: Model

I've had a bit more time to examine the model and its assumptions and there are a few issues here as well.

1) One of these is the assumption of uniform uplift superimposed on to uplift by tilting. Uniform uplift would leave an obvious scarp at the range-front, but no scarp like this has been mapped nor has anyone suggested that uniform uplift has occurred during the Cenozoic. Therefore, there doesn't seem to be a strong basis for comparing the model results (Fig. 3b) to an actual profile (Fig. 10b) in Section 6.1. My concern is that uniform uplift is being added to make the model work right (I've written many models so I understand how this happens), but this boundary condition may be affecting the results in some significant way.

2) In Section 6.1, knickzone geometry is used to estimate tilt; however, this geometry will be sensitive to rock erodibility (K). The authors did not explain how they *independently* determined the erodibility of these rocks. It is important that K be determined without appealing to assumptions regarding uplift, incision, etc (eg, Eqn 5) because then things may get a bit circular.

3) In addition to assuming that rock erodibility is uniform (which I discussed in an earlier comment), the streampower formulation used here assumes that rainfall is uniform as well. However, this assumption is violated by the strong orographic effect whereby annual precipitation at the Sierran crest is 4-5 times greater than in the foothills (see map below). Because of the nature of storm tracks in the region, this precipitation gradient has existed since at least the Eocene (Chamberlain et al., 2012). As shown by several published papers (eg, Roe et al, 2003), properly accounting for precipitation gradient is necessary for investigating the spatial and temporal distribution of channel slopes and this could be easily done by rewriting Hack's Law such that drainage area is a function of both distance and elevation.



Chamberlain, C. P., Mix, H. T., Mulch, A., Hren, M. T., Kent-Corson, M. L., Davis, S. J., Horton, T. W., and Graham, S. A., 2012, The Cenozoic climatic and topographic evolution of the western North American Cordillera: American Journal of Science, v. 312, no. 2, p. 213-262.