# Plio-Quaternary subsidence and exhumation of the southeastern San Joaquin Basin, CA, in response to mantle lithosphere removal

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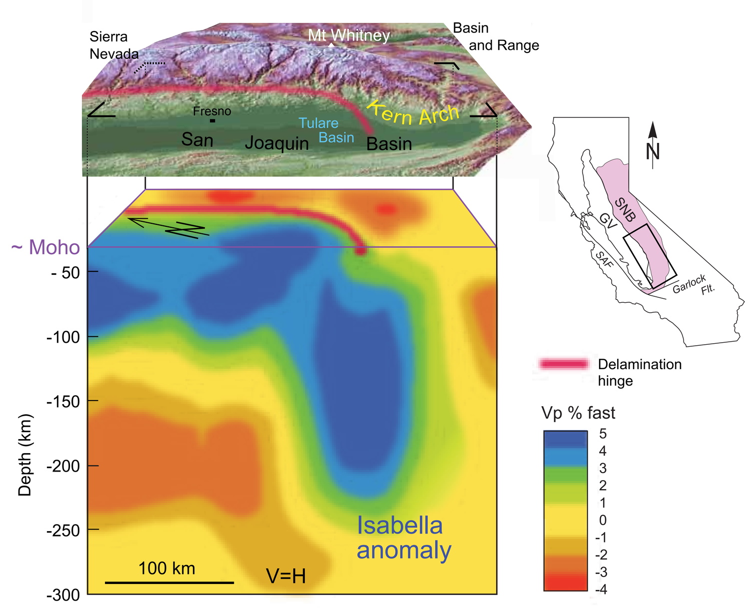
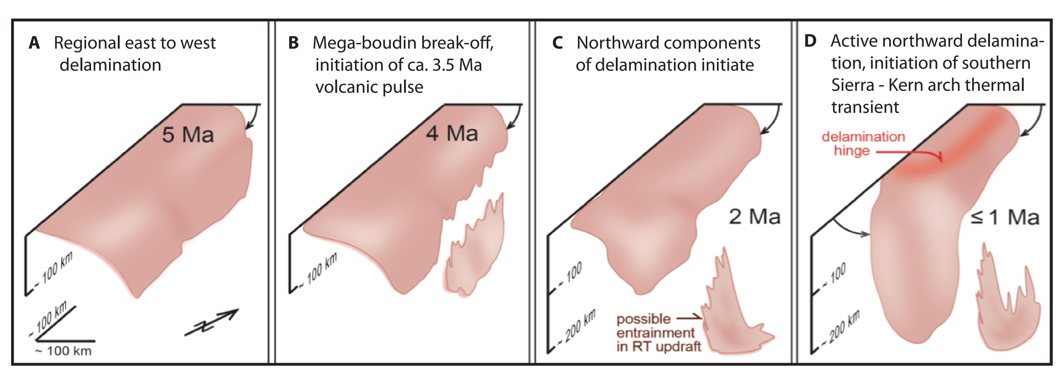
## 1. Introduction and Motivation

Thermomechanical models of mantle lithosphere removal from beneath the southern Sierra Nevada region, California, predict a complex spatio – temporal pattern of vertical surface displacements. We evaluate these models by using (U-Th)/He thermochronometry, together with other paleothermometry estimates, to investigate such topographic transients. We target strata of the Kern arch, a crescent-shaped uplift located in the SE San Joaquin Basin. Kern arch stratigraphy provides a unique record of subsidence and exhumation in a sensitive region immediately adjacent to the delaminating mantle lithosphere at depth.

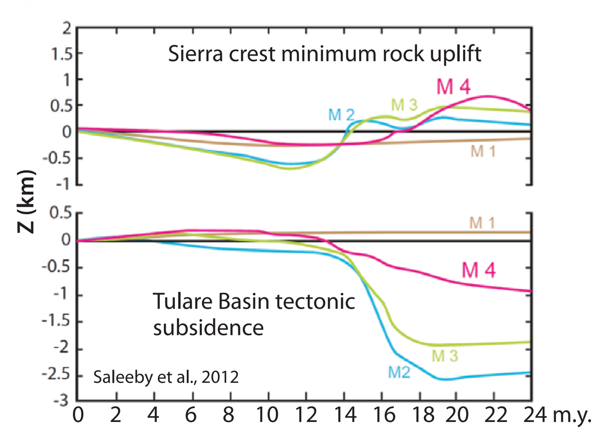



Oblique DEM view of so. Sierra Nevada topographic surface from the west, lifted off of underlying upper mantle structure (tomography from Reeg, 2008). High velocity zone is interpreted as actively delaminating Sierra Nevada arclogite, with delamination hinge approximating locus of separation from lower crust (after Saleeby et al., 2012, 2013). Note Kern arch and Tulare Basin positions relative to anomaly and delamination hinge.

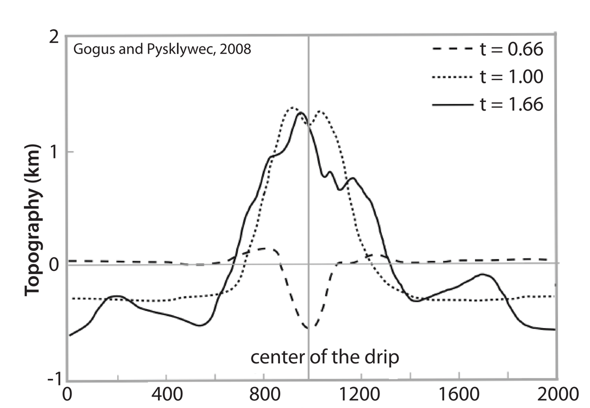



Conceptual model of the 3-D delamination of the arclogite root from the Sierra Nevada batholith. A: Early stages of regional east to west delamination. B: hypothetical necking off of a mega-boundin, which promoted ca. 3.5 Ma volcanism. C: initiation of S to N components along southern end of residual root. D: continued N to S delamination progressing to the current state of the Isabella anomaly suspended southeasteard into the deeper mantle from the area of residual root attachment under Tulare Basin. Figure from Saleeby et al. 2012.

## 2. Delamination and vertical surface displacements

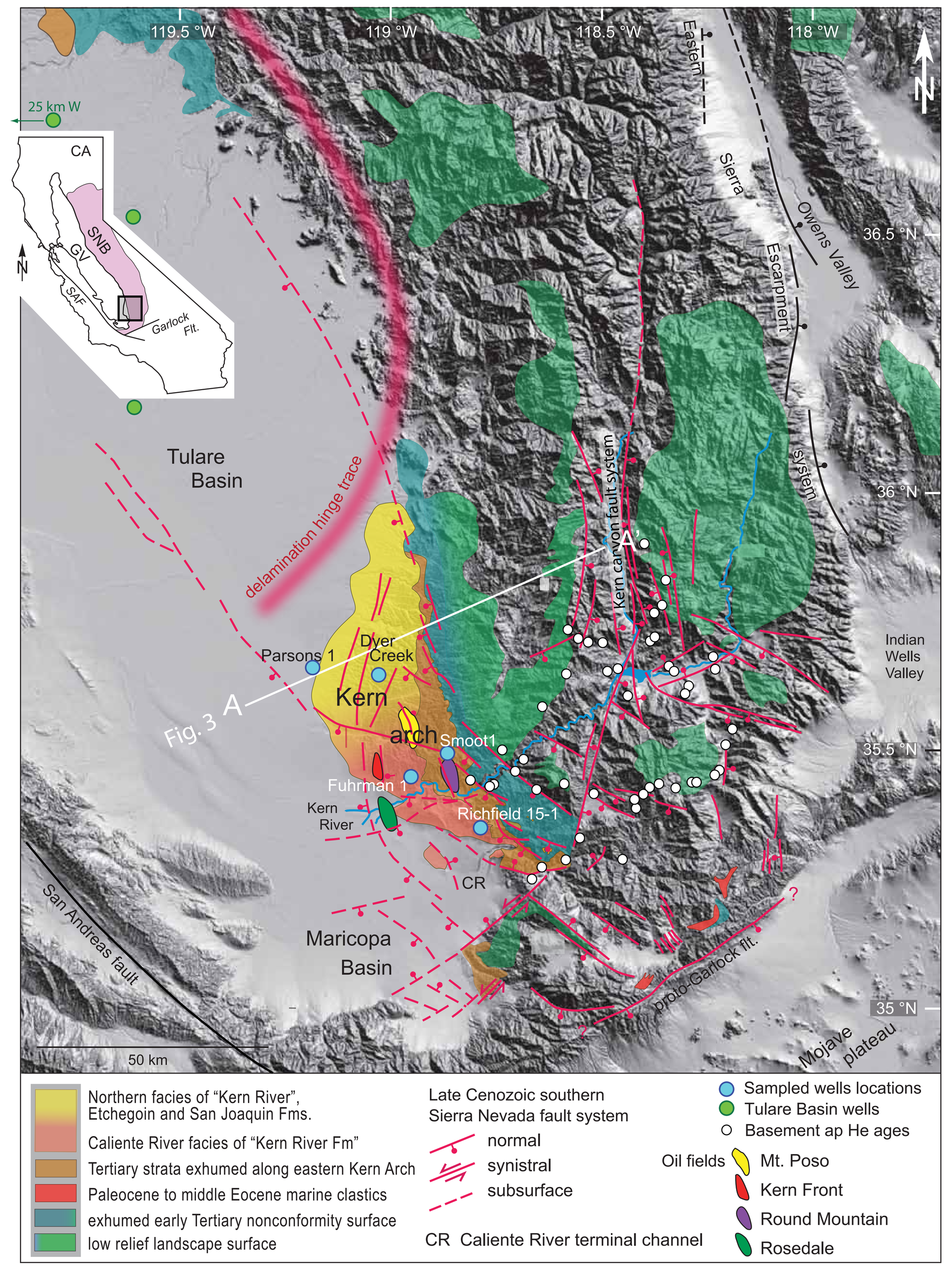


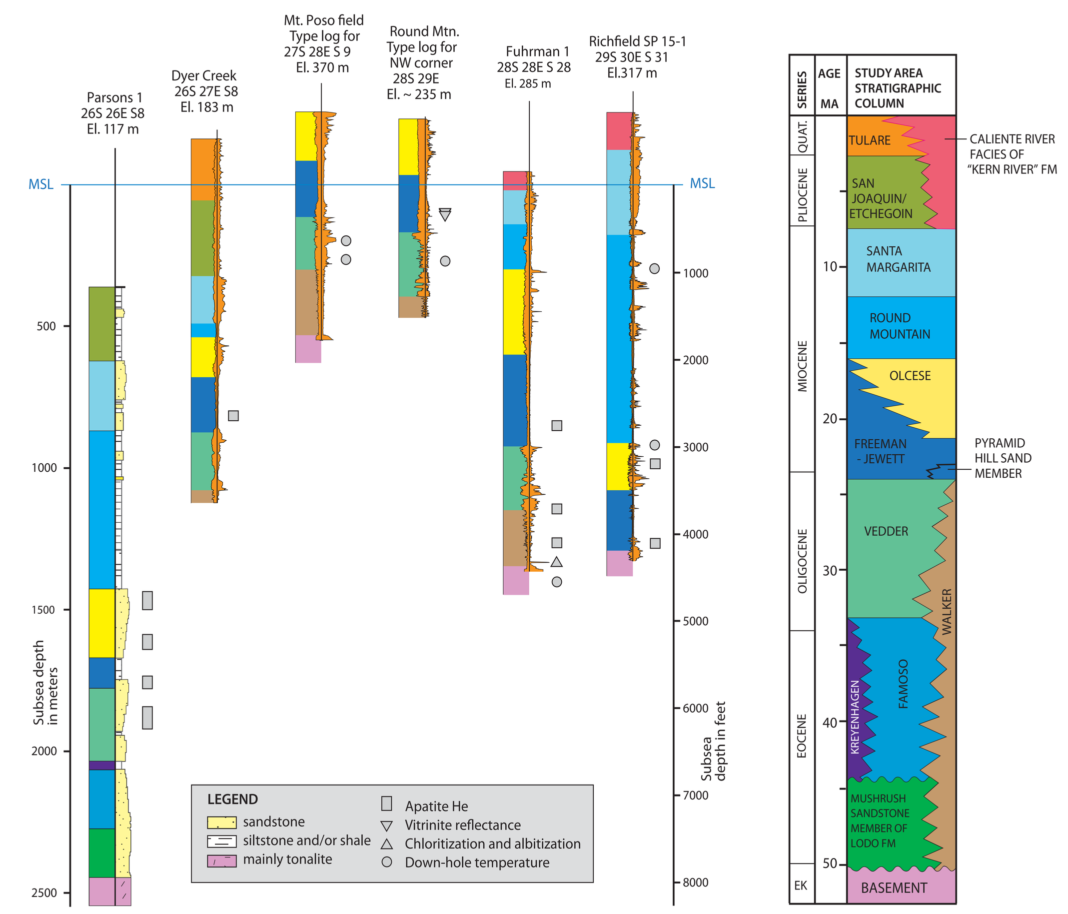

Comparisons of vertical displacement of the eastern Sierra crest and Tulare Basin center over 24 m.y. of model time as predicted by a range of models. The model preferred by Saleeby et al. predicts a minimumof 800 m of rock uplift at the Sierran crest and 500 m of subsidence in the Tulare Basin in mid-Pliocene - Quaternary time.




Plots of surface topography at three time intervals, showing an inital phase of subsidence, followed by uplift. In this model, topography signals are symmetric about the center of a dripping mass. The model assumes the mantle lithosphere instability does not migrate with respect to the overlying plate.

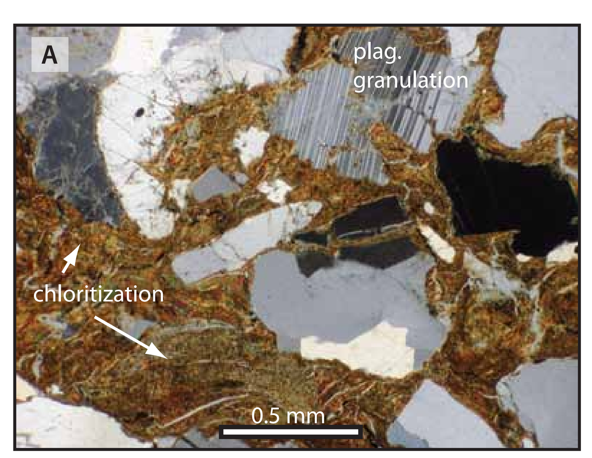
## 3. The Kern Arch

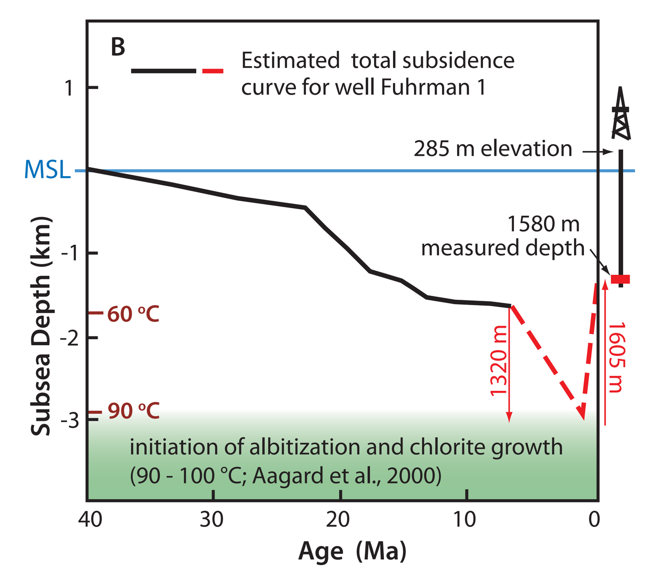


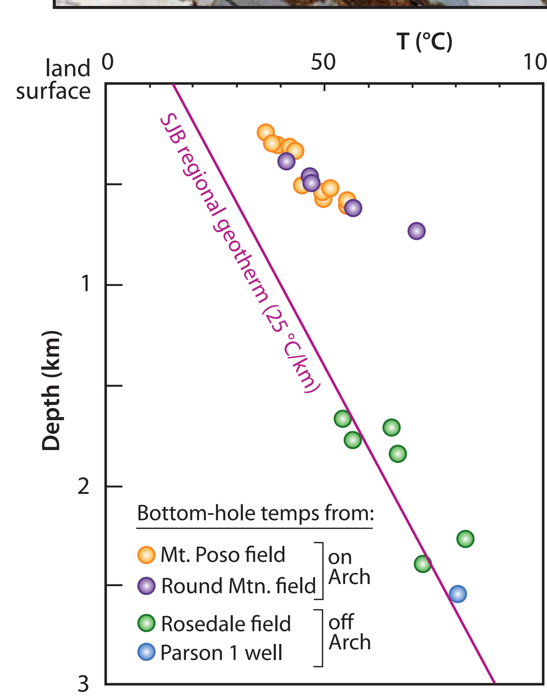




The Kern arch is a crescent-shaped uplift located along the low western flank of the southern Sierra Nevada. It is adjacent to the Tulare Basin, an area of modern anomalous subsidence centered above the area of residual crustal attachment of the delaminating arclogite at depth. Basinal deposits of the Kern arch region comprise up to 4 km of Eocene - Pleistocene marine and nonmarine strata , which unconformably overlie Early Cretaceous Sierra Nevada basement. Although it has been proposed that the Kern arch is a basement salient which existed since the Paleocene, we argue that it is an entirely recent (Neogene) feature that is associated with Plio-Quaternary removal of mantle lithosphere from beneath the region.

## 4. Cryptic subsidence in the Kern Arch



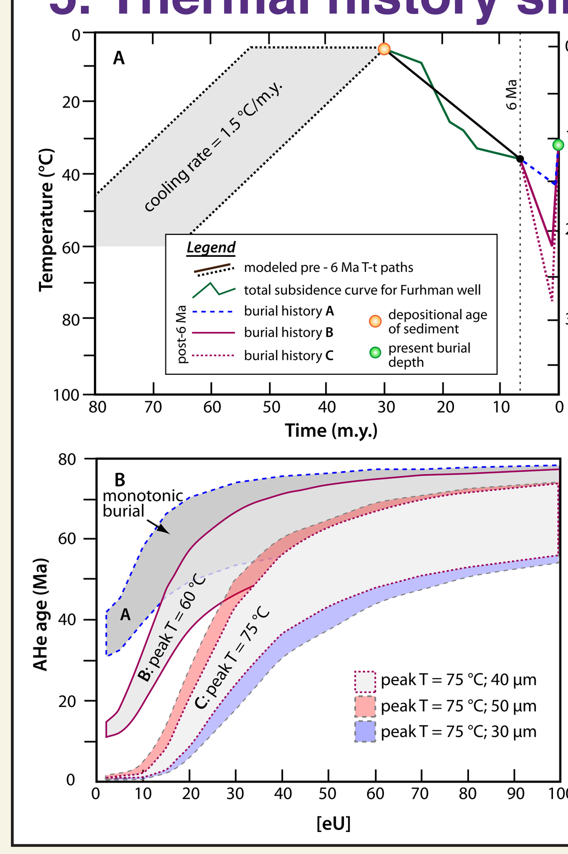




A recent cryptic subsidence event was recognized on the basis of:

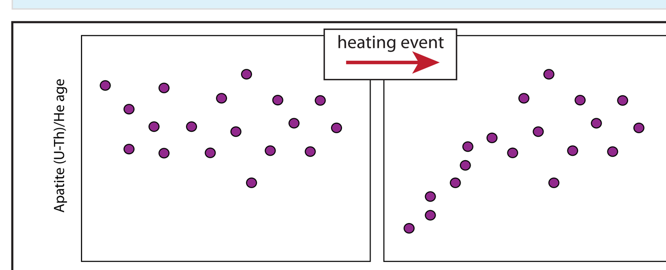
**1)** mechanical granulation textures
**2)** matrix chloritization (see photomicrograph)
**3)** albitization of plagioclase

These textures and / or chemical signatures develop at temperatures corresponding to depths that are much greater than those at which the rocks presently reside, indicating a pulse of heating and subsequent exhumation (see plot top right).
Likewise, anomalously high geothermal gradients observed in Kern arch wells suggest uplift and truncation of the local geotherm (see plot at left)

## 5. Thermal history simulations



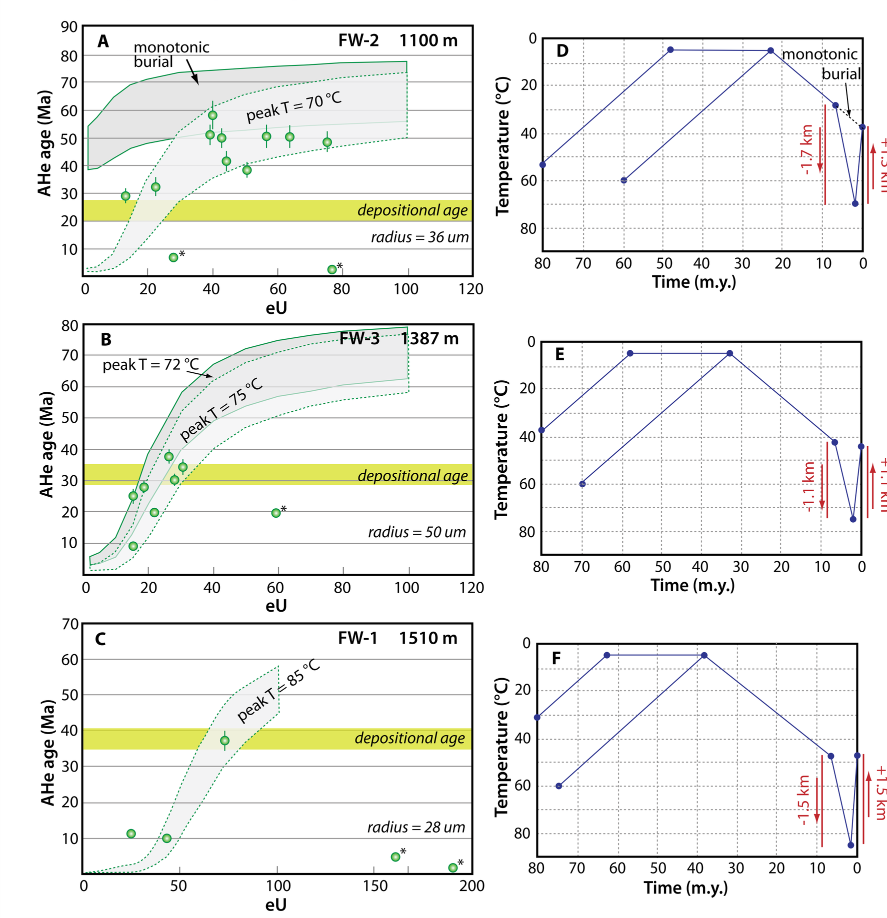

Detrital apatites recovered from Kern arch well samples are assumed to be derived from the southern Sierra Nevada batholith.
--> A pre-depositional cooling rate is based on known Cz cooling / exhumation of the southern batholith.
--> Depositional ages are fairly well constrained by fossil fauna and dating of interbedded ashes.
--> Post-depositional burial and heating is from calculated subsidence curves. The youngest preserved strata are 6 Ma; Plio-Quaternary subsidence cannot be constrained by conventional stratigraphic analysis.



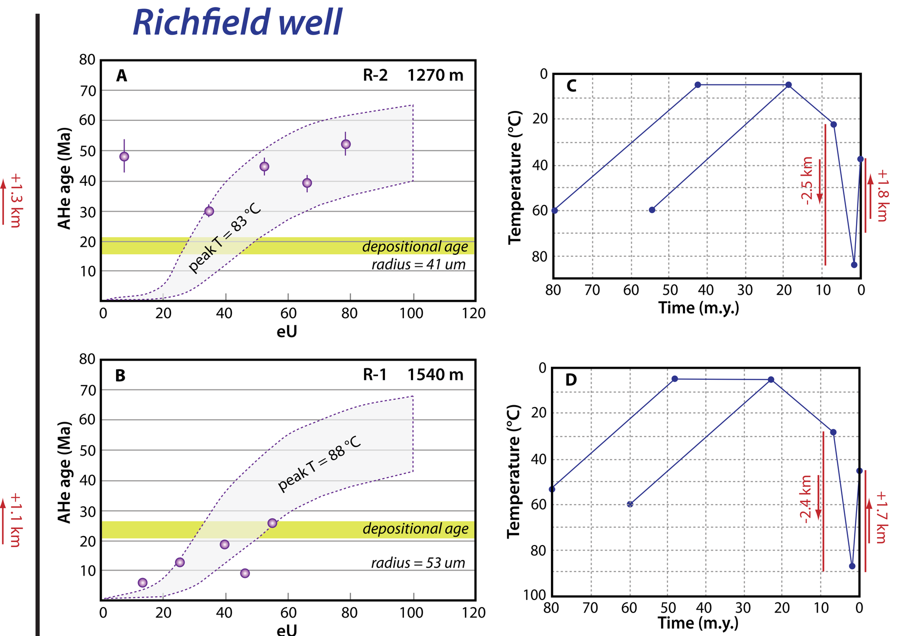

Low - [eU] apatites are more sensitive to thermal resetting, creating positive age - [eU] relationships in a detrital suite. The shape of that relationship and the distribution of reset ages is dependent on: 1) the peak temperature reached, and 2) the duration at that temperature.

## 6. Forward modeling of detrital apatite (U-Th)/He ages

*Fuhrman well*




*Richfield well*



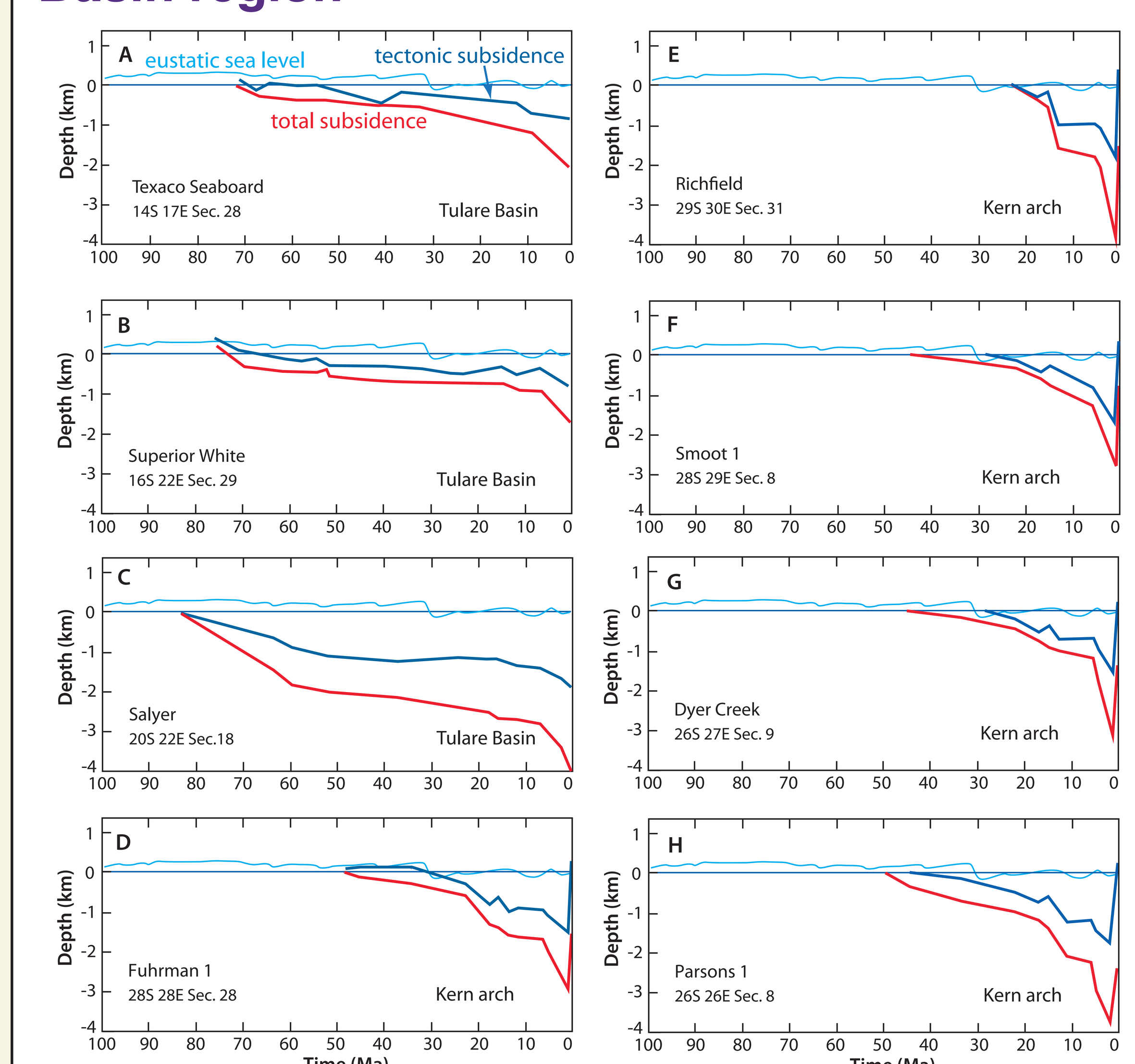

Detrital apatite He ages can only be explained by a post - 6 Ma heating event, which we assert is a funtion of rapid burial in the SE San Joaquin Basin. Real data from the Fuhrman (green) and Richfields (purple) are shown in the panels above. The best fit thermal models to those data indicate heating to temperatures between 70 - 88 °C at 1 Ma. This requires 6 - 1 Ma subsidence of ~ 1 - 2.5 km, followed by rapid post - 1 Ma exhumation of Kern arch rocks to their present burial temperatures / depths.

| Well | Elevation (m) | Range of sample collection depths (m) | Range of peak Temps (°C) | Average post-6 Ma sub. (m) | Average post-1 Ma exh. (m) |
|---|---|---|---|---|---|
| Fuhrman 1 | 285 | 1100 - 1510 | 70 - 85 | 1500* | 1346* |
| Richfield | 317 | 1270 - 1540 | 83 - 90 | 2465 | 1772 |
| Dyer Creek[1] | 183 | 988 | 73 | 1790 | 1515 |
| Parsons 1 | 117 | 1600 - 2020 | 84 - 89 | 1187‡ | 1110‡ |
| Smoot-1 | 239 | 335 - 354 | 69 - 71 | 1655 | 1828 |

Subsidence and exhumation estimates tabulated for all wells studied. Estimates from the Smoot-1 well are based on vitrinite reflectance data, which indicated that rocks as shallow as ~ 350 m today were buried to temperatures of 69 - 71 °C.

These estimates are also represented in subsidence curves for the Kern arch shown below. Note that The timing of rapid subsidence and uplift of the arch is coincident with increasing subsidence rates in the Tulare Basin.

## 7. Surface transients in the Kern arch - Tulare Basin region




## 8. References

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**Flowers et al.**, 2009. Apatite (U-Th)/He thermochronometry using RDAAM. GCA, v. 73, p. 2347-2365.
**Le Pourhiet et al.**, 2006. Mantle instability beneath the Sierra Nevada mountains in California. EPSL, v. 251, p. 104 - 119.
**Reeg,** 2008. Tomographic observations connecting convective downwellings with lithospheric source regions, Sierra Nevada. EOS Trans. AGU, v. 89(53).
**Saleeby et al.**, *in press*, Epeirogenic transients related to mantle lithosphere removal in the southern Sierra Nevada region, California, Part I: Implications of themo-mechanical modeling, Geosphere.