Quaternary Rift-Flank Uplift of the Peninsular Ranges in Baja and Southern California by Removal of Mantle Lithosphere

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Abstract
Regional uplift in southern California, USA and northern Baja California, Mexico is interpreted to result from flexure of the elastic lithosphere driven largely by thinning of the upper mantle beneath the Gulf of California and eastern Peninsular Ranges. The geometry and timing of faulting in the Salton Trough and Gulf of California, the history of recent rock uplift along the Pacific coastline and gravity and heat flow data are used to constrain models of lithospheric thinning based on unloading of a continuous elastic plate. Negative gravity lows centered over the eastern Peninsular Ranges are unlikely to have been produced from crustal extension, and point to dramatic thinning and/or strong heating of the lithosphere beneath this region. Furthermore, high topography that marks the ~400 kilometer-long rift shoulder from southern California to the Vizcaino Peninsula in Baja California matches the pattern of uplift observed along the Pacific coastline as defined by the marine Stage 5e and older marine terraces. Pliocene strata deposited at sea level along the Pacific coastline in southern California have not been uplifted significantly above Quaternary marine terrace deposits. This suggests the onset of rock uplift along the Pacific coast is recent (e.g. post Pliocene) and postdates Miocene crustal extension in the Salton Trough and Gulf of California. Replacement of the mantle lid beneath the eastern Peninsular Ranges thus coincides with crustal extension limited to opening of localized oceanic spreading centers in the Gulf of California. Lower average relief in central and southern Baja California is interpreted to result from active subsidence of previously higher rift flank topography. Marine terraces preserved south of Vizcaino along the Pacific coast lie at the elevation they formed at, suggesting modern subsidence at these latitudes is localized near the Gulf of California.

Measurements of terrace uplift rates (arrows, top panel, scale at right in m/year) and maximum crustal elevation of the Peninsular Ranges (shaded, top, scale at left in km) along the Baja Peninsula and into southern California. Dashed arrows are measurements proposed to be affected by nearby active structures. Map view (bottom panel) with the measurement points shown on shaded topography. Terraces measured are from marine stages 5e and 9e, ~83 ka and ~122 ka.

Examination of the role of more realistic, distributed loads. The crust is thinned by 15 km from the crest of the Sierra Juarez to the edge of the Salton Trough as suggested by refraction measurements and receiver function interpretations (e.g., Jahnke et al., 1986, UNIS Science Team et al., 2001, JGR). We assign a density contrast of 400 kg m⁻³ to the Moho and 100 kg m⁻³ to the lithosphere:asthenosphere boundary, and 150 kg m⁻³ to the sediment:basement boundary. T is 24 ka ± 33 and t≥60 and 10 km in the rift (t≥ 0.33 km). The crust and mantle loads are specified and the amplitude of the technique removal of upper crust is determined such that the total deformation matches the maximum basin depth in the Salton Trough. Note that uplift in the Salton Trough must be removed to the west of the main bounding fault of the Salton Trough and probably extend under the Peninsular Ranges’ crest.

Conclusions:
- Even with substantial thinning and erosion east from the crest of the Peninsular Range, mantle thinning must extend to or even west of the crest of the range.
- Creation of the buoyant load (removal of mantle lithosphere), at least in the western part of the thinned lid, must have occurred over the past ~1 My and continues today.
- New buoyant loads cease to exist south of ~29°30’N.
- Regional coastal uplift is probably due to extensional processes to the east rather than contractional ones along the coastline.

(A, left) Digital topography from 90m SRTM data. Dotted boxes represent locations of swath-averaged topography for north and south models (see at right). (B, right) Simplified provinces: map with 500 m contours modified from Axen (1995). Normal faults of San Pedro Marip Pass (MPF) and Sierra Juarez Fault Zone (SJFZ) marked by balls on downtown sides. Active dextral faults marked by arrows. Hangingwalls of low angle normal faults marked by dextral tick marks. Topography in the Peninsular Ranges slopes gently towards the Pacific Ocean from rift shoulder segments and include the Laguna mountains (Laguna), the Sierra San Pedro Marip (Marip), and Sierra Juarez (Juarez).

Flexure of a continuous plate over a line load (at arrows) compared to topography on the northern transect. Loads of about 5 x 10⁻⁵ and 1 x 10⁻⁷Nm from erosion/extensional removal of upper crust (gap between curves and modern surface) and replacement of basement by sediments under the Salton Trough are insufficient to produce the uplift. Significant loads from the mantle are required.

Flexure of a broken plate over a line load (break and load at arrows) compared to topography on the southern transect. Loads from erosion/extensional removal of upper crust (gap between curves and modern surface) as high as 80% of load needed, but shallowing Moho from west to east indicates significant mantle source needed.