Current Vertical Crustal Movements in Northern Baja California, Mexico

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Geologic Background:
• Northern Baja California, Mexico is dominated by right-lateral transpressional tectonics associated with the Pacific-North America plate boundary zone.
• This tectonic setting has characterized the region since ~5 Ma when the plate boundary jumped inland to its current position in the Gulf of California (Arvaire, 1989).
• The highest topography is associated with the San Pedro Martir Fault, a major listric normal fault system.

Resolution Tests:
• We compared this Poly3D model to the analytical model (Savage, 1980):

Model (1):
This extension rate and locking depth imply the vertical signal shown below.

Model (2):
• We assume there is an additional process influencing the vertical velocity field.
• We extend the model of Wdowinski and Zilberman (1996) to solve for the magnitude and focus of this process.

Model Constraints:
We first use the horizontal, perpendicular, GPS data to constrain the extension rate and locking depth of the fault.

Conclusions:
• We speculate that a new density anomaly in the uppermost mantle, possibly analogous to delamination in the southern Sierra Nevada may explain the high uplift rates observed in Northern Baja California, Mexico.

The Model:
We assume initially that GPS-measured uplift is controlled by
a) The elastic strain field associated with a locked, active normal fault, and
b) The isostatic uplift associated with unloading as the crust extends and thickens.
c) The elastic strain field is calculated using Poly3D, an elastic half-space dislocation model, using a boundary element method (Thomas, 1993).

Faults:
Figure 1: Map of study area including all campaign GPS sites, vertical data, and theography cross-section lines.
Figure 2: Map of study area including all campaign GPS sites, vertical data, and theography cross-section lines. Box indicates sites included in fault profile analysis.
Figure 3: Cross section of theography along the GPS fault profile.
Figure 4: GPS vertical data vs. elevation for the fault profile.

GPS data spanning a decade provide precise (~1 mm/yr) or better estimate of vertical rates in northern Baja California, Mexico.
• The data show that uplift is correlated with elevation.
• This implies either an elevation-dependent systematic error, or that present elevations reflect young (1 Ma or younger) tectonics.
• In this study we explore tectonic explanations.

Figure 5. Savage (1980) analytical model vs. Poly3D model for horizontal displacement on a 60° dipping normal fault, with a locking depth of 15 km and a slip rate of 1 cm/yr. The Savage model is an infinitely long fault plane.

Model 1:
• As the length of the Poly3D model increases, and fault planes approach equal size, the match improves.


Model 2:
The model requires an additional negative line load at near the fault at a depth of 65 km, with a magnitude of 2.8*10^6 N/m.

Figure 6. Fault normal rate vs. distance from fault axis for the best fit Poly3D model compared to GPS data. Extension rate is 1.6 mm/yr and locking depth is 12 km. The best fit values for the horizontal data vs. the model are as follows:

Figure 7. Chi square contour plot for fault normal slip rate vs. vertical locking depth.

Figure 8. Chi square contour plot for horizontal extension rate vs. locking depth. Blue marks best fit. Orange-yellow boundary marks ~95% confidence.