Geophysical Research Abstracts
Vol. 15, EGU2013-6457, 2013
EGU General Assembly 2013

Delamination and Drip-like Secondary Convection under the Western U.S.

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A series of papers suggest that small-scale lithospheric downwellings are occurring or have occurred beneath different parts of the western U.S. since ∼16 Ma, notably beneath the southern Sierra Nevada (Late Miocene-Early Pliocene, Zandt et al., 2004), the Wallowa Mountains of eastern Oregon (Mid-Miocene, Hales et al., 2005), the west-central Colorado Plateau (ongoing, Levander et al., 2011), and along the eastern flank of the Rio Grande Rift (ongoing, Gao et al., 2003, van Wijk et al., 2010). These delamination/drip events are geographically widespread and relatively recent, occur in different tectonic and geologic environments, and are attributed to different types of thermo-chemical instabilities. All are associated with contemporaneous surface uplift. In this presentation we review the evidence for these drips, and discuss the causative processes which include a combination of rheological weakening of existing orogenic lithosphere due to dehydration of subducting oceanic lithosphere (e.g. Humphreys et al., 2003), edge convection at lithospheric thickness gradients that can give rise to thermo-chemical instabilities, and the general upper mantle flow driven by subduction.

We suggest that drip-like phenomena have been and are an integral part of western U.S. orogenesis, at least in the collapse stage, accounting for a large part of vertical motions. We hypothesize that localized downwellings have occurred throughout the west since about the initiation of Basin and Range extension. We speculate that potentially much of the lithosphere along the Wasatch front, under the northern Sierra Nevada, under the Colorado Plateau, and under parts of the Rocky Mountains will destabilize and drip off into the mantle. As this occurs the remaining lithosphere is weakened and can be deformed. The destabilized lithosphere is replaced by asthenosphere forming new thermal and chemical boundary layers. The asthenospheric flow is driven both by the downwellings and by orogeny-wide upper mantle circulation associated with subduction. More globally, these drip phenomena may play an important role in initiating construction of the heterogeneous lithosphere preserved around the peripheries of the cratons. Following the piecemeal loss of orogenically modified lithosphere through drips, asthenosphere emplaced as shallowly as Moho depths cools and solidifies to form an irregular continental lithosphere consisting of new and ancient mantle.