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Synthesizing global lithosphere removal events: Scale, style, and surface deformation

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Removal of lower crust or mantle lithosphere can have a profound effect on the tectonic evolution of orogens and basins. Lithosphere removal events have been inferred throughout the globe to explain enigmatic episodes of uplift, basin subsidence, volcanism, and lithospheric thinning, but the evidence for individual removal events is indirect and sometimes inconclusive. Here we present a synthesis of the literature related to lithosphere removal. The goal of this work is to categorize removal events according to properties such as physical and temporal scale, style of removal, and tectonic setting, and to evaluate the strength of evidence for each removal event.

Over the past few decades, advances in tomography have allowed the direct imaging of bodies of foundered lithosphere, which appear as positive velocity anomalies beneath the Moho. Foundered bodies with spatial scales ranging from 50–300 km have been imaged beneath the central Andes, Basin and Range, Colorado Plateau, and Sierra Nevada. Direct imaging is only possible for relatively recent removal events, but geologic evidence may be preserved in the structural, sedimentary, and volcanic history of a region. A suite of geochemical tracers has been developed to distinguish between lithospheric and asthenospheric sources of melt. Many volcanic geochemistry studies suggest that melting of foundered lithosphere is a source of small volume, mafic (often potassic), volcanism in orogens. In the India-Asia collision, for example, lithosphere removal on the scale of 100–200 km was likely ongoing prior to and during collision. Melting of foundered lithosphere has been inferred as a source of mafic lavas throughout the Puna Plateau of the central Andes, where endorheic basins 50–100 km in diameter also record anomalous subsidence and inversion.

Lithosphere can be removed by dripping of gravitational instabilities, by plate-like delamination of the mantle lithosphere, or by a range of intermediate styles. Counter-intuitively, some studies suggest that larger-scale removal events often do not deform the surface to the extent of smaller-scale events, and may result in fewer, if any, volcanic products. This compilation highlights the range of expressions of lithosphere removal, including spatial and temporal scales, nature of surface deformation, and differing datasets that have been used to identify removal events.