Lithospheric deformation and 3D mantle flow in the Pacific-North American plate boundary corner in southern Alaska

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The pattern of 3D material flow in a continuum is one proxy used to characterize continental deformation and can yield insights into the physics of convergent margin deformation, specifically the interplay between plate boundary forces, the viscosities of the materials within the tectonic plates, and possibly the importance of plate margin geometry. Two-dimensional analytic and numerical models of thin sheet viscous deformation demonstrate that the long-term (10^6 years) deformation of the lithosphere can be modeled as that of a highly viscous (10^{23} Pa s) fluid [e.g., England, Houseman, and Sonder, 1985]. These models predict a regular pattern of diffuse deformation such that the magnitude of material flow in an indented sheet will decay exponentially with the perpendicular distance from the sheet edge and with a characteristic length scale proportional to the wavelength of the indentor.

The characteristic length scale of decay predicted by 2D viscous deformation models does not explain the formation of the central Alaska Range, a young (5–6 Ma) localized region of uplift that hosts North America's tallest peak, Denali (6194 m), located approximately 500 km inland from the plate boundary between the North American and Pacific plates. This corner-shaped plate margin contains a northwest-southeast striking transform plate boundary to the east and to the west of the corner is a northeast-southwest striking subduction zone. The topographic profile from the plate boundary northward through the central Alaska Range is punctuated by basins and mountain ranges with the tallest peaks in the central Alaska Range, as opposed to a concentration of the tall mountains only near the plate boundary.

We use 3D spherical-geometry, finite-element, viscous flow models of the plate boundary system in southern Alaska to test competing hypothesis for the uplift of the central Alaska Range: (1) slab geometry and the degree of interplate coupling may increase the transfer of stress inland to the central Alaska Range, (2) the varying composition, age, and temperature of the accreted terranes in Alaska may result in long wavelength lateral strength variations that may in turn enable discontinuous deformation of the overriding lithosphere, (3) the Denali Fault system is a weak zone in the overriding plate that localizes deformation (uplift) far from the plate boundary, and (4) the ongoing collision of a small terrane (the Yakutat block) is required to initiate uplift.

We present here initial results of models from the first phase of our investigations, that is for models that investigate the influence of the slab geometry on deformation patterns in the overriding lithosphere. The pattern of seismicity at depth indicates that beneath central Alaska Range the slab orientation changes [Ratchkovski and Hansen, 2002] and that south of the eastern Alaska Range there is either a cusp in the slab and/or the slab contains a gap below 45 km

[Page et al., 1989]. The spatial correlation of the central Alaska Range with a change in the geometry of the subducted slab implies that features in the subsurface, such as slab shape and/or mantle flow patterns generated therein, may be genetically linked to the uplift of the central Alaska Range. These first viscous flow models evaluate two end-member geometries of the subducted lithosphere, one with a continous slab and the other with a slab that contains a gap. These end-member models are instantaneous and use a uniform temperature profile and viscosity structure for the overriding lithosphere. The slab is represented by a simplified density (and thermal) anomaly. The results of these 3D numerical models have general applicability to understanding the tectonic processes that occur at plate corners that contain a spatial transition between convergent and transform plate motion as well as how the mantle flows in response to the edges of slabs.

References:

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