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Geodynamic modeling of the onset and demise of Cretaceous-Eocene flat subduction in North America

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The Late Cretaceous-Eocene Laramide orogeny (ca. 80-50 Ma) of the western United States is characterized by migration of magmatism from west to east followed by an absence of magmatism, widespread hinterland deformation and thick-skinned tectonics. These characteristics have been attributed to flat-slab subduction of the Farallon plate until about 50 Ma. Similarly, pre-Laramide subsidence, as evidenced by the Cretaceous seaway, may also be related to the dynamic topography associated with the Farallon slab. Recently, Flowers et al. 2007 argued for the accumulation of at least 1500 m of Late Cretaceous strata along the western margin of the Colorado Plateau followed by significant unroofing.

Since subduction remained continuous following this episode, it suggests that following the flat lying episode, that subduction returned to a normal dip. Observations indeed suggest that this transition back to normal conditions might have occurred: (1) Post-Laramide active magmatism between 50 and 30 Ma; (2) Stable isotopic composition and sediment deposition suggest that a landscape characterized by increased elevations and elevated relief migrated from NE to SW (which occurred between ca. 50 to 47 Ma in SW Montana, between ca. 40 to 35 Ma in North Nevada and by ca. 22 Ma south Nevada) [Chamberlain et al., 2006]; (3) Resumption of exhumation at ca. 28 Ma [Flowers et al. 2007].

The geodynamic causes of flat-slab subduction across at least some major sections of the western U.S. remain a challenge. It requires explaining both the onset and demise of the flat subduction. We present 2 dimensional finite element models that represent

cut-outs of a spherical domain that respect the regional geological history. We attempt to explain one mechanism of the flattening and its demise with models at high resolution (5 km) that include the effects of non-linear temperature-dependent rheology, a low viscosity wedge related to the dehydration of the subducting lithosphere, eclogitization of the subducted oceanic crust, and chemically distinct tectosphere associated with the craton. In the first stage of the numerical experiment, we impose the kinematics at the top boundary of the model and include a low viscosity wedge above the subducting slab, which enables initiation of a flat-slab regime. We then let the model evolve dynamically and observe that the slab returns to a “normal” subduction mode. In addition, the model predicts a change of plate convergence related to the demise of the flat slab, which corresponds to the replacement of the flat Farallon slab by asthenospheric material. These results are compared with updated plate reconstructions [Muller et al, in press]. Interestingly, a clear a change of plate motion is observed, consistent with our simulation.