Flow-Coupled Plate Interaction or How the Alps Helped to Make the Andes

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Key words: Plate motion, Andes, Alps

Recent evidence suggests that some continental plates, especially those of the Atlantic Basin are coupled to and driven by general mantle circulation. Limited candidate driving forces render South America (SA) the most straightforward example of this. Large E-W compressional stresses required to form and maintain the Andes (Russo and Silver, 1996), the absence of an asthenospheric decoupling zone beneath SA as delineated by seismic anisotropy (Silver, 1996; James and Assumpcao, 1996), and tomographic evidence for the coherent translation of the SA plate and upper mantle over the last 100 my (Vandecar et al, 1996), appear to require coupling to the mantle below. We infer that, through coupling, changes in mantle circulation perturb plate velocity; but also, changes in plate motion induce changes in mantle circulation patterns. Thus, we postulate a new type of plate interaction, which we term `flow-coupled' plate interaction. The mantle flow field, perturbed by the motion and shape of one plate, can in turn alter the motion of neighboring plates. The motions of the SA and African (Af) plates provide evidence for flow-coupled plate interaction. Relative to the Tristan hotspot, the motion of both plates changed abruptly about 30 ma (O'Connor and Duncan, 1990; O'Connor and Le Reux, 1992). Africa's eastward motion decelerated, yet SA-Af divergence velocity appeared to be roughly constant, requiring a westward acceleration of SA. A change in plate motion indicates a redistribution in the force-balance. The collision of Africa with a nearly stationary Eurasia (beginning at 38 ma), is the most plausible explanation for Africa's deceleration. The constant divergence velocity can be explained if both plates (or Atlantic opening in general) are driven by a constant mass flux entering the Atlantic basin mantle. The constant mass flux, combined with Africa's deceleration then produces SA's simultaneous acceleration. This flow-coupled plate interaction not only links plate velocities but also establishes a causal connection between the deformation of these two plates, in this case between the Alpine and Andean orogenies. We have argued previously that Andean deformation is due to SA's westward motion and resistance to that motion by the Nazca slab and subslab mantle. An increase in SA's westward velocity should result in increased Andean compressional deformation. The most important change in SA velocity relative to the deep mantle was during the breakup of Gondwanaland, leading to Andean formation shortly thereafter. The increase in westward velocity at 30 my is synchronous with the Quechua phase of Andean orogeny, which gave rise to the Andean Altiplano and the Bolivian orocline. Thus, through a flow-coupled plate interaction, the Quechua phase of Andean deformation may be ultimately caused by the collision that produced the Alps.

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