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INSTANTANEOUS DEFORMATION ASSOCIATED WITH FLAT SUBDUCTION:
INSIGHTS FROM GPS STRAIN RATES AND NUMERICAL MODELING

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INTRODUCTION

Plate coupling at subduction zones is a key to understanding the tectonic and magmatic evolution of the overriding plate and the competing/complementary role of the external and intrinsic control exerted by the convergence kinematics and the inherited geological features. In flat slab subduction, plate coupling may extend further inland than a normal subduction. The flat subduction geometry exerts a primary control on tectonics and magmatism, with a secondary control from pre-existing continental geology. Geodetic data from the Global Positioning System (GPS) present an instantaneous snapshot of deformation

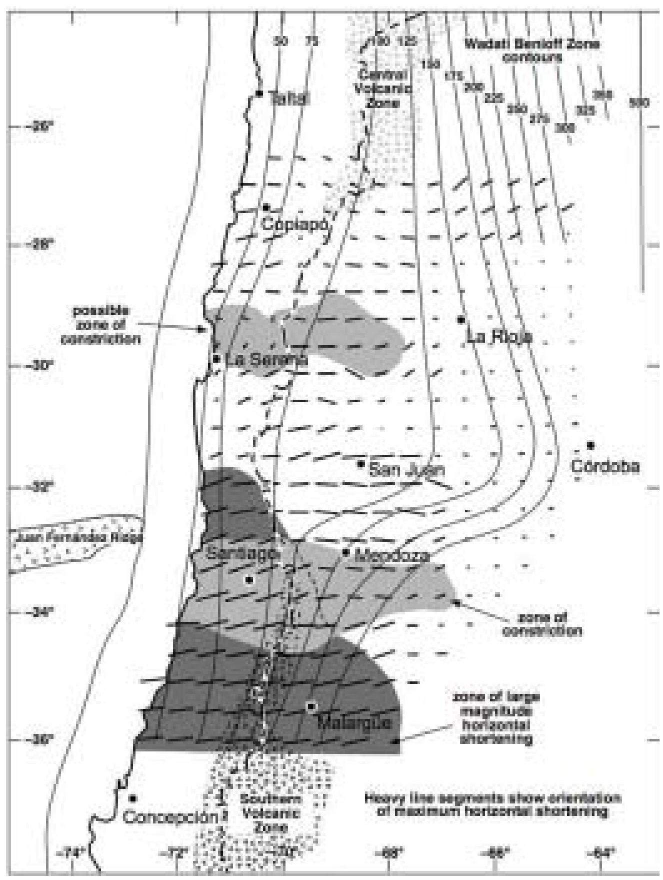

Figure 1. Tectonic setting of the Central Andes. The short line segments show the instantaneous principal horizontal shortening axis calculated from the GPS network. Compare these with the line segments in Figure 2.

associated with flat subduction beneath central Chile and western Argentina. Here, we extract strain rate and rotation rates from the gradients in the GPS velocity field. Although the GPS data represent the elastic response of the interseismic cycle, growing evidence (Allmendinger et al., 2005) points to a closer link between short and long term deformation. We present a numerical model for the shallow subduction of the Southern Central Andes (28-33°S) constrained by geology (long term) and GPS (short term) data.

ANALYSIS OF GPS DATA

The region of study is limited on the north by the rupture zone of the 1995 Antofagasta M 8.1 earthquake and to the south by the 1960 Valdivia earthquake. We use data from both the SAGA network (Klotz et al., 2001) and the CAP network (Brooks et al., 2003). GPS data from the forearc are demonstrably related to the seismic cycle and are commonly analyzed in terms of elastic locking of the plate boundary (Bevis et al., 2001; Brooks et al., 2003; Khazaradze and Klotz, 2003). To relate GPS data to geological features, however, it is more convenient to look at strain and rotation rates.

The maximum shortening rate axis (Fig. 1) is commonly oriented approximately parallel to the GPS vectors and the plate convergence direction (ENE) on the coast, but farther east the axis changes its orientation to be more nearly EW. The strain rate in the eastern Sierras Pampeanas of western Argentina is about five times slower than that in the Precordillera and in the NW Sierras Pampeanas. Shortening strain rate is likewise low in the Chilean Coastal and high Andes north of 32°S and extending up into the southernmost Puna plateau. A 2x – 3x increase in shortening rate occurs across a NW trending line from about 32°S on the Chilean coast to just south of Mendoza, Argentina in the backarc. Extension axes are generally oriented north-south throughout the region. Their magnitudes are generally one third or much less that of the shortening axis at the same grid node. The most important result of the extension magnitudes plot the EW trending zone of constriction located between 33° and ~34°20’ S (Santiago-Mendoza). A second, less robust EW zone of constriction is located just north of La Serena.

SPATIAL GEOLOGICAL CORRELATIONS WITH PATTERNS OF GPS STRAIN

The strain extracted from the total GPS velocity field displays several spatial correlations with both major and minor features of the Andean Orogen. The increase in shortening rate south of 34°S latitude occurs at the northern limit of the Southern Volcanic Zone of the Andes. The increased strain rate there is probably related to thermal weakening in the vicinity of the volcanic arc, probably combined with the greater rigidity of northern Patagonia (Yañez et al., 1994, 1995; Tassara and Yañez, 1996). The northern limit of the zone of higher GPS shortening rate begins where the Juan Fernández ridge interests the South American continental margin (Yañez et al., 2002). The two zones of EW constriction coincide with the northern and southern limits of the Argentine Precordillera thin-skinned fold and thrust belt. Additionally, the southern of those two zones of EW constriction coincides with Melipilla aeromagnetic anomaly, a deep-seated, WNW trending structural anomaly (Yañez and Gana, 1998).

Within the two EW corridors of constrictional strain (at 29-30°S and 33-34°S), geological data document the presence of WNW discontinuities; some of them corresponding to Neogene faults mapped in the field (e.g., Rivera and Cembrano, 2000). Neotectonic fault-slip data support ~ NS shortening within the WNW corridor between the coast and Main Cordillera (Garrido et al., 1994; Lavenu and Cembrano, 1999).

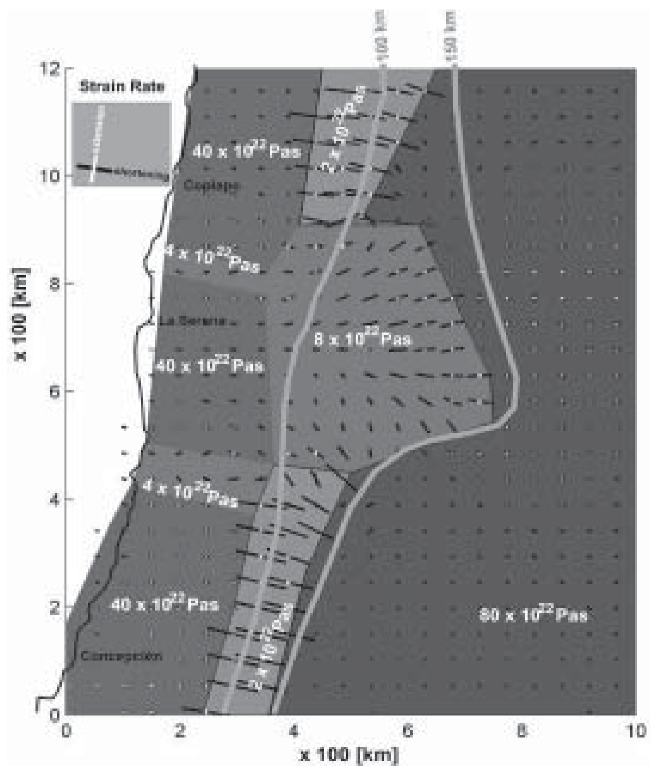

Figure 2. Thin sheet viscous model of deformation in the Central Andes. Short line segments are horizontal principal strain axes. Blocks with different viscosities are shown with different shades of gray. Wadati-Benioff zone contours are shown for reference. Compare to Fig 1.

NUMERICAL MODELING

To understand the context of these observations, we use a thin viscous sheet model with basal shear traction. Shear traction at the interplate contact is controlled by the thermal state of the subducting plate. In the study area, major controlling factors of the thermal field are the Challenger FZ, and the absence/presence of the asthenospheric wedge. Plate geometry is constrained by seismicity at the interplate contact. Preferred model results require different rheological domains (Fig. 2), controlled by thermal constraints and preexisting weak zones. Besides the general agreement with the geology and tectonics of the region, this long term approach reproduces most of the short term evidences derived from the GPS results, reinforcing the causal relationship between elastic and permanent deformation.

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