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Normal faulting in a forearc submitted to slab pull: Numerical models and insight on the structure of the Chilean forearc

M. Gerbault

IRD, Univ. de Chile, Dpto de Geologia, plaza Ercilla #803, Santiago, Chile
E-mail: gerbault@lmtg.obs-mip.fr

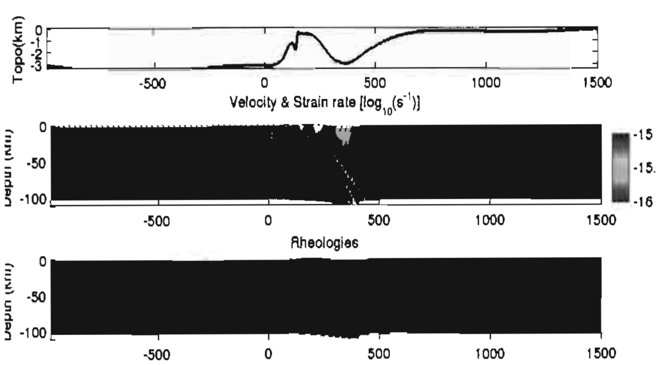
Subduction of the Nazca plate under the peruvian and chilean segments of the Andes is associated with variable characteristic structures of the corresponding forearc. The forearc constitutes this specific zone recognised to deform slowly (of the order of 1mm/yr or less according to different sources), squeezed inbetween the oceanic plate subducting at around 8 cm/yr, and the growing Andes that thicken the border of the South American continent. Depending on its latitudinal position, as well as in east-west directions, this forearc has developped numerous features of either extensional or inverse signature, sometimes co-eval: the coastal escarpment (coastal cordillera), the Central Depression, or the Atacama fault zone, are only some of the most proeminant yet still enigmatic structures that compose the chilean forearc.

Conceptual models have been proposed to explain the origin of these structures and the manner in which they may still be active at present; some are interpreted within the general scheme of an orogenic-scale tapered wedge, producing locally thrust or normal (e.g. gravitational sliding features) faulting that accomodates the growth of Andes (e.g. Von Huene, 2003, Reutter & Adams, 2003, Riquelme et al., 2003; northern Chile). The general variation in height and width of the mountain belt along Chile has also been studied by Yanez & Cembrano (2004), as related to the viscous strength of the subduction interface. In particular, an extensional episode has been argued to have triggered the developenent of a large subsiding basin during late Eocene and Oligocene, characterising the Abanico Formation, from about 32°30' to 44° south along the Chilean forarc (Charrier et al., 2002). Such structural models and geodynamic setting of the forearc are still debated and evolve with the increasing number of data, especially datations, that are necessary to constrain the timing and development of different portions of the forearc relief.

In order to give insight on the cause for the formation of some of the observed structures of the Andean forearc, numerical 2D mechanical models are presented here (using Parovoz, Poliakov & Pod ladchikov, 1993), that idealize the slab-pull force acting on a forearc area. Our starting approach is similar to the model setting proposed by Hampel & Pfiffner, (2005, in press). In this latter study, areas of compression and extension are shown to develop in an elastic forearc, which is submitted to a punctual force applied at the basal tip of an underlying subducting zone, Position and intensity of these deforming areas depend on the friction properties of the subducting plane, and convergence applied to the overriding continental plate.

In our study, a medium of thickness 100 km and width 2500 km is defined, the left and right parts representing the oceanic and the continental lithosphere respectively. At the center of the model, the subducting interface that separates both lithospheres is represented by an arcuate zone that dips from the surface to the base of the model. We wish to test the relative effects of applying convergence and slab pull on surface deformation. This slab-pull is applied as a basal velocity over a certain width, so that stresses and induced deformation increase in time. The resulting pattern of deformation is "partitioned" in either sliding along the subduction interface, and vertical propagation of the downward drag by subsidence of the continental crust and its top surface. This subsidence is accomodated by normal faulting, and its magnitude depends naturally, on the rheology of the subduction interface (elasto-plastic or visco-elastic), as well as the temperature and composition of the overriding continent.

A first simple model (figure) with no applied convergence shows how normal faulting and subsidence of the crust occurs, superimposed on the initial step topography (~3 km) that exists due to density differences between the oceanic and continental lithospheres (isostasy).



In a second step in which horizontal convergence is applied, inverse faulting also develops in the forearc, "superimposed" to normal faults due to the slab-pull effect described above. This mode of deformation suggests that observed structures within the Chilean forearc, indicating either extensional or reverse faulting, may possibly occur in relatively short geological time-scale intervals, depending on variations of the global compressive state, or in the state of stress induced by the slab pull at ~100 km depth in the oceanic lithosphere (what would be this state of stress when the dip of the slab changes?) . The slab-pull driving force being here reduced to a downward velocity at 100 km depth, is certainly idealizing very much the complexity of slab/asthenosphere/overring lithosphere mechanical interactions at depth.

The relevance of this model is confronted with different data along the Chilean forearc: characteristic distances, of surface features, slab geometry, amounts of subsidence, recorded times of exhumation, are investigated.

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