Geophysical Research Abstracts
Vol. 19, EGU2017-7835, 2017
EGU General Assembly 2017

Reactivation of pre-existing mechanical anisotropies during polyphase tectonic evolution: slip tendency analysis as a tool to constrain mechanical properties of rocks

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Intracontinental deformation within the upper crust is accommodated by nucleation of new faults (generally satisfying the Anderson's theory of faulting) or brittle reactivation of pre-existing anisotropies when certain conditions are met. How prone to reactivation an existing mechanical anisotropy or discontinuity is, depends on its mechanical strength compared to that of the intact rock and on its orientation with respect to the regional stress field.

In this study, we consider how different rock types (i.e. anisotropic vs. isotropic) are deformed during a well-constrained brittle polyphase tectonic evolution to derive the mechanical strength of pre-existing anisotropies and discontinuities (i.e. metamorphic foliations and inherited faults/fractures).

The analysis has been carried out in the Eastern Sierras Pampeanas of Central Argentina. These are a series of basement ranges of the Andean foreland, which show compelling evidence of a long-lasting brittle deformation history from the Early Carboniferous to Present time, with three main deformational events (Early Triassic to Early Jurassic NE-SW extension, Early Cretaceous NW-SE extension and Miocene to Present ENE-WNW compression). The study area includes both isotropic granitic bodies and anisotropic phyllosilicate-bearing rocks (gneisses and phyllites). In this environment, each deformation phase causes significant reactivation of the inherited structures and rheological anisotropies, or alternatively formation of neo-formed Andersonian faults, thus providing a multi-directional probing of mechanical properties of these rocks.

A meso- and micro-structural analysis of brittle reactivation of metamorphic foliation or inherited faults/fractures revealed that different rock types present remarkable differences in the style of deformation (i.e., phyllite foliation is reactivated during the last compressional phase and cut by newly-formed Andersonian faults/fractures during the first two extensional regimes; instead, gneiss foliation is pervasively reactivated during all the tectonic phases). Considering these observations, we applied a Slip Tendency analysis to estimate the upper and lower bounds to the friction coefficient for slip along the foliations (μ_s) and along pre-existing faults/fractures (μ_f). If an hypothetical condition with simultaneous failure on the inherited mechanical discontinuity (foliation or pre-existing fault/fracture) and new Andersonian faults is assumed, the ratio between $\mu_s$or μ_f and μ_0(the average friction coefficient for intact isotropic rocks) can be calculated as μ_s (or μ_f) = NTs · μ_0(where NTs represents the normalized slip tendency of the analyzed discontinuity). When just reactivation of foliation/faults/fractures is observed (i.e. no newly-formed Andersonian faults are recognised), an upper bound to $\mu_s$and $\mu_f$can be estimated as μ_s (or μ_f) $<$ NTs · μ_0. By contrast, the lower bound to $\mu_s$and $\mu_f$can be obtained as μ_s (or μ_f) $>$ NTs · μ_0, when the mechanical anisotropies are not reactivated and new Andersonian faults nucleate.

Applying the above analysis to multiple deformation phases and rock types, we were able to approximatively estimate $\mu_s < 0.4$ (gneisses) and $0.1 < \mu_s < 0.2$ (phyllites) and $\mu_f \approx 0.4$ (phyllites) and 0.3 (gneisses).