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Deep architecture and processes of an active orogen – the Andes

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Active orogeny at the Andean convergent margins has created one of the most spectacular orogens on Earth exhibiting a substantial variability in style from the plateau style centre to the south. We explored the deep structure of the orogen along two transects studying the contrasting orogenic styles. The transect ANCORP'96 and a group of related experiments imaged the central Andes at 21˚S and at 38˚S respectively with an integrated active and passive seismological experiment including magnetotelluric depth sounding. Both studies are among the first sections providing a complete image of a convergent margin from the oceanic Nazca plate across the forearc and arc into the backarc. The central Andean section is characterized by several reflective zones occurring at depths of 20-30 km and 40-80 km under the forearc. The latter range among the deepest so far acquired reflections from an active subduction zone. They are linked to the Wadati-Benioff zone and show increasing downdip intensity before gradual breakdown below 80 km, at the onset of intermediate depth seismicity. The mid crustal strong reflections (Quebrada Blanca bright spot) underlie the world's largest concentration of porphyry coppers. The preferred model explains both, the Nazca reflector and the QB bright spot as fluid traps located at the fronts of recent hydration of the mantle (Nazca reflector) and crust (QB bright spot), the fluids being supplied by dehydration of the oceanic Nazca plate. In addition, recent modelling studies and analysis of petrophysical properties suggest that the QB bright spot and underlying deep crust may be strongly affected by intrusion and solid state flow of subducted weak crustal material.

While the arc domain is seismically transparent, suggesting complex structures, the backarc area again shows strong diffuse midcrustal reflectivity below the Altiplano. This reflectivity is associated to a low s-wave velocity zone and high conductivity.

Along with the lack of seismicity and topographic relief this is suggested to reflect widespread partial melting of the deep overthickened crust. The continental MOHO beneath the Andes does not show up in reflection data but is well imaged by converted phases that are interpreted to show a broad transitional character of the crust-mantle boundary. This may be due to active processes, which obscure a sharp crust-mantle boundary like hydration of mantle rocks (in the cooler parts of the plate margin system), magmatic underplating and intraplating under and into the lowermost crust, etc. Crustal thickening in the central Andes is therefore suggested to have involved substantial strain partitioning with stacking of the brittle upper crust above an important decollement separating it from a very weak lower crust that is compressed like a fluid between strong margins. This result is in stark contrast to images from the southern Andes, indicating the substantial difference in petrophysical state along the same margin.

Most reflectivity can be seen to be linked to active processes, which involve the release, trapping, or consumption of fluids. This result is in contrast to seismic sections across most fossil mountain belts which usually can be interpreted in terms of structure and lithological contrasts only. Here, active petrological processes driven by active subduction are the probable causes for most of the conspicuous features seen in the section. Thus, reflection seismic techniques have an unexpected potential to image ongoing intralithospheric processes at active margins.