DOES CRUSTAL THINNING TRIGGER SUBSEQUENT BUILDING OF THE ANDES?

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INTRODUCTION

Crust under the Andes of central Chile and Argentina has been thickened several times. Mechanisms invoked range from microplate collisions during the Paleozoic to Mesozoic underplating and Late Cenozoic underplating combined with tectonic shortening. The last of these thickening events, an ongoing process that started during the early Miocene, has been linked by Jordan et al.(2001) to "a more stable state of the subducting plate" which allowed structural inversion of "active basins" built on crust extended during a previous high convergence rate. The model is rather extreme, in that it considers extension as "a necessary condition to subsequent building of the modern Andes Mountains". Godoy et al (1999), for example, have included inversion of a central Andean extensional basin as only a part of that thickening process Based mainly on studies by previous authors in the chilean-argentinian central and south-central Andes we comment on the validity of such triggering mechanism.

THE CHILEAN-ARGENTINIAN ANDES AT 33º-34º S.L

The **Coya-Machalí Formation** is a *ca* 2 km thick pile of continental volcaniclastics and minor lacustrine sediments, deposited in an Oligocene to earliest Miocene "active-margin" basin. that crops out along the western half of the Andean Main Range, from 33º to 35º S.L. In its northern end, Nystrom et al (1993) report a depleted ε_{Nd} and $^{87}Sr/^{86}Sr$ signature in its tholeitic volcanic rocks, which they relate to an "episode of mantle upwelling and crustal thinning". They also recognized a reverse trend, away from MORB, for the overlying Farellones Miocene calc-alkaline volcanics, a formation that in some huge relict volcanic edifices, such as the Aconcagua, may reach a thickness of over 3 km.

According to Kay et al, (2002).the low pressure pyroxene-bearing phenocryst and residual mineral assemblages of the Oligocene low- to mid-K tholeiitic magmas at 34º show a depleted isotopic signature similar to that at 33º and is also linked with crustal thinning. The high pressure garnet-bearing residual mineral assemblages and enriched isotopic signatures of the Farellones volcanics is, on the other hand, related to dramatic crustal thickening. They recognize distinctive breaks in trace elements trends and isotopic enrichment in the younger high-K calc-alkaline magmas at 18 and 6 to 5 Ma, which coincide with eastward shifts in the arc front and regional uplift. The related thickening events correlate well with early in-sequence and major out-of-sequence thrusting, the latter taking place mainly along the western margin of the Miocene volcanic arc (Fierro Thrust, Godoy et al., 1999). The geochemical breaks are explained by both increases in the depths of basal crustal MASH processes and enrichment of mantle wedge magma sources through incorporation of crustal blocks removed during forearc subduction erosion.

In the Kay et al.(2002) modeling, "changing plate convergence vectors" are held responsible for peaks in forearc subduction erosion, arc migration and ductile thickening of the subarc crust in concert with shortening in the foreland fold-thrust belt. Even though it implies an initial stage of subarc crustal softening, this is a different, more dynamic scenario in which no extensional triggering is needed.

TRIGGERING AT THE 36º-44ºs.l. SEGMENT

A late Oligocene to early Miocene magmatic belt also crops out, from 36º to 44º s.l., west of the Main Range. South of the 38º it interfingers with marine sediments deposited during the initial subsidence of the Central Valley. According to Muñoz et al. (2000) its variable trace-element and isotopic composition "could reflect the interaction between melts derived from upwelling asthenospheric mantle and the subcontinental mantle lithosphere previously contaminated by slab-derived fluids". They link this transient period of invigorated asthenospheric circulation to the late Oligocene three-fold increase in trench-normal convergence rates between the Nazca and South American plates, both processes inducing a 800 km wide crustal extension by rollbacking of the former plate. Minor subsequent deformation of the belt, untriggered by the previous extension and unrelated to crustal thickening, is assigned by Muñoz et al. (2000) to decrease in subduction angle of the Nazca plate, which returned the magmatic activity to its current locus in the Main Cordillera.

Oligocene to middle Miocene volcanic rocks, interdigitated and transitional to thick piles of lacustrine sediments (formational names **Cura-Mallín** in the north and **Ñirihuau** in the south), crop out south of 36º s.l, east of the present arc. They seem to represent an extension of the Coya-Machalí setting yet, south of 40º, their abundant volcanics are not tholeiitic. The NNW trending Ñiriguau depocenters have moreover been interpreted as pull-apart basins (Dalla Salda and Franzese, 1987). These mid-Tertiary rocks overlie Paleocene to Eocene calc-alkaline rhyolitic ignimbrites and andesites of the Pilcaniyeu Formation (Rapela et al., 1988). In contrast, under the Coya-Machalí Formation,.a 30 My long Paleocene-Eocene hiatus seems unavoidable.

CONCLUSIONS AND DISCUSSION

The Andean Oligocene-Early Miocene basins between the 33º and 44ºs.l. do not share a common evolution. Three different tectonic settings may be recognized in them:

In the **Coya-Machalí basins** a strong late Miocene inversion has blurred, through marginal tight folding and out-of-sequence thrusting, their original boundary normal faults, some of which may be inherited from Triassic and late Jurassic rifting. The geochemistry of its lavas is compatible with a thin crust during basin formation, while that of the overlying volcanics matches that of magmas generated under a crust thickened by incorporation of crustal blocks removed during forearc subduction erosion.

In the **Curamallín type basins**, on the other hand, east vergent folding is widespread (Niemeyer and Muñoz, 1983). However, in only one half-graben at 37º s.l.. has a border fault, gently inverted during the middle Miocene, been recognized (Jordan et al.,2001) and no Miocene crustal thickening is reported.

At the latitude of the **Ñirihuau type basins** Oligocene extension was the widest, over 800 km. According to the seismic profiles quoted in Jordan et al.(2001), the western basins, under the Chilean Central Valley, were developed on metamorphic basement and show only moderate inversion. This major extensional event, however, did not trigger crustal thickening.

According to the thermomechanical modeling of Thompson et al. (2001) softening under active rifts are precursors to thickened Orogenic belts, yet and in agreement with Muñoz et al.(2000), "continental back arcs become extended in response to the roll-back of subduction". Jordan et al. (2001), however, consider that lithosphere subducted during the Oligocene in this part of the south-eastern Pacific was not old and cold enough to comply with. the "typical" Molnar and Atwater (1978) situation. They therefore dismiss this extension mechanism in favor of abnormally complex transient invigorated circulation patterns within the asthenospheric wedge. Sharing the slab window proposition of Muñoz et al. (2000), Yañez et al. (2002) relate this invigorated circulation to "a detached segment of the subducted slab south of " 33ºS whose "unbalanced slab pull force triggered…the abrupt change in the Nazca pole of rotation at 25 Ma".

Either with or without rollbacking contribution, a long-wedge of the andean crust did extend during the Oligocene-early Miocene, yet only south of 33ºS and later shortening was concentrated only close to its northern end.

García et al (2002) give convincing evidence that during the oligo-miocene at 18º S deformation was wholly compresional. The small oligo-miocene normal faults used by Jordan el al, (2001) in that area as a hint that the stress state was initially extensional up to that latitude must be forgotten. Margin-parallel extension, also coincident with rapid seafloor spreading, did prevail during the early Cretaceous in much of the Andes. Only locally, however, was it followed by a compressional event. Many of its normal faults were inverted only during the late Miocene.

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