Contamination of arc andesites by crustal melts in the Central Volcanic Zone, Chilean Andes

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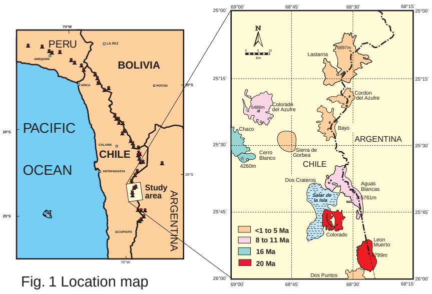

Fig. 1 Location map

This study looks at arc andesites erupted before, during and after late Miocene crustal thickening in the CVZ. Data are presented from 12 volcanic centers (Fig. 1.) which erupted through the same crustal segment fom 20 Ma to the Quaternary.

SUMMARY

The Central Volcanic Zone (CVZ) of the Andes has extreme crustal thickness and high plateaus which are more typical for collisional settings like Tibet. Andesites have erupted in the Andean arc throughout the Mesozoic, but crustal thickening and plateau uplift developed only in the late Miocene. This project explores the relationship between crustal thickening and arc magmatism, focussing on the composition of andesites.

The results show systematic variations in the contents of Rb, Cs, Th, and U; and the isotope ratios of Sr, Pb and Nd over time. We suggest that these changes are due to contamination of andesites by crustal melts:

- Fractionation can be ruled out because the variations are independent of SiO_2 (Fig. 3) and because Isotope ratios and incompatible element ratios (Th/Zr, Ba/Rb) are affected (Figs. 4, 5).
- Element ratios sensitive to fluid interaction (Th/Cs, Ba/Zr) are not affected (Fig. 4).
- The timing of contamination (Fig. 6) corresponds to a phase of intense ignimbrite activity, and the composition of ignimbrites is comparable with the required contaminant (Figs. 3, 4, 5).
- Phenocrysts in post-Miocene andesites contain rhyolitic melt inclusions which are out of equilibrium with the host (Figs. 8, 9)
- There is geophysical evidence of a zone of partial melting in the mid to lower crust beneath the magmatic arc today (Fig. 7).

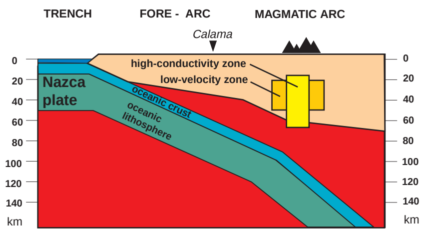

Fig. 7 Zones of low seismic velocity and high electrical conductivity beneath the magmatic arc are interpreted by Schilling et al. (1997) as caused by up to 15 vol. % partial melts.

GEOCHEMICAL COMPARISONS

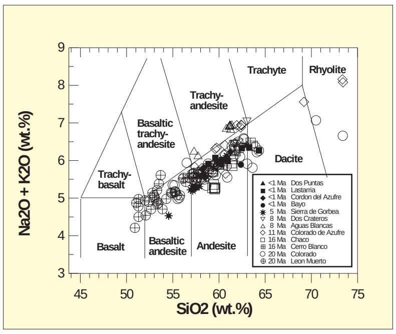

Fig. 2. High-K, calc-alkaline andesites are the most common rock type erupted in all except the early Miocene Leon Muerto center (20 Ma), which is more mafic.

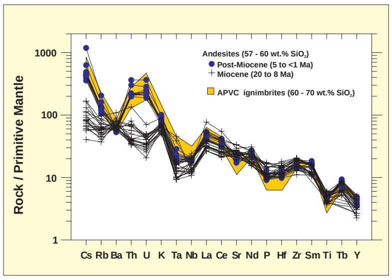

Fig. 3. Positive anomalies at Cs, Rb, Th and U in the mantle-normalized diagram characterise the post-Miocene centers. Shown for comparison is the range of compositions for ignimbrites from the APVC at 23°N.

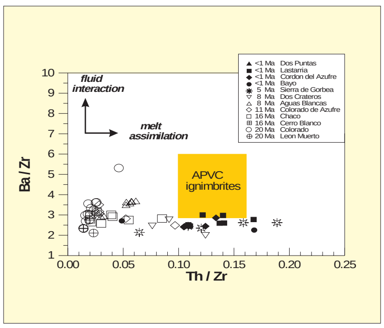

Fig. 4. Plot of the incompatible element ratios Th/Zr against Ba/Zr (no SiO_2 restriction). Fractional crystallization of andesitic melt should not affect either ratio but fluid interaction will change Ba/Zr. The post-Miocene samples have high and variable Th/Zr at constant Ba/Zr. This is best explained by contamination with a melt phase. The APVC ignimbrites are roughly comparable to the felsic melts required.

ISOTOPIC COMPOSITIONS

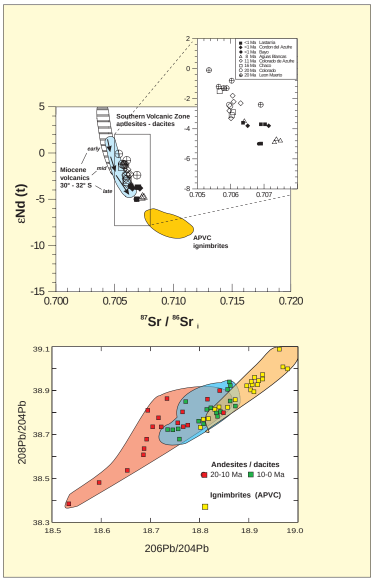

Fig. 5. The isotopic data define a trend of increasing radiogenic Sr and Pb, and decreasing εNd with age. For comparison, fields are shown for Southern Volcanic Zone volcanics, Mesozoic volcanics from 32°- 30°S and ignimbrites from the APVC.

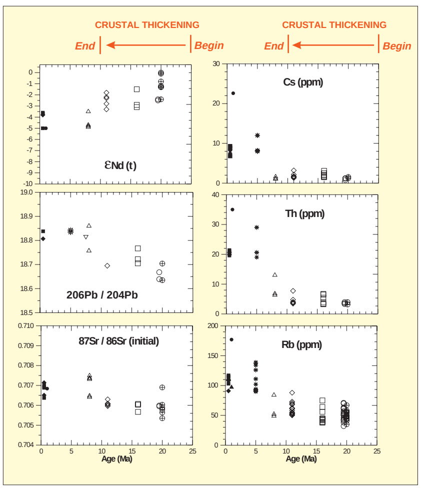

Fig. 6. Variations of Rb, Th, Cs and the isotope ratios of Sr, Pb and Nd with age. Trace element plots are for andesites restricted to 57-60 wt.%. SiO_2.
The components show constant low levels from 20 Ma to 8 Ma, increase sharply from 8 to 5 Ma and stay at a high level to the Quaternary.

RHYOLITIC MELT INCLUSIONS: EVIDENCE OF MAGMA MIXING

Melt inclusions are common in plagioclase but they also occur in orthopyroxene, clinopyroxene and rare biotite. Many inclusions in samples 8 Ma and younger have a rhyolitic composition (Fig. 9). Rhyolitic inclusions are rare in older samples.

The rhyolitic inclusions have compositions corresponding to the water-undersaturated granite minimum(Fig. 10), regardless of host mineral type or inclusion size. Thus, the effects of local crystallization (concentration gradients at crystal surfaces or crystallization of melt on inclusions walls) are negligible.

Chemical and textural attributes of the host minerals suggest that they crystallized in situ from andesitic magma and are not xenocrysts from a felsic magma. We conclude that rhyolitic melts were incorporated into the andesitic magma during or prior to growth of the phenocrysts.

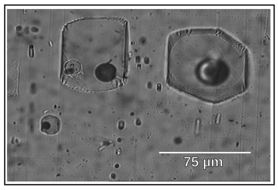

Fig. 8 Photomicrograph in plane light of melt inclusions in plagioclase from Lastarria (<1 Ma).

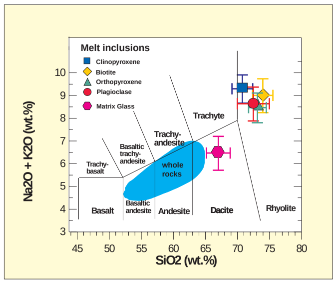

Fig. 9 The chemical composition of whole-rocks, matrix glass and rhyolitic melt inclusions in the TAS diagram.

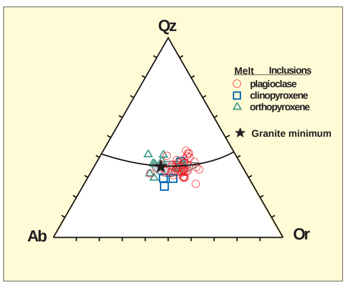

Fig.10 Rhyolitic inclusions plotted on a normative Qz-Or-Ab diagram with minimum melt composition (star), cotectic and 830°C liquidus isotherm determined by Holtz et al. (1992) for the Qz-Ab-Or-H_2O system (2 kbar, a_{H_2O}= 0.5).

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Holtz, F., Johannes, W. and Pichavant, M. (1992) Trans. Royal Soc. Edinburgh: Earth Sciences, 83: 409-416.
Schilling, F.R., Partzsch, G.M., Brasse, H. and Schwarz, G. (1997) Physics of the Earth and Planetary Interiors 103, 17-32.