Magmatic Evolution of Monotonous Felsic Ignimbrites: the Purico Complex, N-Chile

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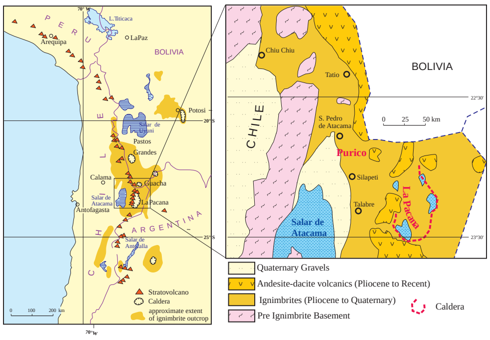

Fig. 1: *Location map and simplified geology of the APVC complex in the Central Andes.*

Geologic Setting

The Altiplano-Puna Volcanic Complex (APVC, 21°-24° S) is one of the largest Neogene ignimbrite provinces of the world. About 70,000 km^2 are covered by **v**oluminous dacitic-rhyolitic caldera-sourced ignimbrites and associated extrusive lavas of dominantly crustal origin. In the APVC this felsic magmatism greatly outweighs the contemporaneous arc-related mafic andesitic activity in volume *(Fig. 1)*. Stratigraphy shows a sudden onset of ignimbrite formation 10 Ma ago, following a period of crustal shortening and thickening. The dacitic ignimbrites predominate over rhyolitic units.

This study of the Purico ignimbrite unit (1 Ma) in the APVC aims to better understand the preeruptive parameters of the ignimbrite forming magmas (P, T, volatile concentrations, viscosity, density). The results contribute to a better understanding of petrological, geophysical and geological problems in the Central Andes.

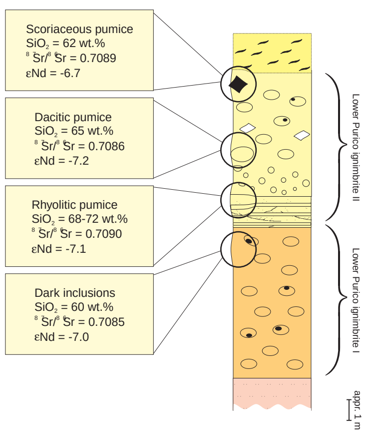

Fig. 2: *Stratigraphy of the Lower Purico ignimbrite*

The Purico Ignimbrite

The Purico ignimbrite is representative of the APVC ignimbrites. Its radiometrically determined age is about 1 Ma. With its volume of about 100 km^3 Purico, however, is one of the smaller ignimbrites.

A new stratigraphic subdivision shows a lower, monotonous dacitic unit (Lower Purico ignimbrite I, LPI I) overlain by a plinian deposit *(Fig. 2)*. This is one of the rare plinian deposits found in the APVC and it forms the basal layer of the second flow unit (Lower Purico ignimbrite II, LPI II).

Distinct pumice types are present in the LPI II:
- dominant, crystal rich (40 - 50 %), dense dacitic pumice
- rare, crystal poor (10 - 20 %) rhyolitic pumice in the plinian and at the base of the flow
- rare scoriaceous andesitic pumice in the upper part
- dark crystal rich inculsions are interpreted as a chilled wall rock facies.

Radiogenic isotopes are very similar despite of the compositional range in the pumice population. Furthermore, they show the crustal affinity of the APVC felsic magmatism.

The Melt Inclusion Approach

Melt inclusions are portions of melt which are trapped in crystallizing phenocrysts. They can provide valuable information about preeruptive volatile contents in magmas, which are otherwise lost during the eruption process. *(Fig. 3)*.

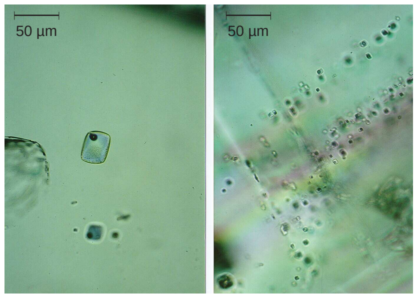

Fig. 3: *Photomicrographs of glassy melt inclusions in quartz (left) and plagioclase (right) from Purico pumice.*

Results 1: Thermal Inversion in the Purico Magma Chamber

Thermometric data based on Purico mineral assemblages *(Fig. 4)* indicate higher temperatures for the rhyolite (~850° C) than for the dacite (~780° C). Temperatures for the more evolved rhyolite magma seem to be closer to the temperature yielded by the andesitic scoriaceous pumice.

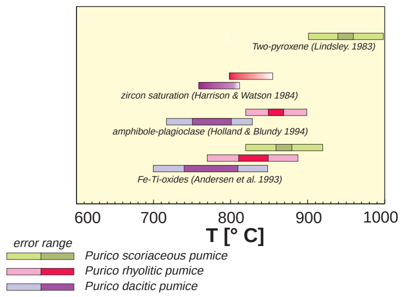

Fig. 4: *Thermometric data based on Purico mineral assemblages*

Results 2: Continous Major but Divergent Trace Element Trends

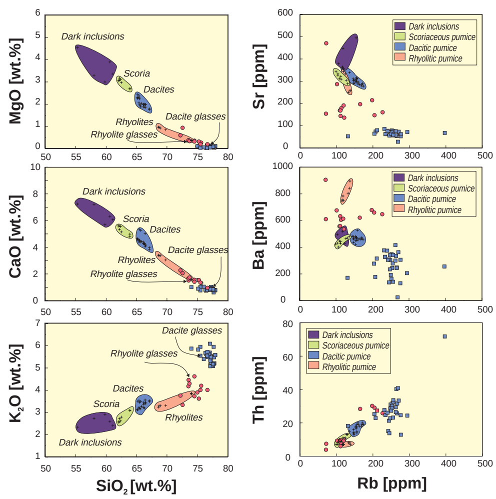

Fig. 5: *Major and trace element variation diagrams for Purico pumices. Crosses represent whole rock data, other symbols glass compositions.*

Whole rock and glass (melt inclusion and matrix glass) major elemental data show continous depletion of elements removed by phenocryst phases (e.g. MgO by hornblende/clinopyroxene or CaO by plagioclase). More incompatible elements (K_2O) are enriched with increasing SiO_2. Glass compositions are generally rhyolitic, but more evolved in the dacites compared to the rhyolites *(Fig. 5 left side)*.
Trace element variation diagrams show divergent trends for both, whole rock and matrix glass compositions. Incompatible trace elements (e.g. Rb vs. Th) are very primitive in some melt inclusions of the rhyolites. This implies that the dacite cannot be parental to the rhyolites *(Fig. 5 right side)*.

Results 3: Preeruptive Volatile Gradients

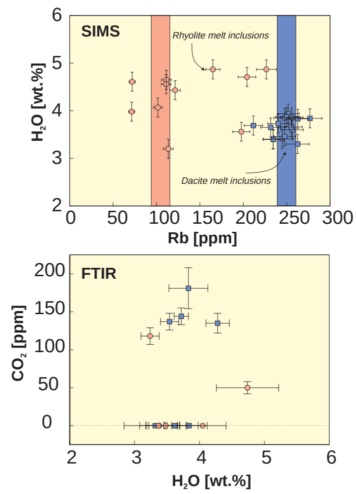

Fig. 6: *H_2O vs. Rb determined by Secondary Ionisation Mass Spectrometry (SIMS) in melt inclusions of Purico dacites (blue) and rhyolites (red). Bars represent matrix glass Rb contents. CO_2 vs. H_2O determined by Fourier Transformed Infrared Spectroscopy (FTIR).*

Water in melt inclusions was determined by Secondary Ionisation Mass Spectrometry (SIMS) and Infrared techniques (FTIR). The results show good agreement between the two methods. H_2O values in quartz hosted melt inclusions of the dacite cluster at 3.5 to 4 wt.%. Melt inclusions in plagioclase of rhyolitic pumices yield higher H_2O of up to 5 wt.%. CO_2 is generally low (< 200 ppm) in both melt inclusion types. *(Fig. 6)*. The similarity of Rb in matrix and melt inclusion glasses shows that the preeruptive H_2O content determined in dacite melt inclusions is representative of preeruptive water in the matrix glass.

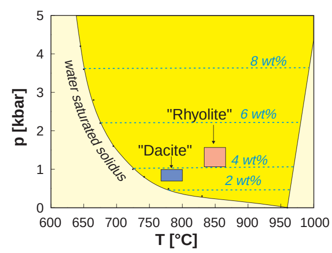

Fig. 7: *Water saturation curves (after Holtz & Johannes 1994) for haplogranite. Inferred temperatures and melt water abundances for dacitic and rhyolitic magmas of the Purico complex shown in boxes.*

Pressure Estimates for the Purico Magma Chamber

Experimentally determined water saturation curves for haplogranitic melts are used to estimate minimum confining pressures *(Fig. 7)*. Water contents and temperatures for dacite and rhyolite compositions of the Purico ignimbrite yield a minimum pressures of approx. 1 kbar to 1.8 kbar (resp.). This corresponds to a magma chamber depth of at least 4 km.

Implications for the APVC Dacitic Ignimbrite Magmatism:

Compositional monotony in dacites

Fractional crystallization of the dacite cannot produce the observed compositional range. Recharge of a hotter, more mafic magma which releases a rhyolitic magma is a viable scenario.

Slushy, shallow magma chamber

The dacite magma was a relatively cool (T = 780° C), dense (ρ = 2.53 g/cm^3 and viscous (logη = 8.3 Pas) crystal mush. Magma chambers seem to be located in shallow crustal levels.

No internally driven eruption mechanism

The dacite magma was close to its solidus temperature and about 50% solidified prior to eruption. A volatile saturation driven eruption mechanism is unlikely. This is consistent to the scarcity of plinian deposits in the APVC ignimbrites. Triggering either by recharge of hotter, volatile saturated magma or external tectonics is required.