Geochemistry of mafic magmas from Sollipulli Volcano, southern Chile: constraints on models of magmagenesis in the Southern Volcanic Zone of the Andes

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Introduction

The Southern Volcanic Zone (SVZ) of the Andes extends from 33°S to 46°S and can be divided into two main regions. In the segment north of 37°S (NSVZ) volcanism tends to be intermediate to silicic, due to the influence of the thick continental crust on mantle-derived magmas. In the southern region (SSVZ) mafic to intermediate magmatism is the norm. Hickey-Vargas *et al.* (1989) distinguished two mafic magma types in the SSVZ. The first type has a typical arc-like signature with high LILE/*LREE* and LILE/HFSE and is associated with a western belt of volcanoes. The second type has high abundances of LILE, *LREE* and HFSE but lower ratios of LILE to *LREE* and HFSE than the first type and is characteristic of an easterly belt of volcanoes, as well as satellite cones of some of the western stratovolcanoes. Two main models were proposed to account for the differences between the two magma types. The first model involved small degree melts of the continental lithosphere coupled with a declining influence from the subducted slab in moving eastwards. The second model considered the differences to be related to large scale inhomogeneities in the fluids released from the down-going Nazca plate.

Sollipulli volcano is situated at 39°S, about 20 km east of the main volcanic front. It is anomalous in the SSVZ in that it has erupted large quantities of silicic magma, predominantly lavas. Two distinct groups of basaltic andesites correlate with the regional high and low abundance groups. Both types have been erupted during a single event. To the authors knowledge, the two magma types have not been previously documented at a single volcanic centre with a definite temporal association. Strong constraints can therefore be placed on previous petrogenetic models. The evidence from Sollipulli makes any hypothesis based on regional homogeneities in the Nazca plate or simple control by crustal thickness untenable.

Geochemistry of sollipulli mafic magmas

The rocks under discussion all have SiO_2 < 54% and MgO > 5%. At a given SiO_2 content, *LREE*, Nb, Hf, Ba, Zr, Y and P are highly enriched in the high- abundance compared to the low-abundance magmas at Sollipulli. K, Na, Ti, Sr, Nd and Sm show pronounced enrichments. Rb is the least enriched of the incompatible trace elements. Fe/Mg, Al/Ca, K/Na and La/Yb are all distinctly higher in the high-abundance magmas. A feature of the depleted rocks is their chemical homogeneity compared to the enriched rocks, which show considerable scatter.

There are no discernible differences between the phenocryst assemblages or mineral chemistry of the different lava types. Both have plagioclase (An_{83-88}), olivine (Fo_{72-83}) with low-pressure spinel inclusions and rare clinopyroxene. In rocks with < 55% SiO_2, titanomagnetite is absent. Total modal abundances of phenocrysts vary from 5–20%. Attempts to quantify differences between the two types in terms of temperature, P_{H_2O} and f_{O_2} by crystal–liquid equilibria have not been definitive but indirect evidence suggests that the enriched types are more hydrous.

Petrogenesis

Crustal assimilation is not considered here to be a fundamental control on the evolution of the two different magma types, although assimilation has influenced the geochemistry of more evolved magmas at Sollipulli. Hickey-Vargas *et al.* (1989) presented strong evidence for a mantle rather than crustal origin for the enrichments which characterise the two magma types. At Sollipulli, the fact that Rb shows the least relative enrichment is a further argument against crustal influence. Rb has been used as an indicator of crustal assimilation at other SVZ centres (Davidson *et al.*, 1988) and tends to have high values in contaminated mafic magmas.

Compared to other SSVZ volcanoes, depleted Sollipulli magmas have lower abundances of many of the elements listed above. The depleted rocks have the highest MgO/FeO ratios in the region. The difference between the regional low- abundance magmas and those at Sollipulli are simply explained by higher degrees of partial melting in the mantle wedge generating the Sollipulli magmas. High degrees of melting could generate large magma batches. This provides an explanation for the homogeneity of the depleted lavas as well as accounting for the abundance of silicic lavas at Sollipulli, whether they have originated by fractionation or some mechanism of assimilation.

Hickey-Vargas *et al.* (1989) argued convincingly against the high-abundance SVZ magmas being derived by smaller degree partial melts of the same source as the low-abundance magmas. Their continental mantle lithosphere model considers the high-abundance magmas to originate by small degree melts in the lithosphere, mixing with wedge-derived magmas, containing a significant slab component. This model is accepted here with the following extension. Previous authors have tended to overlook the correlation between the trace and major elements outlined above. It is proposed here that the lithospheric melts are derived from a modally metasomatised source, containing minor Ti, P, *REE*, HFSE-bearing phases. Stern *et al.* (1986) have documented mantle xenoliths in basalts to the east which have veins of ilmenite, phlogopite and amphibole. Small degree melts of such a source, mixed with low-abundance type magma can produce many of the major and trace element characteristics of the high-abundance magmas. Incongruent breakdown of amphibole can produce residual clinopyroxene at small degrees of melting, producing magmas with high Al/Ca, K/Na and *LREE*/*HREE* relative to the source. Differences in Al/Ca have previously been attributed to fractionation processes at crustal depths. The higher Fe/Mg and more hydrous nature of the enriched melts are also explicable in terms of this model.

In this model, the tholeiitic nature, combined with the high Al and alkali contents of the SSVZ high-abundance magmas is inherited from the melting process. The rocks are transitional in many respects between tholeiites and alkali basalts. Many low-abundance SSVZ rocks are tholeiitic but have low Al and LILE. Different trends among these rocks can be explained by fractionation effects, controlled by P_{total}, P_{H_2O} and f_{O_2}, without invoking different parental magmas. The model may be applicable to some other arcs where tholeiites are characterised by higher LILE, *LREE* and HFSE abundances than associated calk-alkaline rocks. For example, early tholeiites at Santorini volcano have certain similarities to the Andean rocks (L. Edwards, Bristol, unpublished data). In many arcs, such as the NSVZ, divergent trends in Fe/Mg can be explained in terms of fractionation of a single parental magma, with or without crustal assimilation. In these arcs, calc-alkaline magmas tend to be more enriched in LILE and *LREE* than associated tholeiites.

References

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