CRUSTAL CONTAMINATION AT THE NEVADO SOLIMANA, WESTERN CORDILLERA OF THE CENTRAL ANDES, SOUTHERN PERU.

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Abstract

The Nevado Solimana, a Plio-Pliocene composite dacitic shield volcano, is located in the northernmost part of the CVZ. Major and Trace element data and Sr and Nd isotopic ratios give evidence for open system processes. Model AFC calculations indicate that a limited amount of crustal contamination (5%) could be from the upper crust (Paleozoic gneisses). On the other hand a contamination by granulites supposes that the crust underlying the volcano has a large Precambrian component.

Key words: dacitic series, crustal contamination, AFC modellization, Solimana volcano, Western Cordillera, southern Peru

Introduction

The Nevado Solimana (15°24'27"S -75°55'25"W, 6093 m) is located in the Arequipa Province roughly 20 km south of Cotahuasi. In this region, the thickness of the lithosphere is estimated as 80 km (Isacks, 1988). Fukao et al. (1989) show that the maximum thickening of the continental crust of the Central Volcanic Zone (CVZ) is approximately 65 km. The subducting slab of the Nazca plate is separated from the continental crust by a well-developed wedge of astenospheric mantle (Grange et al. 1984). The angle of the subducting oceanic plate beneath the CVZ averages 25-30° E from 25-to 100-km depth as pointed out by many authors (e.g. Barazangi and Isacks, 1979; Hasegawa and Sacks, 1981). The Nevado Solimana and the Nevado Corupuna (6426 m) form a volcanic complex lying at the northern terminus of the active NW-SE volcanic front and situated 220-250 km from the present Peru-Chile trench axis and 100-120 km above the top of the seismic zone. A model indicates that the Nazca plate is nearly neutrally buoyant in this region (Schneider and Sacks, 1987).

Geologic Setting

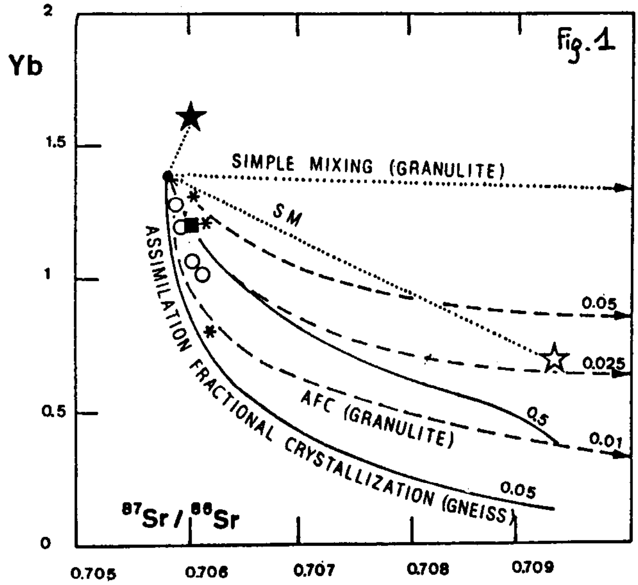
South of 15° S, the structural and magmatic evolution of the Western Cordillera of the Central Andes (southern Peru) has been described in many recent papers (e.g. Sébrier et al., 1985; Marocco et al., 1986). The substratum is made of Precambrian and Paleozoic series locally unconformably overlain by a pre-Oligocene basement including Mesozoic marine clastic formations. A very important magmatic and volcanic activity has been occurred from Oligocene to Present.
The Solimana volcano rises about 1.5 to 2 km above the high cordilleran topography (over 4 km) formed between 26 and 6 Ma (Sébrier et al., 1988) and is covered by an ice-cap with a surface of about 50 km^3. Its asymmetry is due to the formation and subsequent erosion of the southern flank after major collapse structures. Four units have been recognized: (a) the initial mid-Miocene activity (up to 10.5 Ma) represented by a series of breccias and tuffs interbedded with andesite lava flows and coeval with a period of ignimbrite eruptions (Chuntacala Formation); (b) the compound volcano (3.5 to 1.5 Ma) which consists of a complex of andesitic and dacitic lava flows and domes, followed by pyroclastic and lahar flows correlated with the formation of a large caldera-like depression; (c) the post-collapse activity (1.5 to 0.5 Ma) scattered along ring faults and gave rise to cross-cutting N 90° dyke-swarms and andesitic and dacitic lava flows; (d) the last intracaldera activity (<0.5 Ma) includes the youngest phreatomagmatic activity and fumaroles with hot springs and sinter deposits indicate continuing activity of this volcano.

Geochemistry

The series from basaltic andesites to dacites (52-68% SiO_2) is dominated volumetrically by dacite lavas. Mineralogical variations show evidence for two paragenesis and systematically two distinct phenocryst populations of the same minerals and the presence of unequilibrated phase assemblages and zoning patterns.
Major element variations are largely consistent with fractional crystallization of olivine, plagioclase, magnetite and clinopyroxene.
Trace element data show marked enrichment of the LIL elements. Rb and Th show the largest variations whilst Ba shows only small variations suggesting that these lavas had a petrogenetic history slightly different. All the HFS elements, with the exception of Ti and Nb, are enriched with relation to N-MORB values and fractionation trends are seen throughout the series. Contents of the first-transition-series metals indicate a fractionation trend from basaltic andesite to andesite and dacite with decreasing values for all elements with marked exception of Zn. The fractionation of hornblende appears as an important cause of Zn behaviour.
The foremost feature of REE data is a steep-sloped fractionation pattern of all lavas in the series. REE distributions in dacites show a more fractionated and depleted range of HREE abundances than in andesites and this is possibly due to the presence of REE-rich accessory minerals (e.g. apatite, zircon and sphene) forming the fractionating mineral assemblages in the later stages.
A narrow $^{143}Nd/^{144}Nd$ range (0.51254 to 0.51248) and a relatively high Sr isotopic ratio (0.70587 to 0.70621) are characteristics of the Solimana lavas which have a less radiogenic composition than other provinces of the CVZ.

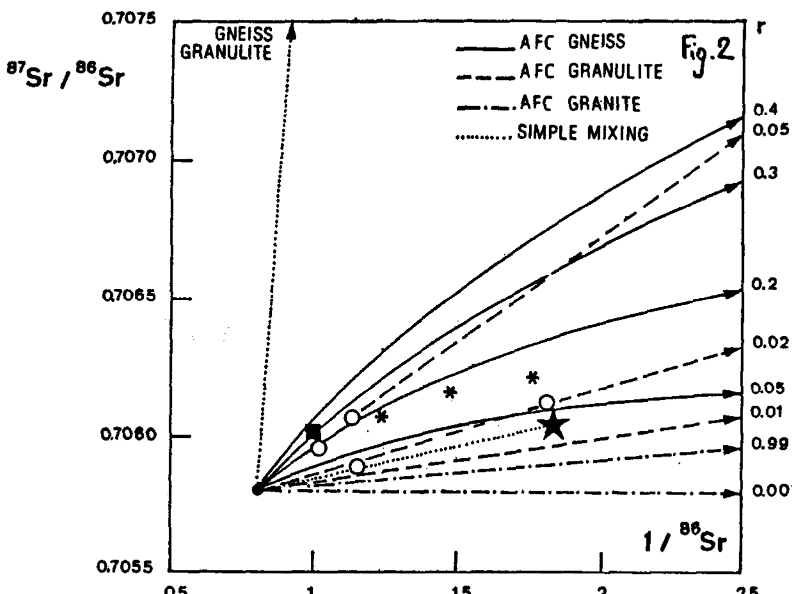
AFC modelling

The AFC calculations for the $^{87}Sr/^{86}Sr$ vs Yb diagram (Fig. 1) are made using local basement Paleozoic gneiss as contaminant. Different r (rate of mass assimilated to mass fractionated) values range between 0.05 to 0.4 and the percentage of assimilated material varies between 2 and 10%. Most of observed values are near r = 0.01 and 5% contamination. Two component mixing lines between the calculated hypothetical basaltic source at Solimana (full dot) and a gneissic (open star), granitic (full star) or granulitic crustal material are linear and are not consistent with the trend of the Solimana series (square, asterisks and open dots). A simple fractional crystallization model would be traduced by an horizontal line and would be no representative of the single possible mechanism because there are no lavas with compositions appropriate.



The $^{87}Sr/^{86}Sr$ = f ($1/^{86}Sr$) diagram (Fig. 2) indicate that a crustal contamination exist because a simple fractional crystallization phenomenon cannot explain the positive slope of the data. Fractional crystallization alone would give an horizontal line from a basaltic parent magma because the $1/^{86}Sr$ remains constant, whilst a simple mixing with a gneiss or a granulite would give sub-vertical lines. The local Paleozoic gneiss, a Precambrian granulite and a Cretaceous granite from the basement were tested by AFC using the same starting source and distribution coefficients as before. The AFC curves are traced for different values of realistic r ratios and for the three possible contaminants. Based on these calculations, the Solimana data appear to be consistent with a main contamination either from the gneiss or the granulite, whereas the granite and likewise each rock with similar Sr isotopic ratio (0.706) and Rb/Sr ratio (0.16) do not provide very close fits because bulk assimilation of a crust with this composition cannot increase $^{87}Sr/^{86}Sr$ ratios significantly. A forward modelling AFC calculation using the granulite gives a good fit and shows that this rock is in the range of potential contaminant compositions. Such a contamination by granulites or other crustal materials presenting a similar high Sr isotopic ratio could explain the increasing of the Sr ratio of the initial CVZ magma from 0.704 to 0.706 with a low percentage of assimilated rock. However, this possibility speculates that a large granulitic component is incorporated in the crust underlying the volcano.

The limited amount of crustal contamination in the case of the Solimana series relative to the Arequipa and Barroso volcanics: 20% of assimilated rocks (James, 1982) suggests that the rate of crustal assimilation is linked to the thickness of the crust as proposed by Boily et al. (1989).



Conclusions

The Paleozoic gneiss from the basement of the volcano and representing the upper crust appears to be the best contaminant used for AFC calculations. A greater crustal contamination for the Southernmost Peru would be consistent with a thicker crust in the Arequipa region and a limited amount of assimilation (5%) could be correlated to a substantially much thinner crust northeastward under the Solimana volcano.

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