GEOCHEMICAL CONSTRAINTS ON CRUSTAL STRUCTURE FROM NEOGENE VOLCANIC ROCKS OF THE SALAR DE ANTOFALLA VOLCANIC FIELD AND ADJACENT ANDEAN CORDILLERA (24°-26°S, 67°-69°W)

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INTRODUCTION

The Salar de Antofalla volcanic field (SAF) is a huge area of Miocene to recent calcalcaline volcanism located in NW Argentina (about 26° S, 67° W) at the southern end of the Andean Central Volcanic Zone (CVZ) (Fig. 1). It is emplaced within the southern part of the Puna high plateau and belongs to the back arc region of the CVZ. Volcanic structures comprise large Middle Miocene - Pliocene stratovolcanic complexes with andesitic to dacitic rocks and Pliocene - Pleistocene monogenetic mafic scoria cones and associated lava flows. Whereas the younger mafic cones are structurally controlled and affected by N-S and NNW-SSE trending strike-slip and normal faults, the older stratovolcanoes are aligned with a NW-SE-lineament but are not affected by true faulting. It is one of the lineaments transverse to the Andean mountain chain which segment the southern argentine Puna (Alonso et al., 1984).

Currently detailed age and geochemical information on the stratovolcanic complexes is lacking whereas data of the monogenetic mafic rocks are interpreted in terms of delamination processes (Kay et al., 1994) and to show both subduction and within-plate geochemical signatures (Thorpe et al., 1984).

Here we discuss new geochemical data on the stratovolcanoes and scoria cones in relation to contemporaneous volcanic rocks of the Andean cordillera in the west.

SAMPLE LOCATIONS, PETROGRAPHY AND AGE

Three stratovolcanic complexes (Cerro Archibarca, Tebenquicho, Beltran) have been sampled which are aligned together with Cerro Galan at the NW-SE trending Archibarca-lineament (Salfity et al., 1985). They consist of andesitic to dacitic domes and flows constructed above a basal platform (Tebenquicho, Beltran) or associated with an older ring structure (Archibarca). Sampling covered both platforms as well as flows and domes. Age relations are constrained by erosional state and by two K-Ar age determinations. Tebenquicho is the oldest complex (12.0 Ma, Gonzales, 1983), followed by Beltran (7.7 ± 0.2 Ma, K-Ar on biotites) and Archibarca volcanics. Additionally to the Archibarca lineament volcanics (ALV) the basal andesitic lava flow of Cerro De La Aguada volcano has been sampled which forms part of the contemporaneous Antofalla stratovolcanic complex 30 km to the south of ALV.

The predominant mineral assemblage of all volcanics is plagioclase-biotite-hornblende-magnetite with minor quartz-apatite-(Beltran: titanite) in the dacites and minor orthopyroxene-clinopyroxene in the

andesites. Fe-Ti-oxides are common to all samples. Disequilibrium textures comprise resorbed quartz and plagioclase grains.

The monogenetic mafic rocks sampled are localized predominantly at the eastern side of the Salar de Antofalla but also occur at its southern end and to the northwest. They are basaltic to andesitic in composition and have typically a microcrystalline/glassy matrix with 5-10 vol-% phenocrysts. These comprise olivine, clinopyroxene and orthopyroxene in basalts/basaltic andesites and mostly plagioclase with olivine, clinopyroxene and orthopyroxene as microlites in the andesites. As noted by former workers (Pichler & Zeil, 1972, Kay et al., 1994) quartz and plagioclase often occur as xenocrysts up to 2 cm showing disequilibrium textures as pyroxene rims and embayment by resorption.

The oldest rocks of this type overlying discordantly folded evaporites were dated with 5,6 ± 0,3 Ma (K-Ar on whole rock sample).

WHOLE ROCK GEOCHEMISTRY

1. Major and trace elements

According to their whole rock composition the volcanic rocks of the SAF region classify as high-K calcalcaline basalts to dacites. Major and trace elements show similar ranges and trends displayed by the Cerro Galan complex (Francis et al., 1989). Archibarca rocks show at given silica content enrichment in Al_2O_3 relative to Beltran and Tebenquicho rocks. This correlates with slightly higher CaO and Sr contens and has to be interpreted as a higher plagioclase content. Archibarca rocks show also higher HFSE (Zr, Nb, Ta, Y) and lower compatible element (Sc, Ni, Cr, V) contents and have a tendency to higher La/Sm and lower La/Yb ratios relative to Beltran and Tebenquicho rocks. This could be due to variation in source composition, crystal fractionation or magma mixing.

At given SiO_2 or K_2O values Ba contents are higher in Archibarca rocks but Th, Pb, Rb and Cs are lower. It has to be noted that potassium feldspar is absent in ALV rocks. Furthermore in a plot Nb/Ta vs Zr/Hf which tries to avoid fractionation effects of biotite/hornblende and zircon, each volcanic complex displays a distinct range (Fig.2). Both facts points to variation of source composition rather than fractionation effects.

2. Isotopes

Monogenetic mafic rocks (50 - 60 wt% SiO_2) of SAF area have $i^{87}Sr/^{86}Sr$ = 0,7051 - 0,7089 and ALV rocks (59 - 65 wt% SiO_2) have $^{87}Sr/^{86}Sr$ = 0,7077 - 0,7091 and $^{143}Nd/^{144}Nd$ = 0,51231 - 0,51243 (ALV rocks have not been time corrected due to uncertain age. However, age corrected values would not be far outside the error limits), which is within the range of basaltic to andesitic rocks of the CVZ. The Pb isotopic data of mafic and ALV rocks fall in the typical range of the southern CVZ: $^{208}Pb/^{204}Pb$ 38,446 - 39,167, $^{207}Pb/^{204}Pb$ 15,594 - 15,703, $^{206}Pb/^{204}Pb$ 18,551 - 18,988.

The $^{87}Sr/^{86}Sr$ initial ratios of mafic rocks correlate with SiO_2, which is commonly interpreted as a feature of open system AFC processes (Francis et al., 1989) in which crustal components are melted and assimilated by parental mantle magmas. Sr and Nd isotopic ratios of ALV rocks are within the range of the monogenetic rocks and can be interpreted also as mixed or AFC melts triggered by injection of mantle melts. This is indicated also by the $d^{18}O$ value = 7,92 of a dacitic lava sample of Cerro Beltran.

We compare these data with Sr, Nd and Pb isotopic compositions of four contemporaneous stratovolcanoes of the Andean Cordillera 50 - 90 km to the west (Azufre, Cordon del Azufre, Lastarria, Llullaillaco) (Fig. 3, Fig. 4). As pointed out by Wittenbrink & Kraemer (1996) intermediate to acid lavas from these centers were derived by interaction of already altered basaltic andesites and crustal melts during their ascent within the middle crust.

Andesites - rhyolites of the Cordillera reach lower Sr and Pb and higher Nd isotopic ratios compared to rocks of SAF region (0,7059 - 0,7071, $^{208}Pb/^{204}Pb$ 38,634 - 38,827, $^{207}Pb/^{204}Pb$ 15,627 - 15,638, $^{206}Pb/^{204}Pb$ 18,688-18,873, 0,51253 - 0,51242 respectively). At given Pb and SiO_2 contents the volcanics of the SAF region are displaced to higher Pb isotopic composition than arc rocks. The enriched

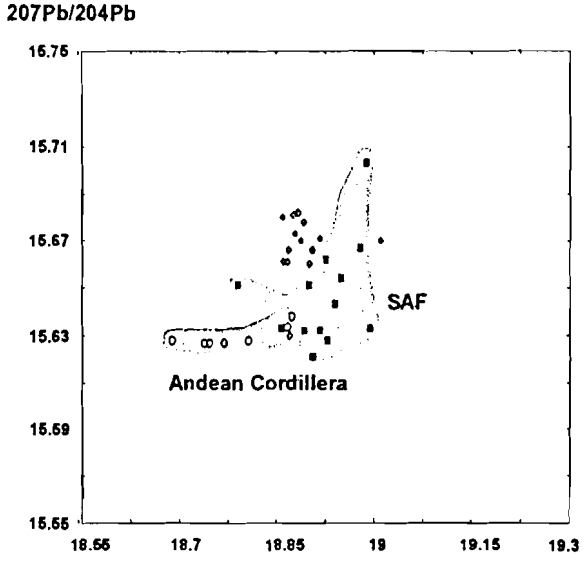
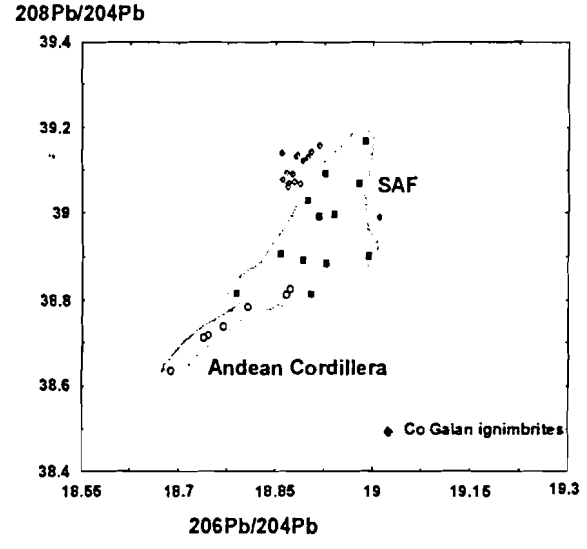


Fig. 4 Pb isotopic ratios in Salar de Antofalla volcanic region and adjacent Andean arc



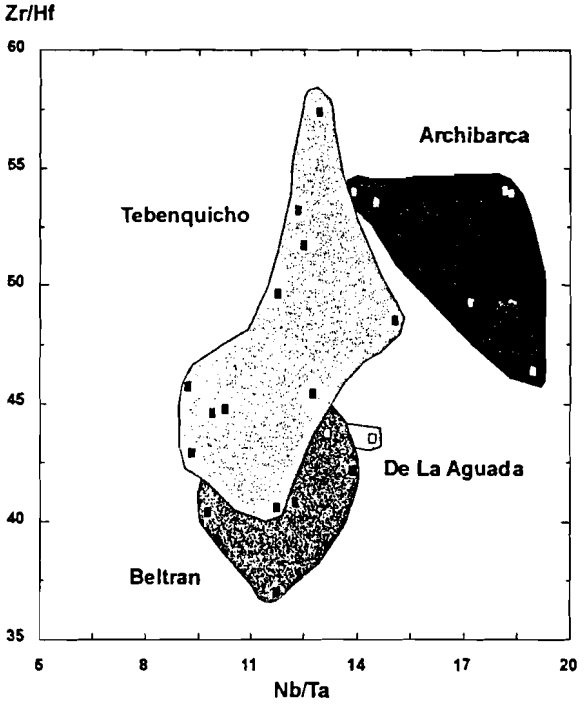
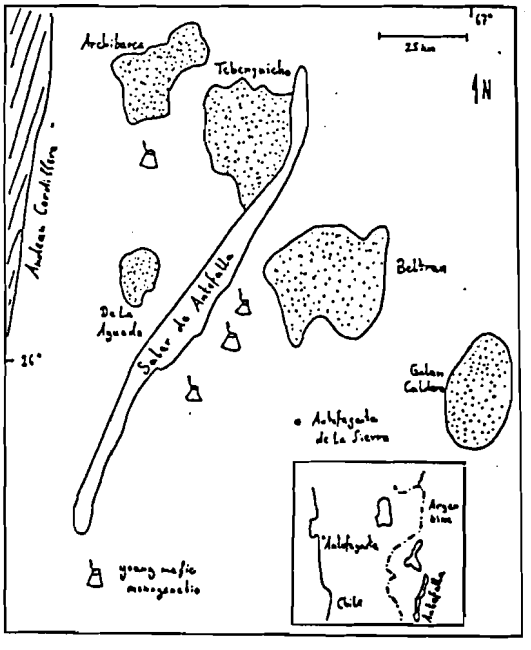


Fig. 2 HFS element ratios in Archibarca lineament rocks

Fig. 1 Location sketch map



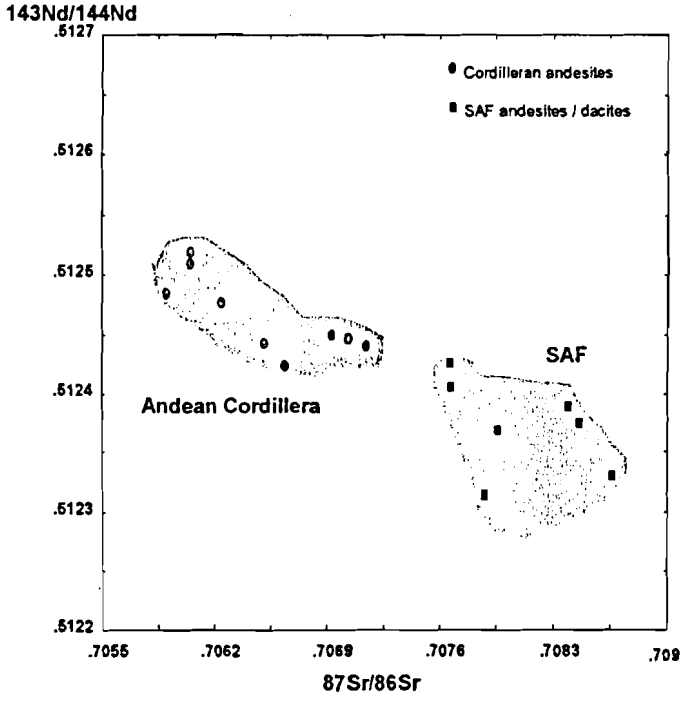


Fig. 3 Sr-Nd isotopic ratios

isotopic ratios of the SAF back arc region can be explained by higher Th/Pb-, U/Pb-, $^{87}Sr/^{86}Sr$ and lower $^{143}Nd/^{144}Nd$ ratios of contaminant(s).

This could be interpreted as variable age and/or composition of the underlying basement rocks. Ramos (1986) postulated two allochthonous terranes of Precambrian and Paleozoic age to have been accreted between the two regions. However, new data on high-grade metamorphic rocks of basement outcrops in N Chile and NW Argentina show similar conditions of metamorphism and a peak-metamorphism age of 500 Ma. This does not support the idea of terrane accretion (Lucassen et al., 1996) and, thus, the isotopical zonation can not be explained by basement rocks of different age.

As noted by Feeley & Davidson (1995) at Ollague volcano assimilation processes in upper crustal regions are of minor importance in the magmagenesis of andesites and dacites. Thus, we conclude that compositional variation within the deep crustal precambrian basement block is most probably to account for the isotopical zonation between the SAF back arc region and the Andean Cordillera. The trace element pattern of ALV rocks also indicates the stated variation of source rock composition.

CONCLUSIONS:

Andesitic to dacitic rocks which extruded at stratovolcanoes of the Archibarca lineament have crustal sources of variable composition mixed with ascending basaltic mantle melts. Compared to contemporaneous intermediate to acid volcanic rocks from the Andean Cordillera 50 - 90 km in the west they reach higher Pb and Sr and lower Nd isotopic ratios.

The zonation of isotopic composition between these two regions is attributed to variation of underlying precambrian rocks of the same crustal basement block. It is not due to allochthonous terranes which have been postulated elsewhere.

REFERENCES:

Alonso, R. et al. (1984) Puna Austral - Bases para el subprovincialismo geologico de la Puna Argentina. IX Congr. Geol. Arg., Bariloche, Actas I, 43 -63 **Feeley, T.C. & Davidson, J.P. (1995)** Petrology of Calc-Alcaline Lavas at Volcan Ollague and the Origin of Compositional Diversity at Central Andean Stratovolcanoes. J. Petrol., 35, 1295 - 1340. **Francis, P.W. et al. (1989):** Petrology and geochemistry of volcanic rocks of the Cerro Galan caldera, northwest Argentinia. Geol. Mag. 126, 515-547. **Gonzales, O. E. (1983)** Geologia, Alteracion Hidrotermal y Edad del Cerro Tebenquicho, Dep. Antofagasta de la Sierra, Catamarca. Asoc. Geol. Argentina Rev., 38, 49 -59. **Kay, S.M. et al. (1994)** Young mafic back arc volcanic rocks as indicators of continental lithospheric delamination beneath the Argentine Puna plateau, central Andes. J. Geophy. Res., 99, 24323 - 24339 **Lucassen et al. (1996)** The Paleozoic Basement of the Central Andes (18° - 26° S) - A metamorphic view. III Int. Symp Andean Geodynamics, this volume. **Pichler, H. & Zeil, W. (1972)** The Cenozoic rhyolite-andesite association of the Chilean Andes. Bull. Volcanol., 35, 424 - 452. **Ramos, V.A. (1988)** Late Proterozoic-Early Paleozoic of South America - A collisional history. Episodes, 11, 168-174 **Salfity, J. A. (1985)** Lineamentos transversales al rumbo andino en el noroeste argentino. IV Congr. Geol. Chil., Antofagasta, Actas 2, 119 - 137. **Thorpe, R.S. et al. (1984)** Relative roles of source composition, fractional crystallization and crustal contamination in the petrogenesis of Andean volcanic rocks. Phil. Trans. R. Soc. Lond., A310, 675-692 **Wittenbrink, R & Kraemer, B. (1996)** Variation in time and space of magmagenesis of neogene to recent volcanic rocks in the southern Central Volcanic Zone (CVZ) of the Andes (24°-26°S, 67°-69°W). VI Goldschmidt Conference, Heidelberg, 31.3.-4.4.1996, Abstracts.