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Geochemistry of the intrusive Miocene arc magmas from the Malargüe area, southern Mendoza, Argentina: An overview and implications on crustal contamination

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INTRODUCTION

Elemental and isotopic compositions of arc magmas reflect the interplay of mantle processes and components, and the geodynamics of subduction zones. The magmatic evolution in the northern part of the Andean Southern Volcanic Zone (SVZ) presents a complex variation in the chemical patterns during the last 25 Ma. These changes can be linked to episodes of crustal thickening at times of back-arc thrusting and to peaks of subduction erosion of forearc crust and mantle lithosphere at times of frontal-arc migration to the east (Kay et al, 2004).

The Southern Paramillos Altos Intrusive Belt (PAIB) (35° 20´-35°-40´) is located in the thick skinned folded-thrust belt of Malargüe, southwestern Mendoza, Argentina (Fig.1). This belt is characterized by episodic arc magmatism that cover the time span from 20-5 Ma (Ostera et al. 2000 and references therein).

In this contribution we present an overview of the chemical and isotopic features of the epizonal –hypabissal arc magmatism of a part of the PAIB based on a collection of 64 whole-rock chemical data that cover a compositional range from basic to acid rocks and 20 data on Nd-Sm, Sr and Pb isotopes. Analytical results and methods can be found at Ostera et al. (1999, 2000, 2003).

GEOLOGICAL BACKGROUND

The SVZ is divided into the northern SVZ segment that lies between the volcanically inactive Chilean flat-slab region (28°S–33°S) and overlies a nearly horizontal part of the subducting Nazca plate to the north (Cahill and Isacks 1992) and an offset in the SVZ near 34.5°S. The subduction of the Juan Fernández Ridge has been argued to have been responsible for the Miocene shallowing of the subducting plate under the Chilean flat-slab (Kay et al., 2004, Kay and Mpodozis, 2002, Yáñez et al. 2002 and references therein) and incipient shallowing under the northern SVZ. The rest of the SVZ, south of 34.5°S, can be divided into the transitional SVZ and the southern SVZ, whose boundary is commonly put at the offset in the volcanic line near 35.2°S (Kay et al. 2004). Traditionally Neogene magmatism in the Malargüe area was separated into the Ciclo Eruptivo Molle (late Oligocene-early Miocene) and the Ciclo Eruptivo Huincan (middle-late Miocene). Recently these cycles were redefined by Nullo et al. (2002) which proposed the ca. 10 Ma Quechua deformation phase at as their limit.

According to Ostera et al. (2000) PAIB was divided into the 20 ± 2 Ma Calle del Yeso Dyke Complex (CYDC), with sills and dykes of andesitic composition with phenocryst of plagioclase and hornblende; the 12.5

± 1 Ma Puchenque-Atravesadas Intrusive Complex (PAIC), composed of dykes and stocks ranging from pyroxene-biotite diorites to biotite granodiorites, the 10 ± 1 and 9.5 ± 0.5 Ma, Arroyo Serrucho Stock (SAS), an epizonal and zoned stock, composed of monzodiorites to granodiorites, the 7.5 ± 0.5 Ma Portezuelo de los Cerros Bayos (PCB), that includes porphyric rhyolites and the 4.8 ± 0.2 Ma Cerro Bayo Vitrophyres (CBV), with andesitic sills. Although pyroxene is dominant in the mineral residua, at similar SiO_2 increasing La/Yb at decreasing time implied a thickened crust at Middle Miocene (Ostera et al, 2003). Whereas a dominant lower crustal component was assigned to CDYC, an upper crustal contribution was inferred for PAIC-SAS (Ostera et al 2000).

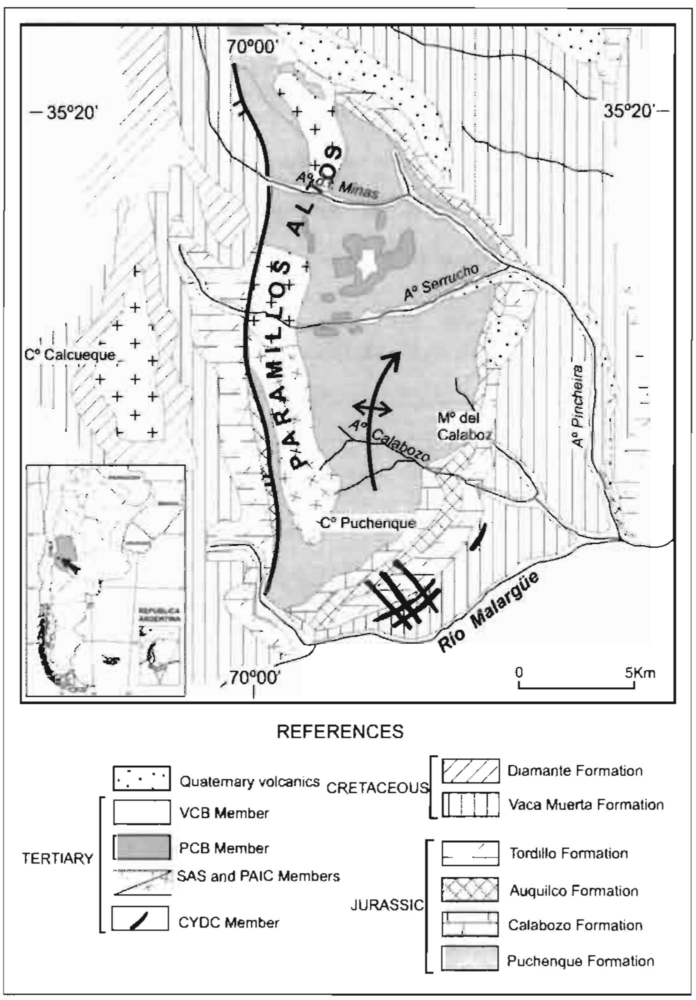
RESULTS

Although samples of the PAIB display the characteristics of arc magmas like high Al, alkali, alkaline-earth, U, and Th concentrations HFSE depletions relative to the REE each unit preserve distinctive features.

The CYDC (51-64% SiO_2) are metaluminous-mildly peraluminous medium-K calc-alkaline rocks. K_2O, CaO, TiO_2, HFSE (except Y), Ba, La, Sm are lower than for the younger units whereas NaO_2 and Sr are higher. Zr/Nb (16-25) is slightly lower than values for MORB. La/Ta 20-35 is lower than for the younger units whereas Ba/La 30-60 is higher. Ba /Ta 400-1600 is on the range of arc related rocks. Low La/Yb 6-9, is coupled with La/Sm 3-6 and Sm/Yb 1-2 and an Eu/Eu* around 1 that is independent of the SiO_2. Chondrite normalized REE pattern presents LREE enrichment with 60x maximum for La, with a small positive or negative anomaly for Eu.. The HREE are enriched nearly in a constant value of 10-20x. This may indicate clinopyroxene crystallization/fractionation. The MORB-normalized spider-diagram shows a mean enrichment of 40x in LILE, pronounced troughs at Nb, Ti and a concave pattern from Nd to Sm (Fig 2 a,b,c). The CYDC is characterized by the widest range in Sr ratios, 0.7047- 0.7064 and $^{206}Pb/^{204}Pb$ (18.59-18.67) whereas values for $^{143}Nd/^{144}Nd$ are mostly closer to the depleted mantle.

The PAIC-SAS (56.8-66% SiO_2) are composed of metaluminous medium to high K calc-alkaline monzodiorites to granodiorites which show a good correlation against SiO_2 in the Harker diagrams. Comparison with CYDC indicate higher content of CaO, K_2O,Ba, HFSE, La and Sm and comparable Y and Yb. Zr/Nb between 20-32 is higher than for CDYC but corresponds to the lower values for MORB. Ba/La 5-30, La /Ta 30-60 and Ba/Ta 600-800 are within the range of arc-magmatism but are less variable than for CYDC. The REE chondrite normalized pattern show a mild enrichment in the LREE, with Eu anomaly increasing for the most evolved rocks. MORB-normalized spider-diagrams show a pronounced LIL enrichment, with values near 100x for Rb and 40x for K. Concave pattern from Gd to Lu may correspond to the fractionation of pyroxene or amphibole. PAIC-SAS are distinctive in having somewhat steeper REE patterns (La/Yb, 12-18; La/Sm, 4-7, Sm/Yb, 2-3) than the early Miocene CYDC (Fig 2 a,b,c). Nd values are comparable to those of the CYDC but $^{87}Sr/^{86}Sr$ ratios is markedly lower 0.7039-0.7046 and $^{206}Pb/^{204}Pb$ (18.66-18.72) higher.

PCB (70-75% SiO_2). are peraluminous calc-alkaline rhyolites. Absolute values for LILE are within the range for the PAIC-SAS whereas HFSE contents are comparable to CYDC. Although trends indicating fractional crystallization are observed for Sr, Eu/Eu and CaO indicating a plagioclase dominating process, most of the chemical trend are scattered. Zr/Nb (8-12) is extremely low. Although degree of evolution of these rocks makes difficult a direct comparison with the contents and ratios for the rest of the units it is interesting to note that values for Ba/La (45-80) are slightly higher than for CYDC whereas La/Ta 10-20 are lower than for arc-related rocks. Ba/Ta (800) is similar to the highest values of the PAIC. La/Yb 15-21 is coupled with a pronounced increment on La/Sm unrelated to an increase in Sm/Yb. Fractionation of pyroxene at the source will allow the increase in LREE and the decrease in Sm and the low Sm/Yb. Isotopic ratios for these rocks (only 3 data) are highly variable with $^{87}Sr/^{86}Sr$ that increases from 0.7047.0,7072 with decreasing Sr and increasing SiO_2. $^{143}Nd/^{144}Nd$ is lower than for the rest of the units whereas $^{206}Pb/^{204}Pb$ varies from 18.62 to 18.7. MORB normalized patterns shows a markedly enrichment at K and Ba and a slight depletion at Th and U. Nb and Ti throughs typical for arc magmas are present. Chondrite normalized patterns are less enriched than for the other two units and show a pronounced negative Eu anomaly.



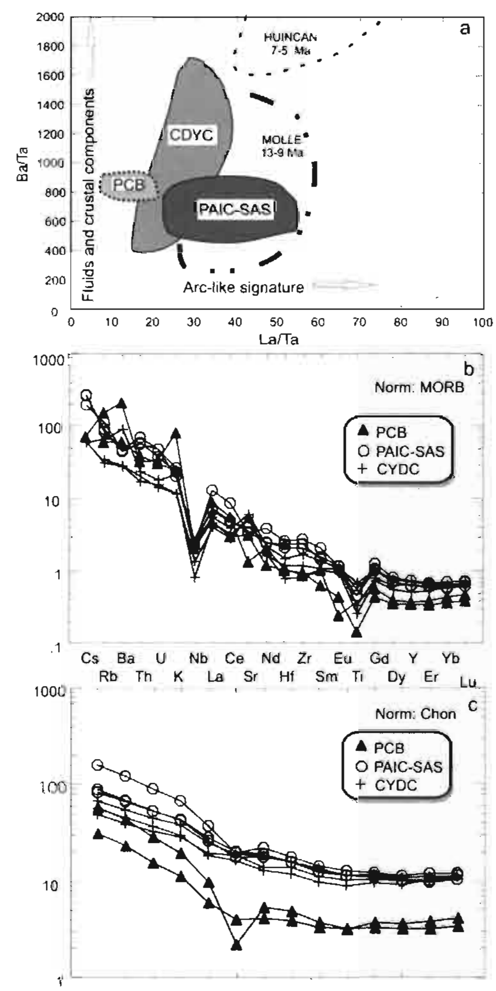


Figure 1: Geological sketch of the Paramillos Altos Intrusive Belt.
Figure 2: Plots for selected samples of the Miocene PAIB. **a:** Plot of Ba/Ta vs. La/Ta. Fields for Molle and Huincán series and trends are taken form Kay and Mpodozis 2002; **b:** Extended trace element diagram normalized to MORB values; **c:** REE diagram normalized to chondrite. Note that in b and c SiO_2 content for PCB are higher than for CYDC and PAIC-SAS. Normalization values are from (NewPet v. 01-17-94

DISCUSSION AND CONCLUSIONS

Compositional variations within the PAIB require differences in magma source regions as shown by isotopic data and in depths of magma generation/fractionation as shown by REE ratios. Back-arc contraction was proposed to explain the ca. 13.9–13.5 Ma volcanic flows that cover Miocene thrusts in the western Malargue fold-thrust belt (Baldauf et al., 1997, Pérez, 2000). Therefore the emplacement of the CYDC and the PAIC-SAS is separated at least by a period of deformation and uplift that may be related with an increase in the crustal thickness.

The Early Miocene magmas have more radiogenic Sr isotopic ratios, flatter REE patterns with less LREE enrichment, and lower Th, Ta, alkali and alkaline earth contents. Such observations rule out a pre-Miocene "enriched" mantle component in the source and mighty point to a lower crust contamination of a depleted source, with relatively high Nd ratios and less radiogenic $^{206}Pb/^{204}Pb$. The geochemistry of the Early Miocene magmatism suggests local process at the magmatic chamber. In a more regional context the early Miocene is a period characterized by a transtensional stress regime (Charrier et al 2002) which would fit with a minor crustal input in a relatively thin crust.

A deeper source is consistent with the steeper REE patterns for PAIC-SAS that may indicate more amphibole-rich residual mineral assemblages equilibrating with magmas in a thicker crust. At equivalent SiO_2 content, samples of the PAIC-SAS show lower Nd ratios and $^{87}Sr/^{86}Sr$ ratios relative to early Miocene magmas which could fit with some crustal contamination within the thickened crust, as well as with any process of contamination of the mantle wedge. Slightly higher Zr/Nb for this middle Miocene rocks point to reduced sedimentary input.

Geochemical and isotopic signature of the rhyolitic dykes of PCB would imply crustal involvement. The low Zr/Nb point to a sedimentary or upper crustal reservoir which fit the isotopic ratios. The higher La/Yb is related to relatively high La/Sm than to higher Sm/Yb therefore it would not directly reflect a deeper source.

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