BARREN IGNEOUS INTRUSIVES IN THE CENTRAL ANDES: U/Pb GEOCHRONOLOGY AND Nd-Hf ISOTOPE GEOCHEMISTRY

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The Mio-Pliocene intrusive magmatism of the central Andes consists of either barren or highly mineralized igneous bodies and apophyses. The mineralized bodies are concentrated in three giant porphyry Cu(-Mo) deposits, from north to south: Los Pelambres (31°42'S), Río Blanco-Los Bronces (33°08'S) and El Teniente (34°05'S). Whereas Los Pelambres is of late Miocene age (Bertens et al., 2003), the central and southern deposits are coeval and of early Pliocene age (Deckart et al, 2005; Maksaev et al., 2004). Numerous barren intrusives are intercalated in the north-to-south occurrence of the mineral deposits and are either of imprecise or unknown age. Magma source discussions have been principally focused on mineral deposits and therefore geochemical information are scarce for comparison with slightly older and coeval barren intrusives.

The aim of this paper is to precisely date by the U/Pb LA-ICPMS method on single zircon grains two barren intrusives located in between the metallogenic fringe of 33-34°S, central Andes. Furthermore, by means of major and trace element geochemistry as well as isotope geochemistry that apply for the first time Nd-Hf systematics the ongoing discussion on the nature of the involved magma source(s) and their evolution in time is reappraised.

RESULTS AND DISCUSSION

Geochronology: The two selected barren intrusives, Cerro Mesón Alto (CMA; 33°40'S) and La Gloria plutons (LGP; 33°27'-35'S) (Fig. 1), are historically assigned to the magmatic group of Miocene age. An unpublished K/Ar biotite age of 9.8 Ma for LGP was mentioned in Cornejo and Mahood (1997), whereas Kurtz et al. (1997) presented an ^{40}Ar-^{39}Ar hornblende age of 12.4 ± 2.5 Ma for CMA. New precise LA-ICPMS ages were obtained on single zircon mineral separates from both granitoids. Crystallization ages are Late Miocene yielding 10.34 ± 0.15 Ma for LGP and 11.29 ± 0.10 Ma for CMA.

Geochemistry: The quartz-monzodioritic to granodioritic Late Miocene granitoids CMA (66-67 wt.-% SiO_2) and LGP (61.6-67 wt.-% SiO_2) show a high-K calc-alkaline and metaluminous character. Both rock types are classified as volcanic arc granites after Pearce et al. (1984). CMA and LGP major and trace element contents indicate plagioclase involvement and clinopyroxene and olivine mineral suppression during differentiation processes. Rare earth element abundance show a stronger enrichment of incompatible than compatible rare earth elements relative to chondrite composition. $(La/Yb)_n$ ratios range from 11.95 to 15.34 for CMA and between 8.96 and 9.33 for LGP rocks.

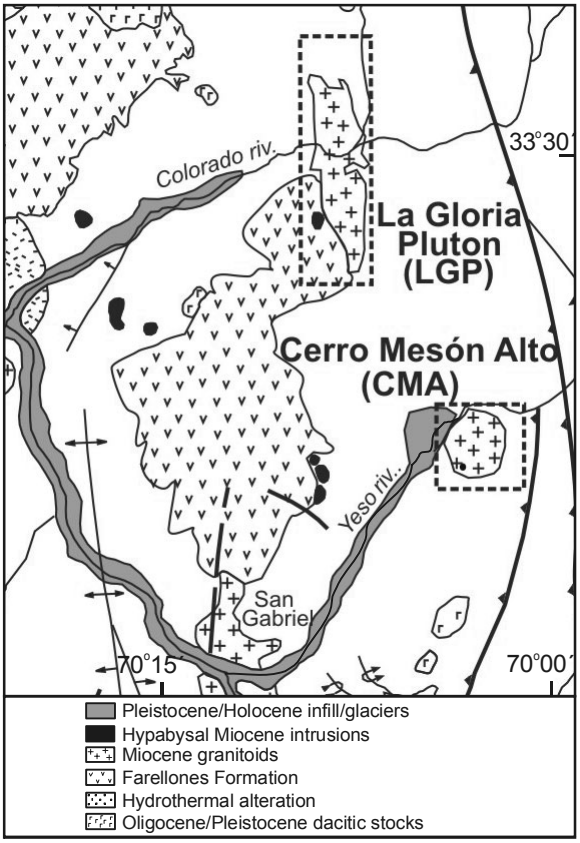

Figure 1. Schematic geology map with Cerro Mesón Alto and La Gloria Pluton locations, central Andes.

Trace elements (Rb, Ba, Sr, Th, U, K, Nd, La, Ce and Pb) show a closer affinity to island arc basalts than to N-MORB and display a strong negative Nb-Ta anomaly. Compared to other coeval barren and slightly younger barren and mineralized intrusive rock units CMA and LGP indicate with their Th/La, Ta/Yb, Ba/La and Ba/Th trace element ratios an enriched mantle influence (eg., N-MORB: Ta/Yb=0.04; Sun and McDonough, 1989) and a possible slight sediment involvement during genesis (Fig. 2). La/Ta > 25 for all samples point generally to an arc mantle source.

Sr, Nd and Hf isotope compositions were analysed on both, CMA and LGP whole rock samples. Initial ratios were calculated back to their individual ages presented herein. CMA $^{87}Sr/^{86}Sr_i$ ratios range from 0.704118 to 0.704064, $^{143}Nd/^{144}Nd_i$ ratios from 0.512882 to 0.512811, whereas $^{176}Hf/^{177}Hf_i$ ratios range between 0.282998 and 0.282999. Initial isotope ratios for LGP range between 0.704023 and 0.704072, 0.512799 and 0.512819 and from 0.282988 to 0.282992 for $^{87}Sr/^{86}Sr_i$, $^{143}Nd/^{144}Nd_i$ and $^{176}Hf/^{177}Hf_i$, respectively. The narrow isotope ranges of the whole rocks excludes mixing processes as major differentiation process. Isotope modelling as assimilation and fractional crystallization (AFC) between an enriched E-MORB type and possible geographically-related end-members which could have been involved during subduction processes -eg., metamorphic basement (Lucassen et al., 2004), pelagic sediments of ODP Leg 141 (Ben Othman et al., 1989; Kilian and Behrmannn, 2003) or the coastal batholith (Parada et al., 1999)- show that AFC as differentiation process in the petrogenetic evolution of major barren magma(s) can be minimized or even suppressed. Simple binary mixing was tested between E-MORB, coastal batholith, pelagic sediments and metamorphic basement. The latter end-member is the only one that explains the entire Nd-Sr isotope range of CMA and LGP granitoids. It is not excluded that pelagic sediments and/or the coastal batholith could have been partly involved during CMA petrogenesis but, none of LGP analytical points are lying on binary mixing lines projected through latter mentioned end-member combinations.

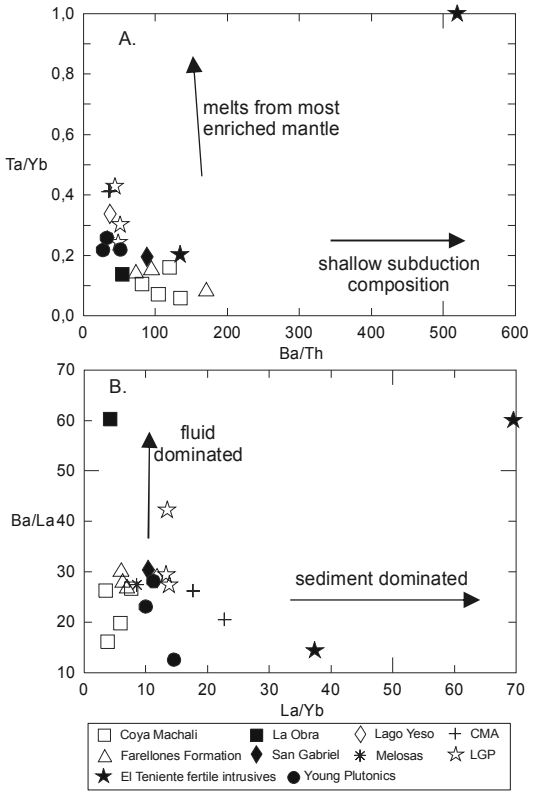

Figure 2A-B. Trace element ratio plots for selected barren and fertile Mio-Pliocene magmatism.

Zircon minerals used for geochronology were at the same time analyzed for $^{176}Hf/^{177}Hf$ isotopes. CMA zircon minerals show a slightly wider range of initial $^{176}Hf/^{177}Hf$ ratios ranging between 0.282964 and 0.283036, whereas LGP zircon minerals range from 0.282967 to 0.283018. The similarity in isotope ratios in minerals and whole rock indicates that zircon is controlling Hf-isotope values of the whole rock.

CAM and LGP initial Nd-Sr isotope ratios display values between depleted mantle and bulk silicate earth poles. Initial εHf and εNd plots confirm this tendency but show a split in isotope ratios of CMA and LPG granitoids (Fig. 3).

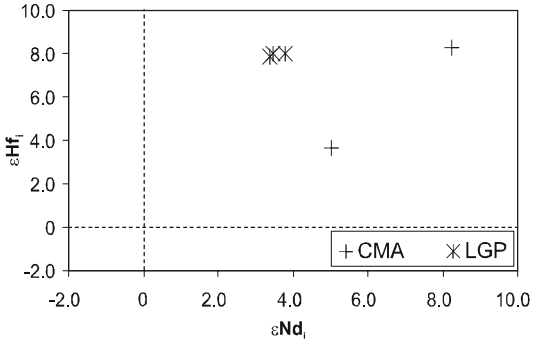

Figure 3. Initial εHf versus εNd isotope ratios for CMA and LGP whole rocks.

CMA is characterized by higher radiogenic initial Nd-isotope ratios with similar or lower εHf_i values than in LGP, whereas initial Hf versus Sr isotope data display no isotopic differences between both intrusives. The εNd comportment could be explained by dehydration reactions which affected more Nd than Sm but had little or no effect on Lu-Hf.

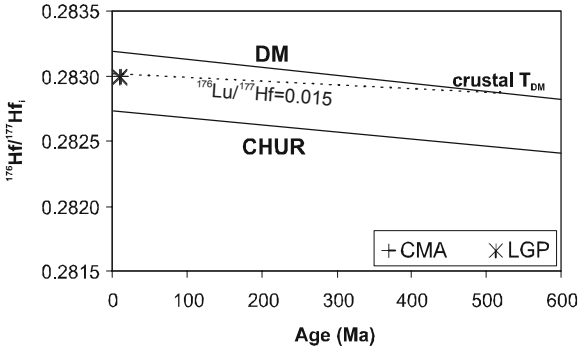

Figure 4. Age versus initial Hf-isotope whole rock values for CMA and LPG. Crustal T_{DM} calculated with $^{176}Lu/^{177}Hf$=0.015.

The age versus initial $^{176}Hf/^{177}Hf$ ratios (Fig. 4) diagram shows that whole rock and zircon data of both barren intrusives plot close together above the CHUR evolution line indicating a certain depleted mantle involvement at an earlier stage (T_{DM}=Late Proterozoic-to-Early Cambrian) of magma generation and that zircons may originate from the same or similar magma as the zircon bearing rocks.

Geochemical and isotope data from CMA and LGP point to a slightly enriched mantle source with assimilation of metamorphic Carboniferous basement.

Until now it is not possible to discriminate whether assimilation happened in the mantle source region or during ascent of the magma. Some trace element ratios and Nd-Hf isotopes of CMA point to source enrichment processes possibly triggered by dehydration fluids from the downgoing slab into the mantle wedge area. Small differences in the geochemical character of both intrusives could be explained through local tectonomagmatic features.

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RESUMEN

Magmatismo estéril del Mio-Plioceno en los Andes central entre 33° y 34°S, se manifiesta intercalado entre tres centros mineralizados de tipo pórfido cuprífero. Dos intrusivos estériles, los plutones Cerro Mesón Alto (33°40'S) y La Gloria (33°27'-35'S), fueron seleccionados para geocronología U/Pb, geoquímica convencional e isotópica (Sr-Nd-Hf). El primero tiene una edad de cristalización de 10.34 ± 0.15 Ma mientras para el segundo se obtiene una edad de 11.29 ± 0.10 Ma. Los granitoides son cuarzo-monzoníticos a granodioríticos, de alto contenido de potasio y carácter calco-alcalino a metaluminoso. Elementos mayores y trazas de estos intrusivos félsicos representan una composición típica de ambientes de arco volcánicos con un enriquecimiento en elementos LIL y un empobrecimiento en Nb-Ta. Elementos trazas indican una fuente de manto tipo arco con un enriquecimiento a través de sedimentos, basamento metamórfico y/o fluidos/fundidos relacionados con la zona de subducción. Isótopos de Sr-Nd-Hf indican una fuente mantélica enriquecida. El modelamento isotópico demuestra que procesos de tipo ACF tienen poca importancia pero, por otra parte, permite reconocer una influencia de mezclas binarias durante la evolución petrogenética de(l) (los) magma(s). Isótopos de Hf en roca total y minerales de circón están en el mismo rango y se proyectan encima de la curva de evolución del CHUR, lo que es compatible con una influencia de manto empobrecido en una etapa temprana. Variaciones geoquímicas entre los intrusivos estudiados están posiblemente relacionadas a condiciones tectonomagmáticas locales.