CHEMICAL CONSTRAINTS ON NEOGENE SLAB WINDOW MAFIC MAGMATISM IN SOUTHERN PATAGONIA

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INTRODUCTION

Extensive Neogene Patagonian plateau lavas (46.5° to 49.5°S; Fig. 1) are related to progressive opening of asthenospheric "slab-windows" associated with collisions of segments of the Chile Rise with the Chile Trench at 12 Ma and 6 Ma. Temporal and spatial variations in trace elements (Fig. 2), volumes of erupted magma, and Sr-Nd-Pb isotope ratios (Fig. 3) are consistent with a model in which variable melting percentages are produced by upward flow of an OIB-like, asthenospheric mantle through a northeastward migrating "slab-window" (Fig. 4). The asthenospheric mantle must have been anomalously hot and/or contained volatiles that lowered its melting point to explain the observed melt volumes and the high percentages of partial melting.

TECTONIC SETTING AND RADIOMETRIC AGE CONSTRAINTS

Abundant Neogene Patagonian mafic plateau lavas occur southeast of the modern Chile Triple Junction (46.2°S), about 100 to 400 km east of the volcanic arc gap between the Southern (SVZ) and Austral Volcanic Zones (AVZ) (Fig. 1). The Late Cenozoic tectonic history of the Chilean margin has been punctuated by the collision of Chile Rise segments with the Chile Trench (Fig. 1). Reconstructions of the oceanic tectonic history (Cande and Leslie, 1986), radiometric age dating of plateau lavas, and kinematic modeling of the subducting Nazca and Antarctic Plates (Ramos and Kay 1992; Gorring et al. submitted) support a model in which these lavas erupted in response to the opening of asthenospheric slab windows that accompanied ridge collisions at 12 and 6 Ma (Figs. 1 and 4). Estimates of Neogene absolute plate motion vectors for South America (Minster and Jordan 1978; Cande and Leslie, 1986) indicate that these lavas do not represent a hotspot track produced by a deep mantle plume. Slab window magmatism is best developed in the backarc where ridge collision occurred at 12 Ma (Fig. 1). In this region, two sequences of slab window lavas have been identified: 1) a voluminous, tholeiitic, Late Miocene to early Pliocene "main-plateau" sequence, and 2) a less voluminous, alkaline, latest Miocene to Quaternary "post-plateau" sequence. A 2 to 5 Ma hiatus separates main- from post-plateau sequences. Both main- and post-plateau lavas postdate ridge collision and become systematically younger (11 to 5 Ma and 7 to 2 Ma, respectively) to the northeast (Fig. 4). The geophysical, geochemical, and radiometric age data fit a slab window model in which main-plateau lavas track the passage of the trailing Nazca Plate edge, and are produced by strong asthenospheric flow into the opening slab window. Post-plateau lavas are produced by weak, upward flow in the slab window when it has fully developed (Fig. 4). Slab windows inferred to have existed south 49.5°S that were associated with mid-Miocene ridge collisions did not produce similar sequences of main-plateau lavas.

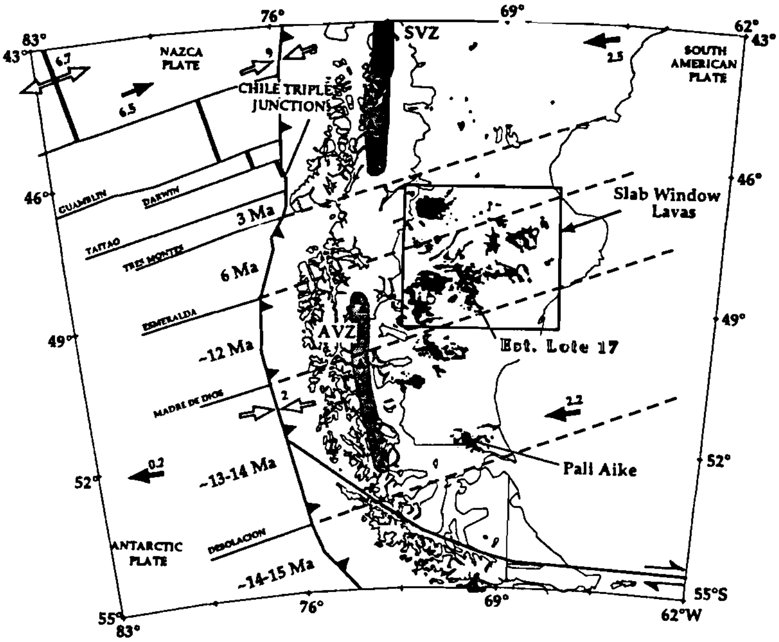

FIGURE 1 - Tectonic map of southern South America showing the distribution of Neogene slab window lavas (boxed area), and relative to other important tectonic features. Timing of ridge collisions (Cande and Leslie 1986) and projected borders of individual slab windows are shown (dashed lines). Important xenolith localities (Pali Aike and Estancia Lote 17) are also shown. Plate motion vectors (open = relative; filled = absolute) from Minster and Jordan (1978).

TRACE ELEMENT CONSTRAINTS ON SLAB WINDOW MELTING

Main- and post-plateau slab window lavas have OIB-like trace element characteristics ($(La/Yb)_n > 1$, La/Ta <20), are unlike MORB or SVZ arc lavas, and show little evidence for crustal contamination. Both sequences have similar incompatible trace element ratios (Th/La = 0.1 to 0.2, Th/U = 3 to 5), suggesting that the mantle source had relatively homogeneous trace element characteristics, therefore, trace element modeling can provide constraints on source region chemistry and spatial and temporal variations in melting percentages. In order to investigate source chemistry and chemical variability generated by melting percentages, trace element characteristics of these lavas are compared with nonmodal, incremental batch melting models (Fig. 2A-B). A trace element-enriched garnet lherzolite, with 2 to 3x chondritic trace element abundances was used as the source. Trace element content of magmas were corrected for crystal fractionation by adding equilibrium olivine and clinopyroxene until major element compositions were in equilibrium with olivine of Fo_{90}, and thus, represent the inferred trace element content of primary magmas. Fractionation-corrected samples match the trend of the melting model well, consistent with an enriched mantle source region with relatively homogeneous trace element characteristics (Fig. 2A).

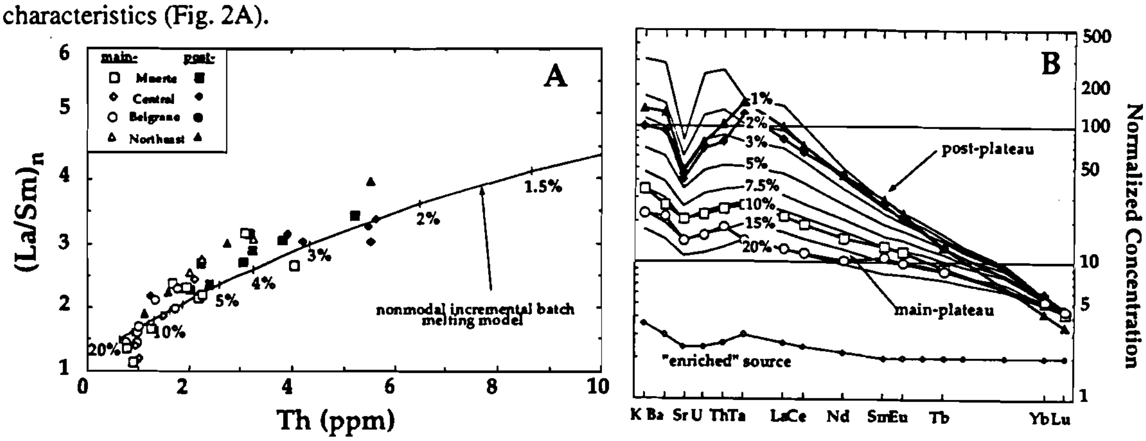

FIGURE 2A-B - Plots showing trace element systematics of fractionation-corrected slab window lavas compared to a nonmodal, incremental batch melting model. Samples in B from the Meseta de la Muerte.

Main- and post-plateau lavas show systematic temporal and spatial chemical variations (Fig. 2A) in a SW-NE transect across the backarc northeast of the 12 Ma ridge collision (Fig. 1). Main-plateau lavas from the southwest and central regions (Mesetas de la Muerte, Central, and Belgrano) can be modeled by the highest melting percentages (6 to 15%), whereas, post-plateau lavas can be modeled by much lower melting percentages (2 to 5%). In contrast, both sequences in the Northeast Region can be modeled by low to intermediate melt percentages (2 to 8%). Major elements (SiO_2, TiO_2, K_2O) correlate well with the trace element variations and with observed eruptive volumes. Depleted HREE signatures indicate garnet is an important residual phase, even at high melting percentages. Melting within the garnet stability field and FeO contents of 9 to 11.5 wt% are consistent with melt generation depths in the 70 to 100 km range based on experimental and theoretical studies in the literature.

ISOTOPIC CONSTRAINTS ON SLAB WINDOW MAGMA SOURCE REGIONS

Sr, Nd, and Pb isotopic ratios of southern Patagonian slab window lavas have strong affinities with southern hemisphere OIBs with positive Dupal Pb anomalies (Fig. 3A-B) that are interpreted to reflect the OIB-like mantle source. Ranges of isotope ratios are similar for main- and post-plateau lavas ($^{87}Sr/^{86}Sr$ = 0.7036 to 0.7047, ε_{Nd} = +4.8 to -0.5, $^{206}Pb/^{204}Pb$ = 18.28 to 18.87, $^{207}Pb/^{204}Pb$ = 15.58 to 15.65, and $^{208}Pb/^{204}Pb$ = 38.2 to 38.8). Regionally distinctive features are higher $^{87}Sr/^{86}Sr$ and lower ε_{Nd} and $^{206}Pb/^{204}Pb$ ratios than for both Neogene slab window lavas from the Antarctic Peninsula (Hole et al. 1995), and Plio-Pleistocene lavas from Pali-Aike (Fig. 1; Stern et al. 1990). Patagonian slab window lavas also have lower $^{87}Sr/^{86}Sr$ ratios at a given ε_{Nd} than most mafic arc lavas of the southern SVZ (Lopez-Escobar et al. 1993), consistent with the lack of significant contamination by subduction-related fluids. Evidence for crustal components is also lacking in that Sr and Nd isotope ratios do not correlate with parameters sensitive to crustal processes (i.e. SiO_2, MgO, Th/La). However, both main- and post-plateau lavas from the east-central backarc have consistently lower $^{206}Pb/^{204}Pb$ ratios than lavas from the western backarc (Fig. 3B). This may reflect minor assimilation of lower crustal components that have distinct Pb isotopic compositions due to variations in basement age. The lack of evidence for large amounts of crustal components indicates that the OIB isotopic signature of these lavas is subcrustally derived. Based on the relatively "depleted" Sr-Nd isotopic signature of southern Patagonian mantle xenoliths thought to represent the lithosphere (Stern et al. 1989; Fig. 3A), the "enriched", OIB-like signature is most likely derived from the asthenosphere.

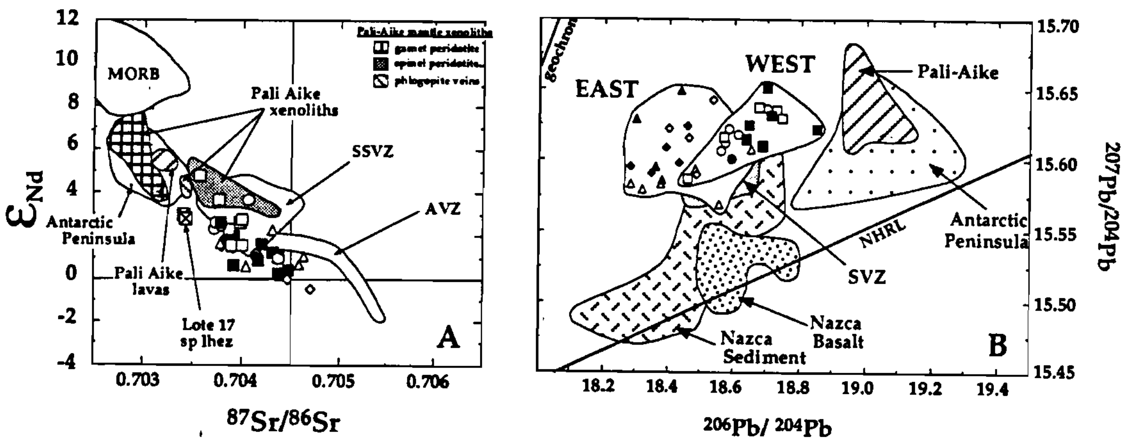

FIGURE 3A-B - Plots showing Sr, Nd, and Pb isotopic data for slab window lavas (symbols as in Fig. 2). Fields for other volcanics and lithospheric xenoliths are from the literature and our unpublished data. NHRL is the Northern Hemisphere Reference Line.

IMPLICATIONS FOR THE SOUTHERN PATAGONIAN SLAB WINDOW MODEL

The geochemical data fit a slab window model in which main-plateau lavas track the passage of the trailing Nazca Plate edge and are produced by strong asthenospheric flow (Fig. 4). Spatial and temporal variations in major and trace elements document a northeastward decrease in percent partial melting, total volumes of melt produced, and average depth of melting that generated the main-plateau sequence. This is consistent with 1) thicker lithosphere beneath the eastern backarc, and 2) suppression of slab window flow as the plate edge is subducted to greater depths. Post-plateau lavas erupt when the slab window is fully developed and are produced by weaker, residual slab window flow (Fig. 4) and show little significant spatial or temporal variation, suggesting that percentages and depths of melting were similar across the backarc. Based on trace element modeling and FeO contents, and estimates of lithospheric thicknesses, melt generation and final equilibration would have occurred in the asthenosphere, at depths of 70 to 100 km. Thus, the Sr, Nd, and Pb isotope ratios of southern Patagonian slab window lavas are interpreted to reflect a dominant OIB-like, asthenospheric source. Two models could explain OIB-like asthenospheric mantle beneath southern Patagonia: 1) the entrainment of a pre-existing, weak plume-like feature (Fig.

4), or 2) ambient OIB-like asthenosphere. The plume entrainment model simultaneously solves the OIB-like asthenospheric chemistry, high temperatures required for anhydrous, high-P magma generation, the large volumes of high percentage melts, and the lack of mid-Miocene slab window lavas south of 49.5°S. In contrast, an ambient OIB-like asthenosphere model eliminates the need for plumes, but requires a H_2O- or CO_2-bearing mantle source to produce melts of peridotite at normal mantle temperatures. In this case, asthenosphere south of 49.5°S would have been relatively cool and dry compared to the north in order to explain the lack of mid-Miocene slab window lavas there.

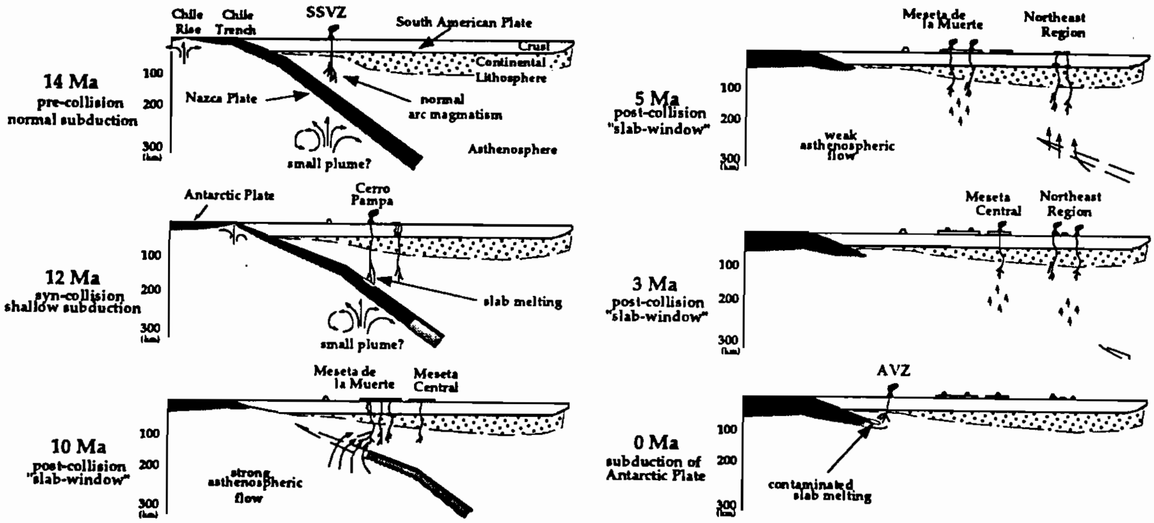

FIGURE 4 - Cross-sections showing slab window magmatic evolution for the region northeast of where the Chile Rise collided at 12 Ma. Active and inactive main- and post-plateau sequences are shown as filled and open surface features, respectively (rectangles = main-plateau; cones = post-plateau).

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