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Miocene to Late Quaternary Patagonian basalts (46–47°S): Geochronometric and geochemical evidence for slab tearing due to active spreading ridge subduction

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Abstract

Miocene to Quaternary large basaltic plateaus occur in the back-arc domain of the Andean chain in Patagonia. They are thought to result from the ascent of subslab asthenospheric magmas through slab windows generated from subducted segments of the South Chile Ridge (SCR). We have investigated three volcanic centres from the Lago General Carrera–Buenos Aires area (46–47°S) located above the inferred position of the slab window corresponding to a segment subducted 6 Ma ago. (1) The Quaternary Río Murta transitional basalts display major, trace elements, and Sr and Nd isotopic features similar to those of oceanic basalts from the SCR and from the Chile Triple Junction near Taitao Peninsula (e.g., $(^{87}Sr/^{86}Sr)_o = 0.70396–0.70346$ and $\varepsilon Nd = +5.5 - +3.0$). We consider them as derived from the melting of a Chile Ridge asthenospheric mantle source containing a weak subduction component. (2) The Plio-Quaternary (<3.3 Ma) post-plateau basanites from Meseta del Lago Buenos Aires (MLBA), Argentina, likely derive from small degrees of melting of OIB-type mantle sources involving the subslab asthenosphere and the enriched subcontinental lithospheric mantle. (3) The main plateau basaltic volcanism in this region is represented by the 12.4–3.3-Ma-old MLBA basalts and the 8.2–4.4-Ma-old basalts from Meseta Chile Chico (MCC), Chile. Two groups can be distinguished among these main plateau basalts. The first group includes alkali basalts and trachybasalts displaying typical OIB signatures and thought to derive from predominantly asthenospheric mantle sources similar to those of the post-plateau MLBA basalts, but through slightly larger degrees of melting. The second one, although still dominantly alkalic, displays incompatible element signatures intermediate between those of OIB and arc magmas (e.g., La/Nb > 1 and $TiO_2 < 2$ wt.%). These intermediate basalts differ from their strictly alkalic equivalents by having lower High Field Strength Element (HFSE) and higher εNd (up to +5.4). These features are consistent with their derivation from an enriched mantle source contaminated by ca. 10% rutile-bearing restite of altered oceanic crust. The petrogenesis of the studied Mio-Pliocene basalts from MLBA and MCC is consistent with contributions of the subslab

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asthenosphere, the South American subcontinental lithospheric mantle and the subducted Pacific oceanic crust to their sources. However, their chronology of emplacement is not consistent with an ascent through an asthenospheric window opened as a consequence of the subduction of segment SCR-1, which entered the trench at 6 Ma. Indeed, magmatic activity was already important between 12 and 8 Ma in MLBA and MCC as well as in southernmost plateaus, i.e., 6 Ma before the subduction of the SCR-1 segment. We propose a geodynamic model in which OIB and intermediate magmas derived from deep subslab asthenospheric mantle did uprise through a tear-in-the-slab, which formed when the southernmost segments of the SCR collided with the Chile Trench around 15 Ma. During their ascent, they interacted with the Patagonian supraslab mantle and, locally, with slivers of subducted Pacific oceanic crust that contributed to the geochemical signature of the intermediate basalts.

Keywords: slab window; slab tear; plateau basalts; alkali basalts; ridge subduction; Patagonia

1. Introduction

Neogene and Quaternary magmatic activity in the Patagonian Andes displays numerous specific features which can be related to the subduction of the segmented South Chile Ridge (SCR) beneath the South American plate. During the last 15 Ma, the location of this ridge subduction (the Chile Triple Junction, CTJ) migrated northwards as a result of the oblique collision between the Chile ridge and the South American margin (Herron et al., 1981; Cande and Leslie, 1986; Cande et al., 1987; Nelson et al., 1994; Bangs and Cande, 1997; Tebbens and Cande, 1997; Tebbens et al., 1997). The present location of the CTJ, ca. 50 km north of the Taitao Peninsula (Fig. 1A), is marked by near-trench magmatic activity (Forsythe and Nelson, 1985; Forsythe et al., 1986, 1995; Lagabrielle et al., 1994, 2000; Bourgois et al., 1996; Guivel et al., 1999, 2003) and a corresponding gap in the Andean calc-alkaline volcanic belt between the southern part of the Southern Volcanic Zone (SSVZ, 41°15′–46°S) and the Austral Volcanic Zone (AVZ, 49–54°S) (Stern et al., 1990; Ramos and Kay, 1992). East of the Andean chain, the Patagonian back-arc domain is characterised by numerous Neogene basaltic plateaus (Mesetas), the emplacement of which does not seem to be connected either with back-arc extension or with a topographic swell or hotspot track (Ramos and Kay, 1992). Numerous authors (Ramos and Kay, 1992; Kay et al., 1993; Gorring et al., 1997, 2003; D'Orazio et al., 2000, 2001, 2003; Gorring and Kay, 2001) have proposed that these basaltic magmas were produced by melting of subslab asthenospheric mantle upwelling through slab windows generated from subducted ridge segments (Dickinson and Snyder, 1979; Thorkelson, 1996; Murdie and Russo, 1999). Especially, Gorring et al. (1997) and Gorring and Kay (2001) pointed out that the spatial distribution, ages and chemistries of the Neogene basaltic plateaus of Southern Argentina fit apparently with the locations of asthenospheric windows which opened successively when segments of the Chile ridge bounded by large fracture zones (FZ) were subducted. Fig. 1B shows that the subduction of these various segments, according to their magnetic anomaly patterns, started at ca. 15–14 Ma (SCR-4, south of Desolación FZ), 14–13 Ma (SCR-3, south of Madre de Dios FZ), 12 Ma (SCR-2, south of Esmeralda FZ), 6 Ma (SCR-1, between Esmeralda and Tres Montes FZ), 3 Ma (SCR0, between Tres Montes and Taitao FZ) and finally 0.3 Ma (SCR1, north of Taitao FZ), respectively (Cande and Leslie, 1986; Forsythe et al., 1986).

In this paper, we test this model using new geochronometric (K–Ar) and geochemical (major, trace element and Sr and Nd isotopic data) on basalts from the Lago General Carrera–Buenos Aires area (46–47°S) in southern Patagonia. This area is located at the latitude of the present Chile Triple Junction position (Fig. 1B), along the Chile–Argentina border, south of Mt. Hudson, the southernmost active volcano of the SSVZ. As shown in Fig. 1B, it overlies the SCR-1 slab window present position inferred from magnetic anomalies (Cande and Leslie, 1986; Tebbens et al., 1997; Lagabrielle et al., 2000). Three Miocene to Quaternary basaltic complexes are exposed in this area on both sides of the Argentina/Chile border (Fig. 1C): Meseta Chile Chico (Chile) which is capped by a basaltic pile dated back to 8.2–4.4 Ma (Espinoza et al., 2005), Meseta del Lago Buenos Aires (Argentina) for which available K–Ar and Ar–Ar ages range from 10.0 to 0.76 Ma (Ton-That et al., 1999) and 10.1 Ma to <110 ka (Brown et al., 2004), and finally Río Murta (Chile) subglacial basalts, previously considered Holocene (Demant et al., 1994, 1998; Corgne et al., 2001). We will show that the timing and geochemistry of most of these basaltic eruptive events do not fit with the hypothesis of their derivation from the subslab asthenospheric mantle from the SCR-1 fragment, and that alternative models of opening of asthenospheric windows or tears-in-the-slab need to be envisioned.