Geochronology and geochemistry of the Miocene to Recent Patagonian basalts (46-47°s): Evidences for slab tearing due to active spreading ridge subduction

Christèle Guivel [1], Diego Morata [2], Ewan Pelleter [3,4], Felipe Espinoza [2], René C. Maury [3], Yves Lagabrielle [5], Mireille Polvé [6], Hervé Bellon [3], Joseph Cotten [3], Mathieu Benoit [3], Manuel Suárez [7], & Rita De La Cruz [7]

[1] UMR 6112, Université de Nantes, 12 rue de la Houssinière, 44322 Nantes, France
[2] Departamento de Geología. Plaza Ercilla 803. Santiago, Chile
[3] UMR 6538, UBO-IUEM, place Nicolas-Copernic, 29280 Plouzané, France
[4] CRPG - CNRS UPR A2300, BP 20, 54501 Vandoeuvre-les-Nancy, France
[5] UMR 5573, Place E. Bataillon, case 60, 34095, Montpellier Cedex 5, France
[6] LMTG-OMP Toulouse (France) and IRD-Depto de Geologia, Universidad de Chile (Chile)
[7] Servicio Nacional de Geología y Minería, Avda. Santa María 0104, Santiago, Chile

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Introduction

Miocene to recent 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 and the northwards migration during the last 15 Ma of the Chile Triple Junction (CTJ) as a consequence of the oblique collision between the SCR and the South American margin (*e.g.* Tebbens *et al.*, 1997, among others). The present location of the CTJ, *c.* 50 km north of the Taitao Peninsula (Fig. 1a), is marked by near-trench magmatic activity (*e.g.* 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) and the Austral Volcanic Zone (AVZ) (*e.g.* Stern et al., 1990). East of the Andean chain, the Patagonian back-arc domain is characterised by numerous Neogene basaltic plateaus (Mesetas, Fig. 1a). Numerous authors (*e.g.* Ramos & Kay, 1992; Kay *et al.*, 1993; Gorring *et al.*, 1997, 2003; Gorring & Kay, 2001; D'Orazio *et al.*, 2000, 2001) have proposed that these basaltic magmas were produced by melting of sub-slab asthenospheric mantle upwelling through slab windows generated from subducted ridge segments, as suggested by their spatial distribution, ages and chemistries.

In this work we present new geochronological (K-Ar) and geochemical (major, trace element and Sr-Nd isotopic data) on Miocene to recent basalts from the Lago General Carrera-Buenos Aires area –LGCBA- (46-47°S and 70-73°W) in southern Patagonia. This area is located within the modern volcanic arc gap, at the latitude of the present CTJ position (Fig. 1b), along and East of the Chile-Argentina border, south of Mt. Hudson (the southernmost active volcano of the SSVZ) and north of the 12 Ma old Cerro Pampa adakite (Kay *et al.*, 1993). The Miocene to recent magmatic rocks investigated (Fig. 1c), which emplaced over and/or intruded into Palaeozoic to Plio-Quaternary units, come from: (i) Rio Murta, (ii) Meseta del Lago de Buenos Aires (MLBA), and (iii) Meseta de Chile Chico (MCC).

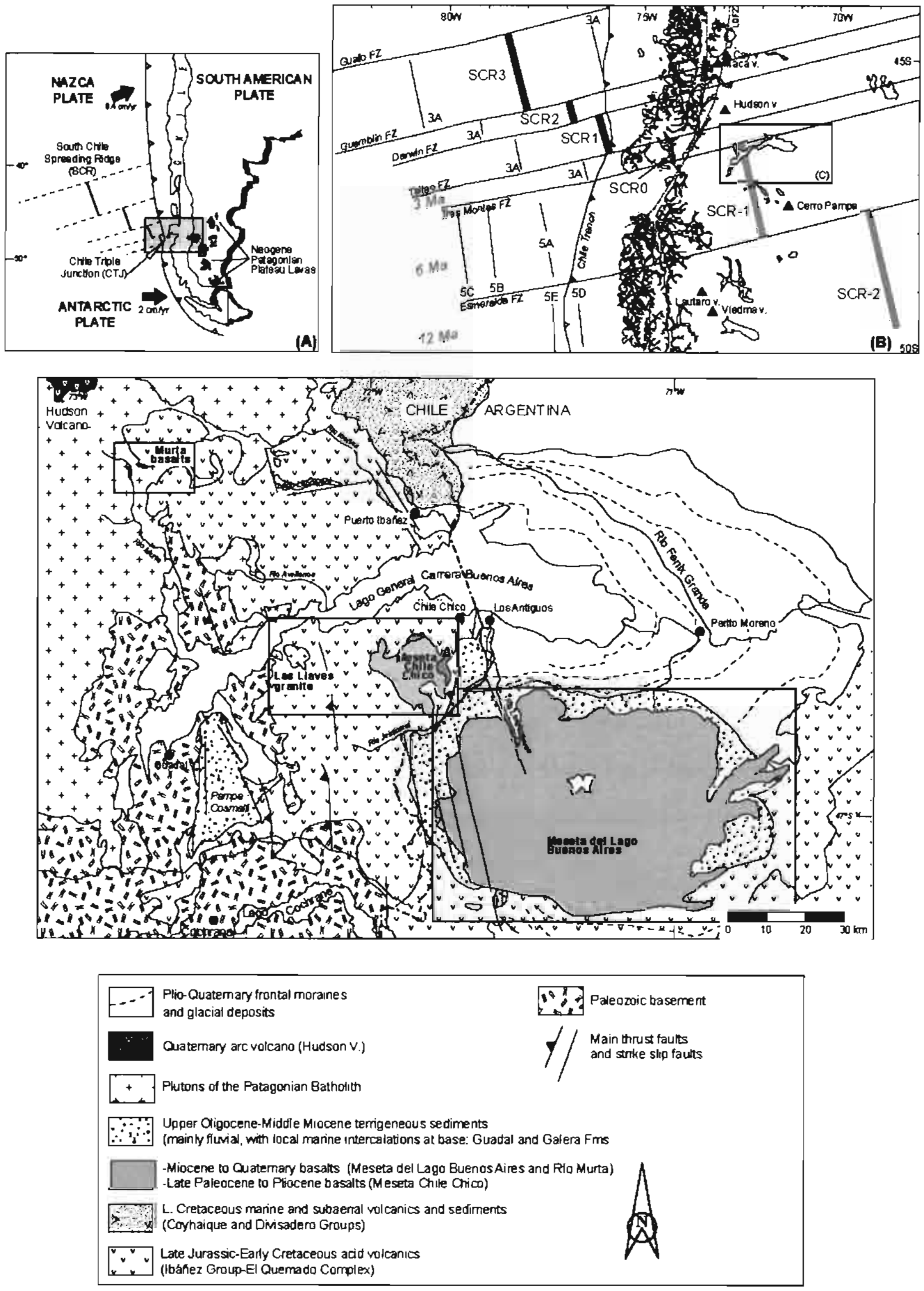

Figure 1. Geological setting of the studied volcanic rocks. - (A) Simplified tectonic sketch map of the present day CTJ showing the location of the studied area and the motions of the Nazca and Antarctic plates with respect to the South American Plate. (B). Simplified map of the CTJ area and location of the fracture zones (FZ) and active segments of the SCR indicating the ridge collision ages and the present-day inferred locations of subducted active ridges (SCR0, SCR-1, SCR-2) (simplified from Guivel et al., 1999; Lagabrielle et al., 2004). Black triangles: southernmost volcanoes of the South Volcanic Zone (SVZ); grey triangles: northernmost volcanoes of the Austral Volcanic Zone (AVZ). (C) Simplified geological map of the LGCBA showing the location of the studied areas in which Neogene and Quaternary volcanic rocks are located (modified from Lagabrielle et al., 2004).

K-Ar geochronology, geochemistry and petrogenesis

The Quaternary Rio Murta transitional basalts display major, trace elements, and Sr Nd isotopic features similar to those of oceanic basalts from the SCR and from the CTJ near Taitao Peninsula (($^{87}Sr/^{86}Sr)_o$ = 0.70396-0.70346 and εNd = +5.5 - +3.0). We consider them as derived from the melting of a Chile Ridge asthenospheric mantle source containing a weak subduction component.

The main plateau basalts of the MLBA and MCC were formed from 12.4 to 3.3 and 8.2 to 4.4 Ma, respectively. In spite of the petrographic homogeneity showed in basalts from these two thick basaltic sequences, two different geochemical groups may be identified. The first one includes alkali basalts and trachybasalts from both mesetas as well as the Plio-Quaternary (<3.3 Ma) post plateau basanites from MLBA, previously study by Gorring *et al.* (2003). This group displays typical OIB signatures and thought to derive from small degrees of melting of OIB-type mantle sources involving the subslab asthenosphere and enriched subcontinental lithospheric mantle sources similar to those of the post plateau MLBA basalts. The second group is only present in the main plateau of MLBA and MCC. They are dominantly alkali basalts, displaing 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 alkalic equivalents by their HFSE-depleted character and their higher εNd (up to +5.4). We ascribe these specific features to their derivation from an enriched mantle source contaminated by *c.* 10% rutile-bearing restite of altered oceanic crust, likely derived from the edges of the slab window.

Slab tearing *vs* slab window model

The petrogenetic features of the Mio-Pliocene basalts from MLBA (main plateau) and MCC suggest the contribution of the deep enriched subslab asthernosphere, the South American subcontinental lithospheric mantle and the subducted oceanic crust. All these features would be consistent with a slab window model as previously developed by Ramos & Kay (1992), Kay *et al.*, (1993), Gorring *et al.* (1997, 2003) and Gorring & Kay (2001). Nevetheless, the chronology of emplacement of main plateau basalts from MLBA (12.4-3.3 Ma) and MCC (8.2-4.4 Ma) is inconsistent with their ascent through an asthenospheric window opened as a consequence of the subduction of the Chile Ridge segment SCR-1 which entered the trench at 6 Ma (see Fig. 1b). This fact allows us to question the slab window model on in which the plateau Neogene basaltic magmas would ascended through asthenospheric windows which opened successively when segments SCR-4, SCR-3, SCR-2 and finally SCR-1 of the Chile ridge were subducted. With the available geochronological and geochemical data, we propose an alternative model in order to explain the distribution and geochemistry of MLBA and MCC basalts. In our preferred geodynamic model, OIB and intermediate magmas of MLBA and MCC, as well as those of other Patagonian plateaus (*e.g.* Mesetas Belgrano, Central, de la Muerte and the Northeast volcanic region) would ascended within a depth tear-in-the-slab, subparallel to the trench, which would formed when the southernmost segments of the SCR collided with the Chile Trench around 15 Ma. OIB-type magmas would be then generated by the partial melting of the sub-slab asthenosphric mantle, ascent through the tear-in-the-slab and, finally, emplaced in the back-arc domain between 52 and 46°S.

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