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Possible sources for monogenetic Pliocene–Quaternary basaltic volcanism in northern Patagonia

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ABSTRACT

The Pliocene- Quaternary times in Extra-Andean Patagonia are characterized by the effusion of intraplate basalts. This work is focused on those basalts outcropping between 40° and 46°S. The age of this volcanism varies between 0.23 and 5 Ma.

Based on the general geochemical characteristics, geographic distribution, and structural framework of the region, we propose that the basalts originated in response to the back arc extension that caused the thinning, doming and fracturing of the lithosphere, and extrusion of mafic magmas with a relatively primitive nature and OIB-like compositions. The geochemical characteristics allow to distinguish three types of basalts: basanites, alkaline basalts and tholeiitic basalts, each one representing different sources and percentages of partial melt and implying a heterogeneous source. A source with these characteristics could be the lithospheric mantle.

1. Introduction

The Plioene-Quaternary basalts in Northern Patagonia are distributed along a 450 km belt extending from 40°S to 46°S, located at a distance of 200–550 km away from the trench of the active subduction zone between the Farallón-Nazca and South America plates. The ages of these rocks range from 5 to 0.23 Ma (Table 1) (Bruni, 2004; Péckscay et al., 2007; Haller et al., 2009). This volcanic belt is composed of several low-volume monogenetic volcanic fields or basaltic lava flows. Some of them have been well documented while others are poorly known. Previous studies on these volcanic fields have been done mainly by Ravazzoli and Sessana (1977), Nullo (1978, 1983), Stern et al. (1990), Cucchi et al. (2001), Bruni (2004), Massaferro et al. (2006) and Pécskay et al. (2007).

In this study, we focus on the less known basalt occurrences. This paper presents field observations, data on petrography and major and trace element compositions, Sr isotopic ratios, K/Ar ages and discusses the petrogenesis of the basaltic rocks and their geodynamic significance.

Three types of volcanic centers were recognized: (1) smaller volcanic plateaus formed by the coalescence of basaltic shield volcanoes (Cerro Fermin, Crater Basalt Volcanic Field); (2) polygenic volcanic complexes and monogenetic volcanoes (Cerro Antitruz, Crater Basalt Volcanic Field, Cerro Pillahuinco Chico) and (3) cinder cones and isolated valley-filling lava flows (Cerro Horqueta, Comallo area). South of 46°S, the Quaternary Extra Andean basalts have been related to an asthenospheric slab window formed after the collision of different segments of the Chile Ridge with the subduction zone (e.g. Ramos and Kay, 1992; Gorring et al., 1997; D'Orazio et al., 2000; Gorring et al., 2003; among others). To the north, between 38°S and 39°S, there are several Plio-Pleistocene volcanic fields attributed to an extension in the back-arc caused by the steepening of the Nazca plate after a period of shallow subduction (Kay et al., 2004, 2006; Folguera et al., 2007, 2008; Søager et al., 2013). To the east, the Somuncura plateau, formed by a large volume of Tertiary volcanic rocks, is composed mainly of alkaline and tholeitic basalts. There are many hypotheses about the origin of this plateau and they will be discussed later.

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Table 1
Whole rock K/Ar ages of Plio-Pleistocene basalts from Northern Patagonia.

Sample	Location	Latitude	Longitude	Age K/Ar	Ref
P 22	Quetrequile	−41.76585	−69.35825	1.3 ± 0.28	
P 20	Moreniyeu	−42.26238	−69.28802	1.55 ± 0.08	
PA-10	Pampa de Agnia	−43.67003	−69.88736	2.49 ± 0.1	
MS 74	Pampa de los Guanacos	−45.25665	−68.95487	2.69 ± 0.09	
MS72	Pampa de los Guanacos	−45.27492	−68.83270	2.89 ± 0.11	
P 8	Mamuel Choique	−41.53413	−70.28500	4.9 ± 0.17	
P 9	Mamuel Choique	−41.76830	−70.15598	5.65 ± 0.21	
GS 10	Río Chico	−42.05513	−70.46728	0.32 ± 0.06	Pécskay et al., 2007
GS 7	Río Chico	−42.05513	−70.46373	0.36 ± 0.13	Pécskay et al., 2007
GS 8	Río Chico	−42.05650	−70.46463	0.23 ± 0.10	Pécskay et al., 2007
GS 4	Eroded scoria cone	−42.07073	−70.16670	1.04 ± 0.43	Pécskay et al., 2007
GS 5	C. Fermín	−42.01907	−70.19487	0.58 ± 0.31	Pécskay et al., 2007
GS 6	C. Fermín	−42.01807	−70.18685	0.61 ± 0.24	Pécskay et al., 2007
PA 382	Sierra de San Bernardo	−45.45389	−69.67139	3.79 ± 0.32	Bruni 2004
PA 400	C. Grande	−45.19806	−69.97333	2.87 ± 0.68	Bruni 2004
PA 421	M. Pedrero	−45.29583	−70.20444	2.71 ± 0.10	Bruni 2004
PA 380	Sierra de San Bernardo	−45.50694	−69.34806	2.65 ± 0.14	Bruni 2004
PA 409	C. Chenques	−44.86917	−70.10806	2.49 ± 0.18	Bruni 2004
PA 406	C. Chenques	−44.87056	−70.07083	2.26 ± 0.11	Bruni 2004
PA 390	C. Ante	−44.71056	−70.77028	1.46 ± 0.20	Bruni 2004

2. Methodology

Only samples without xenoliths and xenocrysts and without alteration were analyzed. The more common and representative type of basalt was selected for each volcanic field. Whole rock major and trace elements (Table 2) were determined using lithium tetraborate fusion at the Activation Laboratories, Ancaster, Ontario, Canada. Major elements and some trace elements (V, Ni, Zn, Rb, Ba, Sr, Y, Ga, Nb, La, Ce and Zr) were determined by inductively coupled plasma-optical emission spectrometry, whereas other trace elements (REE, Th, U, Ta, Nb and Hf) were analyzed using a Perkin Elmer Optima 3000 inductively coupled plasma mass spectrometer. Based on replicate analyses, the precision is generally between 2 and 10% for trace elements and 3–5% for major elements. $^{87}Sr/^{86}Sr$ isotopic ratios of whole rocks were determined in Activation Laboratories, Ancaster, Ontario, Canada. Rb and Sr were separated using conventional cation-exchange techniques. The analyses were performed on a multi-collector mass-spectrometer (TIMS) in static mode.

K/Ar age determinations have been performed at ATOMKI, Hungary following the procedures described in Pécskay and Molnár (2002): Samples were crushed and sieved to 250-100 μm. For Ar determination a portion of sieved fraction was washed with distilled water and dried for 24 h. A portion of the whole rock sample was ground with a mortar and the powder obtained was used to analyze K and Ar. For K determination, finely ground samples were digested in acids and finally dissolved in HCl. Potassium was determined by flame photometry with a Na buffer and a Li internal standard. The measurements were checked using the inter-laboratory standards Asia 1/65 m KO-6, HD-B1 and GL-O. The analytical uncertainty is better than 2%. Argon was extracted from the samples by RF fusion in Mo crucibles. ^{39}Ar spike was added from gas pipette system and the evolved gases were cleaned using Ti and SAES getters and liquid nitrogen traps. The purified Ar was transported into the mass spectrometer and the Ar isotope ratios were measured in static mode, using a 15 cm magnetic sector type mass spectrometer.

3. Geological and structural setting

The studied area comprises the Extra Andean region of Argentina between 40° and 46°S (Fig. 1). The northern part is located between the Somuncura Massif to the east and the Precordillera Patagónica to the west, while the southern edge is located in the area of the Golfo San Jorge Basin. Within this sector, many isolated Quaternary volcanic fields or lava flows are poorly known and had been included in this work, (Fig. 2). Some of them are located about 200 km away from the present magmatic arc and 100 km from the Liquiñe-Ofqui fault zone (LOFZ), while the easternmost outcrops are nearly 550 km from the arc and 200 km from the LOFZ.

The subduction rate of the Nazca Plate is about 7–9 cm/year with an oblique component (DeMets et al., 1990; Norabuena et al., 1998) and a subduction dip angle of 15°–20° (Belmonte-Pool and Comte, 1997). The age of the oceanic subducting plate at 41°S is 15–20 Ma (Müller et al., 1997). The Liquiñe-Ofqui fault zone is a major feature of the Southern Andes developed as a consequence of the oblique subduction of the Nazca Plate beneath the South American Plate and extends from 38° to 46.5°S. It is an active dextral strike slip fault zone that comprises a set of intra arc lineaments that seem to control the Quaternary volcanoes within the arc (Cembrano and Lara, 2009).

The studied area is limited in the east by the Somuncura plateau that is a huge late Oligocene-early Miocene volcanic mainly composed of alkaline and tholeiitic basalts and minor siliceous volcanic rocks (Remesal, 1988; Kay et al., 1993; Mahlburg Kay et al., 2007 and references therein). The Paleozoic igneous metamorphic basement of the region is covered by Jurassic silicic and intermediate volcanics and Cretaceous-Tertiary sedimentary rocks. The structure in this region is controlled by extensional tectonics that formed blocks and half-grabens (Ciciarelli, 1990). The orientation of the main fractures are E–W, NE–SW and NW–SE. The Gastre (N55°W, N55°E) and Comallo (N15°W, N35°E) fault systems are interpreted by Coira et al. (1975) to be ancient basement fractures.

The western limit of the area is the Chubut Precordillera composed of Carboniferous-Early Jurassic sedimentary rocks intruded by Jurassic granitoids and covered by Tertiary volcanics.

The southern part of the study area belongs to the San Jorge Gulf Basin. This is an intracratonic extensional Cretaceous basin that underwent a tectonic inversion (Homovc et al., 1995) during the Tertiary resulting in the formation of fold structures such as the San Bernardo range. The main features that originates the basin shows an E–W orientation. During the Tertiary, profuse basaltic eruptions gave rise to the Canquel plateau that cap the San Bernardo range (Bruni et al., 2008). The basement in this area is composed of several pre Cretaceous lithologic types from Paleozoic granites, metamorphic and sedimentary rocks, Permo-Triassic igneous, sedimentary and pyroclastic rocks and middle to late Jurassic volcanic–sedimentary complexes (Sylwan, 2001).

4. General characteristics of the volcanic fields

As it was mentioned above, several small volcanic fields, lava flows or spatter/cinder monogenetic cones have been included in this work. Sampled localities include: Pampa de los Guanacos, Pampa de Agnia, Moreniyeu, Lipetrén, Mamuel Choique, Quetrequile, Huahuel Niyeu, Comallo, Cerro Horqueta, Trayén Niyeu, El