



Puna (Argentina) and northern Chile Ordovician basic magmatism: A contribution to the tectonic setting

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ABSTRACT

Geochemical characteristics of Ordovician basic volcanic rocks help to define the evolving tectonic setting of the Argentine Puna and northern Chile. Four spatially distinct magmatic groups are defined on geological, petrographical, geochemical and isotopic bases, each associated with particular geodynamic environments.

The Tremadoc western group of subalkaline low K tholeiites with arc and modified MORB like signatures represent early stages of a back-arc basin, where spreading was incipient.

The Arenig western group, medium K calc-alkaline basalts to andesites have volcanic arc in transition to back-arc signatures.

The Tremadoc subalkaline basalts of the eastern group have REE patterns similar to E-MORB and at the same time weak subduction characteristics suggesting a rather mature supra-subduction zone (SSZ) basin. In contrast, the Late Tremadocian-Arenig basalts of the same group have intra-plate signatures, interpreted as magmas that ascended along pull apart regions associated with a transtensional regime.

The geochemical patterns were applied to correlate basic sequences of doubtful geological setting. So, basalts from Chile were related to the Tremadocian western group, where they represent a slightly more mature stage of spreading of the basin. Basic rocks from Pocitos and part of Calalaste represent pre-Ordovician records of a back-arc system similar to that of the Tremadoc western group. Clearly similar arc patterns to those of the Arenig western group allow extending the arc environment to the southern Puna. The Tremadocian basalts from the eastern group were related to metabasites from the southern Puna, as part of a back-arc environment at that time.

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1. Introduction

The geodynamic evolution of southern Central Andes and particularly of the Puna during the Early Paleozoic has been the subject of continual debate. A popular postulate states that part of northwestern Argentina and northern Chile are allochthonous or parautochthonous terranes accreted to the southwestern Gondwana margin during the Late Proterozoic and Early Paleozoic (e.g., Coira et al., 1982; Dalziel and Forsythe, 1985; Ramos 1986; Ramos et al., 1986; Forsythe et al., 1993; Conti et al., 1996; Bahlburg and Hervé, 1997). More recently, Lucassen et al. (1999, 2000) on the basis of petrological similarities and age relationships in high grade basement units between 21° and 26° S postulated a wide “mobile belt” geodynamic scenario for the Late Proterozoic-Early Paleozoic development of what represents the present Andean continental

margin and what was then the continental margin of Gondwana. Also Bock et al. (2000), Zimmermann and Bahlburg (2003), Kleine et al. (2004) conclude that the geochemical and isotopic data support the homogeneous makeup of that margin, excluding allochthonous and parautochthonous accreted terranes.

Looking for additional constraints on the Early Paleozoic models, this paper focuses on the study of basic magmatic rocks to evaluate mantle characteristics beside the previous information on crustal nature and its evolution (Damm et al., 1986; Koukharsky et al., 1989; Becchio et al., 1999; Coira et al., 1999; Lucassen et al., 1999, 2001; Bock et al., 2000; Kleine et al., 2004).

A suite of basic magmatic rocks representing the Puna's Ordovician has been selected along transversal profiles between 22° and 26°30'S for petrological study. Their mineral, geochemical and isotopic compositions, textures and structures, deformation and metamorphism, together with their radiometric ages or paleontological correlations have been considered. Newly obtained data on established magmatic types have been interpreted with existing

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data on basic rocks of the region (e.g., Breitzkreuz et al., 1989; Damm et al., 1986, 1990; Coira and Koukharsky, 1991; Coira and Barber, 1989; Coira et al., 1999; Zimmerman, 1999; Becchio et al., 1999; Lucassen et al., 2001; Bock et al., 2000; Coira and Darren, 2002; Coira et al., 2005). Among the analyzed samples are an important number from the southern Puna, where amphibolite and greenschist facies metamorphic grade sequences containing magmatic rocks are in tectonic contact with Ordovician sedimentary successions. The geochemical inconsistencies among the analysis of magmatic rocks from these localities reflect their uncertain chronostratigraphic position. The magmatic typing obtained in this study provides a useful correlation tool.

New geological, petrographic, geochemical and isotopic data of the Puna basic Ordovician sequences presented in this paper, along with previous results contribute to constrain the origin and evolution of these magmas and help constrain a postulated geodynamic setting for the Puna and northern Chile region during the Early Paleozoic.

2. Geological setting

Ordovician magmatism has an extensive distribution in the Puna (see Fig. 1) with units as old as Early Tremadoc and with magmatism continuing and reaching its maximum expression in the Arenigian. The magmatic rocks comprise two submeridional striking magmatic belts known as Western Puna Eruptive Belt (Palma et al., 1986) and Eastern Puna Eruptive Belt (Méndez et al., 1972).

The western belt includes volcano-sedimentary sequences with trilobite faunas of Lower Tremadoc age (Moya et al., 1993), as well as others with trilobite, brachiopod and particularly graptofaunas of Arenig s.l. to Middle Late Arenig ages and of Early Llanvirn. Magmatic rocks are mainly dacite-rhyolite pyroclastics and lavas with less abundant basaltic to andesitic lavas associated with volcano-clastic turbiditic sequences (Coira and Barber, 1989; Coira et al., 1987; Koukharsky et al., 1989, 1996). Granite-granodiorite-monzo-diorite plutons also occur in this belt. The reported K/Ar, Ar/Ar and $^{207}\text{Pb}/^{206}\text{Pb}$ model ages (502–476 Ma, 450–440 Ma and 420–425 Ma, Palma et al., 1986; Mpodozis et al., 1983; Koukharsky et al., 2002; Blue et al., 2004) reflect at least three main magmatic episodes.

Lavas and subvolcanic intrusives of the Eastern Puna Eruptive Belt, in the north sector, are bimodal (dacitic lavas, hyaloclastites, domes-cryptodomes and minor basic-spilitic lavas, massive and in pillows (Coira and Koukharsky, 1991), with gabbro-basalt sills and dikes (Coira et al., 1999). They are associated with fossiliferous clastic sequences assignable to Late Tremadoc to Early-Middle Arenig, where they occur in the Magmatic-Sedimentary Cochino-Escaya Complex (Coira et al., 1999, 2004). Granitoids with U/Pb (476 Ma, Lork and Balhburg, 1993) and K/Ar (428 Ma, Linares and Gonzalez, 1990) ages belong to the northern portion of the belt. Towards 24°S, the Eastern Puna Eruptive Belt magmatism continues through a group of granitoids and orthogneisses with U/Pb and K/Ar ages of 500–462 Ma, 450–440 Ma and 420 Ma (Linares and Gonzalez, 1990; Lork and Balhburg, 1993; Lucassen et al., 2000). These plutons intrude medium to high grade metamorphic basement with Sm/Nd ages ca. 500 Ma and TDM (Depleted Mantle Model Ages) of 2.2–1.36 Ga (Becchio et al., 1999). Lithological and structural characteristics of the metamorphic basement allow Hongn (1994) to distinguish three belts: (a) a western belt with medium to high metamorphic facies which record three superimposed tectonic events; (b) a central belt characterized by low to very low-grade of metamorphism and evidence of two tectonic events and (c) an eastern belt with medium to high grade of metamorphic rocks and related granitoids. The Pachamama Igneous-

Metamorphic Complex name was proposed on a petrological basis by Viramonte et al. (1993) for these metamorphic and igneous sequences.

Also occurring in the southern Puna, to the south of Salar de Pocitos (as in Sierra de Calalaste) are mafic-ultramafic complexes originally assigned to ophiolitic successions (Allmendinger et al., 1982; Blasco et al., 1996). All of them have been interpreted by Zimmerman et al. (1999), who recognized their tectonic relation with Early Ordovician sedimentary sequences, to be remnants of a pre-Ordovician tectonomagmatic event with magmas having arc-back-arc signatures. This consideration, applied to Pocitos ultramafic (cumulatic) rocks intruded by the Pocitos Igneous Complex (PIC), is in agreement with the Proterozoic age indicated by Kleine et al. (2004) for them, on the basis of the low initial $^{87}\text{Sr}/^{86}\text{Sr}$ determined from the “contact blackwall” isochron significantly lower than those for the PIC. However in Calalaste, Seggiaro et al. (2002) define the Tramontana Basic-ultrabasic Complex as a group of basic to ultrabasic rocks, where at least the basalts are intercalated with sedimentary to volcanic Ordovician sequences (Arenig to Llanvirn and even Tremadoc), while the ultrabasic rocks and some of the gabbros have tectonic contacts.

3. Magmatic types, mode of occurrence and petrography

3.1. Ordovician basic rocks: selected suites of the Western Puna Eruptive Belt

3.1.1. Pinato and Lari

Sedimentary marine sequences bearing Early Tremadoc fossils (Moya et al., 1993; Koukharsky et al., 1996; Rao et al., 2000; Waisfeld et al., 2001) with an important volcanic component (rhyolitic to dacitic lavas, hyaloclastites and tuffs with minor basaltic rocks) crop out in Pinato and Lari creeks (W of Salar del Rincón, sites 6 and 7 in Fig. 1). These rocks are moderately deformed (Coira and Koukharsky, 2002). The sedimentary facies together with the fossiliferous content indicate a shallow marine environment in which submarine to partly subaerial volcanism took place. At Lari, a conglomerate and light colored sandstones with a marine Silurian fauna, unconformably overly the folded Tremadoc sequence.

The volumetrically subordinate mafic members correspond to several meter thick basalts conformably intercalated with a folded sedimentary volcanic sequence. They are composed of albitized and saussuritized plagioclase intergrowths with partly chloritized mafic minerals, abundant opaques and interstitial granophyre with frequent variolitic textures. Typical greenschist facies metamorphic mineralogy (chlorite, actinolite, albitized plagioclase) is incompletely developed.

Acid volcanic debris flows and volcanoclastic rocks associated with marls with an Arenigian trilobite and brachiopod fauna (Benedetto, 2001; Coira and Koukharsky, 2002) lies unconformably over the Tremadoc volcanics at Pinato creek.

3.1.2. Quebrada Honda

Mafic flows, sills and discordant bodies (0.80–70 m thick) are present in a low-grade metamorphic sequence of wackes, siltstones and shales with chert and limestone levels in Quebrada Honda (site 8 of Fig. 1). They are microgabbros and in some cases meladiorites and basalts and basaltic andesites. The more coarse grained facies are composed of clinopyroxene in ophitic to subophitic relation with albitized plagioclase. Granophyric aggregates (2–15%) used to be interstitial. Pigeonite shows partial inversion to hypersthene with exsolution of augite lamellae. Opaque oxides included in the clinopyroxene constitutes up to 10%. Basalts and basaltic andesites are aphyric to poorly porphyritic. Phenocrysts (up to 2%) are mostly of albitized plagioclase and scarce pigeonite

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