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The Early Andean subduction system as an analog to island arcs: Evidence from across-arc geochemical variations in northern Chile

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ABSTRACT

The Upper Jurassic volcanic rocks of the Pre-Cordillera and High Andes of northern Chile (26–31°S) represent a back-arc magmatic chain formed during an earlier stage of Andean subduction. After the Callovian, the back-arc basin gradually changed from marine to continental conditions and was characterized by basaltic to rhyolitic rocks erupted along two belts, parallel to the coeval arc. The western belt comprises the Picudo and Algarrobal formations, whereas the eastern belt comprises the Lagunillas Formation and the Quebrada Vicuñita Beds. New major and trace element data, along with whole rock Sr, Nd and Pb isotopes are presented for these volcanic belts and compared to the geochemical features of the Jurassic and Early Cretaceous arc magmatism. Ar–Ar and U–Pb ages constrain the back arc volcanism to have evolved between 163.9 ± 1.4 and 148.9 ± 1.2 Ma.
Rocks belonging to the western belt have steep multi-element patterns and low concentrations of HREE, suggesting the presence of garnet in the source, and a more radiogenic isotopic composition than the arc magmatism. Parental magmas of these back-arc lavas would have been generated through melting of a depleted mantle, although less depleted than the sub-arc mantle, and interacted with minor amounts of Paleozoic crust. The geochemical composition of the rocks belonging to the eastern belt is more heterogeneous and suggests involvement of different magmatic sources, including depleted mantle as well as an OIB-type mantle within the wedge. In spite the fact that the Jurassic Andean arc was built over a continental plate, the architecture of the volcanic chains and geochemical variations observed among the arc and back-arc rocks in northern Chile resemble those in modern island arcs, and thus support the hypothesis that early Andean subduction developed under extensional tectonic conditions.

1. Introduction

The onset of Andean Tectonic Cycle took place roughly at 200 Ma, after a stage of extension and rifting of the western margin of the South American continental plate due to arrested or very slow/oblique subduction during Late Permian to Early Jurassic (Charrier, 1979; Mpodozis and Ramos, 1989, 2008; Vásquez et al., 2011). The voluminous magmatism developed during the Jurassic to Early Cretaceous in the Coastal Cordillera of southern Peru and northern-central Chile was produced during multi-stage tectonic evolution, with episodes of transtension and extension, expressed in rocks associated to the Atacama Fault System (Grocott and Taylor, 2002; Pichowiak, 1994; Scheuber and González, 1999). The oblique subduction of the cold and dense Phoenix plate under the continent resulted in a roll-back of the oceanic plate, retreat of the trench and progressive thinning of the continental crust (Charrier et al., 2007; Grocott and Taylor, 2002 and references therein). This paleogeographic configuration was characterized by intensive volcanism and plutonism in the arc region (the present day Coastal Cordillera from 17° to 35°S), and along-strike back-arc extension to the east (Amilibia et al., 2008; Martinez et al., 2012; Mpodozis and Ramos, 1989; Vicente et al., 1982). The magmatism exposed in the Coastal Cordillera has been extensively studied, and led to the firm establishment of subduction-related arc magmatism with the upper mantle as the main source of arc magmas and little or no crustal contribution (Kramer et al., 2005; Lucassen et al., 2006; Oliveros et al., 2006, 2007; Palacios, 1978; Vergara et al., 1995). In contrast, volcanism in the back-arc domain, represented between 26° and 31°S by the Quebrada Vicuñitas Beds and the Lagunillas, Picudo

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and Algarrobal formations, has remained largely unexplored. Two possibilities have been proposed for the origin of volcanism to the interior of the main arc: a) the development of an inner arc (Ramos and Alemán, 2000) or b) an extensional back-arc chain (Charrier et al., 2007). Both hypotheses rely on very limited geochemical and petrological data.

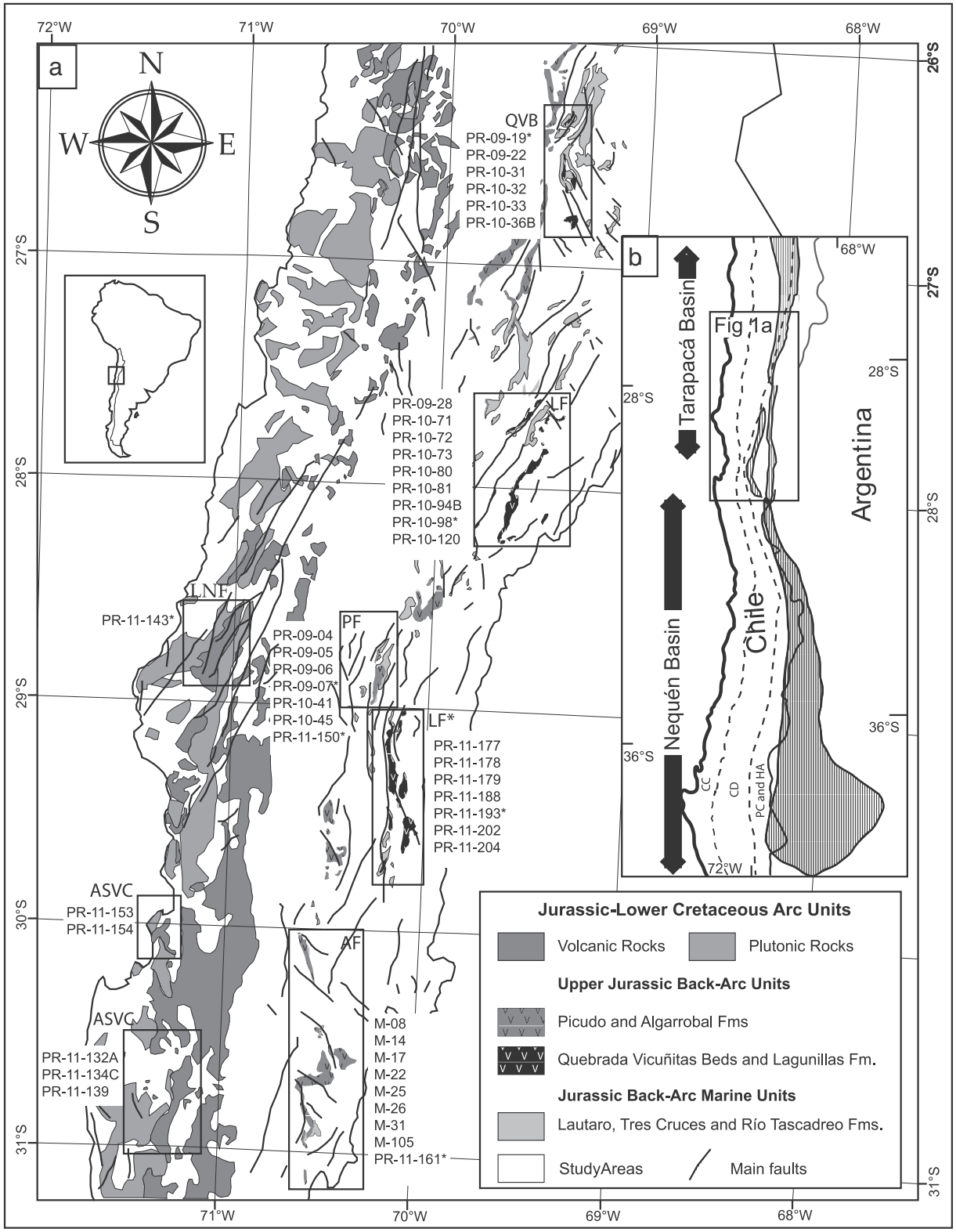

Fig. 1. a) Simplified geological map of the studied area, showing the location of the studied units. QVB: Quebrada Vicuñita Beds. LF: Lagunillas Formation. LF*: Lagunillas Formation-like rocks assigned to other units. PF: Picudo Formation. AF: Algarrobal Formation. ASVC: Agua Salada Volcanic Complex. LNF: La Negra Formation. Sample PR-11-161 belongs to the Los Cuartitos Sequence, included by Martin et al. (1995) as part of the Jurassic back-arc. Samples with "*" have radiometric ages. b) Schematic location of the back-arc basins (hatched areas) during the Jurassic between 24°30′ and 39°30′. Segmented line separates three principal geomorfological domains: Costal Cordillera (CC) to the west, Central Depression (CD) in the middle and Precordillera (PC) and High Andes (HA) to the east.
a) Map modified after SERNAGEOMIN (2003). b) modified after Vicente (2006).