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Petrology of mafic and ultramafic layered rocks from the Jaboncillo Valley, Sierra de Valle Fértil, Argentina: Implications for the evolution of magmas in the lower crust of the Famatinian arc

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ABSTRACT

This work presents the field setting, petrography, mineralogy and geochemistry of a gabbroic and peridotitic layered body that is lens-shaped and surrounded by gabbronorites, diorites, and metasedimentary migmatites. This body exposed at Jaboncillo Valley is one among several examples of mafic and ultramafic layered sequences in the Sierras Valle Fértil and La Huerta, which formed as part of the lower crust of the Ordovician Famatinian magmatic arc in central-western Argentina. The layered sequence grew at deep crustal levels (20–25 km) within a mafic lower crust. The base of the layered body was detached during the tectonic uplift of the Famatinian lower crust, whereas the roof of the layered body is exposed in the eastern zone. In the inferred roof, olivine-bearing rocks vanish, cumulate textures are less frequent, and the igneous sequence becomes dominated by massive or thinly banded gabbronorites. Mainly based on the petrographic relationships, the inferred order of crystallization in the gabbroic and peridotitic layered sequence is: (1) Cr–Al-spinel + olivine, (2) Cr–Al-spinel + olivine + clinopyroxene + magnetite, (3) Cr–Al-spinel + olivine + plagioclase + magnetite ± orthopyroxene, and (4) Al-spinel + orthopyroxene + amphibole. A strong linear negative correlation between olivine and plagioclase modal proportions combined with field, petrographic and geochemical observations are used to demonstrate that the physical separation of olivine and plagioclase results in rock diversity at scales of a few centimeters to tens of meters. However, the composition of olivine (Fo ~ 0.81) and plagioclase (An > 94%) remains similar throughout the layered sequence. Spinels are restricted to olivine-bearing assemblages, and display chemical trends characteristic of spinels found in arc-related cumulates. Gabbroic and peridotitic layered rocks have trace element concentrations reflecting cumulates of early crystallizing minerals. The trace element patterns still retain the typical features of subduction-related arc magmatism, showing that the process of cumulate formation did not obscure the trace element signature of the parental magma. Using the composition of cumulus minerals and whole-rock chemical trends, we show that the parental magma was mafic (SiO_2 ~ 48 wt.%) with Mg-number around 0.6, and hydrous. The oxygen fugacity (fO_2) of the parental magma estimated between +0.8 and −0.6 log fO_2 units around the fayalite–magnetite–quartz (FMQ) buffer is also characteristic of primitive hydrous arc magmas. The initially high water content of the parental magma allowed amphibole to crystallize as an interstitial phase all over the crystallization evolution of the layered sequence. Amphibole crystallization in the inter-cumulus assemblage gives rise to the retention of many trace elements which would otherwise be incompatible with the mineral assemblage of mafic–ultramafic cumulates. This study shows that there exist strongly mafic and primitive magmas that are both generated and emplaced within the lower crustal levels of subduction-related magmatic arc. Our findings together with previous studies suggest that the Early Ordovician magmatic paleo-arc from central-northwestern Argentina cannot be regarded as a typical Andean-type tectono-magmatic setting.

1. Introduction

The widespread existence of cognate peridotitic and gabbroic nodules in volcanic rocks with igneous crystallization sequence in which olivine, Cr–Al-spinel and clinopyroxene precede plagioclase and amphibole crystallization was taken to reveal that arc

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magmas experience continuous differentiation while rising through the lithospheric mantle to the lowermost crust (Arculus and Wills, 1980; Conrad and Kay, 1984; Kay and Kay, 1985; Beard and Borgia, 1989). This result was observational prediction of what igneous rock composition might reflect a primitive mantle-derived magma in arcs. At present, growing consensus is for the view that the great majority of the primitive arc magmas crossing the boundary between the lithospheric mantle and the crust are mafic (SiO_2 < 50 wt.%), high-magnesium (MgO ⩾ 10 wt.%, with MgO/MgO + FeO molar ratio commonly >0.65), and hydrous. The idea is not new (Arculus and Johnson, 1978), and was chiefly constructed upon studying cognate nodules of cumulate dunite, peridotite, wehrlite, pyroxenite, and gabbro in arc volcanic rocks. Since the mineral assemblage dominating the crystallization sequence at pressures higher than the first plagioclase appearance would give rise to melts with lower magnesium but higher aluminum than their closer igneous precursor, high-alumina basalts were thought to be derivative magma produced by high pressure fractionation of high-magnesium basalts (Perfit et al., 1980; Crawford et al., 1987; Sisson and Grove, 1993). Phase relationships in the basaltic system under both hydrous and anhydrous conditions were already known (Holloway and Burnham, 1972; Helz, 1973; Baker and Eggler, 1983; Gust and Perfit, 1987), and were broadly supporting inferences made on the basis of cognate nodules.

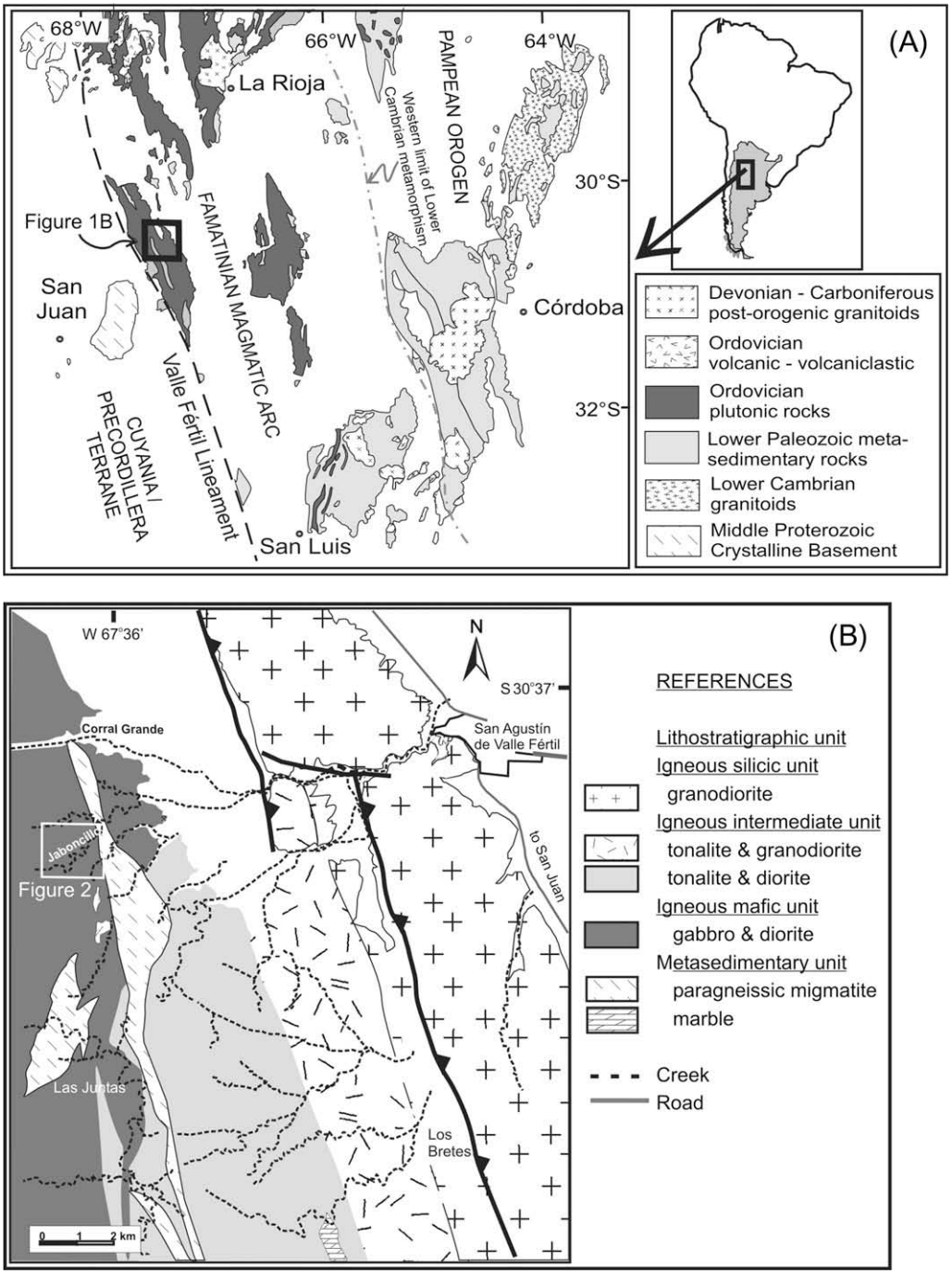

Fig. 1. (A) Map showing the location of the study area with respect to the Pampean orogen, Famatinian magmatic arc and Cuyania and/or Precordillera terrane. This map was modified after Vujovich and Ramos (1999) by using geological information discussed in text. Inset shows the location of the Famatinian arc in Argentina. (B) Simplified geologic map of the Sierras de Valle Fértil taken after the geological maps of Mirré (1976). This also shows the location of the Jaboncillo Valley layered body.