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Metamorphic evolution of migmatites from the deep Famatinian arc crust exposed in Sierras Valle Fértil–La Huerta, San Juan, Argentina

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Abstract

Meta-supracrustal migmatitic packages in the Sierras Valle Fértil–La Huerta of northwestern Argentina occur as wedge- or strip-shaped septa interlayered among mafic to intermediate igneous plutonic rocks. Meta-supracrustal rocks were metamorphosed under granulite-facies conditions during the development of the Famatinian magmatic arc, and are among the structurally deepest rocks exposed within the belt dominated by Ordovician plutonism. Petrographic analysis, mineral chemistry and whole rock geochemistry of granulite-facies migmatites are used to argue that the meta-supracrustal packages comprise a sequence of pelitic to quartzo-feldspathic sedimentary rocks that achieved peak metamorphic *P*–*T* conditions of 5.2−7.1 kbar and 770−840 °C. There are no resolvable differences in peak *P*–*T* conditions for migmatites separated 70 km along strike of the Sierras Valle Fértil and La Huerta, suggesting that similar levels of the Famatinian paleo-arc crust are currently exposed in these ranges. Idioblastic poikilitic garnets displaying weak to absent chemical zoning profiles developed at or close to the peak metamorphic stage are used in conjunction with petrogenetic grid constraints to interpret the prograde evolution. At the time the supracrustal rocks experienced maximum thermal conditions, they underwent dehydration partial melting. Microtextural features show that felsic melt (leucosome) back reacted with the adjacent coexisting mineral assemblage (mesosome). These observations are interpreted as evidence that the migmatites evolved through a continuous heating–cooling cycle with minor pressure change. This is consistent with the general lack of reaction textures denoting decompression at high temperatures, and with the possibility that in some migmatites retrograde reactions formed staurolite. Collectively, these features indicate that when the migmatites attained peak thermal conditions, the deepest exposed arc crust was about 20–25 km beneath the Ordovician surface. Comparing these results with metamorphic studies elsewhere in the Famatinian arc between 31° and 32°S. indicates that much of the main-arc records primarily prograde *P*–*T* trajectories associated with a regional contact metamorphism, but that specific locations in the back-arc, main-arc and accretionary wedge also record post-peak retrogression during crustal exhumation. These differences are attributed to the fact that a collisional orogeny closely followed the cessation of arc magmatism, a collision we infer to be associated with the accretion of a Laurentian terrane to the Gondwana margin. The results of this study therefore provide important insights into the geodynamic context of the formation and closure of the central segment of the Famatinian magmatic arc.

Keywords: Sierras Pampeanas; Famatinian arc; Migmatite; Geothermobarometry; Metamorphism

1. Introduction

The metamorphic temperatures and pressures experienced by crustal rocks are most usefully constrained by assemblages in siliciclastic sedimentary protoliths such as metapelite and quartzo-feldspathic metagreywacke (e.g. Spear, 1993). Pelitic and semipelitic rocks in particular, by virtue of their bulk chemistry, undergo the most exten-

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sive array of mineral reactions during metamorphism and therefore commonly provide the most complete record of temperature and pressure conditions and *P–T* path. In this study, we integrate petrographic and mineral chemical data from a sequence of migmatized pelites and quartzo-feldspathic greywackes at Sierras Valle Fértil–La Huerta in western Argentina in order to identify coexisting equilibrium assemblages and to constrain their *P–T* evolution. These rocks represent the deepest exposed crustal levels of the Famatinian (Ordovician) magmatic arc, and thus provide insights into the development and evolution of the Famatinian event and the role of magmatic additions to the deeper crust in an arc environment.

In the first phase of this study, we have examined high temperature, moderate- to low-pressure pelitic to quartzo-feldspathic migmatites that occur as thick wedges completely surrounded by gabbroic to dioritic layered plutonic sequences. In these migmatites, magmatic activity is the main source of heat sustaining the metamorphic thermal regime. The tectonic–magmatic processes responsible for such high temperatures at relatively low pressures are well understood, and have been addressed in studies of middle to lower crustal rocks exposed in the younger Mesozoic paleo-Andean continental arc (e.g. Lucassen et al., 1996), and in thermo-mechanical forward modelling studies (Wells, 1980; Barton and Hanson, 1990; Bergantz and Dawes, 1992; Annen and Sparks, 2002; Annen et al., 2006). However, the burial mechanism for the supracrustal sequences during arc magmatism, which might involve either shortening or magma loading or a combination of these mechanisms, remains an elusive aspect of our current understanding of continental magmatic arc (e.g. Kidder et al., 2003). Hence, this paper is aimed at providing insight into two issues related to the evolution of the Famatinian supracrustal sedimentary rocks: the crustal levels they originally occupied and the evolutionary *P–T* path they followed as they were migmatized by the addition of magmatic heat. This information is used to establish the minimum thickness for the Famatinian arc crust and to provide constraints on geodynamic models accounting for the subduction-to-collision orogenesis that terminated this magmatic arc (Thomas and Astini, 1996; Pankhurst et al., 1998; Casquet et al., 2001; Ramos, 2004; Astini and Dávila, 2004). By combining our results with those of other studies that have unravelled the tectonic–thermal trajectories of metasedimentary and metaigneous rocks from distinct settings within the Famatinian arc, we are able to present an integrate view of the metamorphic evolution of the Famatinian magmatic belt from the back-arc (Hauzenberger et al., 2001; Delpino et al., 2007) through the contact aureole of plutonic batholiths (Dahlquist and Baldo, 1996; Murra and Baldo, 2006) to the accretionary wedge (Vujovich, 1994; Baldo et al., 2001).

2. Geological setting: Famatinian magmatic arc

The Famatinian belt of central Argentina is a Late Cambrian and Early Ordovician (500–460 Ma) subduction-related magmatic arc that grew in the overriding plate margin while a Laurentia-derived terrane was approaching to the western margin of Gondwana (Toselli et al., 1996; Pankhurst et al., 1998). Magmatic activity in the central section of the arc ended when the allochthonous terrane collided against the Gondwana margin (Ramos et al., 1996; Thomas and Astini, 1996). The deepest plutonic levels of the arc are currently exposed in areas where the Nazca plate is subducting with relatively low angles (Barazangi and Isacks, 1976). This is the reason why deep-seated crustal levels of the arc occurs as a roughly N–S striking wide belt extending about 600 km between 28° and 33°S (Fig. 1) whereas the complementary eruptive igneous rocks interbedded with sedimentary rocks are still on the Earth' surface within the Puna–Altiplano region (Turner and Méndez, 1979; Coira et al., 1999) and in Sierra de Famatina (de Alba, 1979; Mannhein and Miller, 1996). The stratigraphy of the Famatinian arc varies along strike because it was affected by several major tectonic cycles, even after the central section was closed by continent–continent collision during the docking of the Cuyania and/or Precordillera terrane (see Ramos, 1999).

The reconstruction of present-day locations of the fore-arc, main-arc and back-arc of the Famatinian magmatic arc has been successful (Saavedra et al., 1998; Pankhurst et al., 2000; Astini and Dávila, 2004; Delpino et al., 2007; and references therein). Following to Quenardelle and Ramos (1999) the Famatinian arc might be divided into an outboard Famatina terrane being to the west, and an eastern arc intruded into the Pampia terrane (see Ramos, 1995). Studies in the western part of the Famatinian belt have not identified any older, pre-arc, crystalline crustal basement. Nevertheless, further investigation should be directed on the La Resina Complex, a fault-bounded Greenvillian igneous complex outcropping at the western side of the Sierra La Huerta that either was part of the pre-arc lithospheric basement or a slice of the allochthonous Laurentian continent (McClelland et al., 2005). In contrast, the eastern part of the Famatinian arc is thought as having been built up into a pre-existing continental crust called Pampia terrane (e.g. Ramos, 1995). Although consensus for this idea is growing, a puzzling aspect is that not even pieces of the Pampia crystalline basement with crystallization age older than Neoproterozoic were found along the inboard portion of the Famatinian belt. As commonly seen along exposed plutonic batholiths, in the Famatinian belt there is an I-type dominated plutonic belt extending alongside to an S-type dominated belt (see Toselli et al., 1996; Pankhurst et al., 2000; Rossi et al., 2002). Within the Sierras de Famatina, Los Llanos–Chepes–Ulapes, and Valle Fértil–La Huerta, the most abundant igneous rocks making up regional-scale batholiths are calc-alkaline metaluminous I-type granitoids, whereas weakly or strongly peraluminous felsic granitoids appear in lesser amounts (Toselli et al., 1996; Saavedra et al., 1998; Pankhurst et al., 2000). The opposite case occurs in other Sierras among which Fiambalá, Capillita, Zapata,