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Suya Taco and Sol de Mayo mafic complexes from eastern Sierras Pampeanas, Argentina: Evidence for the emplacement of primitive OIB-like magmas into deep crustal levels at a late stage of the Pampean orogeny

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ABSTRACT

The age and petrogenetic features of the Suya Taco and Sol de Mayo mafic complexes reported here provide important new insights into the tectonic setting and evolution of the Pampean orogen. Specifically, the results of this study support models that are capable of explaining the introduction of non-arc mantle-derived mafic magmas into the developing orogen at or very near the time of its metamorphic peak. Although a continental collision model for the Pampean orogen cannot be categorically ruled out, an additional slab break-off or lower crustal delamination event immediately following collision would be required in order to account for the observations presented here. Alternatively, the recently proposed hypothesis of subduction of a mid-ocean ridge beneath an accretionary prism as the cause for Pampean orogeny can account for rise of non-arc, OIB-like mafic magmas through an already thickened supracrustal assemblage, as well as the close spatial and temporal association of this magmatism with the development of high-grade granulitic metamorphic and migmatitic assemblages in the Pampean supracrustal rocks.

1. Introduction

Since the pioneering efforts of Gordillo (1984) and Ramos (1988) in evaluating the geodynamic evolution of the Sierras de Córdoba in the eastern Sierras Pampeanas, several different to strongly divergent ideas have been advanced to explain the tectonic evolution of the eastern Sierras Pampeanas (Kraemer et al., 1995; Rapela et al., 1998a,b; Sims et al., 1998; Simpson et al., 2003; Escayola et al., 2005). The metamorphic evolution of a thick, strongly shortened supracrustal package in the central Sierras de Córdoba was key in many past studies. The supracrustal package is characterized by a clockwise metamorphic P–T trajectory with a nearly isothermal decompression and the widespread development of peraluminous granites, which collectively were interpreted to imply that the crust exposed in eastern Sierras Pampeanas formed in a collisional geologic setting (Ramos, 1988; Kraemer et al., 1995; Rapela et al., 1998a). Other studies (e.g. Simpson et al., 2003; Schwartz et al., 2008) have portrayed the eastern Sierras Pampeanas as consisting of two magmatic/metamorphic belts, an eastern calc-alkaline magmatic belt made up of subduction-derived plutonic and subvolcanic rocks (Lira et al., 1997) and a western metasedimentary accretionary prism belt, which also includes widespread layers of MORB-like basalts (Rapela et al., 1998a) and serpentinized ultramafic rocks that may be of ophiolitic origin and structurally intercalated with the metasedimentary rocks (Escayola et al., 1996). On the basis of structural, metamorphic and age characteristics and relationships that would be difficult to produce in a continental collision environment, Simpson et al. (2003) and Schwartz et al. (2008) have challenged the idea of a collisional origin for the Pampean event and suggested the alternative that ridge subduction was the culminating metamorphic and magmatic event on the Pampean margin.

One aspect that has not received extensive study relative to these alternatives is the role that mafic magmatism generated during the Pampean event may have played in the development of the Pampean orogen. The largest known expression of mafic magmatism in the western belt of the Pampean orogen is an isolated layered gabbronoritic body at Cerro San Lorenzo. From the study of Toselli et al. (1977) it might be inferred that the San Lorenzo mafic complex presents a subalkaline affinity. It has been shown that lens-shaped bodies of gabbronorite and related rocks were tectonically emplaced into upper crustal levels during deformation attributed to the the Pampean event (Chincarini et al., 1998), but

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the original site where these magmatic rocks crystallized is less well constrained. It has been suggested that they were intrusive into the supracrustal pile (Chincarini et al., 1998), but the lack of absolute age constraints make it difficult to evaluate if this magmatism developed in a supra-subduction zone setting as part of the Pampean event, or simply represents the tectonic incorporation of pre-Pampean ocean floor as slivers into metasedimentary rocks of the overlying accretionary prism. The other expressions of mafic magmatism are ferronorites and ferrodiorites having a distinctive OIB-like trace element chemical signature (Demichelis et al., 1996). Ferronorites crystallized from transitional to alkaline rather than tholeiitic magmas (Rabbia et al., 1996), they occur as clusters of small plutonic bodies in the northern part of the sierra (Bonalumi and Gigena, 1987; Demichelis et al., 1996) or as widespread small intrusive dikes and as pillows in migmatites (Otamendi et al., 2004), and they were exhumed together with the hosting supracrustal rocks as their intrusive contacts are preserved. The origins of non-tholeiitic mafic rocks from the western belt (accretionary prism sequence) of the Pampean orogen remains largely unexplained and unconstrained, yet they are potentially of great value in developing insights and constraints on whether the Pampean orogen formed as a result of continental collision, ridge subduction, or other process.

In this contribution we report the results of a petrologic and geochronologic investigation of two mafic complexes that intruded the supracrustal package (accretionary prism belt) in the Sierras de Comechingones, a region of particularly deep-seated metamorphic and igneous rocks in the southern Sierras de Córdoba. We provide evidence that these mafic magmas are mantle-derived with OIB-like characteristics, that they intruded to a range of paleo-depths in the lower to middle crust, that they locally scavenged and reheated host supracrustal rocks leading to partial melting of metasedimentary rocks in their immediate aureoles and enclosed septa under pyroxene-granulite-facies conditions, and that they intruded into the supracrustal package coeval with the late stages of the Pampean (Early Cambrian) orogeny. We explore the possible origins of this distinctive type of mafic magmatism and discuss its implications for the tectonic setting and evolution of the Eastern Sierras Pampeanas during the Early Cambrian.

2. Geological framework

The Suya Taco and Sol de Mayo mafic complexes are located in the northern Sierras de Comechingones region of the southern Sierras de Córdoba (Fig. 1). The mafic complexes are intruded into the supracrustal package that is largely derived from clastic sedimentary rocks, and forms a NNW–SSE trending belt that occupies most of the western half of the Sierras de Córdoba (Kraemer et al., 1995; Martino et al., 1995). The main metamorphic event recorded throughout this supracrustal package is assigned to the Pampean orogeny, which peaked during the Early Cambrian (Rapela et al., 1998a; Sims et al., 1998; Simpson et al., 2003) and reached the transition from amphibolite- to granulite-facies at moderate to low pressures (Otamendi et al., 1999; Rapela et al., 2002).

Several generations of intermediate to felsic plutonic rocks with distinctive petrological characteristics and spatial distributions intruded the supracrustal package from upper-Proterozoic to Devonian times. Earliest are plutonic and subvolcanic rocks with calc-alkaline affinity in Sierra Norte and the northern Sierras de Córdoba, which have been interpreted to represent a late-Proterozoic to Early Cambrian magmatic arc (Lira et al., 1997; Rapela et al., 1998a; Schwartz et al., 2008). Minor calc-alkaline plutonic rocks, including composite orthogneisses, are also found in the easternmost ranges of the Sierras de Córdoba, and are likely part of this magmatic arc (Rapela et al., 1998a). In contrast, the western exposed belt of this orogen is characterized by widespread partial melting of supracrustal rocks giving rise to voluminous, strongly peraluminous, crustally derived granitic magmas that intruded the overlying metamorphic rocks (Rapela et al., 1998b). Later, during the Famatinian orogeny (450–490 Ma) a distinctive group of generally small, dispersed granitoid plutons intruded these same supracrustal sequences (Rapela et al., 1998b; Miró and Gromet, 2005). This Ordovician plutonism covers a broad range of rocks including diorite, tonalite, trondhjemite and granodiorite, and has been associated with the growth of an Ordovician magmatic arc (Pankhurst et al., 2000; Miró and Gromet, 2005). Finally, during and after the Devonian (360–400 Ma), the supracrustal sequences were exhumed to an upper crustal environment and were intruded by batholith-scale weakly-peraluminous monzogranites (Rapela et al., 1982; Pinotti et al., 2002; Sims et al., 1998).

The metasedimentary supracrustal sequence of the Sierras de Córdoba is also associated with mafic and ultramafic rocks, which vary from small intrusions to structurally intercalated bodies. The mafic intrusions occur as small bodies that are widely scattered within the metasedimentary package. In contrast, ultramafic-mafic lensoidal bodies are spatially related to high-strain shear belts and were tectonically emplaced into the metasedimentary sequence (Bonalumi and Gigena, 1987). Hence, the latter types are thought to be the remnant of ophiolites (Escayola et al., 1996). Recently, it has been suggested that these rocks formed in the Precambrian, at 640 ± 25 Ma, and were tectonically emplaced after closure of a back-arc basin that developed above a west-dipping subduction zone during the Pampean orogeny (Escayola et al., 2005). Other expressions of mafic magmatism are ferronorites and ferrodiorites that appear as clusters of small plutonic bodies in the northern part of the sierra (Bonalumi and Gigena, 1987; Demichelis et al., 1996), and complexes of mafic dikes in the Sierras de Comechingones (Otamendi et al., 2003). Previous work has established that the mafic dikes intruded the supracrustal sequence at the time it was residing at middle crustal levels and experiencing amphibolite- to granulite-facies metamorphism (Otamendi et al., 2003), which suggests the magmas are Pampean in age. Two of these complexes are studied in more detail here, and are described in next section.

According to Martino et al. (1995) four major deformation phases characterized the Pampean structure of the Sierra de Córdoba. The first event, D_1, is poorly preserved as a gneissic foliation and often folded by D_2 folds. Foliation S_1 is seen as a metamorphic foliation overprinting continuous relicts of sedimentary beds (Otamendi and Patiño Douce, 2001). The most intense tectono-thermal episode during the Cambrian was coeval with deformation events D_2 and D_3, reaching granulite-facies (Gordillo, 1984; Otamendi et al., 1999). D_2 comprises F_2 folds and S_2 foliation features formed during a major crustal thickening event and lasted until the metamorphic peak was reached (Gordillo, 1984; Rapela et al., 1998b; Otamendi et al., 1999). D_3 deformation, which began close to the metamorphic peak but continued during the cooling stage (Otamendi et al., 1999), is characterized by the formation of high-strain belts. F_3 folds and S_3 foliation transpose and obliterate earlier structures. Within the Sierras de Córdoba, post-peak metamorphic textures typical for decompression suggest a clockwise P–T path following a high-grade metamorphic peak (Rapela et al., 1998b; Otamendi et al., 1999). Exhumation of middle crustal levels has been attributed to an extensional stage associated with D_3 (Martino et al., 1997). The late Pampean deformational event, D_4, developed mainly along narrow shear belts, within which S_4 mylonite foliation is subvertical to east dipping, and strikes roughly N–S. In the central Sierras de Córdoba, open asymmetric F_4 folds have been observed in the San Carlos massif (Martino et al., 1997), and are megascopic (decameter in amplitude). The igneous-metamorphic Pampean