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High-pressure/low-temperature metamorphism in the collision zone between the Chilenia and Cuyania microcontinents (western Precordillera, Argentina)

F.L. Boedo [a, *], A.P. Willner [b, c], G.I. Vujovich [a], H.-J. Massonne [b]

[a] Instituto de Estudios Andinos "Don Pablo Groeber" (UBA-CONICET), Int. Güiraldes 2160 (1428), Departamento de Ciencias Geológicas, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Argentina
[b] Institut für Mineralogie und Kristallchemie, Universität Stuttgart, Azenbergstr. 18, 70174, Stuttgart, Germany
[c] Institut für Geologie, Mineralogie und Geophysik, Ruhr-Universität, 44780, Bochum, Germany

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ABSTRACT

In central-western Argentina, an Early Paleozoic belt including mafic-ultramafic bodies, marine metasedimentary rocks and high-pressure rocks occur along the western margin of the Precordillera and in the Frontal Cordillera. First pressure-temperature estimates are presented here for low-grade rocks of the southern sector of this belt based on two metasedimentary and one metabasaltic sample from the Peñasco Formation. Peak metamorphic conditions resulted within the range of 345–395 °C and 7.0–9.3 kbar within the high-pressure greenschist facies. The corresponding low metamorphic gradient of 13 °C/km is comparable with subduction related geothermal gradients. Comparison between these results and data from other localities of the same collision zone (Guarguaraz and Colohuincul complexes) confirms a collision between Chilenia and the composite margin of western Gondwana and suggests a stronger crustal thickening in the south of the belt, causing exhumation of more deeply buried sequences. During the Early Paleozoic a long-lived marine sedimentation coupled with the intrusion of MORB-like basalts occurred along a stable margin before the collision event. This contrasts with the almost contemporaneous sedimentation registered during accretion in accretionary prism settings and additionally proves the development of a collision zone along western Precordillera and the eastern Frontal Cordillera as well as the existence of Chilenia as a separate microcontinent.

1. Introduction

During Early Paleozoic times, several microcontinents (e.g. Paracas, Cuyania, Chilenia and others) collided with the western margin of Western Gondwana (current South American Plate; e.g. Ramos, 2009). The recognition of their respective sutures was originally mainly based on the presence of mafic-ultramafic belts or regional lineaments along such hypothesized boundaries. Particularly, in central-western Argentina a linear chain of several mafic and ultramafic bodies occurs over 400 km which was first interpreted as a suture zone between the composite western Gondwana margin (after Ordovician collision of the Cuyania microcontinent) and the Chilenia microcontinent by Haller and Ramos (1984) and Ramos *et al.* (1986).

There is still a debate on numerous aspects of the collision event mostly regarding the provenance of the Chilenia terrane (if it is allochthonous or parautochthonous to Gondwana). Do the mafic-ultramafic bodies belong to different geotectonic environments or belong they to the same ancient oceanic lithosphere section? Which was the subduction polarity of the Chilenia terrane when it approached to the Gondwana margin? Where was the corresponding magmatic arc located?

The presence of the mafic-ultramafic belt is so far one of the main evidences that support the existence of Chilenia as a separate microcontinent. Late Neoproterozoic to Early Paleozoic metasedimentary rocks associated to mafic and ultramafic bodies from the Precordillera and the Frontal Cordillera exhibit similar structural styles and polyphase deformation; intense isoclinal and disharmonic folding, crenulation cleavage and double-vergent

* Corresponding author.
E-mail addresses: florenciaboedo@gmail.com (F.L. Boedo), arne.willner@rub.de (A.P. Willner), graciela@gl.fcen.uba.ar (G.I. Vujovich), h-j.massonne@imi.uni-stuttgart.de (H.-J. Massonne).

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deformation (von Gosen, 1997; Davis *et al.*, 1999; Gerbi *et al.*, 2002; López, 2005; Giambiagi *et al.*, 2010). Studies on metamorphism of metabasites and metasedimentary rocks along the belt and further south have provided critical evidence for collision processes (Davis *et al.*, 1999; Robinson *et al.*, 2005; Massonne and Calderón, 2008; Willner *et al.*, 2008, 2011; Gargiulo *et al.*, 2011, 2012, 2013, Boedo *et al.*, 2012, this work).

The purpose of this contribution is to characterize the pressure-temperature (P-T) metamorphic conditions of the metasedimentary and metabasaltic rocks from the Peñasco area, part of the southern sector of the Precordillera mafic-ultramafic belt. Furthermore, we correlate our new P-T data with those obtained from the southernmost sector of the mafic-ultramafic belt (Guarguaraz Complex; Massonne and Calderón, 2008; Willner *et al.*, 2011) and the extension of the corresponding collisional suture to the Colohuincul Complex (Martínez *et al.*, 2012).

2. Geological setting

2.1. The Argentine Precordillera

The Argentine Precordillera is a fold and thrust belt which is located in central-western Argentina and developed along the western margin of the Cuyania composite terrane (Fig. 1a). Its Early Paleozoic stratigraphy is well documented with dominating sequences of platform limestones to the east and marine siliciclastic sedimentary rocks to the west, where mafic-ultramafic bodies, affected by very low to low-grade metamorphism (e.g. Davis *et al.*, 1999; Rubinstein *et al.*, 2000; Robinson *et al.*, 2005; Boedo *et al.*, 2012, 2015), are intercalated (Haller and Ramos, 1984; Astini *et al.*, 1995; Thomas and Astini, 2003).

The western Argentine Precordillera consists of metasedimentary rocks which originated in deep marine and continental slope settings, including platform carbonate and siliciclastic olistoliths from its basement (Thomas and Astini, 2003 and references therein). These rocks are spatially related to mafic-ultramafic bodies within the Precordillera mafic-ultramafic belt. The outcrops of this belt are discontinuous between latitudes 28° and 33°S and consist of serpentinized ultramafic rocks, mafic granulites, together with massive metagabbros, metabasaltic dikes, sills and pillow lavas. The mafic rocks have N- to E-MORB (Normal-to Enriched-Mid-Ocean Ridge Basalts) signature and positive ε_{Nd} values (+6 to +9.3), which are compatible with basalts/gabbros from the oceanic crust (Haller and Ramos, 1984; Kay *et al.*, 1984; Cortés and Kay, 1994; Fauqué and Villar, 2003; González Menéndez *et al.*, 2013; Boedo *et al.*, 2013). The vergence of deformation in Early Paleozoic units is still a matter of debate. Most authors postulate that it is to the west based on the main vergence of major structures (Ramos *et al.*, 1986; von Gosen, 1997; Cortés *et al.*, 1999; Ariza *et al.*, 2015), whereas others propose an eastward vergence on the basis of only localized kinematic indicators within allochtonous granulite lenses (Davis *et al.*, 1999; Gerbi *et al.*, 2002; Álvarez Marrón *et al.*, 2006), which may have been rotated as they show different orientations along strike regarding the main foliation (S_1) in metasedimentary rocks (Boedo, 2015).

The Precordillera mafic-ultramafic belt can be divided in two sectors according to their rock association and metamorphic grade: a northern sector, which comprises the outcrop localities of Jagüé, Rodeo, Tigre and Calingasta, and a southern sector with the outcrop areas of Peñasco, Pozos, Cerro Redondo, Cortaderas and Bonilla (Fig. 1a). A very low to low-grade metamorphic imprint is registered along the northern part of the belt (Cucchi, 1971; Buggisch *et al.*, 1994; Robinson *et al.*, 2005), while a low to medium grade metamorphic imprint affects its southern part, where intercalations of retrograded mafic granulite (a former layered gabbro complex) also occur (Davis *et al.*, 1999; Boedo *et al.*, 2012). Haller and Ramos (1984) assumed that the southernmost part of the mafic-ultramafic belt is located in the Sierra de Guarguaraz within the Frontal Cordillera (Fig. 1b), where serpentinite, metagabbro, metabasaltic dikes and pillow lavas occur in contact with marble and schist of sedimentary origin (Villar, 1969, 1970; Gregori and Bjerg, 1997; López de Azarevich *et al.*, 2009; Gargiulo *et al.*, 2011). These lithological units are grouped in the Guarguaraz Complex (López and Gregori, 2004). Despite their particular differences, the mafic and ultramafic bodies from the Precordillera and Frontal Cordillera are considered to belong to a dismembered ophiolite along the suture zone between the composite western Gondwana margin (after Ordovician collision of the Cuyania microcontinent) and the Chilenia microcontinent (Fig. 1a–b) (Haller and Ramos, 1984; Ramos *et al.*, 1986).

U/Pb ages on detrital zircon show a maximum age of deposition of 555 ± 8 Ma for the (meta)sediments of the Guarguaraz Complex (Willner *et al.*, 2008), which is consistent with findings of cyanobacteria and acritarchs of probable Vendian-Cambrian age and an age of 655 ± 76 Ma (Sm-Nd whole-rock) for an intercalated metabasite (López de Azarevich *et al.*, 2009), interpreted by them as the probable crystallization age of the protolith. Similar to the western Precordillera, the mafic bodies have N- to E-MORB chemical signature and the whole sequence is strongly deformed and metamorphosed. Massonne and Calderón (2008) estimated an early P-T stage of 8 kbar, 470–500 °C in metapelites and a subsequent pressure increase (13.5 kbar, 500 °C) followed by a decompression to 8 kbar, 565 °C. Willner *et al.* (2011) determined similar high pressure conditions (12–14 kbar, 470–530 °C) in metabasite and metapelite, followed by a decompression with a slight increase in temperature (5 kbar, 560 °C).

Regarding P-T conditions in the northern part of the Precordillera, Rubinstein *et al.* (1998, 2000) and Robinson *et al.* (2005) estimated very low to low-grade and low pressure conditions (2–3 kbar, 250-350 °C) in metabasite and metapelite from the Alcaparrosa and Yerba Loca formations in the Calingasta and Rodeo areas, respectively. P-T estimates by Davis *et al.* (1999) for the Cortaderas mafic granulites in the southern part of the Precordillera yielded temperatures between 850 and 1000 °C at 11 kbar. Boedo *et al.* (2012) estimated similar conditions in mafic granulite from the Cordón del Peñasco area (P > 9 kbar, T~885 °C).

To the south, in the North Patagonian Andes, rocks from the Colohuincul Complex (Fig. 1a) exhibit metamorphic trajectories deduced to be the result of thermal relaxation after crustal thickening (Martínez *et al.*, 2012). These authors also interpret these processes as a consequence of the Chilenia collision against the western Gondwana margin and extend the microcontinent up to the 41°S (present coordinates).

Dating of the metamorphic event in low and medium grade rocks from the Precordillera, Frontal Cordillera and North Patagonian Andes generally yielded Devonian ages (Cucchi, 1971; Buggisch *et al.*, 1994; Davis *et al.*, 1999; Willner *et al.*, 2011; Martínez *et al.*, 2012).

The mafic-ultramafic belt, which is considered as an almost complete ophiolite sequence, represents oceanic crust that may have been subducted shortly before the collision of the Chilenia microcontinent with the western Gondwana margin in the Middle Devonian (Haller and Ramos, 1984; Ramos *et al.*, 1986; Willner *et al.*, 2011). However, Davis *et al.* (2000) proposed that the mafic granulite in the Precordillera could partly represent the roots of a magmatic arc.

After exhumation of the Chilenia collision zone, marine sediments of Early Carboniferous age unconformably overlie all basement rocks (Amos and Rolleri, 1965).