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Constraining a mafic thick crust model in the Andean Precordillera of the Pampean flat slab subduction region

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ABSTRACT

Elastic properties in twelve representative rock samples from Central and Western Precordillera in the Andean backarc region of Argentina between 30 and 31°S were estimated from detailed petrological analysis. Thus, P and S seismic-wave velocities (Vp, Vs) as well as Poisson's ratio (σ) among other parameters were derived for gabbros, leuco-gabbros and wehrlites, in greenschist and amphibolite metamorphic conditions using a framework of a wide variety of empirical observations from active continental margins. In addition, Vs lithosphere models along two west–east cross sections were obtained using a joint inversion of teleseismic Rayleigh waves and receiver functions. These models clearly delineate the upper-plate crustal structure and the flat-slab subduction of the Nazca plate at about 100 km depth in this region. The suggested seismic velocity structure shows a relatively low (<3.3 km/s) Vs layer located in the first 15–18 km depth, then an increase of it from 3.3 to 4 km/s between 20 and 55 km depth with a mayor change at 40 km depth beneath the Precordillera showing an increase in Vs from 3.3 to 3.8 km/s. The Moho discontinuity was identified at around 65 km depth beneath the Precordillera (Vs = 4.3 km/s) and shows a low shear-wave velocity contrast in comparison with the upper continental mantle's parameters. Using this seismological model, Vs estimations derived from the petrological analyses for the 12 collected samples can be projected at depths greater than 30 km. These geophysical and petrological results agree with the hypothesis of a mafic thickened and partially eclogitized lower crust beneath the Precordillera, which has been predicted previously on a base of seismological studies only. Our petrological and seismological results collectively support a thick crustal model of a mafic–ultramafic composition extending to middle-to-lower crustal levels beneath Central and Western Precordillera; this region correlates with a suture zone between the eastern Cuyania terrane and the western Chilenia terrane.

1. Introduction

1.1. Geotectonic framework

The basement of the Andean backarc region between 28 and 33°S is composed of different terranes accreted to the southwestern margin of Gondwana during Paleozoic times (Ramos et al., 1986) (Fig. 1). The boundaries between them are represented by regional lineaments, mafic–ultramafic ophiolite belts, presence of ancient magmatic arcs and other tectonic features. Particularly, the composite Cuyania terrane juxtaposes the Argentinean Precordillera and the westernmost part of the Sierras Pampeanas (Vujovich et al., 2004).

The Precordillera of Argentina comprises the outer zone of the Andes between 29 and 33°S in an elongated 400 km long, 80 km

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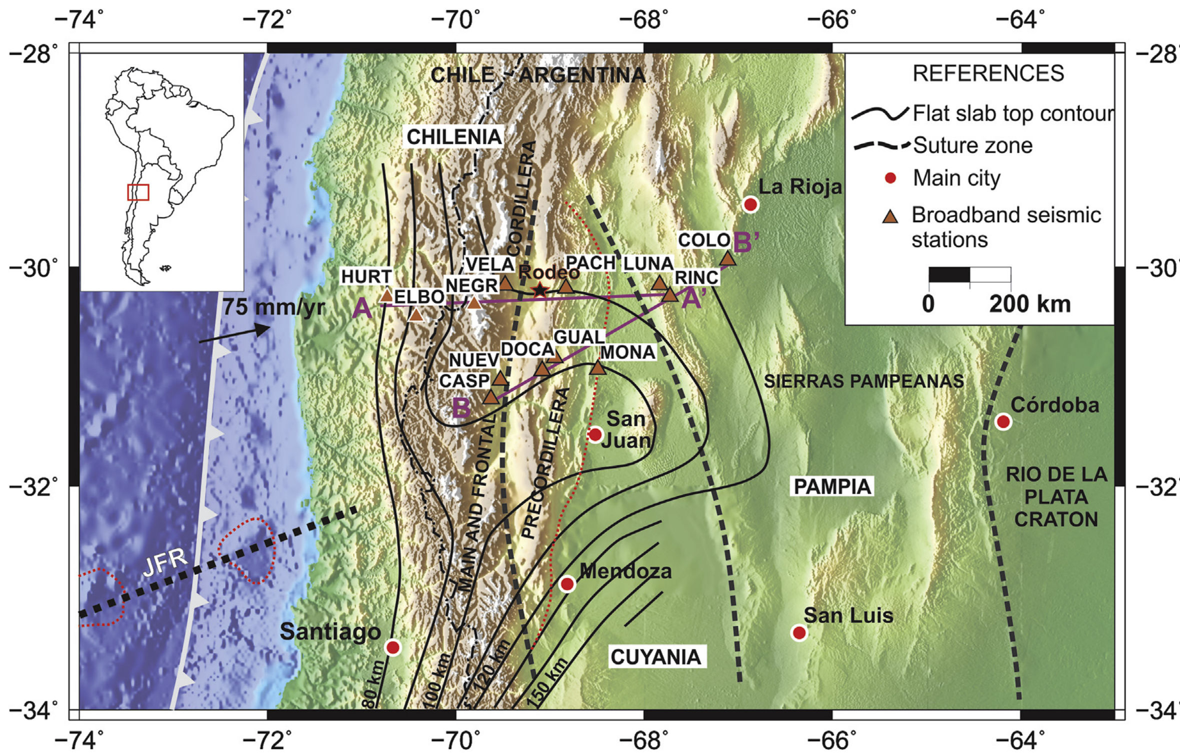

Fig. 1. Location map of the Pampean flat slab subduction region. Continuous black lines represent the top of the subducted Nazca plate (Anderson et al., 2007). Dashed black lines represent suture zones between different Paleozoic accreted terranes (see references in the text). Dotted black line represents the path of the Juan Fernández ridge (JFR). Triangles symbolize location of seismological broadband stations from CHARGE and SIEMBRA experiments (Beck et al., 2001). Convergence rate between the Nazca plate and Southamerican plate (DeMets et al., 2010) and selected cross-sections in this study (AA′ and BB′) across the morphostructural units of Main and Frontal Cordillera, Precordillera and Western Sierras Pampeanas, are also shown.

wide belt of mostly Paleozoic rocks that reaches maximum elevations of 4000 m (Ramos, 1988) (Fig. 2). It overlies an horizontal portion of the subducted Nazca plate (Cahill and Isacks, 1992; Anderson et al., 2007) and has a lack of major magmatism since 10 My (Kay et al., 1988).

This geological province can be separated into three morphostructural units based on stratigraphic and structural characteristics and their intervening valleys (Baldis and Chebli, 1969; Ortiz and Zambrano, 1981; Baldis et al., 1982). The Western and Central Precordillera constitutes an east-vergent thin-skinned belt whereas the Eastern Precordillera corresponds to a west-vergent basement block. The basement of the Central Precordillera is indirectly known from xenoliths of Miocene volcanic rocks (Leveratto, 1968), which have yielded U/Pb zircon ages near 1100 My (Kay et al., 1996; Rapela et al., 2010). In addition, the Western Sierras Pampeanas (McDonough et al., 1993) seem to be part of the same basement structure with an intra-Grenville suture (Vujovich and Kay, 1998; Vujovich et al., 2004).

The main stratigraphic difference between the three morphostructural Precordilleran units is a well-developed thick carbonate Cambrian to middle Ordovician platform sequence in the Eastern Precordillera, which changes to slope and deep sea siliciclastic facies towards the Central and Western Precordillera. These association facies are temporally and spatially related with mafic and ultramafic bodies grouped into the Precordillera mafic–ultramafic belt (Haller and Ramos, 1984; Ramos et al., 1984, 1986). This belt is represented by a series of discontinuous exposures that outcrop from north to south at La Rioja (Jagüé area), San Juan (Rodeo, Sierra del Tigre, Sierra de La Invernada and Calingasta area) and Mendoza (Peñasco, Cerro Redondo, Cortaderas, Bonilla and Guarguaraz localities) (Fig. 2).

There is a general consensus that the Western and Central Precordillera mafic–ultramafic belt and related metasedimentary rocks belong to an almost complete ophiolite sequence which has been exposed by the collision of the Chilenia terrane against the western Gondwana margin in the middle-late Devonian (Haller and Ramos, 1984; Ramos et al., 1984, 1986).

The probable continuation of the mafic–ultramafic belt to deeper levels into the crust has not been explored. This can be estimated using P and S-wave velocity determinations which are expected to be distinctive for different rock type composition, discontinuities and lithosphere structure imaging (e.g., Birch, 1960; Christensen, 1965, 1978; Poster, 1973; Peterson et al., 1974; Kroenke et al., 1976; Christensen and Mooney, 1995). Our study constrain seismic velocities as derived from detailed petrological observations and compared to seismological observations in Rodeo, Sierra del Tigre and Sierra de La Invernada area. This allows us to elaborate a structure model for the crust and deeper levels. Preliminary results studying 4 samples and a Receiver Function (RF) local model beneath one single seismic station DOCA located in the Sierra de La Invernada western flank (Ammirati et al., 2013 and Pérez Luján et al., 2013) showed a composition compatible with greenschist to amphibolite mafic rocks down to 36 km depth at medium-to-lower crustal levels, with P-wave velocities between 6.5 and 7 km/s. In this work we present a regional study considering a larger sample dataset from the Western and Central Precordillera between 30 and 31°S using a more refined seismological model involving a joint inversion of Rayleigh waves and RF along some transects. The methodology can be followed in Ammirati et al. (2015); it basically constrains absolute seismic wave velocities