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Seismic structure of the crust and uppermost mantle of South America and surrounding oceanic basins

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ABSTRACT

We present a new set of contour maps of the seismic structure of South America and the surrounding ocean basins. These maps include new data, helping to constrain crustal thickness, whole-crustal average P-wave and S-wave velocity, and the seismic velocity of the uppermost mantle (P_n and S_n). We find that: (1) The weighted average thickness of the crust under South America is 38.17 km (standard deviation, s.d. ±8.7 km), which is ~1 km thinner than the global average of 39.2 km (s.d. ±8.5 km) for continental crust. (2) Histograms of whole-crustal P-wave velocities for the South American crust are bi-modal, with the lower peak occurring for crust that appears to be missing a high-velocity (6.9–7.3 km/s) lower crustal layer. (3) The average P-wave velocity of the crystalline crust (P_{cc}) is 6.47 km/s (s.d. ±0.25 km/s). This is essentially identical to the global average of 6.45 km/s. (4) The average P_n velocity beneath South America is 8.00 km/s (s.d. ±0.23 km/s), slightly lower than the global average of 8.07 km/s. (5) A region across northern Chile and northeast Argentina has anomalously low P- and S-wave velocities in the crust. Geographically, this corresponds to the shallowly-subducted portion of the Nazca plate (the Pampean flat slab first described by Isacks et al., 1968), which is also a region of crustal extension. (6) The thick crust of the Brazilian craton appears to extend into Venezuela and Colombia. (7) The crust in the Amazon basin and along the western edge of the Brazilian craton may be thinned by extension. (8) The average crustal P-wave velocity under the eastern Pacific seafloor is higher than under the western Atlantic seafloor, most likely due to the thicker sediment layer on the older Atlantic seafloor.

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1. Introduction

The construction of continent-scale maps of geophysical properties provides a broad picture of the structure of the Earth. For example, a map of crustal thickness indicates the lateral extent of tectonic provinces such as highly extended regions and orogenic zones. Likewise, maps of crustal seismic velocities can help to delineate platforms, shields, sedimentary basins, and exotic accreted terrains (Christensen and Mooney, 1995). Geophysical maps provide a means of identifying crustal properties that delineate geologic provinces (e.g., Prodehl, 1984; Meissner, 1986; Collins, 1988; Pakiser and Mooney, 1989; Blundell et al., 1992; Pavlenkova, 1996; Yuan, 1996; Chulick and Mooney, 2002; Fuck et al., 2008; Cordani et al., 2009; Cordani et al., 2010).

We present the first set of contour maps based on seismic-refraction work combined with other forms of seismic data (i.e., seismic reflection, sonobuoy, receiver function and earthquake models) for the entire continent of South America and the surrounding ocean basins. There are several reasons why new maps are warranted at this time. First, the quantity and quality of data on South American crustal structure has grown substantially in the past decade or so, with new seismic surveys (e.g. Wigger et al., 1994; Flueh et al., 1998; Patzwahl et al., 1999; Bohm et al., 2002; ANCORP Working Group, 2003; Berrocal et al., 2004; Schmitz et al., 2005; Rodger et al., 2006; Scherwath et al., 2006; Soares et al., 2006; Greenroyd et al., 2007) conducted that cover hitherto unexplored regions (e.g. the Chilean Andes and Amazonia) as well as provide better resolution in previously studied areas (e.g., the Peruvian Andes, and eastern Brazil). However, this work in South America has generally not been done at the continental scale and frequently depends on passive source data (e.g. Schmitz et al., 1999; Assumpção et al., 2002, 2004; An and Assumpção, 2005; Tavera et al., 2006; Lange et al., 2007; Heit et al., 2008; Wölbern et al., 2009). This study consolidates the

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work of previous studies by combining different types of crustal structure data taken from throughout the continent, including numerous geological provinces and tectonic regimes. The main geologic provinces of South America are shown in Fig. 1.

We also present contour maps and statistical analyses of the S-wave velocity of the crust and Moho of South America. Such presentations are particularly relevant given the recent publication of tomographic S-wave velocity maps of the South American mantle (e.g. van der Lee et al., 2001, 2002; Feng et al., 2004, 2007).

Our newly-collected data, mentioned above, have been incorporated into a comprehensive seismic database (website address provided at the end of the article). Each data point used in this study consists of a one-dimensional velocity-depth function extracted from a published crustal model. More than 75% of the data points were taken from 2D seismic velocity cross sections derived from seismic-refraction data. Every effort has been made to include results published through 2011; however, some important and/or recently-completed seismic surveys are not fully available. Nonetheless, we can for the first time produce reasonably detailed maps of P-wave crustal properties for all of South America, as well as corresponding generalized maps of S-wave crustal properties. The locations for all seismic data points used in this study are shown in Fig. 2.

The maps presented here include crustal thickness (H_c), average P-wave velocity of the whole crust (P_c) and of the crystalline crust (P_{cc}), sub-Moho P-wave velocity (P_n), average S-wave velocity of the whole crust (S_c) and of the crystalline crust (S_{cc}), and sub-Moho S-wave velocity (S_n). Furthermore we provide a statistical analysis of these parameters, as well as of the velocity ratios P_c/S_c, P_{cc}/S_{cc}, and P_n/S_n. We also present several crustal cross-sections through the South American continent synthesized from our velocity data compilation.

2. Previous work

Maps of deep crustal properties for South America based on seismic-refraction data have hitherto been limited in extent, primarily to local regions of the Andes (e.g. Wigger et al., 1994; Schmitz, 1994; Bohm et al., 2002; ANCORP Working Group, 2003; Alvarado et al., 2005; Gilbert et al., 2006; Alvarado et al., 2007; Yoon et al., 2009)

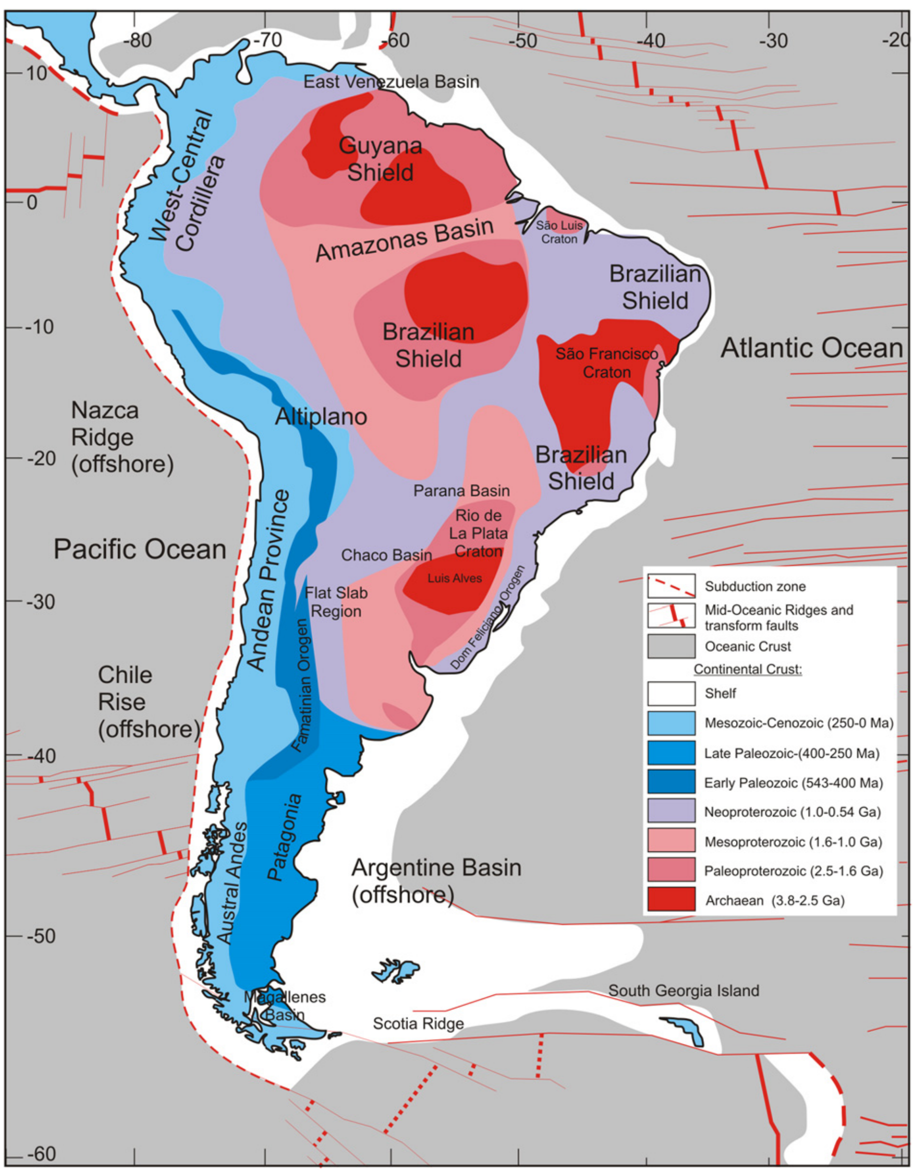

Fig. 1. Main Geological Provinces of South America. (After Gubanov and Mooney, pers. comm., 2012).