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Western Paraná suture/shear zone and the limits of Rio Apa, Rio Tebicuary and Rio de la Plata cratons from gravity data

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ABSTRACT

We present a new gravity map between 45°–70° W and 5°–40° S integrating open source terrestrial gravity data of Argentina with the South American Gravity Model 2004 (SAGM04), a 5 min-arc resolution gravity model. The Bouguer anomaly map reveals a 2000 km long linear gravity feature from 15° S to 30° S at longitude 55° W, with a steep horizontal gradient separating two gravity domains. The eastern domain is the Paraná basin, with NE-SW trending Bouguer anomalies of −80 mGal in average. The western domain comprises the Chaco-Paraná, Chaco-Tarija and Pantanal basins, with circular positive anomalies of up to 20 mGal in amplitude. Previous seismic studies mapped a thinner crust of less than 35 km in the western domain and the present gravity models indicate a 10–20 kg/m^3 denser crust. On the other hand, the eastern domain has a thicker crust of more than 40 km. Seismic tomography models also show P- and S-wave velocity reduction in the western domain whereas high-velocity characterises the Paraná basin. These geophysical data indicate that the gravity gradient marks a transition between two distinct lithospheres. The gravity gradient is associated with a tectonic feature referred to as the Western Paraná suture/shear zone. Granites of 530–570 Ma ages, located parallel or over the gravity gradient, suggest a Neoproterozoic to Early Cambrian age suture/shear zone, thus approximately synchronous and parallel to the Pampean belt. Sediment corrected residual gravity map and its vertical derivative allow us to define the limits of the Rio Apa, Rio de la Plata and Rio Tebicuary cratons. Their eastern and western limits are the Western Paraná suture and the Pampean belt, respectively. This study unravels Precambrian tectonic elements concealed by the Phanerozoic sedimentary basins adding new constraints for the amalgamation history of SW Gondwana.

1. Introduction

A major advance in understanding the Neoproterozoic to Cambrian tectonic history of the SW Gondwana supercontinent evolution has been achieved in the last decade with the acquisition of new geochronological data (Ar-Ar and U-Pb ages) and isotope geochemistry studies of igneous and metamorphic rocks of the exposed basement of cratons and ancient terranes (Cordani et al., 2001, 2010; Rapela et al., 2007, 2011; Oyhantçabal et al., 2010; Escayola et al., 2011; Casquet et al., 2012). Together with a few paleomagnetic (Trindade et al., 2006; Tohver et al., 2010; Rapalini et al., 2013) and sediment provenance studies using zircon detritus ages and the geochronology of Neoproterozoic Pampean back-arc basins (Rapela et al., 1998, 2007, 2011; Escayola et al., 2007; Ramos et al., 2015) and of the Paraguay orogenic belt (Bandeira et al., 2012; Babinski et al., 2013; McGee et al., 2015), a new view of the final amalgamation of the SW Gondwana is emerging.

Essential to the advancement of the Precambrian history of the SW Gondwana is the definition of the main tectonic units and their limits. Difficulties arise due to the post-Cambrian sedimentary sequences that cover more than 70% of the southwestern South America basement. These Phanerozoic sedimentary deposits are the intracontinental Paraná, Chaco-Paraná, Chaco-Tarija, Parecis and Pantanal basins (Fig. 1). Therefore, to unravel the Precambrian basement history, geophysical data are essential, and the number of regional and lithosphere scale geophysical studies in South America has progressively increased in the last decade. We use gravity data and integrate them with other available geophysical

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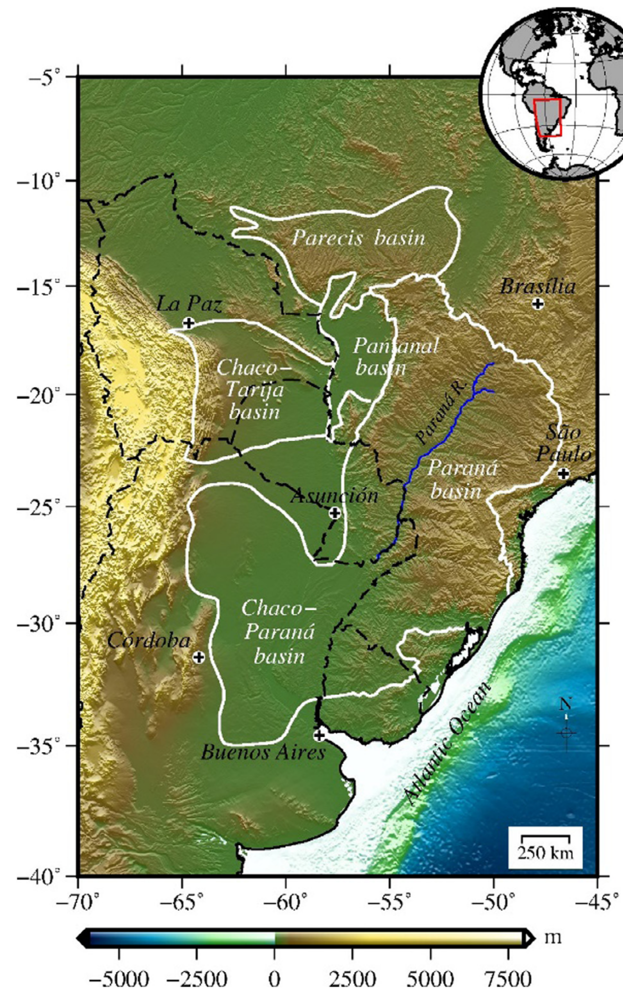

Fig. 1. Topographic map (ETOPO1, Amante and Eakins, 2009) of the study area. Dashed lines are the political limits of Brazil, Uruguay, Paraguay, Argentina and Bolivia. Continuous white contours are the limits of the Paraná, Chaco-Paraná, Chaco-Tarija, Pantanal and Parecis sedimentary basins. The continuous blue line is the Paraná River. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

data such as magnetotellurics in Argentina (Favetto et al., 2008, 2015; Orozco et al., 2013; Peri et al., 2013, 2015) and Brazil (Bologna et al., 2014; Padilha et al., 2015), and regional seismological studies (Feng et al., 2007; Assumpção et al., 2013; Rosa et al., 2016). This integration provides a more robust lithospheric physical model for this segment of the South American plate.

For lithospheric scale tectonic studies, good resolution global gravity models are available thanks to several satellite gravity missions integrated with conventional terrestrial gravity surveys. One of such a model is the EGM08 (Earth Gravitational Model, Pavlis et al., 2012), a 5 min-arc resolution model which combines terrestrial gravity and GRACE satellite data. However, the documentation on the source of the South American terrestrial gravity data used for constructing the EGM08 model is not readily accessible. Therefore, some caution is required when using this model for regional scale tectonic studies in South America, as discussed by Bomfim et al. (2013) for the Amazonian craton region.

We integrate the SAGM04 model (South American Gravity Model 2004) by Sá (2004) with the open access data over the Chaco-Paraná basin from the Instituto Geográfico Nacional (IGN) of Argentina. To accomplish it, we use the most recent gravity model entirely derived from GOCE data (Gravity field and steady-state Ocean Circulation Explorer, ESA, 1999; Bruinsma et al., 2013) publically available at the **I**nternational **C**entre for **G**lobal **E**arth **M**odels website (ICGEM, 2016), which allow us to tie all gravity measurements to the same reference system and to evaluate the IGN data quality.

Three results from the present gravity study are the most relevant. First, we identify a 2000 km long Neoproterozoic-Early Cambrian lithospheric suture/shear zone along the western border of the Paraná basin. Second, we propose that the Archean/Paleoproterozoic age continental crust (Cordani et al., 2001) under the Chaco-Paraná basin (between 65° W to 55° W longitude and 30° S to 35° S latitude) to be a new tectonic and cratonic unit, hereafter referred to as the Rio Tebicuary craton. The suture/shear zone separates the Rio Tebicuary, Rio de la Plata (Ramos, 1988; Rapela et al., 2007, 2011) and Rio Apa (Cordani et al., 2010) cratons from the Paraná basin lithosphere. Finally, positive gravity anomalies characterise these three cratons whereas negative gravity anomalies are predominant in the Amazonian and African cratons suggesting distinct crustal and lithospheric thickness and composition.

2. Gravity map

We present a new gravity anomaly map between 45° W to 70° W in longitude and 5° S to 40° S in latitude (Fig. 2b), which results from the integration of IGN terrestrial data (Fig. 2a, blue dots) in Argentina and the South American regional model, the SAGM04 (Fig. 2a, green).

Sá (2004) elaborated the SAGM04 gravity model integrating Brazilian terrestrial gravity data collected by several institutions and open access gravity data from neighbouring countries (Supplementary material, Fig. S1). The SAGM04 lateral resolution is a 5 min-arc in areas with good terrestrial coverage. In regions devoid of terrestrial data, the EGM96 (Earth Gravitational Model 1996, Lemoine et al., 1998) and GPM98C (Gravitational Potential Model 1998 C, Wenzel, 1998) were used with an estimated lateral resolution of 30 min-arc and 15 min-arc, respectively. Due to a denser and larger terrestrial and marine dataset used, the SAGM04 is so far the best regional gravity model for most parts of South America.

The Argentina IGN dataset comprises 7509 gravity and orthometric altitude measurements. The latitude correction was carried out using the 1980 Geodetic Reference System ellipsoid (GRS80) (Moritz, 1984) and calculating the theoretical gravity on each station coordinates using Somigliana's formula (cf. Moritz, 1980). The Bouguer correction was determined using a density of 2670 kg/m^3. A −14.97 mGal corretion was applied to the IGN dataset to tie the Miguelete local gravity datum (Introcaso, 1997) to the 1971 **I**nternational **G**ravity **S**tandardization **N**et (IGSN71) (Morelli et al., 1972). Figs. S2 and S3 (Supplementary material) describe the homogenisation and integration of the IGN gravity data into the SAGM04 model.

The final gravity data set comprises the SAGM04 model in areas inside Argentina where no terrestrial data were available within a 50 km radius (Fig. 2(a)). The gravity map shown in Fig. 2(b) comprises Bouguer anomalies over the continent and free-air anomalies over the ocean, with a lateral resolution of 5 min-arc. The digital map interpolation uses a splines in tension routine (Smith and Wessel, 1990) available in the GMT package (Wessel and Smith, 1991). Gravity anomalies referred to the geoid are in colour whereas the contour lines at 10 mGal interval are the gravity anomalies upward continued to 30 km height.

The upward continued gravity field suppresses short wavelength anomalies and highlight regional gravity features. In order to correlate the main gravity features with main geologic units, the upward continued gravity field was superimposed to a regional geological map, as shown in Fig. 3.