PERGAMON

Journal of South American Earth Sciences 14 (2001) 271–276

Journal of
South American
Earth Sciences

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Magnetic and gravity anomalies in the Sierra del Padre and Sierra del Tala, San Luis Province, Argentina: evidence of buried mafic–ultramafic rocks

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Received 1 December 1999; revised 1 July 2000; accepted 1 January 2001

Abstract

This paper presents the results of a geophysical study of the southern portion of the Sierra Grande de San Luis, San Luis Province, Argentina. A 26 mGal amplitude Bouguer anomaly (Charlone anomaly), measuring 40 km long by 7 km wide, between Sierra de los Padres and Zanjitas reflects the presence of high-density rocks located at approximately 2000 m depth. Geophysical models based on more than 300 gravimetric, magnetometric, and geological field measurements and observations suggest that the mafic–ultramafic belt of Sierra Grande de San Luis continues south of San Luis. The low magnitude of the terrestrial magnetic field anomalies indicates that these mafic–ultramafic rocks do not carry a base metal sulfides (BMS) mineralization. The Charlone gravimetric anomaly is generated by a belt of mafic– ultramafic rocks whose amplitude is comparable with that responsible for the Virorco-Las Aguilas gravimetric anomaly. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Mafic–ultramafic; BMS; Geophysic; Argentina

Resumen

El estudio geofísico de la porción de la Sierra Grande de San Luis, localizada al sur de la ciudad de San Luis, permitió determinar la presencia de una anomalía de Bouger (Anomalía Charlone) de 26 miligales de amplitud, cuyas dimensiones son 40 km de largo y 7 km de ancho. Los modelos geofísicos sugieren que esta anomalía es debida a la presencia de rocas de alta densidad localizadas en el basamento metamórfico a una profundidad aproximada de 2000 m. La escasa magnitud de las anomalías del campo magnético indican que estas rocas no son portadoras de mineralizaciones de sulfuros de metales base (BMS). La anomalía gravimétrica Charlone es comparable, en amplitud, con la anomalía gravimétrica Virorco-Las Aguilas, generada por una faja de rocas máficas–ultramáficas. Los modelos geofísicos, basados en la medición de mas de 300 estaciones de gravedad y magnetismo, demuestran que la faja de rocas máficas–ultramáficas aflorantes en la porción norte de la Sierra Grande de San Luis, se extienden al sur de la ciudad de San Luis a lo largo de 50 km. © 2001 Elsevier Science Ltd. All rights reserved.

1. Introduction

Geophysical studies performed north of the city of San Luis on the NE–SW trending mafic–ultramafic belt of the Sierra Grande de San Luis, using induced polarization and magnetometric methods, recognized the presence of a base metal sulfide (BMS) mineralization (Sabalúa, 1986). The results of recent gravimetric and magnetometric surveys carried out in the same portion of the Sierra Grande de San Luis have been reported by Mogessie et al. (1994, 1995, 1996, 1998), Bjerg et al. (1996, 1997), Felfernig et al. (1997, 1998, 1999), Felfernig (1999), Hauzenberger et al. (1996, 1997), Hauzenberger (1997), Hoinkes et al. (1999), and Kostadinoff et al. (1998a,b).

These studies showed that the outcrops of the mafic–ultramafic belt in Sierra Grande de San Luis are minor exposures of larger buried bodies. This conclusion is supported by the magnitude of both the gravimetric and magnetometric anomalies (Kostadinoff et al., 1998b). The magnitude, position, and trend of the Virorco-Las Aguilas

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PII: S0895-9811(01)00030-X

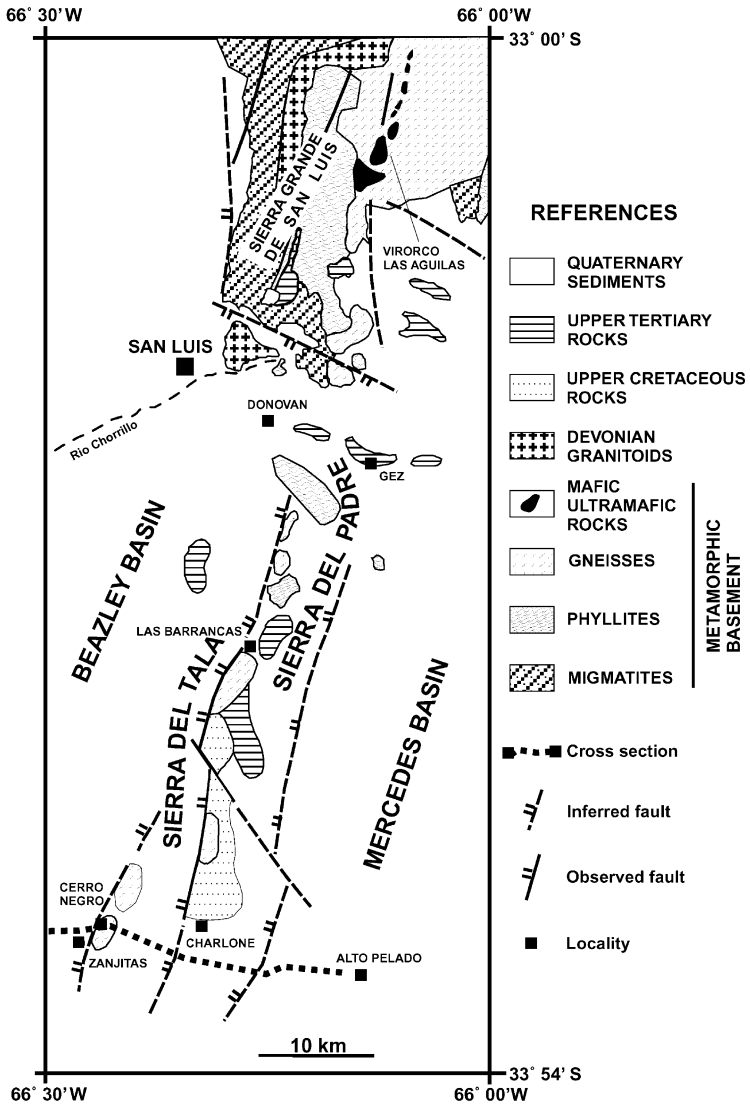

Fig. 1. Geological sketch map showing the location of the mafic–ultramafic belt and the regional cross section (Fig. 4). Modified from Yrigoyen (1981).

gravimetric anomaly in the Sierra Grande de San Luis suggest that they continue farther south.

In order to confirm this hypothesis, a 50 km wide and 80 km long area, including the Sierra del Padre and Sierra del Tala between San Luis in the north and Zanjitas in the south, was selected to perform geophysical studies (Fig. 1).

2. Geological setting

The Sierras Pampeanas of San Luis consist of the Precambrian to Paleozoic crystalline basement; mafic–ultramafic rocks, of presumably Precambrian–Paleozoic age, Paleozoic granitic stocks, and Tertiary andesitic volcanism (Gordillo and Lencinas, 1979; Ramos, 1988). The structure is a large, uplifted, faulted and folded basament block (Delpino et al., 2001). The crystalline basement is composed of greenschist, amphibolite, and granulite facies rocks, numerous mafic–ultramafic bodies, metagranites, and pegmatites. The greenschist facies rocks, phyllites and phyllonites, crop out mainly in the eastern part of the Sierra Grande de San Luis.

The outcrops of mafic–ultramafic bodies in the Las Aguilas-Virorco area are a part of large buried bodies, according to geophysical and geological studies (Kostadinoff et al., 1998a; Mogessie et al., 2000). Their intrusion into the amphibolite facies rocks caused local granulite facies metamorphism (Hauzenberger et al., 1997, 2001).

The first amphibolite facies metamorphic episode can be interpreted as regional metamorphism following a geothermal gradient of about 40°C/km. The mafic–ultramafic intrusion heated, a part of the basement to granulite facies conditions. During cooling, a second deformation event took place at amphibolite facies conditions. The most likely geotectonic setting of the Sierras de San Luis is an extensional back-arc that developed at the late stage of a compressional orogeny (Hauzenberger, 1997).

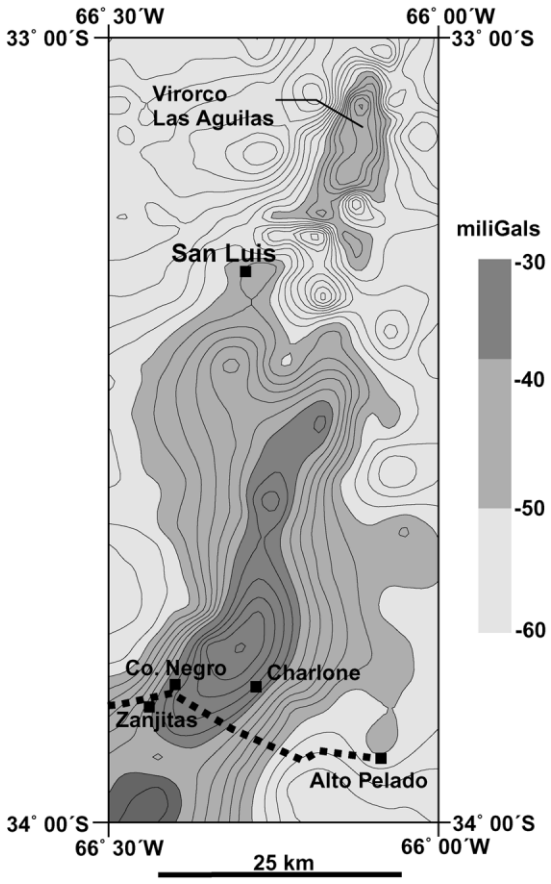

Fig. 2. Bouguer gravity anomaly map showing the localities included in the regional profile.

Several mafic–ultramafic bodies occur as intercalated lenses in the basement, following a tholeitic differentiation trend. Major and trace element variation diagrams, as well as rare earth element spider plots, indicate that these rocks were formed during the same magmatic event (Hauzenberger 1997). However, Rb–Sr and Sm–Nd isotopic patterns show inconsistencies within and between the different lenses. An inhomogeneous mantle source, mixing of different mantle magmas, and crustal contamination might have played important roles during the intrusion of these rocks.

According to Ramos (1988) the southern portion of South America is a complex collage of cratonic blocks that were brought together along the southwestern Gondwanaland margin in Late Precambrian to Early Paleozoic times. The formation of the Sierras Pampeanas has evolved in two cycles:

- formation of the Eastern Sierras Pampeanas during the Precambrian–Early Paleozoic Brasiliano Cycle,
- formation of the Western Sierras Pampeanas during the Paleozoic Famatinian Orogenic Cycle.

The Eastern Pampeanas belt appears to have formed as a result of a period of normal subduction, followed by a marked continent–continent collision. During this time, a large calc-alkaline magmatic arc was formed that is approximately 1200 km long and associated with regional metamorphism (Ramos, 1988).

A belt of differentiated mafic–ultramafic bodies and associated metabasalts (Virorco back-arc belt; Kilmurray and Villar, 1981) developed west of the magmatic arc. During the Famatinian Orogenic Cycle (Ordovician), a new subduction zone evolved along the western margin of the Pampean Terrane (Ramos, 1988).

Magmatic activity reached a maximum at the Ordovician–Silurian boundary and, subsequently, moved westward to the Precordillera in Siluro-Devonian times. Seismic profiles and deep drilling has demonstrated that, to both the east and west, the Sierra Grande de San Luis is bordered by Triassic to Tertiary sedimentary basins (Yrigoyen, 1981). The Beazley basin located to the west extends over an area of 12,000 km^2 and is filled by approximately 3400 m of sediments. The Mercedes basin is located eastwards and occupies an area of approximately 4000 km^2, with a maximum depth of 3500 m, but very little is known about its sedimentary fill.

3. Methodology

The geophysical measurements taken for this study included gravimetric, magnetic susceptibility, and magnetometric determinations. The regional values of the terrestrial gravimetric field were obtained with a Worden gravimeter, with a station density of 4 km. The terrestrial magnetic field was measured with a nuclear precision Geometric G-826 magnetometer, taking into account the daily geomagnetic variation correction and the value of the International Geomagnetic Reference Field (IGRF). The daily geomagnetic variation was corrected with a nuclear precision Geometric G-860 magnetometer located in the Trapiche area. The values were used to draw anomaly profiles and maps and to model the configuration and attitude of the anomalies. Density determinations of selected samples were done in laboratory in order to obtain realistic geological models. Magnetic susceptibility was measured in situ with a Kappameter.

4. Results

The data obtained in the area between San Luis and Zanjitas (SL-Z) were smoothed using a Kriegin filter (Figs. 2 and 3). According to these results, no positive correlation can be established between the gravimetric and magnetic anomalies.

The Bouguer anomaly map (Fig. 2) shows a 26 mGal amplitude singularity (Charlone anomaly) measuring 40 km long by 7 km wide. The amplitude of this anomaly is similar to the Virorco-Las Aguilas (V-LA) gravity anomaly located in the Sierra Grande de San Luis (Bjerg et al.,

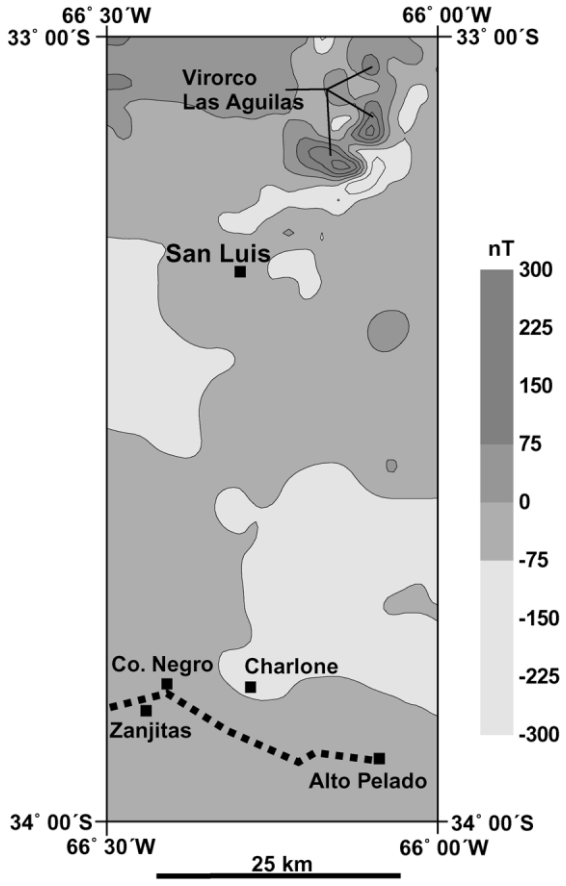

Fig. 3. Magnetic anomaly map. The largest observed anomalies are located in the northern portion of the Sierra Grande de San Luis (V-LA area).

1996; Kostadinoff et al., 1998a), where mafic–ultramafic bodies crop out. The latitudinal extent of the Charlone anomaly is twice as long as the V-LA anomaly, although mafic–ultramafic rocks do not crop out in the San Luis-Zanjitas area.

In the Zanjitas-Alto Pelado profile (Fig. 4) a 20 mGal gravity anomaly was observed at Cerro Negro. In view of the V-LA gravimetric anomaly, a reasonable explanation for this anomaly is the presence of buried high-density rocks in the basement. No correlation between the free air gravimetric anomaly and the topography was observed. The outcrops at Cerro Negro are 1.5 km in diameter, whereas the free air gravimetric anomaly has a 10 km wavelength (Fig. 4). The gneiss that crops out at Cerro Negro has an average density of 2.60 g/cm^3. Triassic Cretaceous sediments in the Mercedes basin that crop out 15 km east of Zanjitas have a density of 2.41 g/cm^3.

To the west, Triassic-Cretaceous sediments and interbedded porphyritic rocks are present in the Beazley basin. They were recognized in the Corral de Totoras (CDT.es.-1) drill hole (Manoni, 1985), which is located 15 km west of Zanjitas. A density contrast of 0.19 g/cm^3 was used to evaluate the mass deficiency of the basins located west and east of Zanjitas.

Two-dimensional density models (Talwani et al., 1959) do not explain the observed anomalies (Fig. 4). Therefore, the 20 mGal anomaly of the Cerro Negro is attributed to the presence of mafic–ultramafic rocks emplaced in the basement.

Fig. 3 shows that south of 33°20′S there are no high amplitude magnetic anomalies; the highest measured value is 150 nT in the area of Gez. In the V-LA area in Sierra Grande de San Luis, values higher than 3000 nT have been measured (Kostadinoff et al., 1998a).

The mafic–ultramafic rocks in the V-LA area carry BMS with associated platinum group minerals (Mogessie et al., 1995; Bjerg et al., 1996, 1997; Felfernig et al., 1997, 1999; Felfernig, 1999; Hauzenberger et al., 1997; Kostadinoff et al., 1998a). The gravimetric and magnetometric profiles in the V-LA area show that the anomalies are positively correlated with the location of the BMS mineralization (Kostadinoff et al., 1998a).

The reported results suggest that the high-density basement rocks located in the SL-Z area (Charlone anomaly) do not carry ferromagnetic minerals — i.e. no BMS mineralization. The Charlone gravimetric anomaly can be explained by the presence of buried mafic–ultramafic rocks not previously recognized south of San Luis. Assuming that these rocks have a density of 2.97 g/cm^3 (Mogessie et al., 1995), the Charlone anomaly can be explained by 600 km^3 of mafic–ultramafic rocks located at an approximate depth of 2 km (Fig. 4).

5. Tectonic implications

Several hypotheses were invoked to explain the origin of the mafic–ultramafic belt in the Sierra Grande de San Luis. Kilmurray and Villar (1981) suggested that these bodies are comparable with Alaskan and Uralian differentiated mafic–ultramafic complexes. Ramos (1991) proposed that these rocks are the result of the accretion of volcanic arcs developed on oceanic crust or attenuated juvenile continental crust. Another possible explanation is that they were emplaced under extensional conditions during the Pampean Cycle in a back-arc basin regime (Ramos, 1988; Hauzenberger, 1997).

Regardless of these interpretations, our contribution supports the southern continuity of the mafic–ultramafic belt and therefore, a reconsideration of the latitudinal development of the Famatinian Orogeny.

6. Conclusions

The new geophysical results presented here support the preliminary hypothesis — i.e. that the mafic–ultramafic rocks present in the Sierra Grande de San Luis extend farther south of San Luis. The observed Charlone gravity anomaly greatly increases the areal extension and amplitude of the V-LA gravity high. Since the V-LA anomaly is

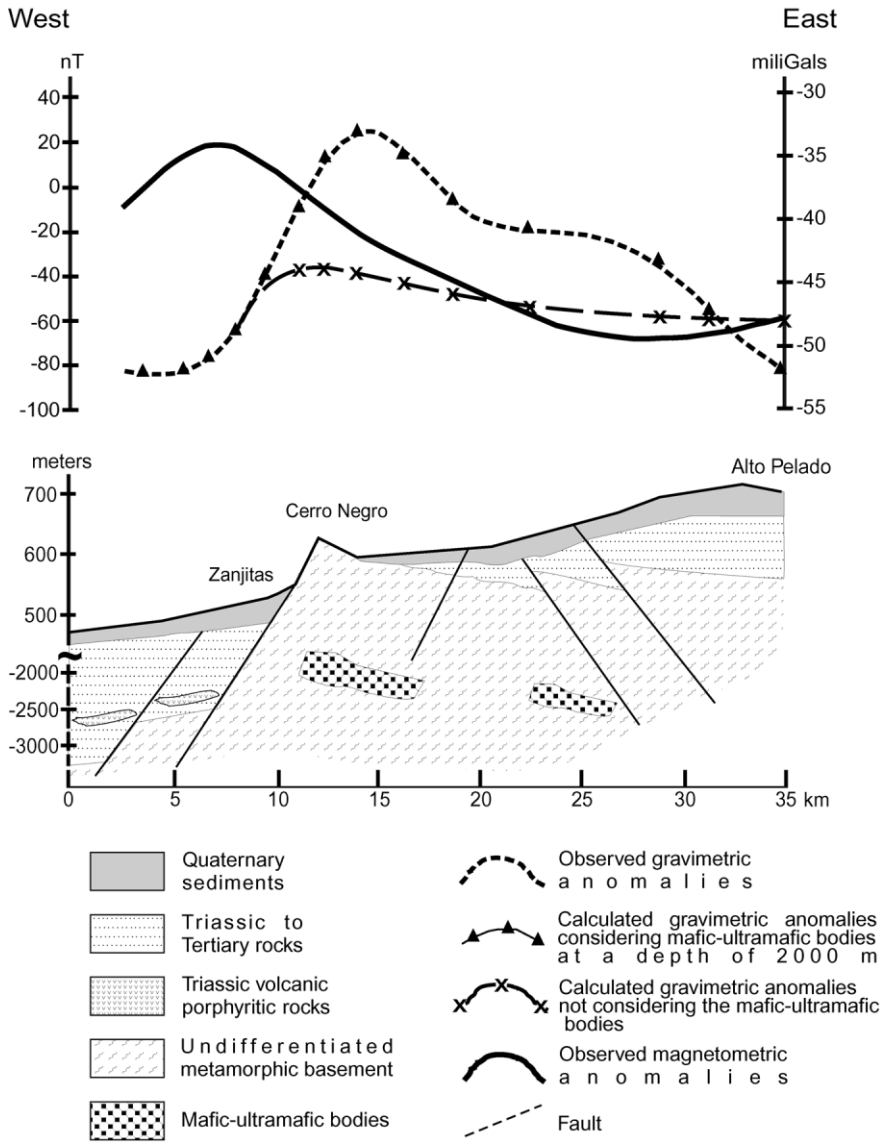

Fig. 4. Geological cross section model based on gravity and magnetic profiles between Zanjitas and Alto Pelado. The gravity anomaly is the result of buried mafic–ultramafic rocks. No correlation exists between the free air gravity anomalies and topography. The small amplitudes of the magnetic anomalies suggest the absence of ferromagnetic minerals in the country rocks.

generated by a belt of mafic–ultramafic rocks, it is proposed that the Charlone anomaly is also generated by a belt of mafic–ultramafic rocks. This would imply that the Sierra Grande de San Luis mafic–ultramafic belt extends for approximately 50 km south of San Luis, although this southern portion does not carry any BMS mineralization. Establishing the continuity of the mafic–ultramafic belt is an important issue that deserves detailed geological and structural studies due to its tectonic and economic significance.

Acknowledgements

We gratefully acknowledge financial support by the Argentine CONICET (BID-CONICET No. 11) and SGC.yT-UNS (No. 212/97) to J.K. and E.A.B., and by the Austrian FWF (P10623-TEC) to A.M. and G.H. We thank G.T. Alvarez for laboratory measurements and Carl Bowin, James Kellogg, Víctor Ramos, and two anonymous reviewers for their critical reading, which improved this paper.

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