Magnetotelluric evidences for the suture between the Río de la Plata and Pampean cratons at 31° 40´s, Córdoba province, Argentina

Mónica G. López de Luchi [1], Alicia Favetto [1], Cristina Pomposiello [1], & John Booker [2]

1 Instituto de Geocronología y Geología Isotópica. Ciudad Universitaria, Pabellón INGEIS, 1428, Buenos Aires, Argentina (deluchi@ingeis.uba.ar; favetto@ingeis.uba.ar, cpomposi@ingeis.uba.ar)
2 Dept. of Earth and Space Sciences, Box 351310, University of Washington, Seattle WA 98195, USA (booker@ess.washington.edu)

KEYWORDS: Eastern suture, Sierras de Córdoba, Sierras Pampeanas, Magnetotellurics, Electrical resistivity

INTRODUCTION

The location of terrane boundaries and their geometry at depth is in some cases controversial in the Sierras Pampeanas because boundary definition is often based on relatively scarce surface geologic information and borehole and seismic reflection data. The magnetotelluric (MT) method is a passive surface geophysical technique, which uses the Earth's natural electromagnetic fields to investigate the electrical resistivity structure of the subsurface. The natural electric and magnetic fields are recorded in two orthogonal, horizontal directions and the vertical magnetic field is also recorded. The MT method is particularly well suited for studying regional structures and may help in defining crustal variations and terrains based on lateral changes of conductivity.

The evolution of the southwestern margin of Gondwana is characterized by a series of accretionary events that involved terranes of different age and provenance that collided during the early Paleozoic. Central and northwest Argentina is characterised by generally NS striking mountain ranges that represent the terranes assemblage that was accreted to the southwestern margin of Gondwana and comprise a late Proterozoic to early Paleozoic metamorphic and igneous basement. Different models concerning the collisional history along the southwestern margin of Gondwana were proposed (Dalla Salda *et al.*, 1998; Ramos, 1999, Rapela, 2000 and references therein). Although the models differ on the timing of the first accretion, i.e. the early Paleozoic accretion of the Pampean terrane (Rapela et al. 1998) or late Proterozoic collision of the Pampia Terrane (Ramos, 1999) they have in common that the first collision was followed by the Ordovician Famatinian cycle, i.e the approaching of and the collision with the Precordillera (Cuyania) Terrane. Collisional activity ceased after the Achalian cycle during the Devonian with the accretion of the Chilenia Terrane (Stuart-Smith *et al.*, 1999; Siegesmund *et al.* 2004, Steenken *et al.*, 2004).

The Precambrian-Cambrian tectonic evolution of the Sierras Pampeanas of Córdoba (central Argentina) includes the Neoproterozoic development of a passive margin on the western side of the Río de La Plata Craton. Subsequently, this passive margin evolved into an eastward dipping subduction zone and a magmatic arc that corresponds to the present northeastern sector of the Sierras Pampeanas Orientales. The sedimentary basin would have corresponded to the Puncoviscana basin. Timing of the first accretionary events as well as the nature of the involved terranes has received different interpretations.

Ramos (1999) considered that the collision between the Río the la Plata Craton and the Pampia Terrane which followed the closure of the ocean basin to the west of the magmatic arc occurred at the latest Precambrian The suture between the Río de la Plata Craton and the Pampia Terrane is located in the western ultramafic belt of the

Sierras de Córdoba whereas the eastern ultramafic belt would be the result of the closure of a back arc basin and therefore the so-called Córdoba terrane should be a fragment of the Rio de la Plata craton (Fig.1).

Rapela et al. (1998) considered that the suture between their Pampean terrane (Pampia and Córdoba terrane) was the result of a *circa* 530 Ma accretional episode that led to the closure of the Puncoviscana basin. The Pampean orogeny is regarded as a continental collision event that affected a large sector of the proto-Andean margin of Gondwana from at least 17° to 33°SL. A common crustal history for the Pampean-terrane and the Arequipa-Antofalla massif was proposed by Steenken et al. (2004 and references therein) based on the analysis of the Sm-Nd systematics of magmatic and metamorphic rocks that are located on the Pampean Terrane, i.e. no data were included for rocks located to the east of the Carape shear zone (Martino 2003 and references therein).

This paper presents the interpretation of magnetotelluric data along a west-east profile that extended from the central part of the Sierra Grande de Córdoba (Pampa de Achala) to the limit between Córdoba and Santa Fe provinces. Therefore our results focused on analysing the eastern border of the Sierra Grande de Córdoba.

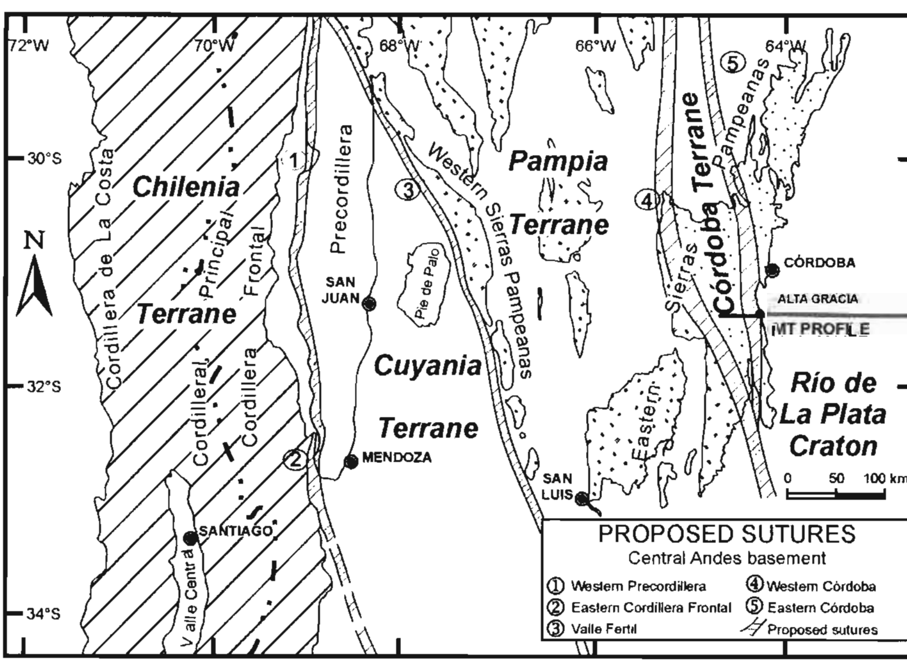

Figure 1.Schematick sketch showing the main terranes and suture in the basement of central Argentina (modified after Ramos, 1999). Location of MT profile is indicated.

MAGNETOTELLURIC DATA AND ANALYSIS

In 2001, we collected 18 sites along a 200 km long east-west profile through the city of Alta Gracia at about 31.5° S. This profile extends from the top of the Sierra Grande de Córdoba east across the plains up to the west of the Santa Fe province (Fig. 1). These data are the first collected with a new generation of low power, long period GPS-controlled systems. The data were processed using robust statistical time series methods and remote reference (Egbert, 1997). The regional strike was determined to be very close to north-south at all sites using impedance tensor decomposition for electric and magnetic distortion (Chave and Smith, 1994).

When the structure is 2D, the data separate into two independent modes with electric current flowing parallel (TE) and perpendicular (TM) to the strike. MT data were inverted using the NLCG algorithm of Rodi and Mackie (2001). This algorithm minimizes model roughness subject to fitting the data to prescribed misfit. We first inverted TM mode starting from a 1000 Ohm-m halfspace using a large value of the regularization parameter (tau=300). This produced a very smooth model that was used as starting model for subsequent inversions. Then this result was used as starting model to invert both MT polarization and Tzy for decreasing values of the regularization parameter. Misfit improves and model roughness increases as tau decreases and a value of tau=10 was used and a normalized root mean square near 1.0 was obtained in the final model.

The 2D model (Fig. 2) presents west-east changes in the resistivity patterns on the analyzed 50 km of the continental crust. At the eastern sector the first 5 km with low resistivity correspond to the sedimentary sequence of the Chacoparanse basin. Bellow this basin a more resistive area grading in depth into relatively more conductive zone is depicted. From the central part of the profile to the west a highly resistive vertical zone that involves the complete 50 km section is observed. At western sector the first 4 km are represented by a zone of comparable resistivity that grades in depth into a more conductive zone. The limit between the highly resistive vertical zone and the more conductive zone below Pampa de Achala runs approximately along the longitude of Alta Gracia. To the east of the zone a highly resistive crustal segment grades into a sector of relatively enhanced conductivity below the Chaco–Parananense basin. To the west the more resistive crustal segment is thinner and an area of enhanced conductivity appear below the block of the Sierra Grande de Córdoba.

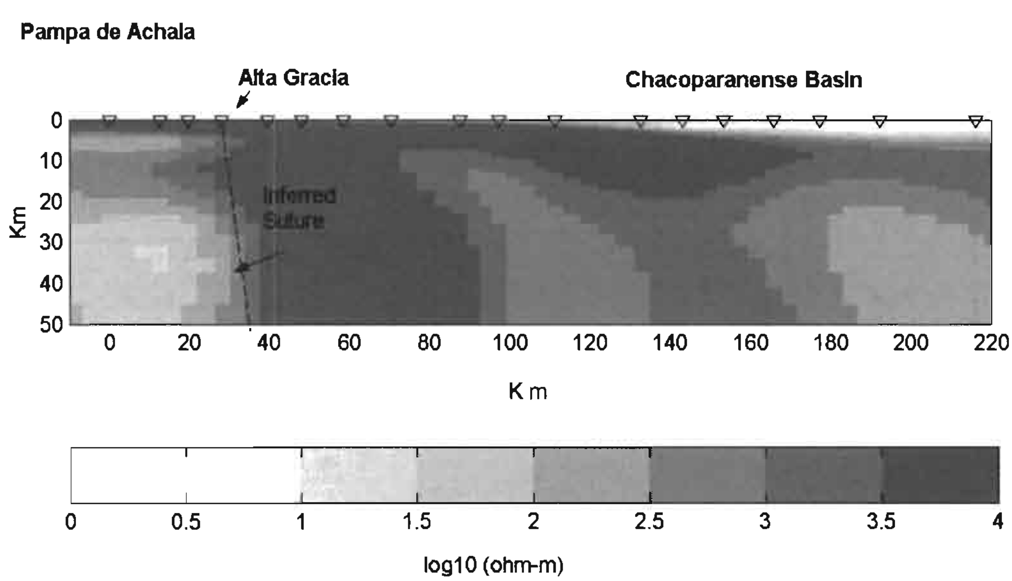

Figure 2. Resistivity model. Sites are inverted triangles.

DISCUSSION AND CONCLUSIONS

Our results indicate electrical boundaries which seem to cut through large parts of the crust separating electrical units, each with a particular conductivity structure.

The major discontinuity located at the longitude of Alta Gracia is a steeply east dipping zone that separates two units with a different resistivity pattern. This zone is almost coincident with the trace of the eastern suture that was defined for the Sierra de Córdoba (Fig. 1) and with the zone in which the flat-slab change to a steeper profile (Booker et al. 2004).

As this eastern suture would result from the closure of a back arc basin (Ramos 1999 and references therein) no different crustal patterns should be expected because both crustal blocks would belong to the Río de la Plata craton. On the contrary our model suggest that the steeply dipping zone constitutes a major discontinuity that we interpret as the suture between the Río de la Plata Craton and the Pampean terrane. Available isotopic information indicates that to the west of the eastern suture a common crustal unit, the Pampean craton could be defined (Rapela et al, 1998, Steenken et al, 2004).

Further work in progress will allow us to analyse the meaning of the western ophiolite of the Sierra de Córdoba, i.e the inferred suture between the Pampia terrane and the Río de La Plata craton

Acknowledgements

This research was supported by National Science Foundation Grants EAR9909390 and EAR0310113 and by Agencia Nacional de Promoción Científica y Tecnológica PICT 99: 07-06316. MT systems were provided by the EMSOC Instrument Facility supported by NSF Grants EAR0236538 and EAR9616421. Gabriel Giordanengo provided field technical support throughout this project.

References

Booker, J., Favetto, A., Pomposiello C., 2004. Low electrical resistivity associated with plunging of the Nazca flat slab beneath Argentina. Nature 429, 399-403.

Chave, A.D., Smith, J.T, 1994. On electric and magnetic galvanic distortion tensor decompositions. J. Geophys. Res., 99, 4669-4682

Egbert, G.D., 1997. Robust multiple station magnetotelluric data processing. Geophys. J. Int 130, 475-496.

Martino. R.D., 2003.Las fajas de deformación dúctil de las Sierras Pampeanas de Córdoba: una reseña general. Rev. Asoc. Geol. Arg 58(4), 549-571.

Ramos, V. 1999. Rasgos Estructurales del territorio argentino. In: Geología Argentina, Instituto de Geología y Recursos Minerales Anales 29: 715-784, Buenos Aires.

Rapela, C.W., R.J. Pankhurst, C. Casquet, E. Baldo, J. Saavedra, C. Galindo, C.M. Fanning (1998a), The Pampean Orogeny of the southern proto-Andes; Cambrian continental collision in the Sierras de Cordoba, in The proto-Andean margin of Gondwana, Rapela, C and Pankhurst, R.J (eds) Geol. Soc. Spec. Publ., 142, 181-217, London

Rodi, W., Mackie, R., 2001. Non-linear conjugated gradient algorithm for 2-D magnetotelluric inversion. Geophysics, 66, 174-178.

Siegesmund, S., A. Steenken, M.G. López de Luchi, K. Wemmer 2004, The Las Chacras-Potrerillos Batholith: Structural evidences on its emplacement and timing of the Intrusion, Int. J. Earth Sci., 93, 23-43

Steenken, A., M.G. López de Luchi, S. Siegesmund, K. Wemmer, and S. Pawlig 2004, Crustal provenance and cooling of the basement complexes of the Sierra de San Luis: An insight into the tectonic history of the proto-Andean margin of Gondwana, Gondwana Res., 7, 1171-1195.

Stuart-Smith, P.G., A. Camacho, J.P. Sims, R.G. Skirrow, P. Lyons, P.E. Pieters, L.P. Black, and R. Miro 1999, Uranium-lead dating of felsic magmatic cycles in the southern Sierras Pampeanas, Argentina; implications for the tectonic development of the proto-Andean Gondwana margin, in Laurentia-Gondwana connections before Pangea, edited by V.A. Ramos and J.D. Keppie, Spec. Pap. Geol. Soc. Am., 336, 87-114.