International Journal of Mining Science (IJMS)
Volume 7, Issue 2, 2021, PP 20-30
ISSN 2454-9460 (Online)
DOI: http://dx.doi.org/10.20431/2454-9460.0702003
www.arcjournals.org

Aeromagnetic Surveys as a Tool for Regional Geological Mapping: A Review of the Case Study of the Southeastern Pampean Ranges, Argentina

Carlos J. Chernicoff

Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Servicio Geológico-Minero Argentino (SEGEMAR), Argentina

***Corresponding Author: Carlos J. Chernicoff,** *Consejo Nacional de Investigaciones Científicas y Técnicas, c/o Servicio Geológico-Minero Argentino, Predio INTI , Buenos Aires province, Argentina*

Abstract: *A geological interpretation of the aeromagnetic survey of the southeastern Pampean Ranges of Argentina –referred to as "Sierras Pampeanas Orientales" in Spanish– , whose basement ages range from late Neoproterozoic to early Paleozoic, was carried out. This interpretation was mostly focused on the identification of the main structural features and the contrast in the magnetic signatures between the different igneous and metamorphic units of the region.*

The main outcome of the present study is a "solid geology" map that comprises lithomagnetic units or domains constituted by zones with a largely uniform magnetic signature i.e. a locally uniform intensity and gradient of the magnetic field. The lithomagnetic units so defined are bounded by conspicuous changes in the magnetic signatures, often caused by faults and/or fractures. The lithomagnetic units do not fit exactly the exposed lithologic units of the region due to the "transparent" nature of some lithologies to the aeromagnetic method.

In addition, the deeper configuration of some units has been investigated by applying an upward continuation filter to the total magnetic field reduced to the pole data; this method was particularly focused on a Lower Paleozoic supracrustal sequence mainly referred to as the San Luis Formation and composed of metasediments. The latter unit, although thin and sub-exposed in some areas, reaches a calculated thickness of ca. 3 km in some sectors of the study area; notably, the latter thickness of metasediments has been interpreted to pertain to a foreland basin developed immediately after the Pampean orogeny, i.e. after ca. 530 Ma.

As part of the overall geological interpretation, a deep structural section is also presented, a possible tectonic evolution of the southeastern Pampean Ranges as well being suggested. This evolution would record, after the early Cambrian Pampean orogeny, the inception of a magmatic arc (Famatinian Arc) and an associated back-arc basin during the late Cambrian to early Ordovician, which were later closed and deformed during the collision of the allochthonous Cuyania terrane against the southwestern Gondwana margin in middle Ordovician times.

Keywords: *Aeromagnetic Survey, "Solid Geology" Map, Southeastern Pampean Ranges, Upper Neoproterozoic-Lower Paleozoic Basement, Argentina*

1. INTRODUCTION

The objective of the present study was to analyze the magnetic features of the southeastern segment of the Pampean Ranges of Argentina –referred to as "Sierras Pampeanas Orientales" in Spanish– , on the basis of the aeromagnetic survey carried out by the Argentine Geological-Mining Survey (SEGEMAR) in that region (Fig. 1).

The studied area is between 66º25´W and 64º45´W, and between 32º40´S and 33º 20´S, encompassing the southeastern sector of the Pampean Ranges (San Luis province, Argentina), where a mostly late Neoproterozoic to early Paleozoic basement is exposed. The citation SEGEMAR [1] refers to the digital data of the aeromagnetic coverage.

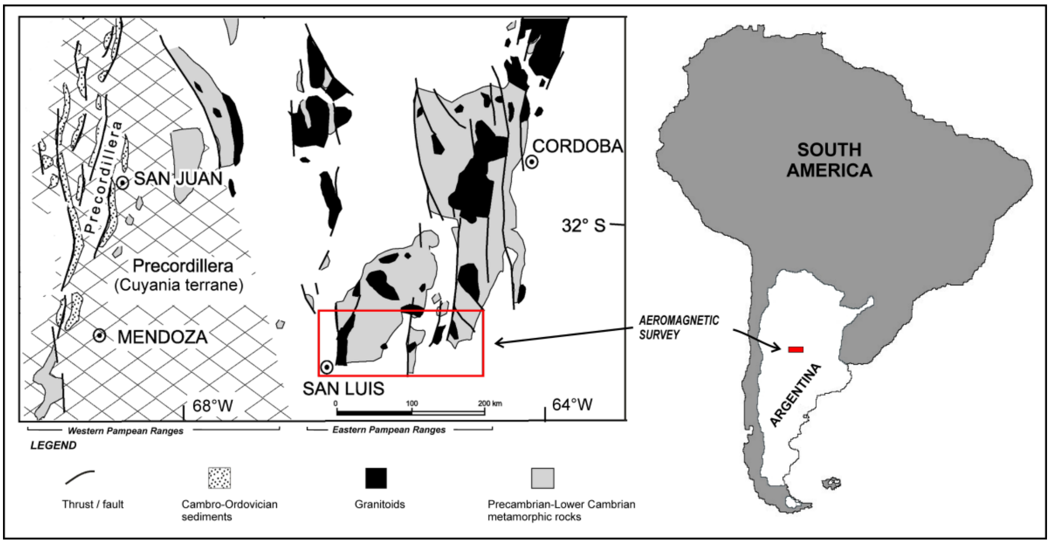

Fig1. *Locality map of the study area in the Pampean Ranges of Argentina. Red rectangle: area with aeromagnetic coverage under study (see figures 2, 3 and 4).*

2. Regional Geological Framework

The Pampean Ranges represent a large geological province of central Argentina, consisting of a number of fault-bounded, roughly N-S trending ranges or "sierras" where late Neoproterozoic to early Paleozoic basement rocks are exposed.

This type of structural style resulted from the uplift caused by the Cenozoic reactivation of old shear zones into high-angle thrusts that became the boundaries of asymmetric basement blocks; this event occurred during the Andean orogeny, as firstly pointed out by Caminos [2] both for the western and eastern Pampean Ranges.

The present study area represents the southeastern most portion of the Pampean Ranges (Fig. 1), where the basement consists mainly of metamorphic units, granitoids and mafic-ultramafic rocks.

From the geotectonic point of view, the eastern Pampean Ranges form part of the Pampia terrane which would have been accreted to the western margin of Gondwana during early Cambrian times (Pampean Orogeny, ca. 530 Ma), whereas the western Pampean Ranges form part the the Precordillera-Cuyania terrane (Fig. 1) which collided againt the Gondwana margin during the Middle Ordovician, causing the Famatinian Orogeny.

Among the many studies carried out in the present study region we should mention e.g. those of Llambías *et al.* [3][4], Quenardelle and Ramos [5], Rapela *et al.* [6], Sims *et al.* [7], Söllner *et al.* [8], Stuart Smith *et al.* [9] and Von Gosen *et al.* [10], amongst others. In addition, a preliminary interpretation of the aeromagnetic data has early been proposed by Sims *et al.* [11] and Chernicoff and Ramos [12].

3. Geophysical Method

The starting point for the present study has been the aeromagnetic survey of the southeastern Pampean Ranges carried out by the Geological-Mining Survey of Argentina [1]; figure 2 shows a map of this survey.

The latter survey involved flying 26,000 line kilometers of east-west profiles, with a line spacing of 500 m and a terrain clearance of roughly 120 m; the sampling rate of the differential GPS was 1 second, and the positioning error was less than 5 m. The airborne magnetometer employed was a SCINTREX CS-2 cesium vapour magnetometer (in-flight sensitivity 0.001 nT, dynamic range 15,000 to 100,000 nT), with a sampling rate of ten readings per second, equivalent to roughly 8 m at average aircraft speed of 130 knots). The base station magnetometers employed were GEM GDM-19, and their recording interval was set at 3 seconds. Other relevant instruments employed were: radar altimeter (sampling rate 0.25 seconds), barometric altimeter (sampling rate 0.25 seconds) and video camara.

The processing of the magnetic profiles included despiking, noise filtering, magnetic diurnal correction, removal of IGRF and leveling. This processing was double checked, i.e. both by the contractor and by the Argentine Geological-Mining Survey. The final magnetic values were then gridded –cell size 120 m– using the minimum curvature method of the gridding module of the software Oasis Montaj^{TM}.

As part of the analysis of the gridded magnetic data, several tests and filters were applied to the ´raw´ magnetic grids, enabling to generate several intermediate maps that were used as a tool for the geological interpretation, herein two of them being presented, i.e. map of the total magnetic field reduced to the pole (Fig. 2) and map of the upward continuation (to 6 km) of the total magnetic field reduced to the pole (Fig. 3).

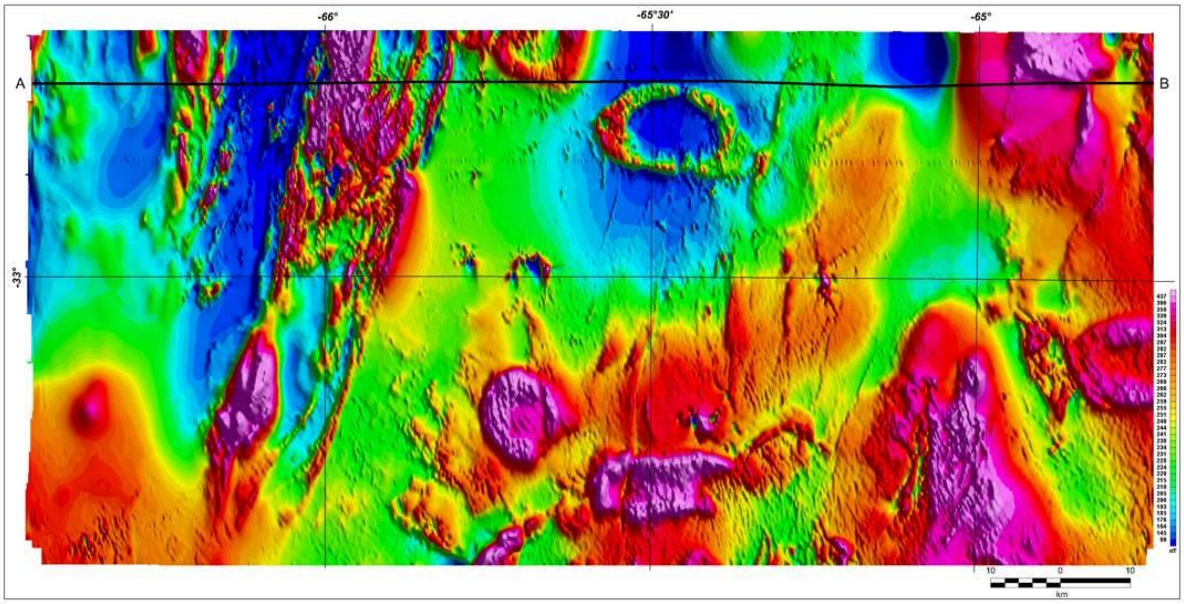

Fig2. *Aeromagnetic map of the study region (total magnetic field, reduced to the pole). See location in figure 1.*

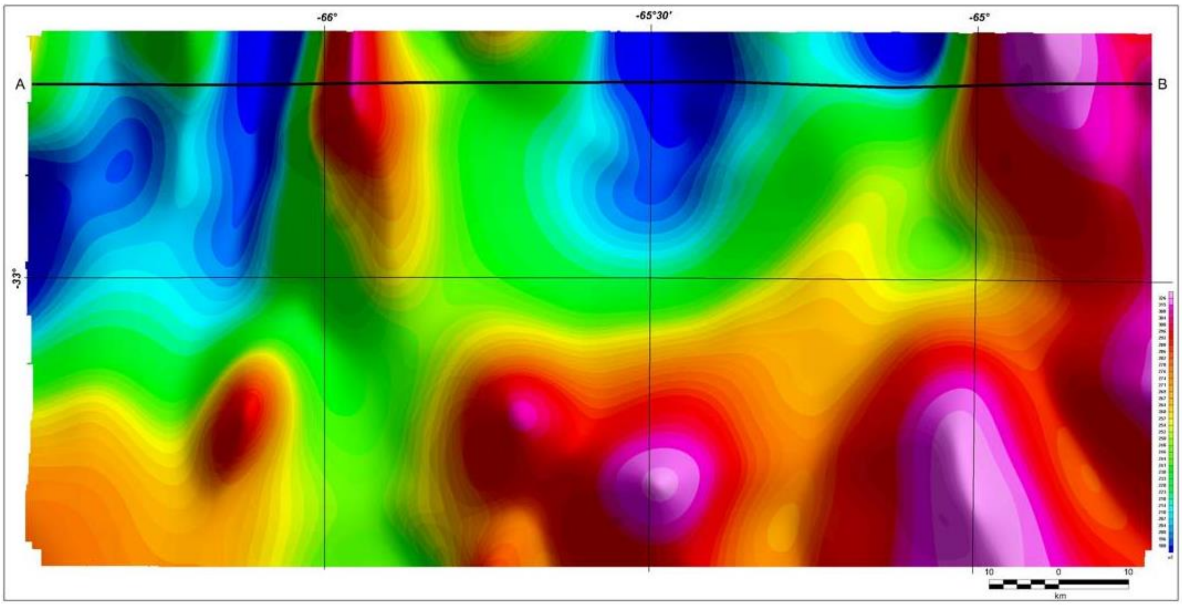

Fig3. *Aeromagnetic map of the study region (upward continuation, to 6 km, of the total magnetic field reduced to the pole). Note how magnetic features from shallow sources ´disappear´. See location in figure 1.*

4. RESULTS

The distinct characteristics of the southeastern Pampean Ranges of Argentina have allowed to establish divisions in terms of different magnetic textures and intensities recognized both at shallow and deeper levels in this region, leading to define a group of lithomagnetic units. On this basis, and also by means of the correlation with the previous geological knowledge, a crustal section of the basement of the present study region has also been drawn.

The present geological interpretation (Figure 4) particularly emphasizes the structural features and contrasting magnetic signatures between the different types of granitic bodies occurring in the region. Figure 4 represents a "solid geology" map, that is to say a map where the units identified – lithomagnetic units or lithomagnetic domains– are constituted by zones with broadly uniform magnetic signatures i.e. zones with broadly uniform magnetic intensity and gradient, as measured locally and as shown by the aeromagnetic maps of the region [13]. The lithomagnetic domains defined herein are bounded by conspicuous changes in the magnetic signatures that, in many cases, arise from the occurrence of faults and/or fractures. The lithomagnetic units do not fit exactly with the lithologic units exposed in the study region due to the ´transparent´ nature of some local –largely surficial– lithologies to the aeromagnetic method. To define the domains from the aeromagnetic maps, a number of features such as the intensity and gradient of the magnetic field and the configuration of the anomalies arising from both shallow and deep levels were considered; these characteristics were contrasted in conjunction with the magnetic signature of each and every lithologic unit known from previous geological maps of the study region. In the concluding part of this work a tectonic interpretation of the region is also provided.

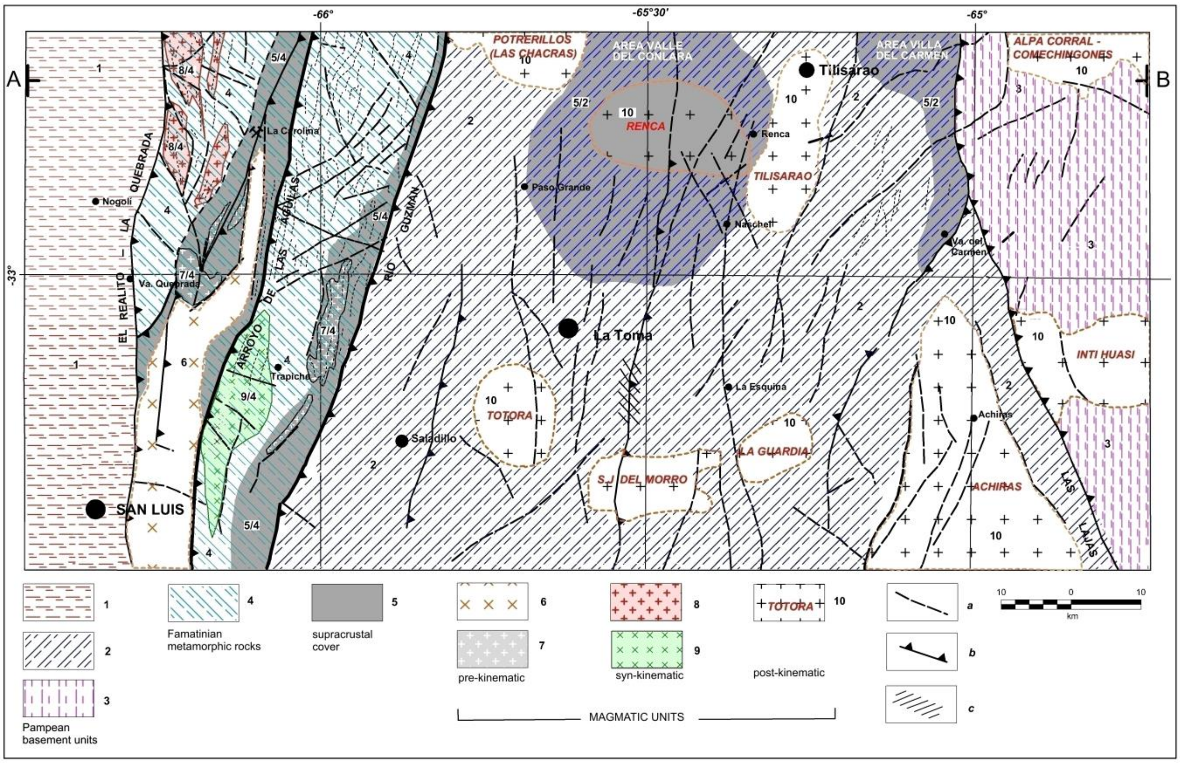

Fig4. *Geological interpretation of the aeromagnetic survey of the study region. References: 1: Nogolí Metamorphic Complex; 2: Conlara Metamorphic Complex; 3: Monte Guazú Metamorphic Complex; 4: Pringles Metamorphic Complex; 5: San Luis Formation; 6 and 7: pre-kinematic eruptive bodies; 8 and 9: syn-kinematic eruptive bodies; 10: post-kinematic eruptive bodies; a: fault/fracture; b: thrust; c: amphibolite of the Morro hills. Major shear zones: El Realito-La Quebrada, Río Guzmán and Las Lajas. Major thrust: Arroyo de las Aguilas. See location in figure 1.*

4.1. Lithomagnetic Units Identified

The several lithomagnetic units described herein have been analyzed within the broad conceptual geological framework proposed by Sims *et al.* [11][7]; for this purpose, the study region has been divided into four major sectors, i.e. western, central-western, central and eastern.

4.1.1. Western Sector

This sector is located in the extreme west of the study region, and corresponds to the lithomagnetic unit No. 1 of figure 4. It encompasses the Nogolí Metamorphic Complex [11] formed by felsic orthogneisses, amphibolites and minor pelitic gneisses. The crystallization age of the igneous protoliths of this Complex is late Neoproterozoic (553 ± 3 Ma; [14]), whereas the superimposed metamorphism occurred during the Famatinian orogeny (Lower Paleozoic).

The Nogolí Metamorphic Complex or lithomagnetic unit No. 1 shows a uniformly low magnetic gradient, and a magnetic intensity particularly low in its northern segment; the latter features allow to distinguish the latter Complex from the Pringles Metamorphic Complex (lithomagnetic unit No. 4, in figure 4), from which it is separated by a roughly N-S trending, west verging thrust that corresponds to the so called El Realito-La Quebrada shear zone [15].

4.1.2. Central-Western Sector

This sector is located between the El Realito shear zone on the western side, and the Río Guzmán shear zone on the eastern side (Fig. 4). This is the more structurally complex sector, and largely corresponds to the Pringles Metamorphic Complex or lithomagnetic unit No. 4. However, several lithomagnetic units could be identified within this central-western sector.

a) Pringles Metamorphic Complex

It is bounded by north-northeast trending, west verging regional thrusts. It comprises pelitic gneisses and schists, intruded by mafic and ultramafic rocks, and a large number of leucogranitic and pegmatitic bodies. The contact between the gneisses and the amphibolites is usually mylonitic.

In addition, The Pringles Metamorphic Complex is formed by two blocks separated by the conspicuous Arroyo de las Aguilas thrust, also north-northeast trending and west-verging (Fig. 4). The eastern block coincides with the hanging wall of the thrust, and it is equivalent to the *Eastern Basement Complex* of von Gosen *et al.* [10]. Its northern segment has a strong magnetic signature, both in intensity and gradient; here the foliation or schistosity of the Pringles Metamorphic Complex can be recognized by the conspicuous north-northeast trending magnetic fabric even where this Complex is covered by the younger phyllites and mica-schists of the San Luis Formation. The western block represents the footwall of the Arroyo de las Aguilas thrust, and it is equivalent to the *Western Basement Complex* of von Gosen *et al.* [10]. It is characterized by its medium to high magnetic gradient and intensity, which is consistent with the occurrence of pre- to syn-kinematic granitoids of intermediate composition and high magnetic susceptibility, though apparently without pegmatoid components of low magnetic susceptibility. This western block is also covered by the metasediments of the San Luis Formation.

As regards the age of this Complex, a zircon U-Pb SHRIMP age yielded 460 to 450 Ma [7], hence this Complex being interpreted as an association of rocks metamorphosed during the Middle Ordovician.

b) Las Aguilas Group

The southern sector of the eastern block shows a magnetic high that arises from the syn-kinematic emplacement of the mafic and ultramafic rocks of the Las Aguilas Group (lithomagnetic unit No. 9 , in figure 4). These rocks are characterized by bodies of mafic and ultramafic rocks metamorphosed in granulite facies; they include dunites, pyroxenites, hornblendites and amphibolites. The crystallization age of these rocks was calculated at 478 ± 6 Ma [11], from felsic segregations

These rocks have been interpreted either as a series of lineal intrusions unrelated to an ofiolitic assemblage [16], or a suture of a backarc basin [17], or a series of mafic-ultramafic rocks and amphibolites emplaced synchronically with the regional deformation in either a backarc setting or an island arc setting [11].

c) San Luis Formation

Both the eastern and the western blocks are covered by a supracrustal sequence referred to as the San Luis Formation [18][19], which gives rise to conspicuos north-northeast trending magnetic lows. These supracrustal rocks correspond to lithomagnetic unit No. 5 (in figure 4). The subtle displacement of the upward-continued magnetic anomalies pertaining to this unit towards the east (Fig. 3), with respect to their location in the aeromagnetic map without applying the upward continuation filter (Fig. 2), suggests that these belts dip towards the east. These belts are in tectonic contact with higher-grade metamorphic rocks; their thickness has been estimated at ca. 500 m.

The phyllites and mica-schists that constitute the San Luis Formation contain thin interbedded acidic metavolcanic layers which have been dated at 529 ±12 Ma [8], hence allowing to assign this Formation to the early Cambrian. These rocks are correlated with the Puncoviscana Formation exposed in the northwestern zone of Argentina, as well as with the Cantera Green Formation [20] exposed towards the south. Both these sequences have in common that they have undergone the Famatinian (Ordovician) metamorphism.

d) Granitoids

In the southern segment of the Central-Western Sector, a lower magnetic gradient and intensity, caused by the occurrence of syn-kinematic granites and pegmatites with very low magnetic susceptibility, is detected both in the eastern and in the western blocks. The most southern portion of this belt is intruded by the La Escalerilla Granite corresponding to lithomagnetic unit No. 6 (Fig. 4), which also gives rise to a magnetic low. The latter Granite is pre-kinematic [3][5], and together with the nearby Rio Claro Granite, have been dated at 507 Ma and 490 Ma [10], indicating a late Cambrian to early Ordovician age.

Other smaller-scale intrusive bodies occurring in this area are pre-kinematic tonalites-granodiorites (Bemberg, Las Verbenas, Gasparillo and Tamboreo units) jointly grouped into lithomagnetic unit No. 7 (Fig. 4); they show low magnetic intensity and gradient, and their small magnetic contrast only allows to roughly draw their outlines. A similar case is that of the syn-kinematic granites mapped by Llambías *et al.* [3], included in the lithomagnetic unit No. 8 (Fig. 4). Finally, there are pre- and syn-kinematic bodies that due to their small dimensions as well as their little contrasting magnetic features cannot be detected in a regional aeromagnetic survey.

4.1.3. Central Sector

This sector comprises biotitic schists and paragneisses of the Conlara Metamorphic Complex. On the basis of its magnetic signatures, three lithomagnetic units can be distinguished in this region, namely 1) an homogeneous basement corresponding to the Conlara Metamorphic Complex (*sensu stricto*), 2) a supracrustal cover, with metamorphic rocks characterized by a thick metasedimentary sequence, with minor syn-sedimentary volcanism and 3) several post-orogenic and anorogenic granites.

a) Conlara Metamorphic Complex

The Conlara Metamorphic Complex, as named by Sims *et al.* [11], corresponds to the Proterozoic-Lower Paleozoic Basement located between the San Luis and Comechingones ranges. It corresponds to lithomagnetic unit No. 2 (Fig. 4) that in the extreme south of the Comechingones range includes the Achiras (metamorphic) Complex [21].

The western boundary of the Conlara Metamorphic Complex is defined by a strong, north-northeast trending magnetic lineament, that corresponds to the remarkably west-verging Rio Guzman shear zone. The latter shear zone separates the Conlara Metamorphic Complex from the Pringles Metamorphic Complex which is locally overlain by San Luis Formation metasediments.

The metamorphic basement of the Conlara Metamorphic Complex comprises metapelitic and metapsammitic schists and gneisses, as well as minor amounts of felsic orthogneisses, calc-silicatic rocks and marbles which, in conjunction, present an homogeneous magnetic fabric, with few lineaments. One of them, located immediately north of San José del Morro (“c” in Fig. 4), at 65º 31´W /33º 07´S, has been interpreted as a west-verging, north-northeast trending Cenozoic thrust, i.e. roughly parallel and coincident with the north-northeast striking alignment of amphibolite bodies previously identified and described by Delakowitz *et al.* [22] west of the Morro range. The Cenozoic thrust referred to above has affected the Morro Granite (see figures 2 and 4). These amphibolites were initially interpreted as pertaining to a Pampean (Cambrian) backarc basin [22] located within the sialic basement of the San Luis ranges. However, a new inspection of these amphibolites as well as their magnetic signature do not lead to identify any discrete discontinuity within the local basement associated with them, hence it is herein interpreted that the latter intra-oceanic magmatic arc would be completely ´cratonized´ i.e. no crustal discontinuity whatsoever being preserved associated with the amphibolites. This context is consistent with the newly, preliminary geochronological data that places the amphibolites referred to above as pre-Pampean, i.e. pre-530 Ma, indicating that their location points to a zone of weakness that was later taken advantage of by the Cenozoic compressive regime (thrusts) in the study region.

b) Supracrustal Cover

The map of the total magnetic field reduced to the pole presented in figure 2, as well as its upward continuation (Fig. 3), allow to infer the occurrence of two sectors of a thick, unexposed supracrustal sequence geophysically similar to that of the supracrustal sequence exposed in the Central-Western Sector of the study area, referred to as the San Luis Formation (see above). The thickness of the (unexposed) sequence has been estimated using the Euler deconvolution of the magnetic data, neglecting the locally thin layer of Cenozoic sediments for this calculation. Given the latter assumption, the depth of the supracrustal sequence equals its thickness.

The first sector corresponds to the Villa del Carmen area (see Fig. 4) and comprises a sequence of metasedimentary rocks, roughly 3 km thick, that extends along a nearly north-south trending belt bounded by the western fault of the Comechingones range. The latter fault coincides with a strong magnetic lineament that delineates the western boundary of the Las Lajas shear zone, and separates the supracrustal sequence from the Monte Guazú Metamorphic Complex. This major structure would correspond to the contact between the Rio de la Plata craton and the Pampia terrane. Although the supracrustal rocks herein referred to are largely covered by Cenozoic sediments, to the north of the study area, equivalent low-grade phyllites are better exposed and have been dated at ca. 525 Ma (Los Túneles phyllite; [6]).

The second sector corresponds to the Valle del Conlara area, and it is characterized by a conspicuous magnetic low 33 km in diameter (see Fig. 4), encompassing the region between the localities of Tilisarao, Naschel and Paso Grande. In this central sector, the sequence of metapelites and metapsammites reaches a thickness of ca. 2 km. The magnetic signature of this sector is similar to that of the most eastern supracrustal sequence (Villa del Carmen area).

c) Post-Orogenic and Anorogenic Granitoids

The present aeromagnetic survey allows to identify a group intrusive bodies which clearly cut the foliation/schistosity of the metamorphic basement in the eastern sector of the study area (see lithomagnetic unit No. 10, in figure 4). The inferred geometry of these bodies point out to two different types of granitoids in this sector, as previously suggested from field evidence [4][5].

The first group is characterized by concentric magnetic facies of circular to elliptical shape. The most conspicuous example in the study area is the Lower Devonian Renca Granite (see Fig. 4). This body presents concentric facies of growing intensity towards its outer rim, as it can be seen in the halos of high magnetic frecuency and intensity in figure 2. The magnetic susceptibility varies from 100×10^{-5} to 1000×10^{-5} SI in the outer rim, to less than 10×10^{-5} SI in the central nucleus, consistent with the facial variation from a biotitic granite-porphyritic monzogranite to an equigranular two-mica granite, respectively [23]. These bodies are interpreted as anorogenic, given that at the moment of their emplacement, no stress was being exerted; an additional reason for considering them as anorogenic bodies is that at their emplacement time they presented high thermal contrast with their host rocks [3]

The second group corresponds to the post-orogenic granitoids that cut the Pampean (Cambrian) metamorphic fabric, but whose emplacement occurred while deformation stress was still active. The latter feature is inferred from the elongated subcircular shape of the bodies.

In the extreme south of the Comechingones range the Achiras Igneous Complex (Fig. 4) has been identified. This Devonian unit (382 ± 6 Ma; [24]) is characterized by a conspicuous magnetic high, part of which, additionally, also presents high gradient where rocks pertaining to this unit are exposed or are nearly exposed.

4.1.4. Eastern Sector

This sector comprises the Monte Guazú Metamorphic Complex (lithomagnetic unit No. 3, in figure 4), consisting of pelitic gneisses and tonalitic orthogneisses, as well as minor orthoamphibolites and metagabbros. This unit is upthrust on the Conlara Metmorphic Complex (lithomagnetic unit No. 2) that has comparatively lower magnetic intensity. The Cenozoic thrust between lithomagnetic units No. 2 and No. 3 is likely a reactivation of the Paleozoic Las Lajas shear zone (see Fig. 4) which, in turn, represents a segment of the early Cambrian suture between the Rio de la Plata craton and the Pampia terrane.

The metamorphic rocks of this Eastern Sector are intruded by post-orogenic granitoids similar to those intruded in the Central Sector.

4.2. Structure

Figure 5 shows an east-west magnetic profile at 32º 45´S, combined with a relevant portion of the aeromagnetic map (upward continuation to 6 km) and of the corresponding portion of the map of geological interpretation (figures 3 and 4, respectively). The interpretation of the magnetic profile is done on the basis of the different lithomagnetic units identified, and it is also done in accordance with the geological framework previously described. Finally, the structural section presented in figure 6 summarizes the knowledge about the basement exposed in the study region, to which the present interpretation of the aeromagnetic survey is also added. Figure 6 shows the main geologic units and the main structures, as well as an interpretation at depth based on the characteristics of the lithomagnetic units.

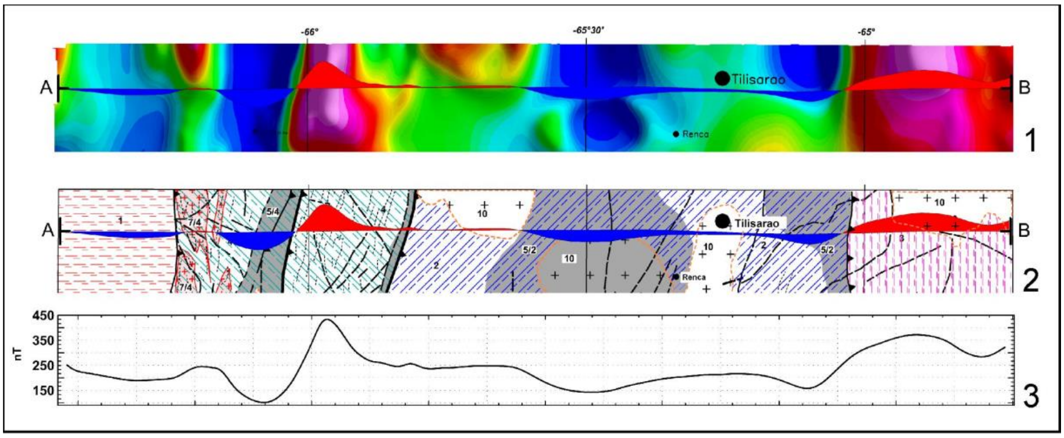

Fig5. *East-west magnetic profile at latitude 32º 45´S. Residual values (colour of the filling: red = positive, blue = negative; range of values: -132 / 199 nT), combined with 1) Aeromagnetic map (upward continuation, 6 km, of the total magnetic field reduced to the pole) and 2) Map of geological interpretation of the aeromagnetic survey (references in caption of figure 4); 5/2 indicates lithomagnetic unit No. 5 partly covering lithomagnetic unit No. 2. See location of A-B transect in figure 4.*

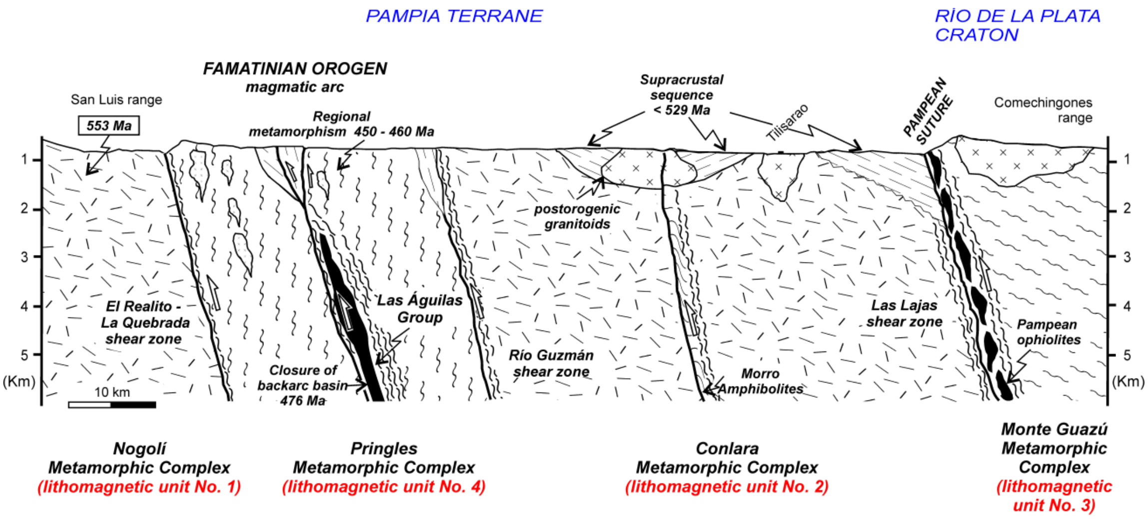

Fig6. *Structural section of the eastern Pampean ranges (between the San Luis and Comechingones ranges) prepared on the basis of the lithomagnetic units herein identified, as well as on previous structural data [10]. Not to scale.*

One of the more salient characteristics is the mimmicking of the Precambrian-early Paleozoic shear zones by the Cenozoic (Andean) structures. These older shear zones bound the main metamorphic complexes previously described. It is interesting to see the continuity of the supracrustal cover at the western side of the Pampean (ca. 530 Ma) suture between the Rio de la Plata craton and the Pampia terrane. Otherwise, within the Conlara Metamorphic Complex the Morro Belt of amphibolites [22] is indicated (c, in figure 4), which although it does not show any magnetic contrast *per se*, it coincides with a younger fault that stands out as a magnetic feature. The Rio Guzman shear zone juxtaposes the Conlara Metamorphic Complex with the San Luis Formation herein interpreted as part of the supracrustal sequence. The latter Formation is repeated by a group of west-verging high-dipping thrusts; the most conspicuous feature of this sector is the tectonic emplacement of the (mafic-ultramafic) Las Aguilas Complex which, although strictly, it is exposed to the south of the trace of the geological transect of figure 6, it has nevertheless been projected slightly to the north, so as to reach the profile. In this sector, the Pringles Metamorphic Complex (lithomagnetic unit No. 4, in Fig. 4) is the unit most severely deformed, with a large number of roughly north-south trending sub-parallel faults

The El Realito – La Quebrada shear zone has placed the metamorphic rocks of the Pringles Complex over the pre-Famatinian (pre-Ordovician) basement. The latter basement is herein (Fig. 6) interpreted as part of the Pampia terrane, which has been reworked in the Central-Western zone by a regional metamorphism of Ordovician age.

5. Discussion

The data analyzed plus the structural section described allow to suggest a tectonic interpretation based both on the lithomagnetic units herein identified as well as on the previous geological knowledge of the study region. The salient points of this interpretation are as follows:

- The polarity of the subduction zone corresponding to the main Pampean (early Cambrian) magmatic arc is towards the East, below the Monte Guazú Metamorphic Complex (lithomagnetic unit No. 3, in Fig. 4).
- The oldest rocks of the eastern sector (Monte Guazú Metamorphic Complex) correspond to the Rio de la Plata craton (or Cordoba terrane [25]). The roughly north-south structural trend of this area may indicate a strong reworking with respect to the N50-70°W “Transamazonian” (or “Transplatense”, *sensu* Santos *et al.* [26]) trend, typical of the Rio de la Plata craton. The Monte Guazú Metamorphic Complex is bounded to the west by the Las Lajas shear zone that marks the suture with the Pampia terrane.
- It is interpreted that the supracrustal sequence (San Luis Formation) is post- Pampean orogeny (i.e. post ca. 530 Ma), and equivalent to the Los Túneles Phyllite dated at ca. 529 Ma. In addition, the San Luis Formation is bound to be also equivalent and partly coeval with the Cantera Green Formation [20] exposed to the south of the present study region, where it has been assigned to the same tectonic context, i.e. a post-Pampean foreland basin developed during the Upper Cambrian-Ordovician in the southwestern margin of Gondwana.
- A subduction with polarity towards the east, occurred to the west of the San Luis range, gave rise to the Famatinian (Ordovician) magmatic arc , developed on the Pampia terrane; its onset would have occurred at least at ca. 507 Ma i.e. the maximum age of the pre-kinematic granitoids of the study region, e.g. La Escalerilla Granite [10], and would have persisted until at least the lower Ordovician. A synchronous extension in the Famatinian back-arc region gave rise to the basic rocks of the Las Aguilas Group, emplaced tectonically in the eastern sector of the Pringles Metamorphic Complex in the Middle Ordovician, by means of major, roughly north-south trending structures reactivated during the Devonian.
- The post-orogenic granitoids of the eastern region were emplaced at the latest stage of the deformation, or immediately after the cessation of the regional stress, showing typically circular or sub-circular emplacement shapes.

6. Conclusions

The interpretation of the aeromagnetic data of the present study region, combined with previous geological studies of this region, have allowed to identify a number of lithomagnetic units objectively defined. Many of these units have a direct correlation with the different metamorphic complexes, mafic-ultramafic rocks, and granitic bodies already recognized in the basement of the southeastern Pampean Ranges of Argentina, although providing a better identification of their contacts, particularly when the latter contacts are partly or totally covered.

One of the greatest contributions of aeromagnetometry in the study region is to have permitted to objectively discern, in accordance with the prevailing stress regime, the characteristics of the post-orogenic granitic bodies. Additionally, the aeromagnetic data have been very useful to delimit the supracrustal sequences, which present a significant thickness and a wide distribution in the region

On this basis, a tectonic evolution model has been proposed, interpreting that as a result of the collision of the Pampia terrane against the cratonic margin (Río de la Plata craton) approximately at ca. 530 Ma, a thick foreland basin was given rise. The latter basin was later reworked and deformed during the Famatinian (Ordovician) orogeny, characterized by a late Cambrian-early Ordovician magmatic arc and an oceanic backarc basin, that were jointly closed coevally with the subsequent collision of the Cuyania terrane (basement of the western Pampean ranges; see Fig. 1) during the Middle Ordovician.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the Geological-Mining Survey of Argentina (SEGEMAR) for the use of their proprietary aeromagnetic data and for their permission to publish.

REFERENCES

[1] SEGEMAR, 2019. Catálogo de productos 2019. Instituto de Geología y Recursos Minerales, Servicio Geológico-Minero Argentino. Datos digitales (Magnetometría y Espectrometría de rayos gamma) del Área San Luis. See page 27 of Catalogue, in www.segemar.gov.ar/descargas/catalogo/catalogo.pdf

[2] Caminos, R., 1979, Sierras Pampeanas de Tucumán, Catamarca, La Rioja y San Juan, in Turner, J. C., ed., Segundo Simposio Geología Regional Argentina: Academia Nacional de Ciencias, Córdoba, Argentina, p. 41-80.

[3] Llambías, E., Quenardelle, S., Ortiz Suárez, A., Prozzi, C., 1996, Granitoides sincinemáticos de la Sierra Central de San Luis. In 13° Congreso Geológico Argentino and 3° Congreso de Exploración de Hidrocarburos, Proceedings 3: 487-496, Buenos Aires.

[4] Llambías, E.J., Sato, A.M., Ortiz Suárez, A., Prozzi, C., 1998. The granitoids of the Sierra de San Luis. In Pankhurst, R.J. and Rapela, C.W. (eds.) The Proto-Andean margin of Gondwana, Geological Society of London, Special Publication 142: 325-341.

[5] Quenardelle, S and Ramos, V.A., 1999. The Ordovician western Sierras Pampeanas magmatic belt: record of Precordillera accretion in Argentina. In: Ramos, V.A. and Keppie, D. (eds.) Laurentia Gondwana Connections before Pangea. Geological Society of America, Special Paper 336: 63-86.

[6] Rapela, C.W., R.J. Pankhurst, Casquet, C., Baldo, E., Saavedra, J. Galindo, C., Fanning, C.M., 1998. The Pampean Orogeny of the southern proto-Andes: Cambrian continental collision in the Sierras de Córdoba. In: Pankhurst, R.J. and Rapela, C.W. (Eds). The Proto-Andean Margin of Gondwana. Geological Society of London, Special Publications, 142: 181-217, London.

[7] Sims, J.P., Ireland, T.R., Camacho, A., Lyons, P., Pieters, P.E., Skirrow, R.G., Stuart-Smith, P.G., Miró, R., 1998. U-Pb, Th-Pb and Ar-Ar geochronology from the southern Sierras Pampeanas, Argentina: implications for the Palaeozoic tectonic evolution of the western Gondwana margin. In Pankhurst, R.J. and Rapela, C.W. (eds.) The Proto-Andean margin of Gondwana. Geological Society, London, Special Publication 142: 259-281.

[8] Söllner, F., Brodtkorb, M., Miller, H., Pezzutti, N., Fernández, R., 2000. U-Pb zircon ages of metavolcanic rocks from the Sierra de San Luis, Argentina. Revista de la Asociación Geológica Argentina, 55: 15-22.

[9] Stuart-Smith, P.G., Camacho, A., Sims, J.P., Skirrow, R.G., Lyons, P., Pieters, P.E., Black, L., Miró, R., 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: Ramos, V.A. and Keppie, J.D. (Eds.): Laurentia-Gondwana before Pangea.Geological Society of America Special Paper 336, p. 87-114.

[10] Von Gosen, W., W. Loske y C. Prozzi, 2002. New isotopic dating of intrusive rocks in the Sierra de San Luis (Argentina): implications for the geodynamic history od the Eastern Sierras Pampeanas. Journal of South American Earth Sciences, 15(2): 237-250.

[11] Sims, J.P., Stuart Smith, P., Lyons, P., Skirrow, R., 1997. Informe Geológico y Metalogénico de las Sierras de San Luis y Comechingones, provincias de San Luis y Córdoba. Servicio Geológico Minero Argentino Anales 28: 1-148.

[12] Chernicoff, C.J. and Ramos, V.A., 2003. El basamento de la sierra de San Luis: nuevas evidencias magnéticas y sus implicancias tectónicas. Revista de la Asociación Geológica Argentina, 58 (4): 511-524.

[13] SEGEMAR, 1996. Carta aeromagnética de las sierras de San Luis y Comechingones, escala 1:250.000. Servicio Geológico-Minero Argentino. Buenos Aires.

[14] Vujovich, G.I. and Ostera, H., 2003. Evidencias del Ciclo Pampeano en el basamento del sector noroccidental de la Sierra de San Luis. Revista de la Asociación Geológica Argentina 58 (4): 541-548.

[15] Sato, A.M., González, P.D., Llambías , E.J., 2003. Evolución del Orógeno Famatiniano en la Sierra de San Luis: magmatismo de arco, deformación y metamorfismo de bajo a alto grado. Revista de la Asociación Geológica Argentina, 58 (4): 487-504.

[16] Villar, L.M., 1975. Las fajas y otras manifestaciones ultrabásicas en la República Argentina y su significado metalogenético. II° Congreso Ibero-Americano de Geología Económica, Proceedings III: 135-155, Buenos Aires.

[17] Ramos, V.A., 1988. Late Proterozoic – Early Paleozoic of South America: a collisional history. Episodes, 11: 168-175.

[18] Prozzi, C., 1990. Consideraciones acerca del Basamento de San Luis. Actas 11° Congreso Geológico Argentino, 1: 452-455, San Juan.

[19] Prozzi, C. and Ramos, G., 1988. La Formación San Luis. Abstracts 1° Jornadas de Trabajo de las Sierras Pampeanas, p. 1, San Luis.

[20] Chernicoff, C.J., Santos, J. O.S., Zappettini, E.O., McNaughton, N. J., 2007. Esquistos del Paleozoico Inferior en la cantera Green, sur de San Luis, Argentina: edades U-Pb SHRIMP e implicancias geodinámicas. Revista de la Asociación Geológica Argentina, 62 (1): 154-158.

[21] Otamendi, J.E., Nullo, F.E., Patiño Douce, A.E., Fagiano, M., 1998. Geology, mineralogy and geochemistry of syn-orogenic anatectic granites from the Achiras Complex, Córdoba, Argentina: some petrogenetic and geodynamic implications. Journal of South American Earth Sciences, 11 (4): 407-423.

[22] Delakowitz, B., Höll, R., Hack, M., Brodtkorb, M.K., Stärk, H., 1991. Geological and geochemical studies of the Sierra del Morro Oeste (San Luis Province, Argentina): meta-sediments and meta-volcanics from the probable back-arc setting. Journal of South American Earth Sciences 4(3): 189-201.

[23] Lopez de Luchi, M.G. 1996. Enclaves en un batolito postectónico; petrología de los enclaves microgranulares del batolito de Renca, Sierras Pampeanas, San Luis. Asociación Geológica Argentina. Revista: 51 (2): 131-146. Buenos Aires.

[24] Camacho, A., and Ireland, T.R., 1997. U-Pb Geochronology: Final Report. Geoscientific mapping of the Sierras Pampeanas, Argentine-Australian Cooperative Project, Australian Geological Survey Organization (unpublished), SEGEMAR, 53 p. Buenos Aires.

[25] Ramos, V.A., 1995. Sudamérica: un mosaico de continentes y océanos. Ciencia Hoy, 6(32): 24-29, Buenos Aires.

[26] Santos, J.O.S., Chernicoff, C.J., Zappettini, E.O., McNaughton, N.J., Hartmann, L.A., 2017. Large geographic and temporal extensions of the Rio de la Plata Craton, South America and its metacratonic eastern margin. International Geology Review, 61 (1): 56-85.

Citation: *Carlos J. Chernicoff (2021) " Aeromagnetic Surveys as a Tool for Regional Geological Mapping: A Review of the Case Study of the Southeastern Pampean Ranges, Argentina", International Journal of Mining Science (IJMS), 7(2), pp.20-30, DOI: http://dx.doi.org/ 10.20431/2454-9460.0702003*