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Interpretación Geofísica (Magnética) Sierras de Córdoba Septentrionales

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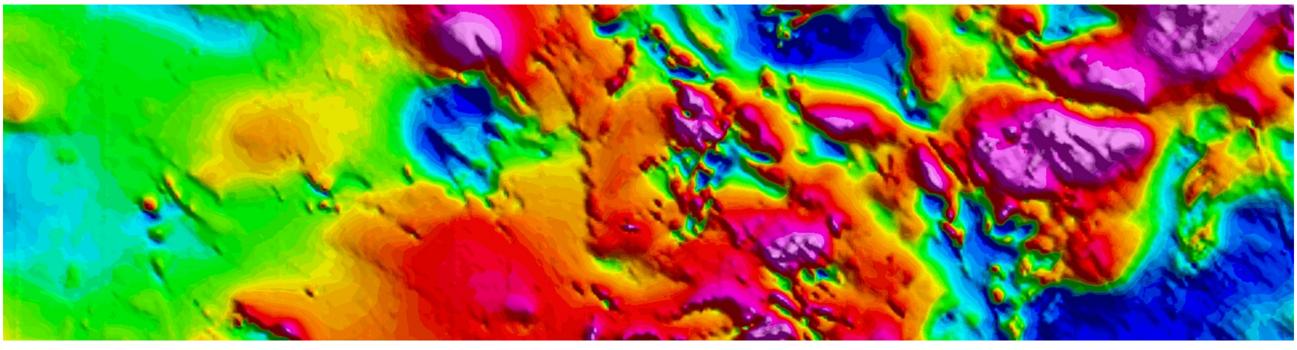
AGSO

MAPEO GEOCIÉNTIFICO DE LAS SIERRAS PAMPEANAS
PROYECTO COOPERATIVO ARGENTINO-AUSTRALIANO

Versión en inglés

Carta Aeromagnética de las Sierras de Córdoba Septentrionales



Buenos Aires, 1996

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ABSTRACT

An airborne geophysical survey of the *Sierras septentrionales de Córdoba*, covering an area of 5.600 km^2 from west of the Sierra Grande to east of the Sierra Chica, was done as part of the AGSO-DNSG cooperative geoscientific mapping program. Magnetic and radiometric (U, K, Th) data were obtained along flight lines spaced 500 m apart from a mean height of 100 m. Magnetic data were processed by Hungerford Geophysical Consultants and radiometrics were processed at AGSO. The data were interpreted by Hungerford Geophysical Consultants and geoscientists from AGSO at 1:100.00 scale and a number of geophysical domains have been identified. In conjunction, some anomalies were modelled at 1:250.000 scale in order to obtain dip and an estimation of the depth to source. Magnetic susceptibilities of rock types were measured in the field and employed to assist magnetic interpretation. In general, the overlap in susceptibility data precludes rock type identification from the magnetics alone.

The rocks of the Sierra Grande are generally only week to moderately magnetised. A number of domains delineating various packages of metamorphic rock, granite (*sensu lato*), and the northern continuation of the Guamanes Shear zone have been identified. In the Sierra Chica a number of granite and granodiorite bodies can be subdivided on the basis of their magnetic character, a fault-bounded marble-schist-gneiss belt marks a thrust, and a number of poorly exposed granite bodies east of the Sierra Chica have also been identified. In addition, probable thrusts, splays, and potentially mineralised cross faults have been locates. Geophysical domains are, in some places, sourced under Recent cover thus confirming or establishing continuity between areas of outcrop.

Although there are obvious similarities and regional continuations between the Córdoba project area and the project areas in La Rioja and San Luis, the distances between them and the absence of survey tie-lines does not allow substantive comparisons to de made on the geophysics alone.

1.0 INTRODUCTION

Funded by Government of the Argentine Republic, the Geoscientific Mapping of the Sierras Pampeanas is a cooperative project between the Australian Geological Survey Organisation (AGSO) and the Dirección Nacional del Servicio Geológico (DNSG) of the Subsecretaría de Minería. As a pilot second generation mapping program, the project aims to update the geoscientific knowledge base, provide a modern framework for resource assessment; and, promote exploration and development in the region.

The project covers three separate areas totalling 27 000km^2 in the southern part of the Sierras Pampeanas, Argentina (Figure 1), where basement Precambrian to Palaeozoic metamorphic and granitoids crop out at the eastern margin of the Andean Mobile Belt. The area, best known for its production of industrial and construction materials, also contains metallic deposits. Mineral resources include gold and polymetallic (Au, Ag, Pb, Zn) vein deposits with past production of tungsten, bismuth, tin, manganese, and chromium. The areas were selected to provide key information on their geology and mineral potential through the application of integrated geophysical and geological mapping, as well as metallogenic analysis, and to provide a continuous section of the major tectonostratigraphic packages comprising the southern Sierras Pampeanas.

As a major part of the program, a high resolution airborne magnetic and gamma-ray spectrometrics survey was carried out over three project areas in the Provinces of Córdoba, La Rioja y San Luis. This report details the interpretation of magnetic data from the Northern Sierras de Córdoba area (Córdoba Province) and accompanies the 1:250.000 scale magnetic interpretation map.

The principal objective in the selection of this area was to integrate de geology of the Sierra Chica with that of the Sierra Grande in the Southern Sierras Pampeanas and to provide a modern geological framework for evaluation of know gold and other mineral occurrences in the Sierras de Córdoba.

The transect includes areas under shallow cover around Cruz del Eje and the mining districts of La Candelaria (Au), El Guaico (Ag), La Argentina (Au & Ag), La Bismutina and Agua de Ramón (W, Bi & Au).

1.1. Location and access

The Northern Sierras de Córdoba project area forma and east-west transect within the Córdoba Province. 140 km x 40 km through Cruz del Eje between 30º45’-31º05’ S and 64º00’-

65º30’W. The area includes part of four 1:250.000 scale Sheets: 3166-II (Cruz del Eje), 3166-IV (Villa Dolores), 3163-I (Jesús María), and 3163-III (Córdoba).

The northern extremities of several north-trending mountains ranges are traversed by the area and include the Sierra de Pocho, Sierra de Guasapampa, Sierras San Marcos and the Sierras Chicas. The western and central portions of the ranges are drained by the northwards flowing courses of the Ríos Soto, Pintos and the Candelaria. In the east Ríos Ascochinga, Santa Sabina and Pinto drain eastwards off the Sierras Chicas.

Access to the region is via Jesús María and Route 9 in the east, and Route 38 in the centre which connects the main population centres of La Cumbre, Capilla del Monte and Villa Soto.

1.2. Airborne geophysical survey

The airborne geophysical survey was flown by World Geoscience between January and August 1995 under the supervision of the Australian Geological Survey Organisation (AGSO), using a line spacing of 500 metres flown in an east-west direction. Mean sensor height was 100 metres for all survey areas.

Survey specifications are given by Hone (1994) and technical details and survey logistics are documented by Chambers (1996) and World Geoscience (1996).

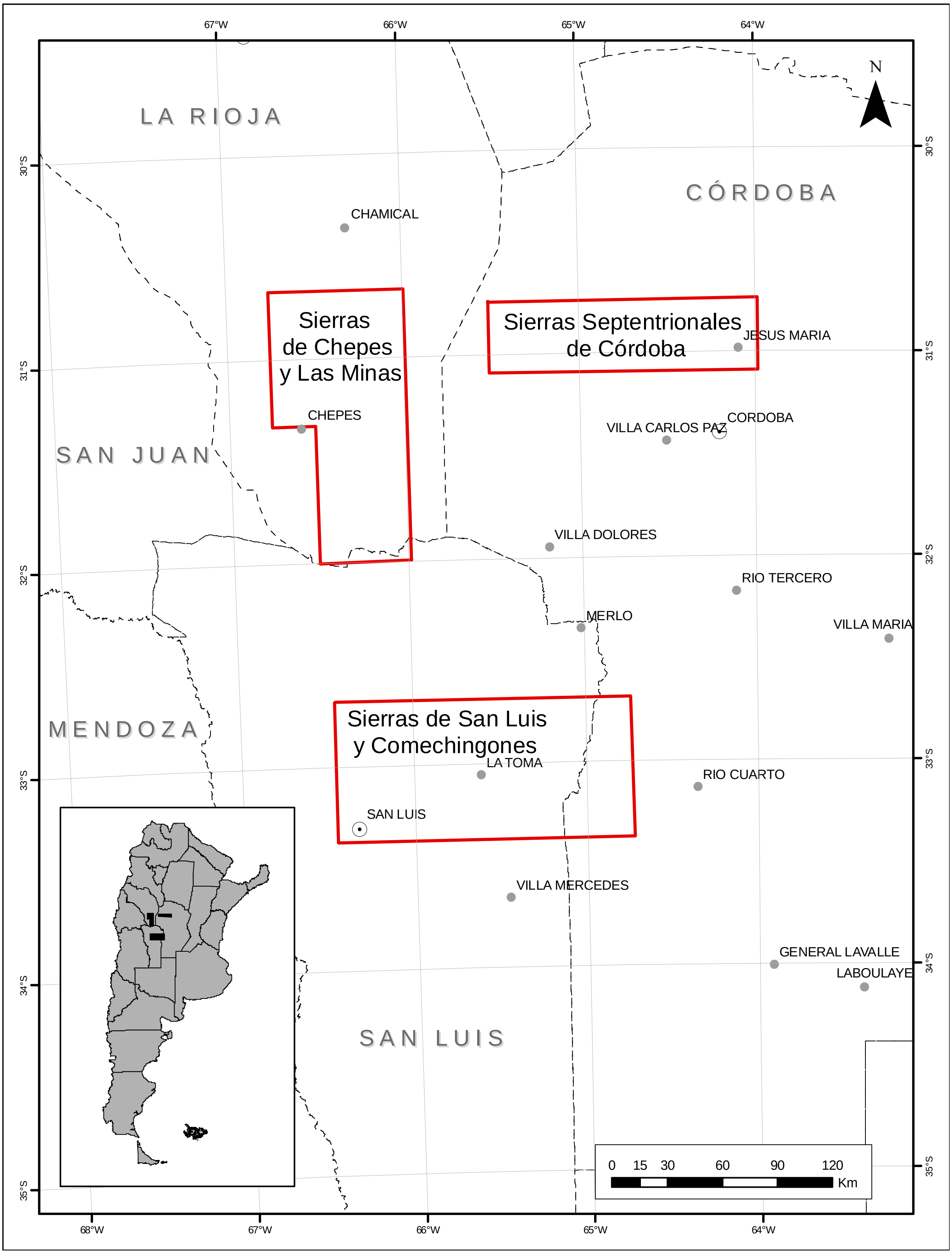

Figure 1 – *Location of the project area*

2.0 METHODS

2.1. Data processing

All magnetic and gamma-ray spectrometric data were supplied to Hungerford Geophysical Consultants (HGC) by AGSO in the form of ER-Mapper grids of Total Magnetic Intensity. These grids were produced by AGSO using a mesh size of 120 m.

HGC converted the ER-Mapper grids to Geosoft grids for subsequent filtering, shadowing, printing, and interpretation. Colour images at 1:100 000 were generated and printed at AGSO, Canberra, using a HP Design Jet.

Images include:

a) Total Magnetic Field, Reduce to Pole,

b) First Vertical Derivative, Reduce to Pole,

c) And Analytic Signal (selected areas only).

In addition, HGC used images of the Total Field, and Reduce to the Pole Field at 1:250.000, printed using an in-house HP Paint Jet.

Landsat images and Radiometric Ternary images of U, K and Th, produced by AGSO at 1:100.000 and 1:250.000 scales were also used in conjunction with magnetic images to assist interpretation, particularly in indicating lithological contacts and areas covered by recent alluvials.

2.2. Image processing

In processing images of the magnetic data for interpretation cognisance was made of the local magnetic field inclination, the presence of high-frequency noise, and the local geological strike.

1.1.1 *Magnetic field inclination*

The magnetic field inclination in the northern Sierras de Córdoba is about -33 degrees. As a consequence of such a shallow inclination, induced magnetic anomalies are considerably offset from their magnetic sources thus creating a false impression of the true geological structure. This problem was solved by calculating the magnetic field Reduced to the Pole (RTP) (i.e., assuming a vertical magnetic field), which places a magnetic anomaly over its causative source, allowing an accurate interpretation to be carried out. Only RTP images were used in the interpretation

Reduction to the Pole can be misleading, however, when a strong degree of natural remanence is present in a particular rock type. In which case an assumption of purely induced magnetisation will lead to an incorrectly calculated source position. Calculation of the Analytic Signal, which is a function of all three orthogonal derivatives of earth's field, will place the resultant anomaly correctly over the magnetic source whether that source is remanently magnetised or not. Except for some Mesozoic volcanic rocks, remnant magnetised sources do not appear to be likely in the metamorphic basement. The Analytic Signal results need to be treated with some caution however, and should be used in conjunction with the RTP images.

1.1.2 *High frequency noise*

The 1st Vertical Derivative images show that some of the survey area has an incoherent low-amplitude, high-frequency noise superimposed on the magnetic background. Investigation of some individual profiles, from the located labelled data, revealed that the noise has sub-nT amplitudes and wavelengths of 10 m to 100 m (sample spacing is about 7 m). The noise is likely to be a combination of instrumental a surficial geological noise, the latter due to iron-rich material on the ground surface such as maghaemite or laterite on the ground. It's unlike to contain any bedrock geological signal since the wavelength should be at last 100 m for a sensor height of 100 m above the source. Bedrock geology signals should be improved by applying a low pass filter prior gridding.

1.1.3 *Geological strike*

In some parts of a survey area the local geological strike may be an acute angle to the flight lines. This creates problems for the gridding process resulting in a lack of continuity along strike, the "string of pearls" effect. This, in turn, can lead to a misinterpretation of magnetic trends as north-south rather than, say, north west-south east. For such regions, consideration should be given to gridding them separately, or using a different gridding algorithm that will allow discordant geological trends to be incorporated into the overall grid.

2.3. Interpretation procedures

The aeromagnetic interpretations for each survey area were done at 1:100 000 scale. Boundaries of each magnetic domain were selected on the basis of magnetic character (e.g., anomaly wavelength, amplitude, strike dimension) and, to some extent, radiometric response (in areas of basement exposure).

Shear zones have been identified on the basis of their magnetic continuity and where there is a linear low magnetic trend that could be caused by magnetite destruction along the zone of shearing.

Cross faults were selected from magnetic linears revealed by shadowing grey scale images of the 1st Vertical Derivative and the Analytic Signal. They are often seen as the cause of dislocations of magnetic units and may also indicate their sense of movement.

The geophysical signatures of the various rock types are classified in Table 1. These characteristics were used to outline domain boundaries on the image maps. Low, weak, moderate, etc. refer to relative anomaly amplitudes.

2.4. Magnetic modeling

Estimates of source depth and dip for selected anomalies were made for each survey area. These are plotted on the 1:250.000 scale map.

Most modelling was done across each anomaly via profiles extracted from the Total Field grid. Since the grid mesh is 100 m, the along-line reading interval is also 100 m. This limits the accuracy of depth determination but is a simpler and quicker way of obtaining regional structural information than windowing out individual profiles from the original flight line data.

Table 1 – *Geophysical signatures of common rock-types*

Magnetics	**Radiometrics**	**Rock type**
low, narrow, discontinuous	low, variable	schist, marble, migmatite
moderate, narrow, discontinuous	low, variable	gneiss, granodiorite, granite (near surface)
low, broad, long trends	low	mylonite (shear zone)
moderate-strong, narrow, elongated	low	amphibolite
moderate-strong, extensive	low	diorite
moderate-low, broad	high, variable	deep granite
high, broad	low	deep granodiorite, diorite (unexposed)

The Geosoft modelling inversion program MAGMOD was employed in the modelling. This program allows for the input of simple tabular, ribbon (dike), or step (fault) bodies, and although care is required when deciding on likely input parameters (particularly the background base level and slope), the technique is very rapid. Experience shows that the output model is generally realistic.

More complex multibody modelling could be carried out but, at present, this is probably unnecessary unless sufficient geological constraints established by outcrop mapping are applied. Under recent cover depth to bedrock can be difficult to estimate where no magnetic anomalies from which to calculate depths exist. Where anomalies do exist they may be caused by large deep batholiths and depth to source do not truly reflect the cover thickness.

2.5. Comparison of survey areas

In a comparison of aeromagnetic responses in the three survey areas, of Sierras Las Minas – Chepes (La Rioja), Northern Sierras de Córdoba (Córdoba), and Sierras San Luis – Comechingones (San Luis-Córdoba) there are major similarities between the latter two, although the latter does contain more outcropping magnetic granites. This may imply a deeper erosional level over San Luis (i.e. grater uplift). Since the distance between these two survey areas is also great (about 150 km), it is not possible to draw many conclusions about their structural relationships based on the geophysical data alone.

The zone in La Rioja has distinctly different aeromagnetic characteristics with generally more intense responses, both negative and positive. The background magnetic field appears to be substantially lower than the other survey areas to the east and south, by about 100 nT. This may be a true indication that the regional geological setting at Sierras Las Minas – Chepes is significantly different to that other areas (e.g. thinner crust), or it could be that the IGRF used by the contractor, when subtracting the regional earth's magnetic field, is incorrect.

The La Rioja area does contain more granites and granodiorites than the other areas which is also likely to be a contributing factor to markedly different magnetic characteristics.

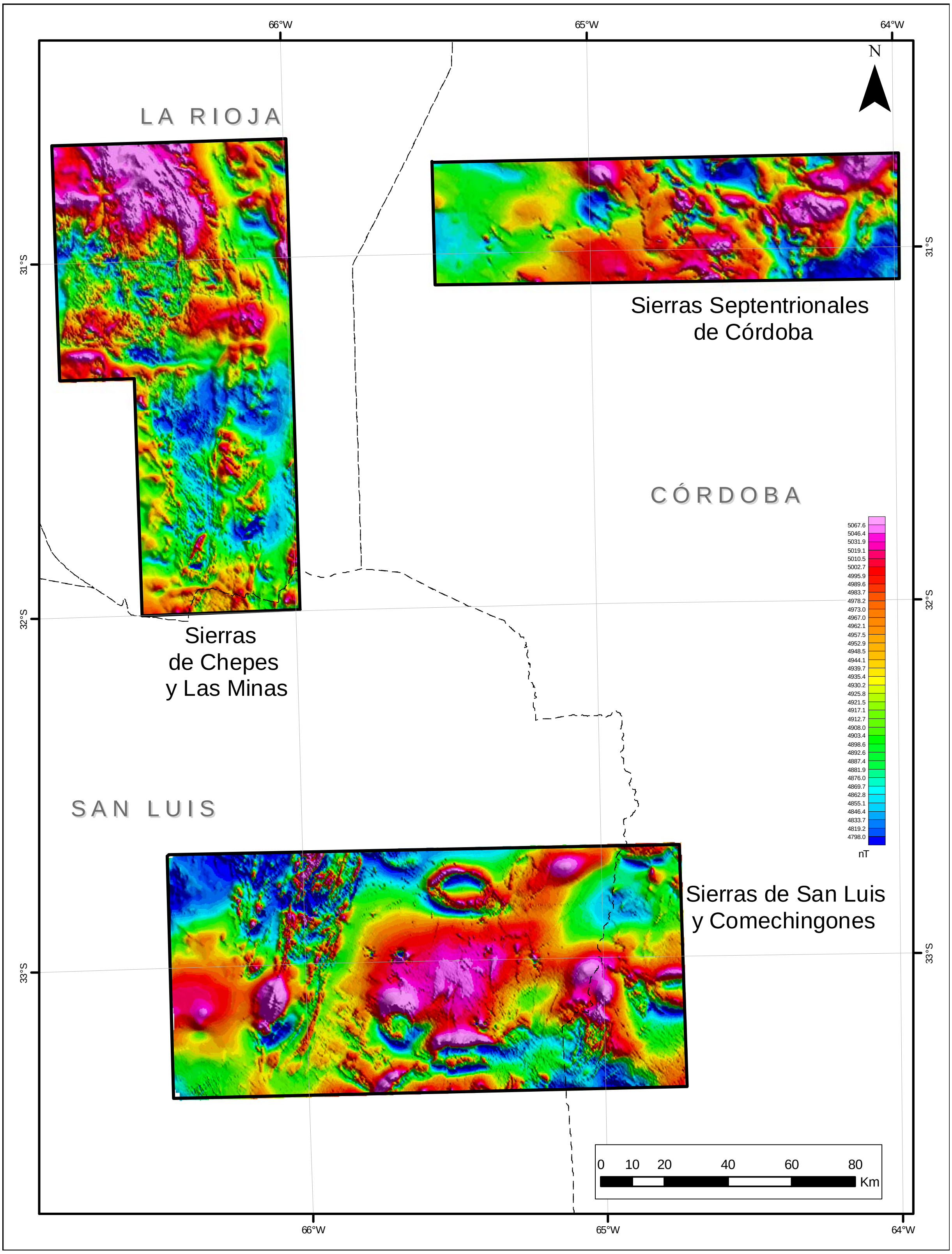

Figure 2– *Total Magnetic Field (TMI) of survey areas*

3.0 MAGNETIC DOMAINS

3.1. General relations

The Sierras Pampeanas are distinct morphotectonic province comprised of Neoproterozoic to early Palaeozoic metamorphic rock and Palaeozoic granitoids, they form a series of block-tilted, north-south oriented ranges separated by intermontane basins, which are bounded by escarpments developed on moderate to steeply dipping reverse faults developed during the Andean uplift (Jordan and Allmendinger, 1986).

3.2. Description of magnetic domains

Results from the airborne geophysical survey show that the Northern Sierras de Córdoba, part of the Sierras Pampeanas, comprises largely non-magnetic metamorphic rocks intruded by non-magnetic to strongly magnetic granitoids. Major shear zones separate domains in places. Magnetic anomalies in the east and north indicate continuity of basement rocks beneath shallow Cretaceous and younger non-magnetic cover. The geophysical character of interpreted domains and their interpretation is given in Table 2

4.0 MAGNETIC PROFILE

The magnetic profile on the accompanying 1:250.000 scale map, extracted along a line less one minute north of 31ºS (UTM line 6571000N), was derived from the Total Field and individual magnetic anomalies were modelled using Geosoft MAGMOD inversion program. As the profile was obtained from a grid where samples points along line are 120 m (equal to the grid mesh size), modelled depths are about ± 200 m for shallow sources. However, as the eastern end of the line was modelled using located data, depths there should be more accurate where recent cover is probably 100 m to 200m thick.

Dips and depths can only be obtained from magnetic units. It is evident from both the images and the magnetic profile that there are few anomalies along the western part of the line where it travers migmatites and gneiss. The more evident anomalies along the east are due to an increased number of mafic intruded by granite (*sensu lato*).

This model shows that most structures dip to the west except for the structures east of about 64º23’W and the main fault and shear zones which dip to east.

Table 2 – *Description of magnetic domains.*

Domain	Magnetic Response	Radiometric Response	Comments
1	Weak		Short strike length magnetic anomalies; probable schists or metasediments under very thin recent cover. Cover U-rich in south, K-rich adjacent to bounding fault.
2	Weak	Low	Weakly magnetic terrane, bound to west and east by N-S non-magnetic shear zones or faults cut by cross faults. Slightly more magnetic in the south. Generally radiometrically low, but a little higher in the south. Mapped granite and gneiss.
3	Weak	Low	Agua de Ramón Granite.
4	Weak	High K	La Playa Granite. Weakly magnetic, erratic high-K areas indicating pegmatite.
5	Weak	Low	Similar to 2; less magnetic indicating proportionally more schist or migmatite. Slightly higher K.
6	Weak	Low-med	NS-SE trending moderately magnetic units terminating against western shear zone; N-E cross faults. Magnetic anomalies likely due to thin, strike limited gneiss ± amphibolite units. Variation in magnetisation suggest possible magnetite destruction adjacent to hear zone. Rock types are migmatite and gneiss with low-medium radiometrics responses. Likely subset of domain 7
7	Weak	High K	Large area of narrow, weak, short magnetic anomalies (indicating shallow sources); appear to trend N but may be artefact due to gridding methods. Radiometric images show prominent SW-SE trends indicating presence of pegmatite dykes. Apparent deep sources (>1000 m), possible granite. Outcrop a mixture of migmatite, schist, gneiss; magnetically indistinguishable; gneiss probable cause of weak anomalies. Gradual increase in magnetic response towards east.
8	Weak	High	Probable shallow felsic intrusion.
9	None	High K	Possible large non-magnetic granite, El Pilón. High-K response where not covered by recent sediments. Marked magnetic response around northern edge (under recent cover) may be contact metamorphic effect (9a). Smaller shallow intrusions to north and east.
9a	Weak-moderate		Possible metamorphic aureole. Refer to domain 9.
10	Moderate	Medium	Large granodiorite or granite mostly under shallow recent cover. More radioactive to south where granite or pegmatite may occur. Decrease in magnetic field suggest plunging to the south and covered by gneiss and migmatite.
11	Weak-moderate	Low-medium	Slightly more magnetic than adjacent domain 7; underlain by relatively small magnetic intrusive. Area radiometrically low like gneiss and migmatite.
12	Weak	Low-medium	Guamanes Shear Zone; contains mylonites, gneiss, felsic intrusive, thin (1-2 m) andesite dykes; overlaps domains 10 and 11 to west. NE-SW cross-faults on eastern side may provide good foci for mineralising fluids.
12a	Moderate		Faults splays off Guamanes Shear Zone of mafic dykes.
13	Weak	Low, Th	Domain is radiometrically low a weak Th response. Mostly gneiss, schist, carbonate, intercalated granite.

13a	Moderate	None	Suggestion of semi-circular metamorphic aureole; parent intrusive likely to be unexposed Achala Batholith.
14	Moderate-strong	Low	Magnetic domain un to 100 nT above background; erratic anomalies generally striking N-S. Marble, amphibolite, gneiss, granite.
15	None	High	Granites. Partially exposed.
16	Weak	None	Major NW-SE characterised by generally weak magnetic response. Apparent sinistral component of displacement indicated by minor deflection of magnetic trends. Appears to cross-cut granites of domain 16, probably as a later event.
17	Weak-moderate		Slightly more magnetic than domain 13. Possibly grater proportion of granite to gneiss.
17a	Weak-strong		Mixed domain of low and relatively high magnetic response; contains non-magnetic granites and elongate bodies of magnetic gneiss. SW-NE cross-faulting may be present.
18	Moderate-strong		Magnetic units surround granite 16b and extend south. Possible amphibolite, marble, gneiss, granite; similar response to domain 14. Linear anomaly between granites 16 y 16b may be contact metamorphic effect.
19	Weak	Low	Fault-bounded marble and gneiss, strikes NNW. Magnetic anomalies along edge suggest east over west thrust fault. Weakly magnetic inliers at northern end.
20	Moderate	High	Broad elongate magnetic regions; radiometrically active granodiorite; western edge bound by shear zones.
21	Strong (erratic)	Medium	Characterised by erratic and fairly strong (5-200 nT) magnetic responses. Decrease to north probably due to increasing cover thickness. Medium radiometric response: identified as granodiorite, tonalite, granite.
21a	Strong	Low	Magnetically similar to domain 21; distinctive low radiometric response except from U. Similar radiometric response to 21b but more magnetic. May mark different granite phase (s.l.).
21b	Strong (erratic)		Same as 21 but under recent cover. Underlain by a large deep magnetic intrusive, FMP, which elevates magnetic background; may come to within 400 m of surface.
22	None	High	Non-magnetic intrusives; strong radiometric response; superimposed scattered weak anomalies suggest roof pendants of outcropping magnetic rocks.
23	Strong	Low	Low amplitude noisy responses similar to domain 21; same lithology likely but under thin cover. Radiometric response uniformly low. Area is underlain by elongated deep N-S strongly magnetic intrusives. Small exposure of granite and minor gneiss occur near Jesús María. Domain bounded to the west by E-dipping thrust faults. Splay off main thrust may be focus for mineralising fluids.
24	Strong		Shallow magnetic source possibly marking upthrown block. Granite crops out in far north east.
GNM	None	High	Non magnetic; highly radiometric: Devonian? granite.
FMP	Weak, Moderate, Strong		Deep magnetic sources; 400 – 2000 m; response variable depending on the depth but highly magnetic at source. Most likely granite (s.l.).
ZC	Weak, Moderate, Strong		Linear, magnetically continuous. Shear zone.
ARK	None	High	Non-magnetic, high-K response. Pegmatite dykes.

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