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Magnetic interpretation of the San Juan Londó Basin, BCS, Mexico

J.A. Arzate, R.E. Chávez and J. Rodríguez
Instituto de Geofísica, UNAM.

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RESUMEN

La cuenca de agua subterránea de San Juan Londó está situada al norte de La Paz, Baja California. Se efectuó una prospección magnética terrestre para definir la geometría y los límites estructurales de la cuenca. En un total de 173 estaciones se hicieron mediciones magnéticas corregidas, tomando en cuenta la variación diurna y el campo geomagnético. Los datos fueron interpolados en una red de espacios iguales, de 256 km^2. Se aplicó un análisis de Fourier para efectuar una separación regional-residual mediante un diseño adecuado de filtros de paso alto y bajo, combinado con una reducción al polo de los datos magnéticos para centrar las anomalías sobre los cuerpos que las generan. La interpretación sugiere que el valle está dividido en tres principales subcuencas separadas por una formación de tipo horst.

PALABRAS CLAVE: Agua subterránea; Baja California Sur (BCS); San Juan Londó, prospección magnética.

ABSTRACT

The San Juan Londó ground water basin is located north of La Paz, Baja California. A ground magnetic survey was carried out to define the geometry and structural boundaries of the basin. A total of 173 magnetic stations were measured and corrected for diurnal variation and for the geomagnetic field. The data were interpolated on an equally spaced grid of 256 km^2. A Fourier analysis was applied to perform a regional-residual separation by designing suitable high and low pass filters, combined with a reduction to the pole of the magnetic data to center the anomalies over the bodies. Interpretation suggests that the valley is divided in three main sub-basins separated by a horst-like formation.

KEY WORDS: Ground water; Baja California Sur (BCS); San Juan Londó; magnetic survey.

INTRODUCTION

This ground magnetic survey carried out in the San Juan Londó basin (Fig. 1) is part of a wider geophysical study by the National University of Mexico (UNAM), through the Instituto de Geofísica (SARH-IGF, 1986). The purpose of the magnetic study was to provide information about the geometry of the magnetic basement and to define, as far as possible, the physical parameters needed for evaluating the hydrologic potential of the area.

Magnetic susceptibility tests of some rock samples collected in various parts of the area were performed in the laboratory of Paleomagnetism (IGF-UNAM). The analysis constrained the magnetic interpretation of the area. The modelling was done under the following basic assumptions:

a) Magnetic susceptibility varies within narrow limits around the values encountered.

b) Magnetization of rocks is due mainly to induction by the external geomagnetic field, where the magnetic susceptibility is:

$\Delta\chi \leq 10^{-3}$ emu.

GEOLOGICAL SETTING

The oldest outcrops in the area belong to the Californian Batholith, wich is mainly composed by gabbros, granodiorites and granites. The granite outcrops in the eastern margin of the Sierra La Giganta, northeast of Loreto (Fig. 2). The age of this group of rocks varies between the Cretaceous and the Lower Tertiary (Gastil *et al.*, 1976).

On top of the batholith is the Comondú Formation (Miocene), wich consists of sandstones, conglomerates, volcanic breccia and tuffs. It has a wide distribution, covering 60 % of the basin. This geologic formation features massive horizontal bedding with layers up to 1000 m. thick.

The Salada Group (Pliocene) comprises mainly semi-consolidated sediments of marine origin. This horizon is composed of sandstones, conglomerates, claystones and a limestone unit; its thickness is over 400 m. (Ortega, 1986).

Plio-Pleistocene and Pleistocene units are overlain by alkaline volcanics related to the Gulf of California Rift, (Demant, 1975) and to a continuing process of erosion wich generated important sedimentary deposits. These sediments accumulated in the valley forming unconsolidated conglomerates. The tectonic setting was inferred from a satellite image, combined with the photointerpretation of 70 aerial photographs: this resulted in a very detailed geological map of the area (SARH-IGF, 1986). This study concluded that the region is a composite graben wich has several subsystems (Fig. 3), all of them bounded by a main faulting system. On the westerly side,the graben is bounded by a long fault that can be followed for more than 100 km (left of Fig. 3).

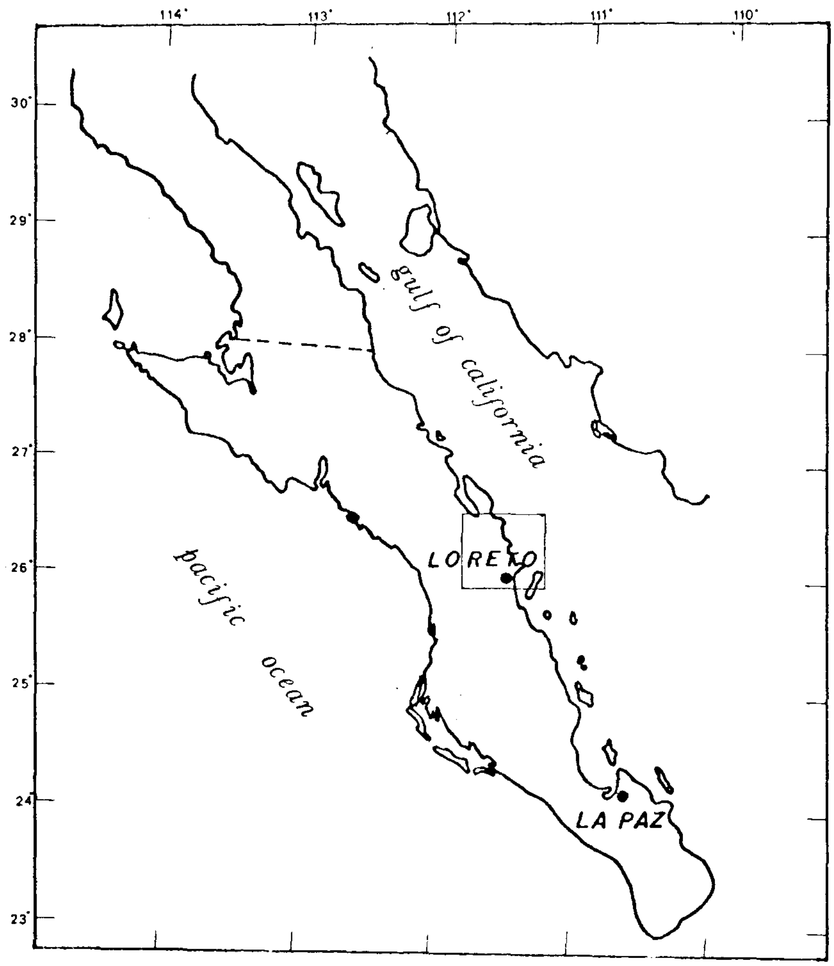

Fig. 1. Location of the area under study.

MAGNETIC DATA ANALYSIS

The magnetic survey comprised 173 stations covering the area with a spacing of 0.5 km. A total-field magnetometer was used to collect the data; a base station magnetometer was used to observe the geomagnetic field variations every 5 min. Magnetic observations were corrected for diurnal variations of the magnetic field. Such corrections averaged 8 nT during the survey .

That randomly spaced data were interpolated using a spline function (González-Casanova and Alvarez, 1985). Cell dimension was 0.5 x 0.5 km^2, with a total of 1024 points. The contoured magnetic anomaly map is shown in Fig. 4.

The presence of a regional trend in the SE-NW direction is evident. This trend is probably related to the structural pattern of the area. A series of dipolar anomalies are also seen, with amplitudes of 400 nT to 600 nT. This feature might be evidence for a series of igneous intrusions related to the Comondú Formation. A magnetic low is observed at the center of the area, where the crystalline basement is deep. An apparent magnetic basement uplift is suggested by a positive magnetic gradient. Unfortunately there are not sufficient data to confirm this. A gravity survey carried out in the area features a negative gravity gradient (SARH-IGF, 1986).

A regional-residual separation process in the Fourier domain for data such as Fig. 4 is in general difficult and ambiguous. In our case, the magnetic signals produced by the crystalline basement and the volcanic component of the Comondú Formation must be resolved.

As a first step, the Spectral Factorization Technique (Gupta and Ramani, 1980) was applied to compute the power spectrum of the field in the frequency domain. This method has been shown to be highly efficient (Lezcano *et al.*, 1987). The method proposed by Spector and Grant (1970) was then applied to define the upper limit of the low frequency interval. This value was found to be 5.5 c/km. A low-pass filter was designed to remove high frequencies from that value. Then, the resulting magnetic map was reduced to the pole to center the anomalies over the sources. The inverse Fourier transform was finally applied to the filtered spectrum to obtain the anomaly map of Fig. 5.

This map is free from shallow noise and provides a better picture of the magnetic behavior of the crystalline basement. A clear horst structure is seen on this figure. The series of magnetic highs to the north, with amplitudes between 300 to 500 nT, are now better resolved. Unfortunately, edge effects remain at the top and bottom of the map. This might be due to the filtering process and the interpolation routine, as well as the lack of observations in these areas. However, the central region is well defined. A modelling procedure was now applied to compute the geometry of the magnetic structure.

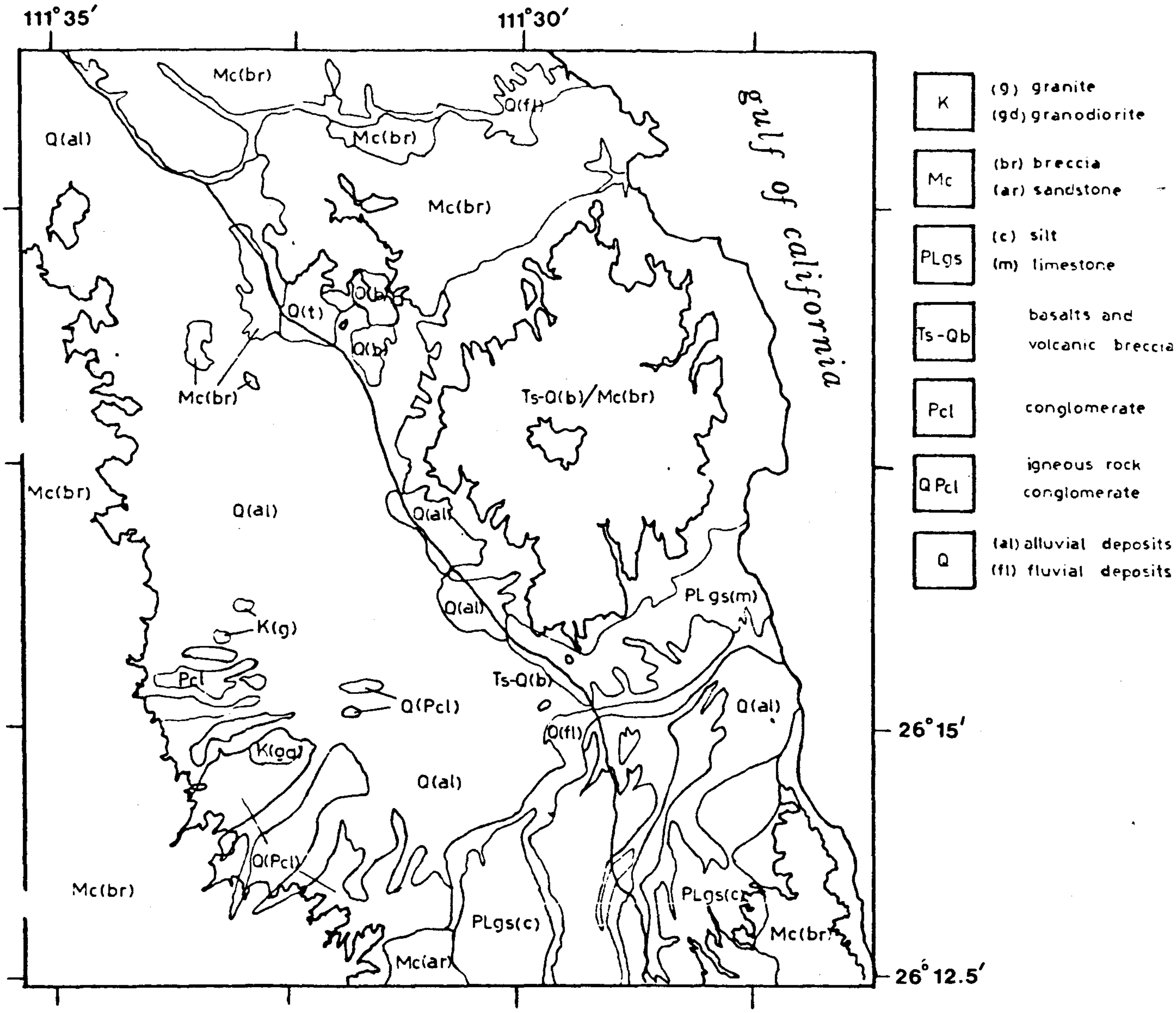

Fig. 2. Surface geological map of the studied area showing the distribution of the main geological units (from SARH-IGF, 1986).

MAGNETIC INTERPRETATION

Eight profiles in the E-W direction were selected from the reduced-to-the-pole map to be modelled. The profiles were 2 km apart. The northern and southern zones were not taken into account; neither was the spurious magnetic high located at the top right of the map. A two-dimensional model was selected for each profile and was manually modified until a satisfactory fit was obtained. Unfortunately, wells in the area are quite shallow (≈ 150 m); thus no physical evidence of the basement could be found. Fig. 6 displays the magnetic profiles 3 and 5. Profile 5 crosses the magnetic low located near the center of the area, where the crystalline basement presumibly reaches its greatest depth. The algorithm is a modified version of Talwani and Heirtzler (1964). The program allows complicated models; however, we have selected models having no more than two interfaces, thus confining ourselves to modelling the magnetic basement, and neglecting shallow magnetic sources.

In this process, three main assumptions were made:

(a) the magnetic susceptibility of the granitic basement varies between 1.5×10^{-3} emu and 6×10^{-3} emu . These values were obtained from samples measured in the Laboratory of Paleomagnetism, and other reported values.

(b) the magnetization of the basement is solely induced. Remanent components found in a granite sample were relatively small as compared with the measured induced magnetization (1:5).

(c) The magnetic contrast between the sediments and the magnetic basement is very low, about 10^{-3} emu. This is supported by our measurements and by reported values.

About ten samples were obtained from the granite outcrops located to the west of the basin; from the Comondú Formation (east of the area), mostly basalts; and from the northern part of the area, namely volcanic breccias and sedimentary rocks.

A three dimensional model was calculated, as shown in Fig. 7. The models for all eight profiles were integrated and interpolated to construct this diagram.

The figure shows the behavior of the magnetic basement. Three basins separated by topographic highs were interpreted. The deepest section was found at 2.8 km deep. Magnetic highs may be related to the faulting system, where granites (Fig.3, K(g)), and volcanic materials (Mc (br), Q (Pcl)) were emplaced .

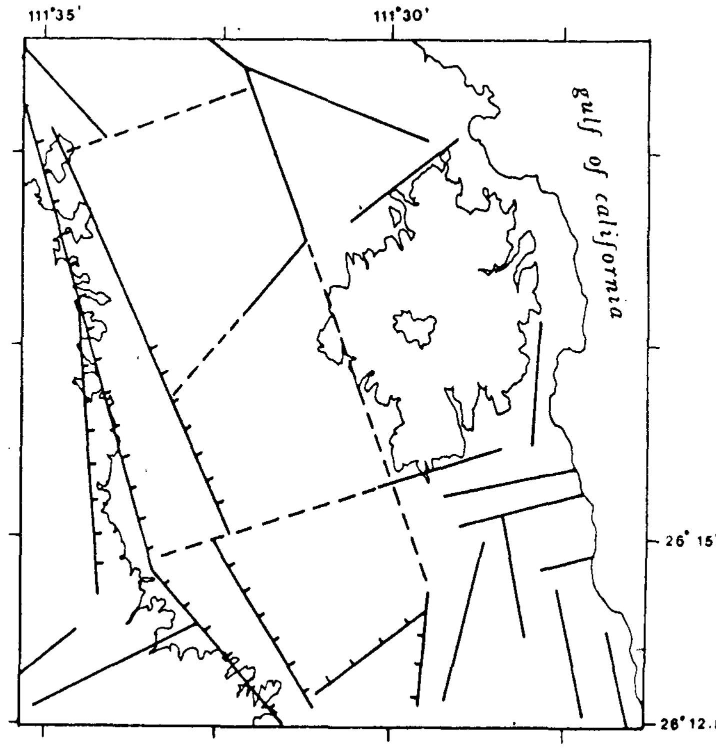

Fig. 3. Tectonic map of the area as inferred from satellite image interpretation. Continuous lines represent observed faulting; dashed lines, inferred faulting (modified from SARH-IGF, 1986).

CONCLUSIONS

Use of Fourier analysis has allowed us to make a regional-residual separation and to enhance the signal from the magnetic basement. Through the use of suitable band-pass filters, high frequency information related to near surface sources was removed.

The reduced-to-the-pole transformation is an efficient tool to improve the picture of the tectonics of the San Juan Loñdó Basin.

The series of magnetic highs defined by the N-S continuous line in Fig. 5, correlates with the faulting system that controls the basin. These magnetic highs are probably related to buried intrusives that were emitted through the faults.

The magnetic model obtained by modelling selected profiles shows a good correlation with the tectonic map inferred from satellite images (SARH-IGF, 1986).

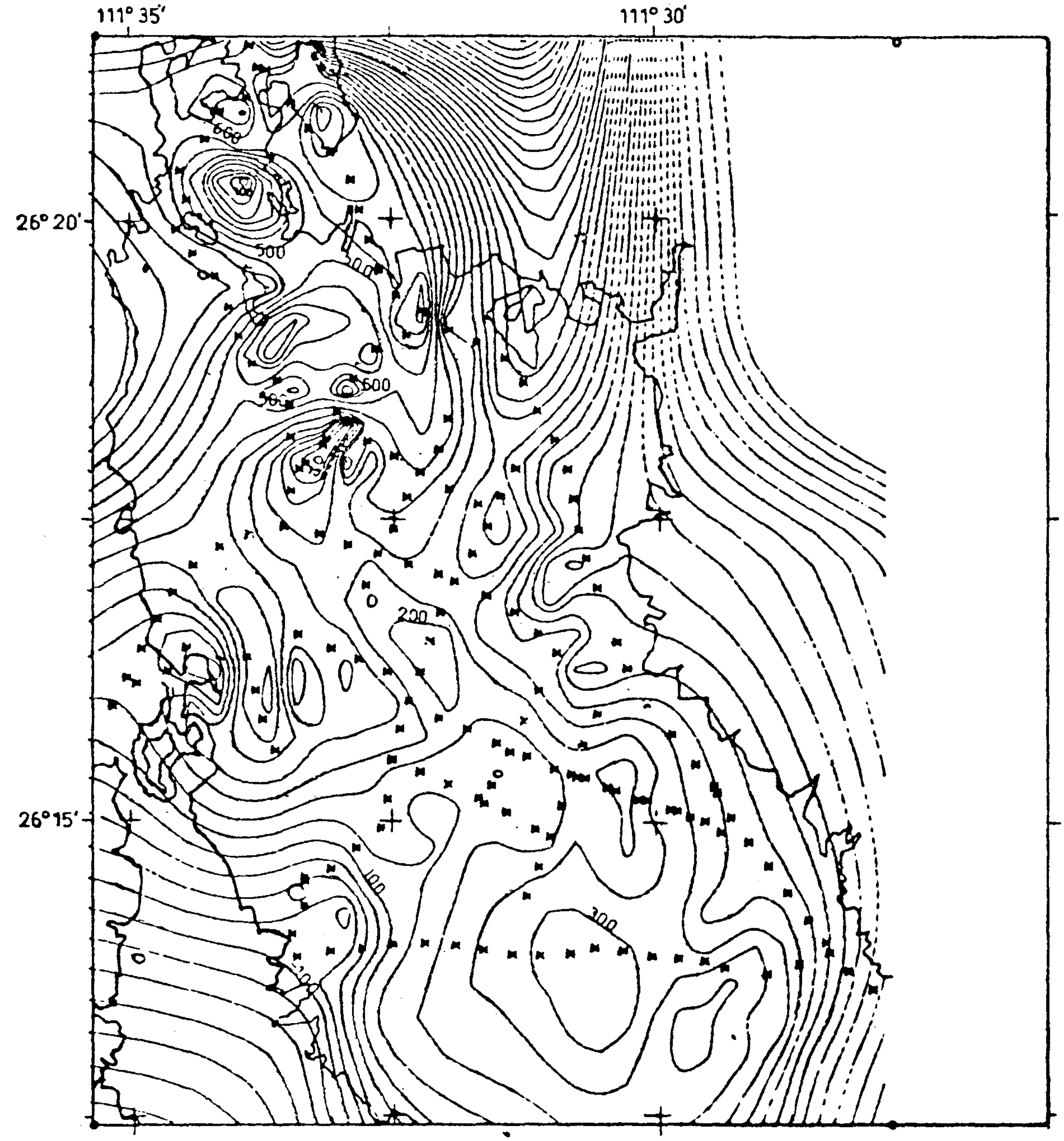

Fig. 4. Total field magnetic anomaly map. Magnetic data were interpolated over a square grid of 32 x 32 points. Points represent magnetic stations. Contour interval is 50 nT (modified from SARH-IGF, 1986).

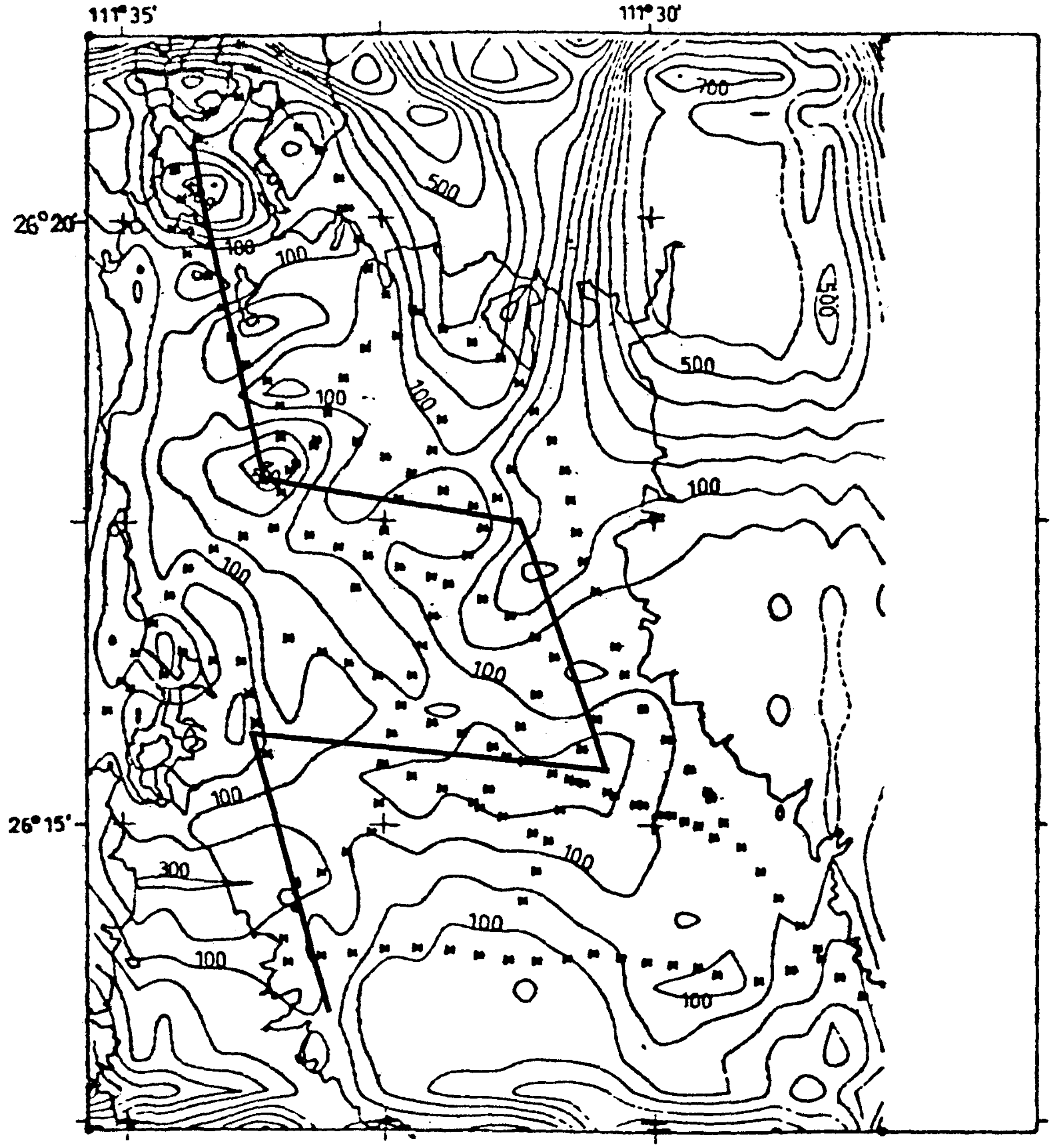

Fig. 5. Magnetic anomaly map reduced to the pole. Straight lines indicate the inferred basement highs. Contour interval is 100 nT (modified from SARH-IGF, 1986).

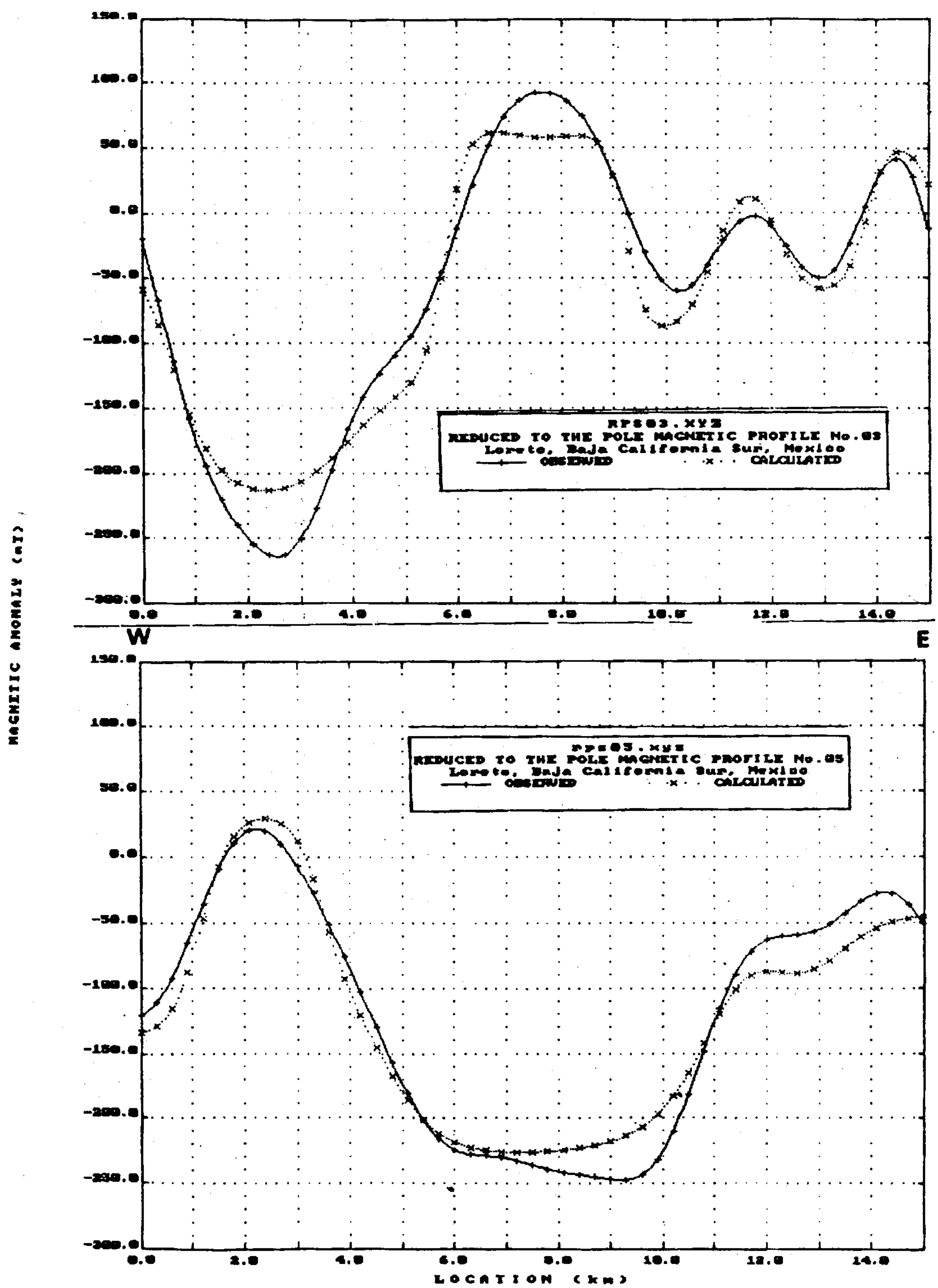

Fig. 6. Magnetic profiles 3 and 5. Profile 5 crosses the low of the magnetic basement. Observed (continuous line) and computed (crosses) magnetic anomalies are shown.

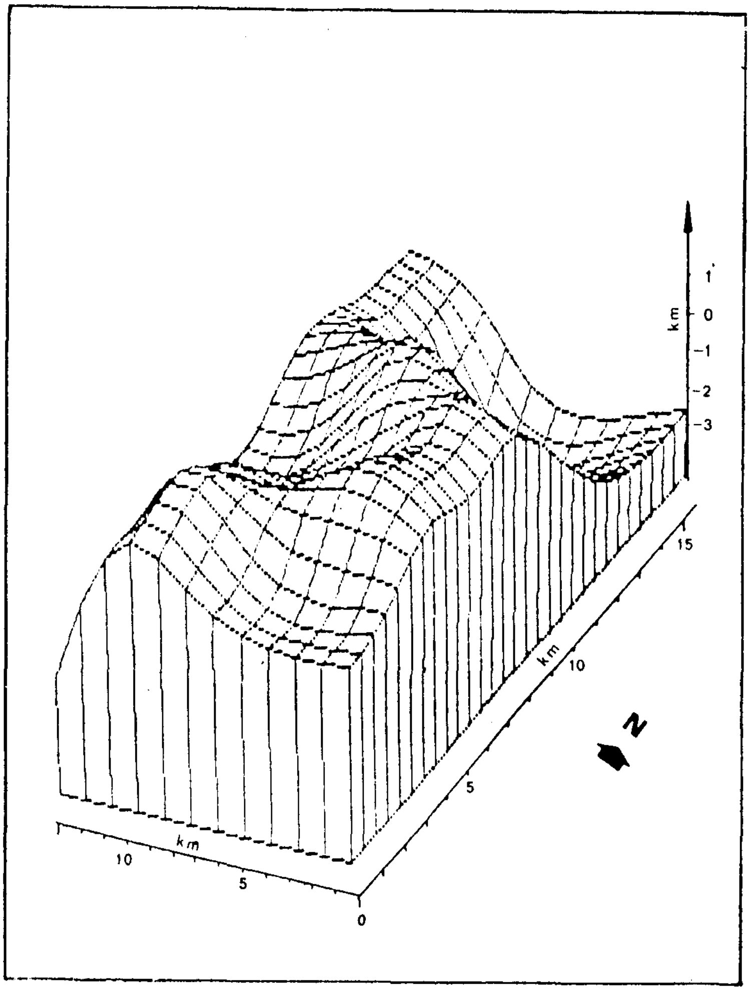

Fig. 7. Three-dimensional model of the magnetic basement obtained from the analysis of eight selected E-W magnetic profiles separated 2 km.

Hydrological and ground water studies reported in that reference underscore the importance of the area studied, from the groundwater point of view. Present wells are very shallow and do not reach the 'magnetic basement'; however, this magnetic study represents an important indicator of the geometry of the aquifer.

A more detailed magnetic survey may help to improve and modify the model presented here. A more sophisticated three-dimensional approach could be used together with a more realistic geological structure. Geochemical and paleomagnetic studies could also help to define the model parameters of the San Juan Londó Basin, and incidentally to assess the potential ore deposits associated with the faulting systems found in the area.

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J.A. Arzate, R.E. Chávez and J. Rodríguez
Instituto de Geofísica, UNAM, 04510, México, D.F.