The gravity field of the Tucumán Plain and its implications in structural geology

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Abstract: *The results of tectonic research with gravimetry methods in the Tucumán Plain show an important subsurface trough. A sedimentary sequence more than 3,000 m thick was deposited in it. This feature has special significance for the prospection of geothermal and oil resources in the area.*

Key words: Gravimetry - Tectonic - Trough - Geothermic - Oil.

Résumé : Le champ gravimétrique dans la plaine de Tucumán et ses implications en géologie structurale. *Le résultat de la prospection gravimétrique de la plaine de Tucumán montre une fosse ayant plus de 3 000 mètres de sédiments. Cette fosse est intéressante pour la prospection des hydrocarbures et l'examen géothermique.*

Mots clés : Gravimétrie - Tectonique - Fosse - Géothermie - Hydrocarbures.

Resumen : El campo gravimétrico en la Llanura Tucumana y su implicancia en la geología estructural. *Se presentan los resultados de la investigación tectónica con métodos gravimétricos de la Llanura Tucumana que muestra la existencia de una importante fosa subterránea con mas de 3 000 m de sedimentos. Este rasgo es significativo para la prospección de los recursos de hidrocarburos y geotérmicos del área.*

Palabras claves : Gravimetría - Téctonica - Fosa - Geotérmia - Hidrocarburos.

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INTRODUCTION

The Tucumán Plain, extending along the eastern border of the Andes between 27° and 28° S (fig. 1), is a structural depression infilled by a thick sedimentary sequence, as shown by preliminary seismic studies (TINEO, 1988).

Although thermal water occurrences of economic interest have been recognized and hydrocarbons accumulations are thought to be possible, its deep structure still remains almost completely unknown.

The fact led the authors to take up an extensive program of gravimetric surveying, as well as a geological and structural analysis aimed to obtain valid data to replace the speculative surface data-based models available at present.

The results can be used to direct future more detailed subsoil research.

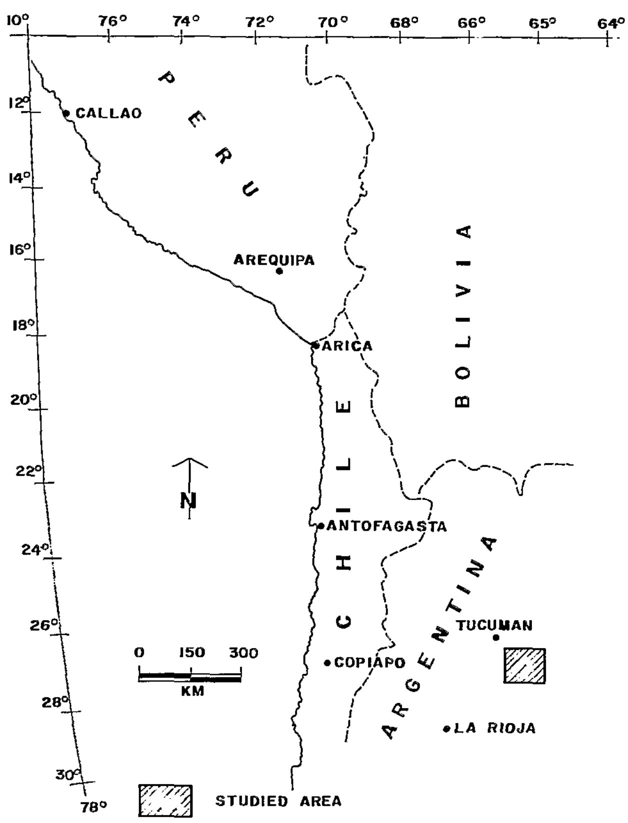

Fig. 1. — Location map showing the region studied by the gravimetric method.
Carte de la région étudiée par gravimétrie.

GRAVIMETRIC FIELDWORK

In order to complete measurements done by IGM (Instituto Geográfico Militar, Buenos Aires, Argentina), we established a 400 gravity station net using a LaCoste and Romberg gravity meter. The pure reading accuracy of this instrument amounts approximately to 0.01 mgal.

All gravity stations were tied to the BACARA-System (Base de Calibración de la República Argentina) and to some stations previously established by the IGM. The gravity stations were located principally on the existing high-precision levelling lines established by the IGM. In a few cases the elevation of gravity stations was determined from measurements made with two Paulin and a Thommen barometers. These records were corrected by daily drift functions. The barometrically determined heights are considered to be accurate to within ± 3 m.

The determination of geographic coordinates of each station is indispensable in order to calculate the normal gravity : we used topographic maps scaled 1 : 100,000 and 1 : 250,000. The accuracy of location was considered to be within ± 200 m.

The Free-air and the Bouguer anomalies were calculated using the Geodetic References System (1980) — SRG 80 —, a free air gradient of 0.3086 mgal/m and a reduction density of 2.67 gcm^{-3}.

We didn't consider terrain corrections because they are less than 0.5 mgal (POMPOSIELLO *et al.*, 1989). The maximum possible errors of the computed Bouguer gravity values are ± 1.5 mgal. Stations elevation and having not considered terrain corrections are the main contributions to the total error. Figure 2 shows the Bouguer anomaly map of the Tucumán Plain contoured at 10 mgal intervals and the distribution of the gravity stations.

GEOLOGY

The Tucumán Plain is an extensive depression bounded to the west by the Sierra de Aconquija range and to the east by the Sierra de Guasáyan range and a buried structural high, the Alto de la Mujer Muerta, which expresses as a topographic elevation with no rocky outcrops.

Both the Sierra de Aconquija and Sierra de Guasáyan are mainly formed by cristalline rocks, possibly of Precambrian age which are unconformably overlaid by tertiary rocks of continental origin (fig. 2 and 3b).

No units of ages between Precambrian and Tertiary crop out in the area but a refraction surveying by YPF (Yacimientos Petrolíferos Fiscales, Buenos Aires, Argentina) — reformulated by TINEO (1988) —

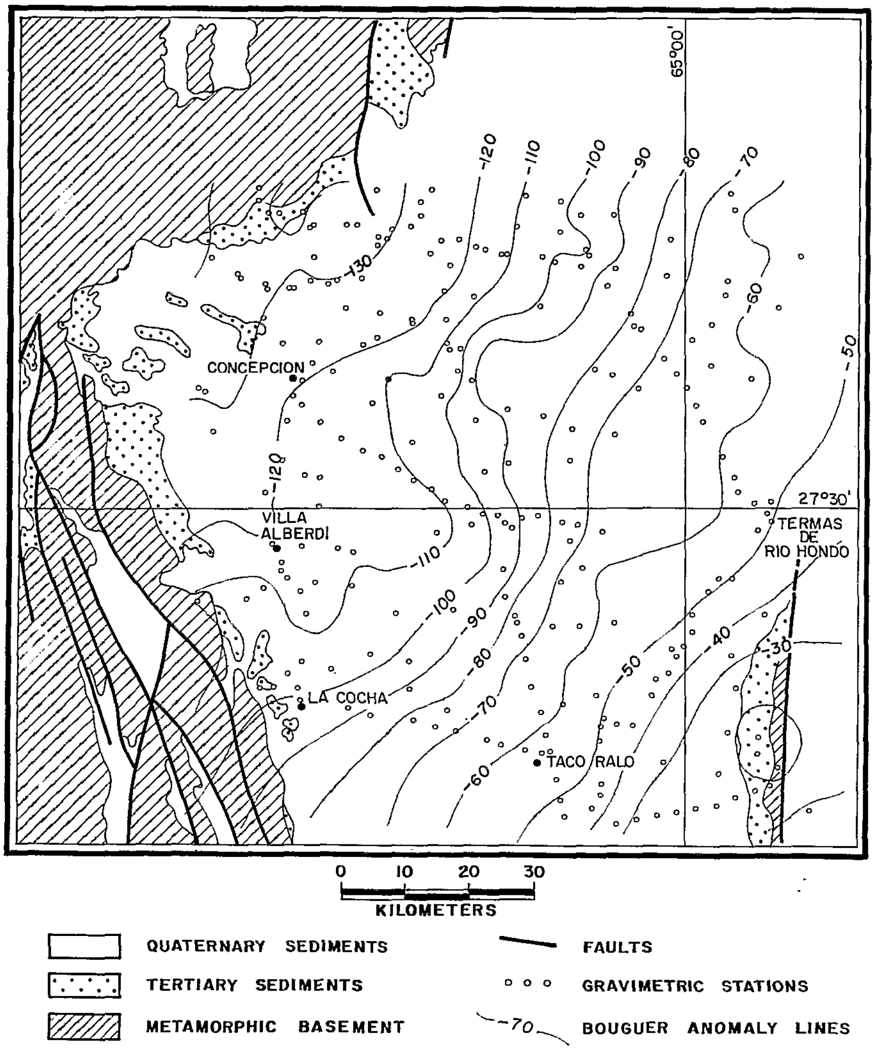

Fig. 2. — Geological map of the Tucumán Basin, Bouguer anomaly field contoured at 10 mgal intervals and the distribution of the gravity stations.
Carte géologique du bassin de Tucumán. Cartographie du champ des anomalies de Bouguer avec des intervalles de 10 mgal et distribution des stations gravimétriques.

showed units yielding refraction values intermediate between those corresponding to the Precambrian and Tertiary. Whether these units belong to the Paleozoic or Mesozoic sequences is at the present a matter of speculation.

As for the structure, the model shown in the cross-section is proposed. The Sierra de Aconquija is formed by succession of basement slabs thrusting westward through regional inverse faults, with dip angles decreasing in depth.

On the other hand the Sierra de Guasáyan together with the Mujer Muerta buried high are part of a block moved eastward. This divergent movements system is thought to have generated an intermediate zone of distensive stress.

The basement slabs are supposed to have detached from their substrate at depths ranging from 7 to 8 km. It is this depth at which a strongly conductive layer was detected (BALDIS *et al.*, 1983 and POMPOSIELLO *et al.*, 1991) which could coincide with a crustal layer at high temperature, trending to ductile behavior and thus able to favor the detachment process.

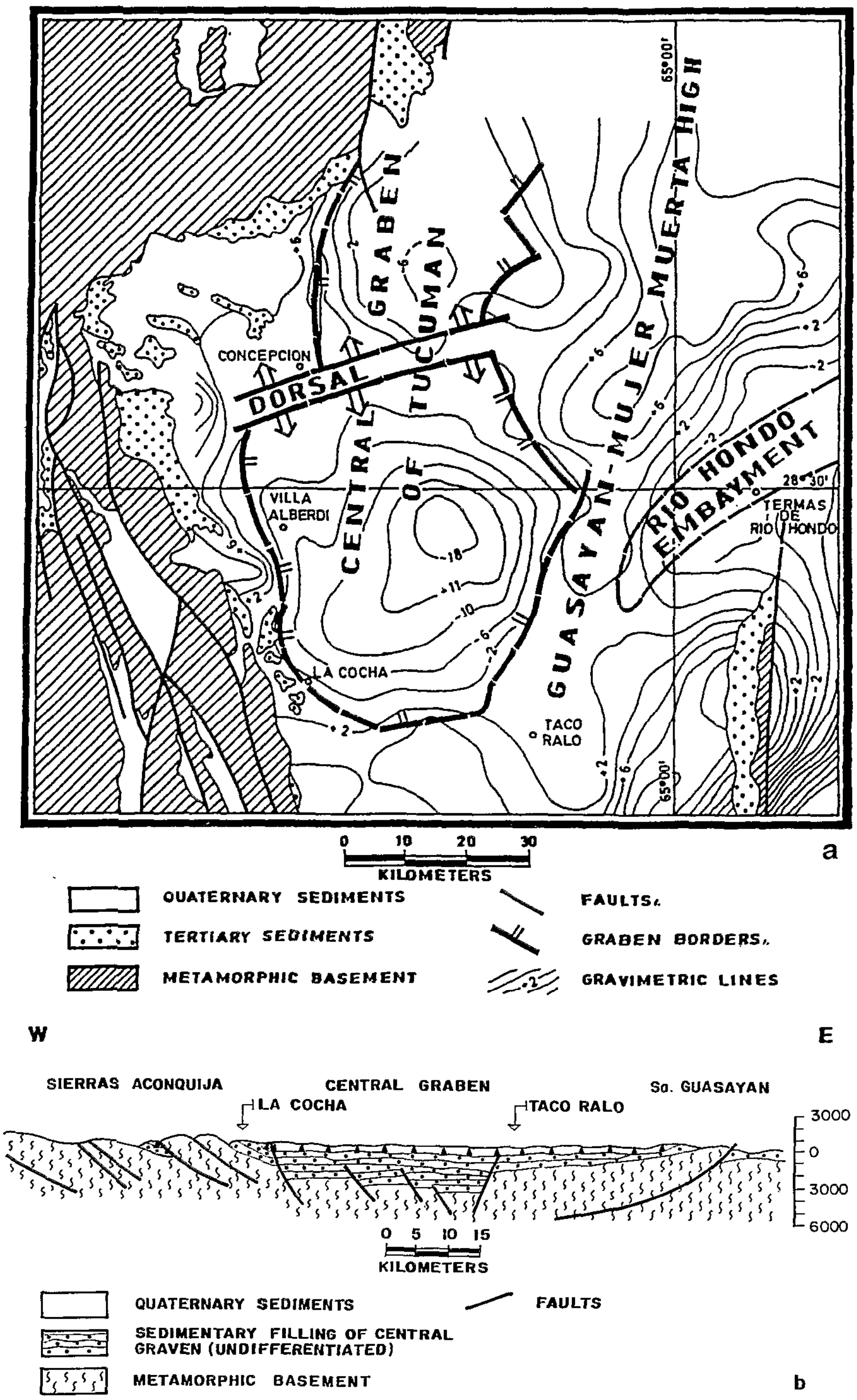

Fig. 3. — Geological map of the Tucumán Basin
a - Residual anomaly field contoured at 4 mgal.
b - The qualitative model.

Carte géologique du bassin de Tucumán.
a - Cartographie du champ des anomalies de Bouguer avec des intervalles de 4 mgal.
b - Modèle qualitatif.

GRAVIMETRIC STUDIES AND ITS GEOLOGICAL INTERPRETATION

Data were obtained for about 400 stations which, together with some already existing data, allowed to build a map of residual field contours (Fig. 3a) (POMPOSIELLO y DIAZ, 1989 ; POMPOSIELLO *et al.*, 1989).

The qualitative model of figure 3b seems to be the most suitable to explain the gravimetric and geologic features. Since in the area neither deep drilling nor detailed seismic were found it is impossible to have a better controled one. The gravimetric residual field is tightly related to the depth of the crystalline basement. The lowest gravimetric measurements correspond to the areas where the basement is the deepest. According to the regional structure, a rifting process seems to be responsible of the sinking of a narrow deep graben filled with sediments. It is some 25 to 40 km wide, elongated in north-south direction, occupying a restricted area located between the high Guasáyan-Mujer Muerta and the Sierra de Aconquija range (see Fig. 3a). Maximum thickness of the sedimentary sequence should be of about 3,000 m.

Since the borders of the gravimetric depression are sharp and steep, it is proposed that it may be representing a graben bounded by high angle normal faults.

Another interesting feature clearly shown by the residual anomalies is the tectonic depression (Rio Hondo Embayment) located between the structure of Guasáyan (plunging northward) and the Mujer Muerta buried high (plunging southward). The Guasáyan threshold of basement which crops out in the Sierra de Guasáyan range, largely extends westward in subsoil (Fig. 3a).

DISTRIBUTION OF THERMAL WATER OCCURRENCES

The best known thermal waters occurrences are associated to the deepest drilling of the region (MON and VERGARA, 1987). All of them, including that at Taco Ralo (Fig. 3a), are out of the deepest zone of the basin, overimposed to the Guasáyan-Mujer Muerta high, where the basement is at a rather low depth (when compared to that at the zone of the tectonic depression).

It is worth wondering whether this fact is the result of geological factors or is simply due to the distribution of the drillings.

Future studies of the thermal behavior of the depression shown by gravimetry are considered of special relevance.

FINAL DISCUSSION

The proposed model must be considered as a preliminary one, and it is particularly aiming to explain the present geometry of the basin. Once the type and age of sedimentary filling will become well known more precise ideas would be presented about the origin of the basin. Has it been originated by movements related to the Andean phases responsible for the thrusting which lifted the range or has it been due to the deformation of an already existing basin, that cannot be said at the present. No data on the structure of the sedimentary sequences can be presented either so that the sections shown are schematic and purely conceptual.

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