Spectral analysis and gravity modelling in the Yagoua, Cameroon, sedimentary basin

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RESUMEN

Se presenta un mapa de anomalías residuales de gravedad para la cuenca de Yagoua, Camerún. Esta cuenca se encuentra al NW de la cuenca de Doba, productora de hidrocarburos. Una anomalía negativa de -18 mGal es interpretada como una formación sedimentaria (arenisca) de 3.1 km de espesor. La estratigrafía se comprueba mediante análisis espectral y modelación en 2.5 D.

PALABRAS CLAVE: Gravimetría, anomalías residuales, análisis espectral, Cuenca de Yagoua.

ABSTRACT

A gravity survey is carried out in the far north of Cameroon, covering an area of about $15\,000$ km^2 in the Yagoua sedimentary basin, located between longitudes 14°20' to 15°50'E, and latitudes 9°45' to 11°N. Using a density of 2.7 g/cm^3 for the crust and removing a second-degree trend surface for modelling, we determined the residual anomalies. Further investigations provide depth of gravity sources, basement structural trend, nature of intrusive bodies and thickness of sediments in the basin. A negative anomaly of about -18 mGal near Moulvouday suggests a thickness of sediments of 3.1 km extending north east. A 2.5D modelling has been carried out along two profiles P_1 and P_2. The depths estimated from spectral analysis and 2.5D modelling are coherent. The combination of the spectral analysis and 2.5 D modelling has led to the demarcation of the Yagoua basin.

KEY WORDS: Gravity survey, residual anomaly, spectral analysis, Yagoua basin.

INTRODUCTION

The studied region is part of the Chad Basin, near the high-yield Doba Basin where the giant Doba oil field has been discovered, and where more than 15 oil and gas discoveries have been found. The area of investigation (Figure 1) is located between longitudes 14°20' to 15°50'E, and latitudes 9°45' to 11°N. It is situated in the transitional zone between the West-Central African rift system (WCAS) (Genik, 1992). It is a large plain, of an average altitude of about 0.3 km above mean sea level. Lateral and vertical changes of density close to the surface produce variations in the gravitational field values that, although very small, can be detected and used in order to improve information on a given geological surface area (Blum *et al.*, 2000; Tidjani, 2000). The aim of this work is to estimate the thickness of the sedimentary layer and the structural model of the Yagoua Basin along two profiles P_1 and P_2. For this purpose, we carry out a 2.5D modelling and spectral analysis of the observed residual gravity anomalies. These elements are discussed, taking into consideration the geological knowledge of the region and mean densities.

REGIONAL GEOLOGY

The region was affected by the Pan African orogeny (750-550 Ma), which produced major basement lineaments and faults of Palaeozoic (550-130 Ma), Cretaceous (130-75 Ma), Maastrichtian-Paleogene (75-30 Ma) and Neogene-Recent (30-0 Ma) age. It is located in the Central African mobile belt, bordered to the east by the Bongor basin and to the north by the Chad basin (Figure 1). Generally, the area contains Quaternary alluviums and sandstones, and post Cretaceous volcanism such as basalts. The basement consists of granites and gneiss materials (Elf Serepca, 1981; Vicat and Bilong, 1998; Maurin, 2002).

GRAVITY DATA

For the collection of the gravity data, LaCoste & Romberg (model G, n° 471 and 823) and Worden (n° 313, 1153) gravimeters were used. The coordinates were obtained from a GPS 55 AVD instrument of Garmin International, Inc., with an approximate horizontal error of 100 m. Elevations in relation to sea level were obtained with a
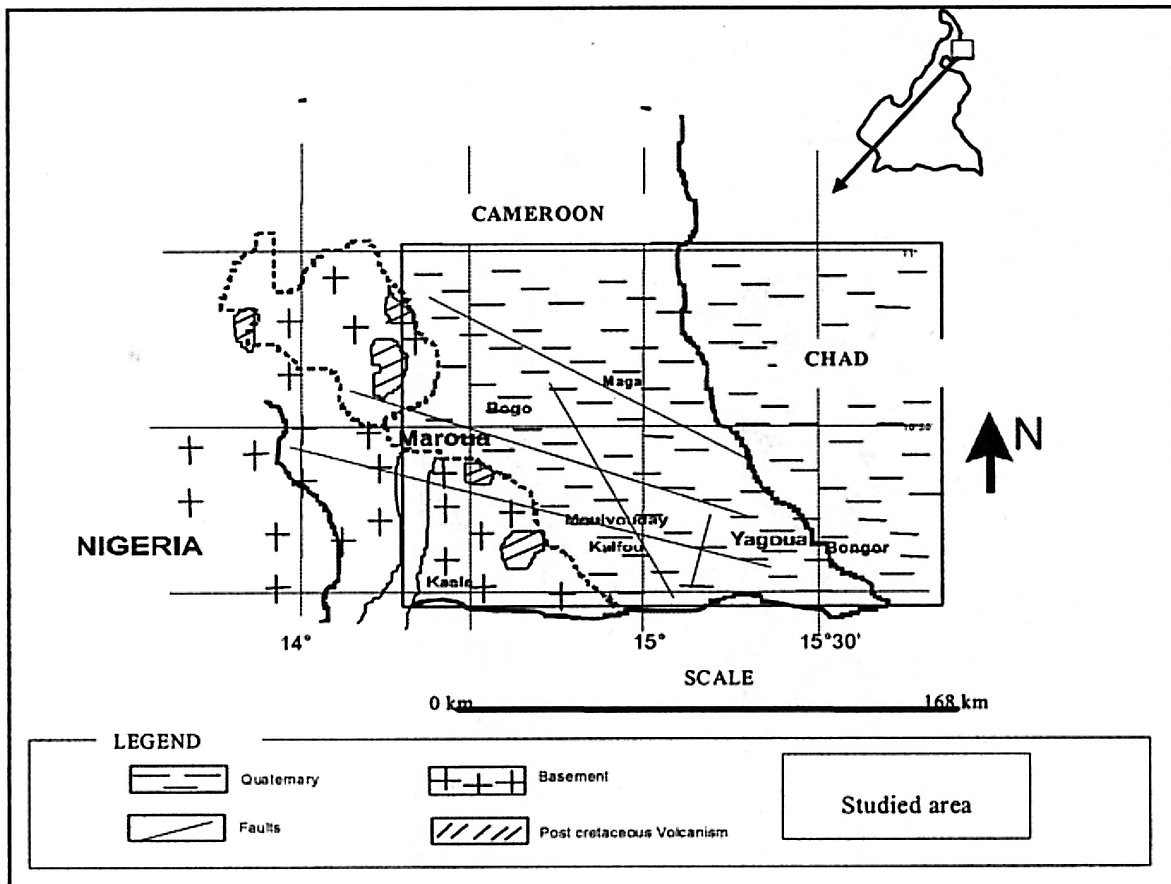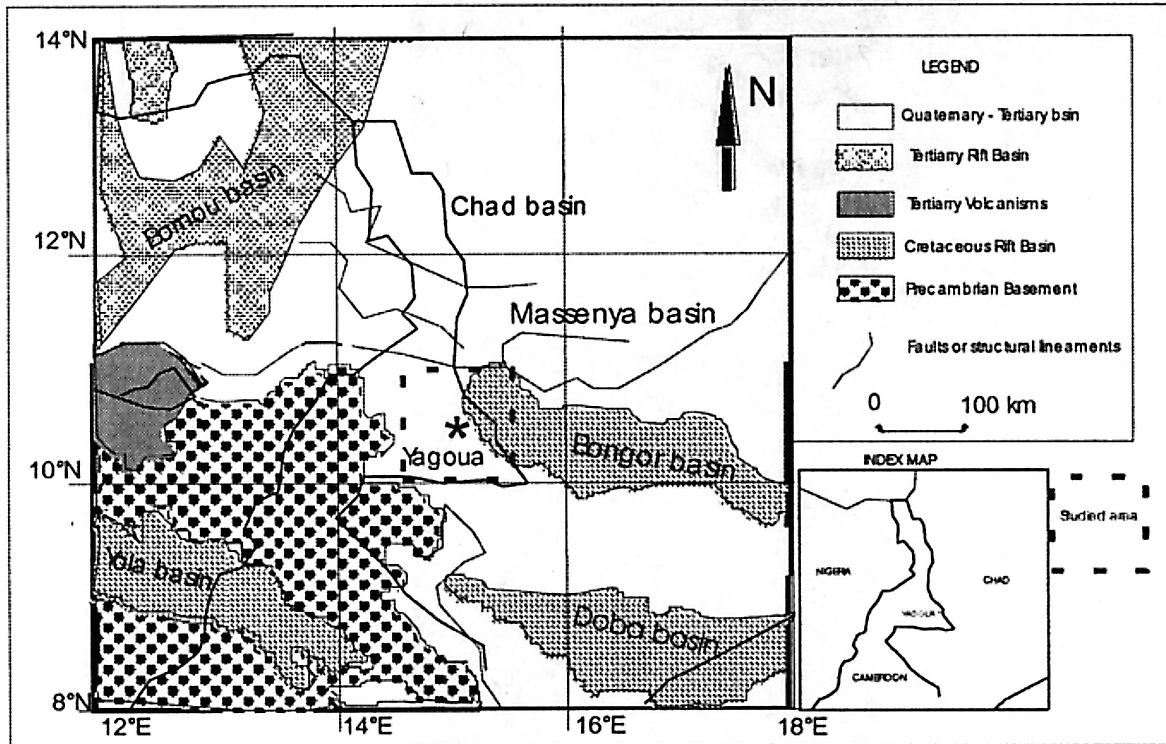
Fig. 1. Simplified geological map of the region from Elf Serepca, 1981; and Genik, 1992, modified.

Wallace & Tiernan (n° 3b4) altimeter accurate to the meter. Base-stations were defined using the International reference IGSN71 (Poudjom *et al.*, 1996). The spacing between stations varied from 1 to 5 km, depending on access facilities. The data were collected at 496 different points. All readings were corrected for tides due to the sun and to the moon, drift, and latitude, free-air, Bouguer corrections. The calculations of terrain corrections were done after Hammer (1939) with a digital terrain model (El Abbass *et al.*, 1990). The map of Bouguer anomalies is presented in Figure 2a. The Yagoua and Bongor basins are easily observed with negative gravity anomaly values.

A second-degree trend surface was removed from the gravity data using a regional-residual separation anomaly code (Njandjock *et al.*, 2003). The residual anomaly data was used to construct residual anomaly map (Figure 2b), for spectral analysis calculation and modelling.

METHODS

We combined two methods: spectral analysis and 2.5D modelling.

Spectral analysis has been widely used by several authors (Spector and Grant, 1970, Gerard and Debeglia, 1975; Bhattacharyya, 1978) for depths of magnetic or gravity anomalies. Energy spectral analysis provides a technique for quantitative studies of large and complex aeromagnetic or gravity data sets. The logarithm of the radial average of the energy spectrum (the square of the Fourier amplitude spectrum) is plotted versus the radial frequency. The slopes of the linear segments of the spectrum correspond to separate depth ensembles and provide parameters used for the design of numerous filters. The slope of each segment provides information about the depth to the top of an ensemble of magnetic or gravity bodies (Kivior and Boyd, 1998).

We have used the 2.5D modelling program of Chouteau and Bouchard (1993) to carry out models of the subsurface. The program is based on several algorithms (Talwani *et al.*, 1959; Talwani and Heirtzler, 1964; Broom, 1986). It has constraints concerning the depth of investigation, the strike of the model and the density contrast between the anomaly which is responsible for the observed anomaly and the basement.

RESULTS AND DISCUSSION

Spectral analysis

Two profiles P_1 and P_2 were selected in the area of survey. The first profile (P_1) has a NW-SE direction, and crosses Bogo and Kalfou towns. The second (P_2) has a N-S direction and crosses Maga and Kalfou towns (Figure 2b). The power spectrum curves obtained for the profiles are presented in Figure 3.

The energy spectrum for the basin (Figure 3), shows two strong linear reflecting depths at 3.25 km and 3.06 km. These depths may be interpreted as the average depth of the Yagoua basin in each profile. The depths of 0.08 km and 0.12 km presented in the figure are neglected or can be interpreted as some intermediate layer in the basin.

The average depths determined for each profile from spectral analysis are given in Table 1.

2.5D Modelling and interpretation

Negative anomalies (Figure 2b) have been attributed to materials lighter than the basement, because the topography in the region is nearly uniform (Nnange *et al.*, 2001). Positive anomalies are correlated with materials which are denser than the basement complex. According to Elf Serepca (1981) and Maurin (2002). Quaternary sands and sandstones are considered to justify the negative anomalies near Moulvouday, whereas the second group can be justified by basalts, gneiss or post Cretaceous volcanic materials, which create positive anomalies in the Mindif, Kalfou, Vele and Maga regions.

The models of Figure 4 are plotted using the 2.5 dimension program of Chouteau and Bouchard (1993). The lateral extension used for each model is 10 km (Figure 4). The density contrast between the average density of the suspected body and the basement complex are given in the Table 2 (Astier, 1971). In general, each model in Figures 4 and 5 has two principal bodies. The bodies with density 2.2 g/cm^3 are correlated to sediments such as sandstones, and can reach 3.75 km and 5.00 km deep, for the P_1 and P_2 profiles respectively. The bodies with density 2.7 g/cm^3 are attributed to the complex basement. Those with densities 2.8 and 2.9 g/cm^3 are correlated to gneiss or basalt. According to the two profiles, the basin has a half-graben structure consisting

Table 1

Depths obtained from spectral analysis

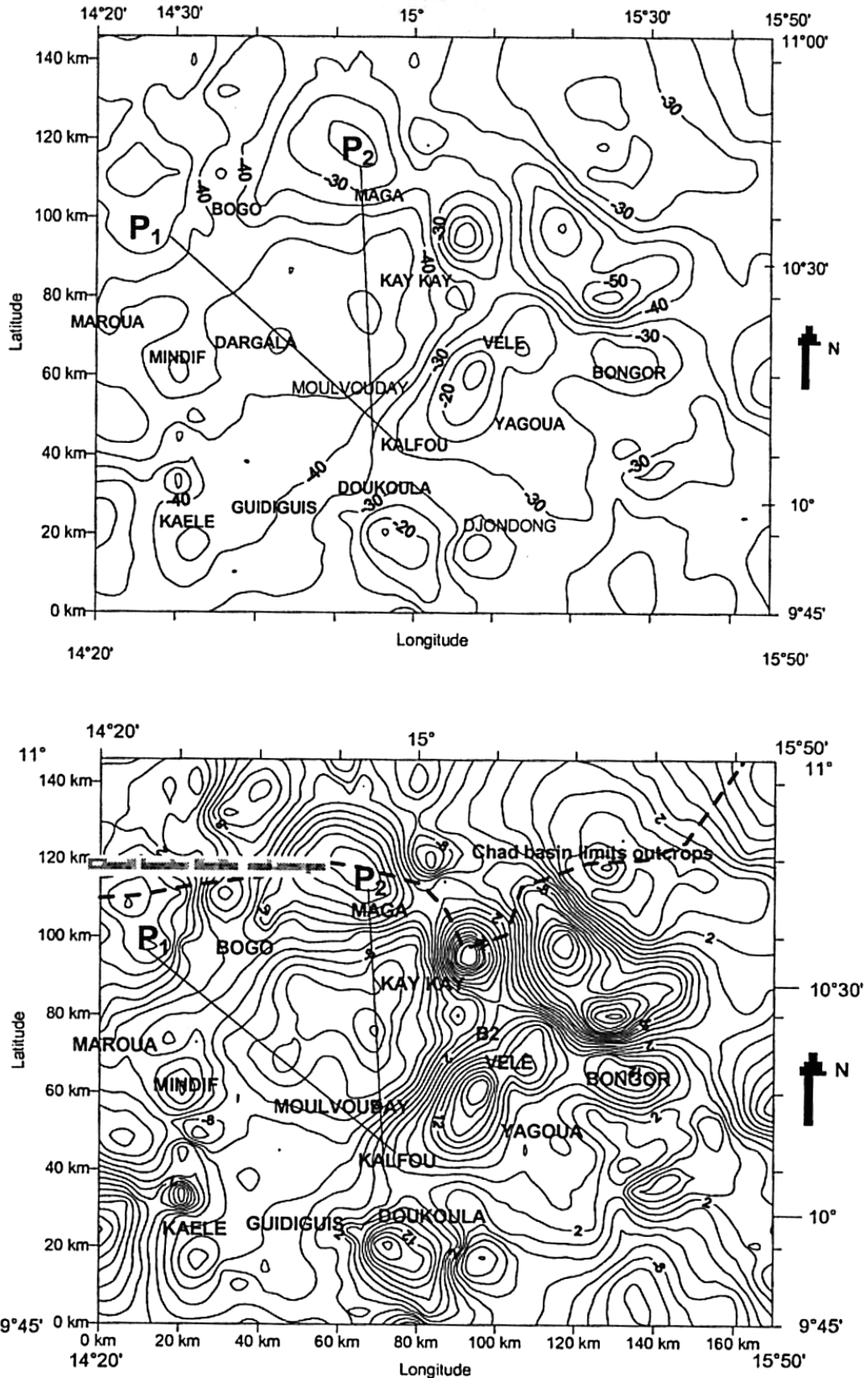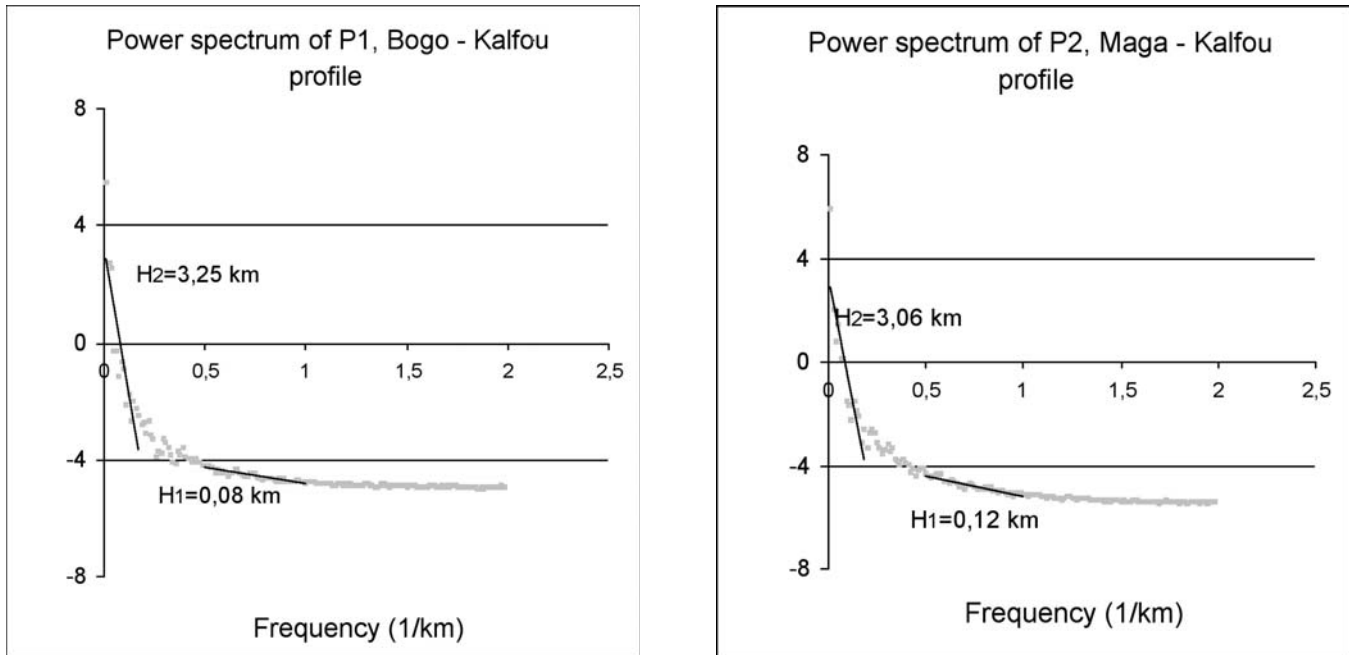| Profile	H_1(km)	H_2(km)
Bogo-Kalfou (NW-SE) P_1	0.08	3.25
Maga-Kalfou (N-S) P_2	0.12	3.06

Fig. 2. Bouger and residual maps of the Yagoua region-Cameroon.

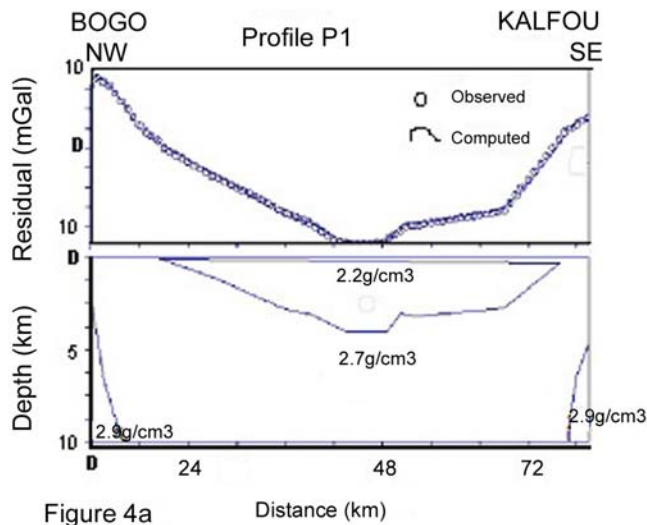Fig. 3. Power spectrum of profiles from spectral analysis program.
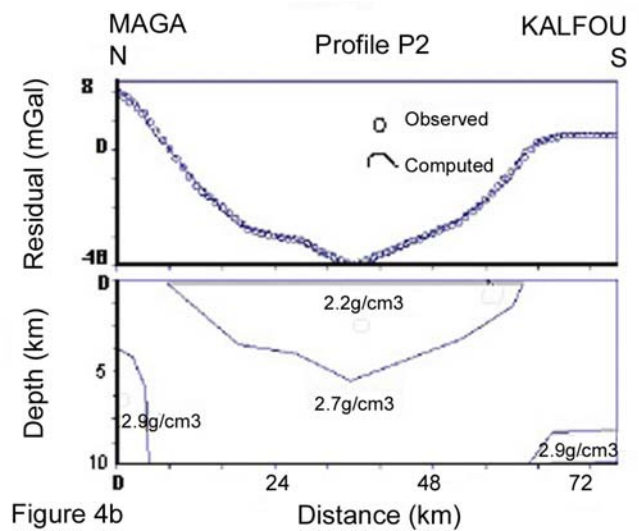

Fig. 4. Interpreted models of profiles from IGAO Ω program.

of sandstones, generally covered with sands. The geological sections of (Figure 5) deduced from 2.5D models (Figures 4a-4b) show some known and unknown faults in the basement complex that confirm results from recent works (Detay, 1987; Maurin, 2002 and Njandjock, (2004).

The Kalfou region is situated on a dome and the basement complex depth is not deep in this region, as shown by Detay (1987) and Maurin (2002). According to Genik (1992), the southern borders of the Chad basin in this region

(Figure 2b) correlate well with the positive anomalies in the North of the region (Maga and Bogo regions) caused by post Cretaceous volcanism materials (Figure 4 and 5b).

CONCLUSION

Gravity modelling and spectral analysis have improved knowledge about this region of Cameroon. The study suggests that the Yagoua basin is correlated with a large sector of negative residual anomalies near Mouvouday,
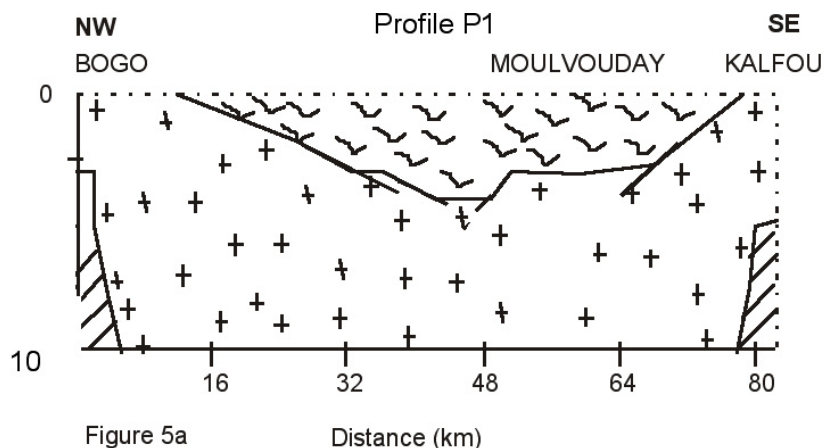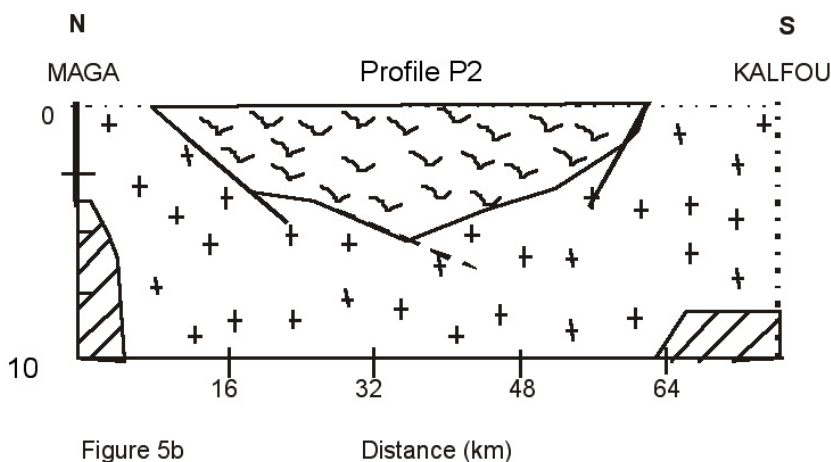
Fig. 5. Geological section of profiles

Table 2

Average densities of materials from (Astier, 1971)

Material	Density (g/cm³)
Sandstone	2.2
Basement complex	2.7
Gneiss	2.8
Basalt and post cretaceous volcanism	2.9

separated by denser geological structures such as basalts or gneiss, which correlate with positive residual anomalies zones. The average depth of the Yagoua basin according to P_1 and P_2 profiles can reach 3.25 km and 3.06 km. Therefore, the sedimentary layer in the basin could be up to 3.1 km deep, from mean sea level. This study has also shown known and unknown faults in the basement complex, generally covered by sand, as well as intrusions of dense materials, associated with post Cretaceous volcanism, gneiss or basalt.

BIBLIOGRAPHY

ASTIER, J. L., 1971. Géophysique Appliquée à l'hydrogéologie. Masson & Cie.

BLUM B. L. M., B. C. A. PIRES and V. A. R. DE MORAES, 2000. Gravity inversion on granite-greenstone belt areas/ Crixäs, Guarinos and Pilar de Goiäs, Brazil.

BHATTACHARYYA, B. K., 1978. Computer modeling in gravity and magnetic interpretation. *Geophysics, 43, 5,* 912-929.

BROOM, J., 1986. Magrav2: An interactive Magnetics and Gravity Modelling Program for IBM-compatible Microcomputers, open file 1334, Commission Géologique du Canada.

CHOUTEAU, M. and K. BOUCHARD, 1993. Igao 2.5D , version 2.0 Janvier 1993, Laboratoire de Géophysique Appliquée, Département de Génie Minérale, École Polytechnique de Montréal.

DETAY, M., 1987. Prospection et identification des aquifères: Reconnaissances préliminaires et méthodes d'implantation des ouvrages par étude de terrain et photo-interprétation. Session internationale de formation au Celigre. Exploitation et gestion des ressources en eau souterraine.

EL ABBASST, C. JALLOULI, Y. ALBOUY and M. DIAMENT, 1990. A comparison of surface fitting algorithms for geophysical data. *Terra Nova, 2*, 467-475.

ELF-SEREPCA, SERVICE D'EXPLORATION, 1981. Carte géologique du bassin de Garoua.

GENIK, G. J., 1992. Regional framework, structural and petroleum aspects of rift basins in Niger, Chad and the Central African Republic (C.A.R.). *Tectonophysics, 213*, 169-185.

GERARD, A. and N. DEBEGLIA, 1975. Automatic three-dimensional modeling for the interpretation of gravity or magnetic anomalies. *Geophysics, 40, 6*, 1014-1034.

HAMMER, S., 1939. Terrain corrections for gravimeter stations. *Geophysics, 4*, 184-194.

KIVIOR, I. and D. BOYD, 1998. Interpretation of the aeromagnetic experimental survey in the Eromanga/ Cooper basin. *Can. J. Explor. Geophys., 34*, 1 and 2, 58-66.

MAURIN, S., 2002. Géomorphologie. Atlas de la Province de l'Être-Nord, Cameroun. Planche 1. MINREST, INC.

NJANDJOCK, N. P., H. L. KANDÉ, E. MANGUELLE-DICOUM, C. T. TABOD, M. T. NDOUGSSA and J. MARCEL, 2003. A Turbo Pascal 7.0 program to fit a polynomial of any order to potential field anomalies based on the analytic least squares method. *AJST, 4, 2*, 1-4.

NJANDJOCK, N. P., 2004. Investigation gravimétrique et cartographie des structures géologiques superficielles et profondes dans la région de Yagoua-Cameorun. Thèse de Doctorat/ Ph.D. Univ. Yaounde I, 134 p

NNANGE, J. M., Y. H. POUDJOM DJOMANI, J. D. FAIRHEAD and C. BINGER, 2001. Determination of the isostatic compensation mechanism of the region of the Adamawa dome, west central Africa using the admittance technique of gravity data. *AJST, 1, 1*, 29-35.

POUDJOM, D. Y. H., A. LEGELEY-PADOVANI, D. B. BOUKEKE, J. M. NNANGE, ATEBA-BEKOA, Y. ALBOUY and J. D. FAIRHEAD, 1996. Levés gravimétriques de reconnaissance-Cameroun. Orstom, France, 30 p.

SPECTOR, A. and F. S. GRANT, 1970. Statistical models for interpreting aeromagnetic data. *Geophysics 35*, 293-302.

TALWANI, M., J. L. WORZEL and M. LANDISMAN, 1959. Rapid gravity computations for two-dimensional bodies with application to the Mendocino submarine fracture zone. *J. Geophys. Res., 1, 64*, 49-59.

TALWANI, M. and J. R. HEIRZLER, 1964. Computation of magnetic anomalies caused by two-dimensional bodies or arbitrary shape. Computers in the Mineral Industry, School of Earth Sciences, Standford University.

TIDJANI, M., 2000. Application de la gravimétrie à l'interprétation géophysique de la chaîne Panafricaine des Dahomeydes et du domaine du bassin volcano-sédimentaire de Daho-Mahou (Benin Afrique de l'Ouest). Thèse de Doct. ès Sciences Physiques. Université Nationale du Benin, 170 P.

VICAT, J. P. and P. BILONG, 1998. Géologie et environnement au Cameroun. Presses Universitaires de Yaoundé, 45-56.

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