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THE CRUSTAL STRUCTURE ALONG THE MBERE TROUGH IN SOUTH ADAMAWA (CAMEROUN) FROM SPECTRAL ANALYSIS AND GRAVITY MODELLING

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ABSTRACT

The Mbere Cretaceous trough is located in the southern part of the Adamawa province. A gravity interpretation based on data obtained from three NW-SE profiles on the residual anomaly map has been carried out using a 2.5D modelling program. Spectral analysis has been used to estimate the depth of geological structures. The results obtained show that the metamorphic formations consist of gneiss and migmatite which are located in the north of the trough at a mean depth of 9 km. The gradient observed on the Bouguer anomaly map along the trough might not only be due to the northern fault but also due to the contact between the gneiss (and migmatite) and granite under the trough. The thickness of sediments along the trough varies between 1500 and 2250 m with a minimum at Yariban and a maximum at Djohong. The trough is bounded on its sides by faults related to the Central African Shear Zone. Basaltic rocks associated with the Cameroon Volcanic Line are present as intruded rocks lying at a minimum depth of 7200 m.

KEYWORDS: Bouguer anomaly, residual anomaly, fault, trough.

INTRODUCTION

The Adamawa plateau represents a post-Cretaceous uplifted and elongated zone which trends SW-NE in Central Africa. The plateau is bounded to the NW by the Benoue trough and to the south by the South-Adamawa trough, consisted of Mbere and Djerem basins which are separated by a volcanic outflow (Fig 1-a). These basins are bounded on their sides by faults trending ENE and WSW and are associated with thick mylonite stripes found within the basins. A Bouguer anomaly map of Cameroon shows that the Adamawa plateau is characterized by a long wavelength negative Bouguer anomaly of about -120 mgals which is about 200 km wide (Collignon, 1968). Two main directions: ENE and NNE to NE can be identified on the map. These directions correspond respectively to the northern fault of the Mbere trough and the orientation of the plateau.

In this study, gravity data were interpreted in order to estimate the thickness of the sediments within the Mbere trough and the geological formations present using spectral analysis. 2.5D models for this region are also proposed.

GEOLOGIC AND TECTONIC SETTING

The Mbere trough is located to the south of the Adamawa plateau in Cameroon between latitudes 6°30' and 7°30'N and between longitudes 14° and 15 °E. The trough which is about 100 km long and 10 to 20 km wide is bounded by faults. The trough disappears under the basaltic outflows of Adamawa (Fig. 1-b). The volcanic rocks are related to those of the Cameroon Volcanic Line (CVL) and are made up of extensive basaltic outflows in the Adamawa plateau and Mbere trough overlying the sediments and granitic basement (Le Marechal and Vincent, 1971; Fitton and Dunlop, 1985). The outflows are post-Cretaceous and have followed the tectonic setting of that period. The deepest basaltic rocks are located along the trough. Their mean depth in the Tibati region in the SW of the Adamawa is 5.5 km (Ngako et al., 1991). The sediments are made up of polygenic conglomerates and arkosic sandstones (Ngangom, 1983) (Fig. 2). The thickness of the sediments is estimated to lie between 1500 and 2500 m at Djohong (Chevassus-Agnes, 1971) and between 1600 and 2000 m using geophysical data (Collignon, 1970). The basement is made up of plutonic and metamorphic Precambrian rocks. They are mainly gneiss, amphiboles, migmatites and granite which outcrop on the edge of the plateau.

The tectonic evolution of the region is characterised by a transformation through metamorphism, at the end of the upper Proterozoic, of plutonic and metamorphic basement rocks into granite and migmatite (Ngangom, 1983). The post-Panafrican evolution is characterised by a mylonitisation of rocks of a few kilometres wide and extending from the Atlantic coast to the south west to beyond the Adamawa in the north east. The phenomenon is related to a compressive episode in the E-W direction and by a dextral fracture in the N70°E direction, which coincides with the orientation of the Mbere trough. The fault zone is part of Central African Shear Zone (CASZ) that extends some 2000 km from Cameroon to Sudan (Cornacchia and Dars, 1983).

GEOPHYSICAL SETTING

A number of geophysical studies have been carried out in the whole of the Adamawa.
Seismic refraction studies by Stuart et al. (1985); Dorbath et al. (1986) situated the upper and lower crustal limit between 10 and 14 km under the Adamawa region. The seismicity study of the Cameroon volcanic provinces (Tabod et al., 1992) showed two zones of evident seismicity in the region. One of them is related to the Foumban fault, which cuts through the Adamawa province and the other to the northern border of the Congo Craton. Some low magnitude earthquakes were registered between 1983 and 1987, with the epicentres along the fault (Nnange et al., 1985). Some of the earthquakes occurred at depths greater than 30 km.

The study of profiles of total magnetic field in the Mbere trough by Collignon (1970) showed magnetic contrasts, which he associated with the effect of the presence of basic rocks in the northern part. The magnetic anomaly map of Africa obtained from the satellite MAGSAT (Langel et al., 1982) showed that the Adamawa region is characterised by extended longitudinal anomalies trending ENE-WSW to E-W with a magnitude of 2 nT. The anomalies are greater at low altitudes, suggesting that they might have a deeper origin (Regan et al., 1975; Regan and Marsh, 1982). Dorbath et al. (1986) suggested that these anomalies originated in the lithosphere.

Aeromagnetic data have been used to study the Foumban fault, which traverses the Adamawa region (Nnange, 1991). The principal directions registered by the aeromagnetic study showed that the region might be made of rocks with different magnetic susceptibilities. This study brought out the N30°E direction which is same as the interpretation from satellite pictures (Moreau et al., 1987).

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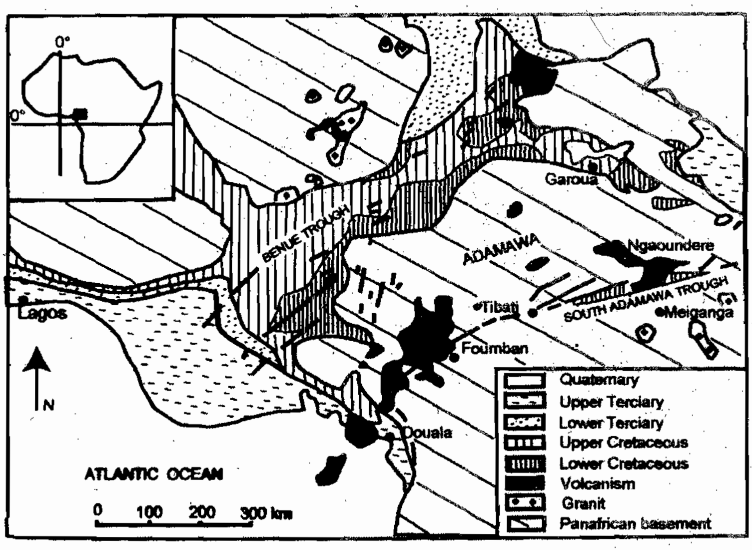

Figure 1-a : Geological setting of the Adamawa and the neighbouring troughs, modified from Dumont (1987)

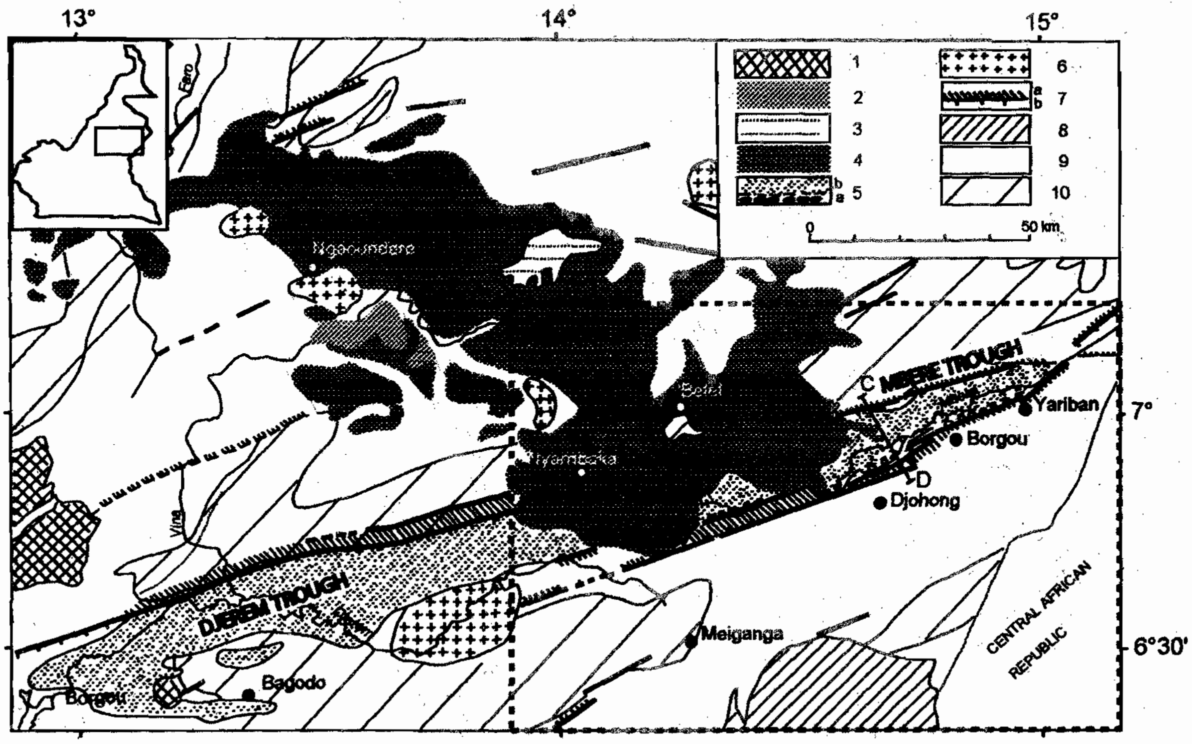

Figure 1-b. Geological setting of the Adamawa Plateau, modified from Lassere (1961) and Le Marechal and Vincent (1971). 1. lateric crust ; 2. basalt of upper units ; 3. trachytes trachy-andesites and rhyolites of middle unit ; 4. basalts of the lower units ; 5. sedimentary formations of the South Adamawa trough, a : metamorphic conglomerates ; b : conglomerates and arkoses ; 6. late Panafrican granites ; 7 faults, a : with considerable morphologic epaulment, b : with mylonites ; 8. epimetamorphic schists (Lom unit) ; 9. syntectonics (Panafrican) granite ; 10. migmatites and gneiss. (The study area is marked by dotted lines)

The gravity studies by Collignon (1968) revealed that the Adamawa region is characterized by a long wavelength negative Bouguer anomaly of about -120 mgals and about 200 km wide. Okereke (1984) from the isostatic studies showed that the topographic loads under the Adamawa region are in compensation for wavelengths more than 100 km. The gravity study in the Adamawa region by Poudjom-Djomani (1993) showed that the long wavelengths are due to the lithospheric thinning related to the asthenospheric ascent. Recent studies by Noutchogwé (2004) in the Adamawa region showed that the large fracture oriented N70°E that affected the basement is located in the lithosphere. The basement is intruded with volcanic rocks located at 8 km mean depth with a minimum depth of 5.5 km under the Tibati region in the SW of Adamawa.

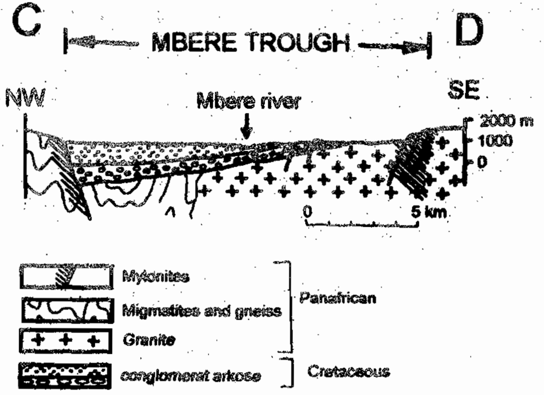

Figure 2. Schematic geological section of the Mbere Trough as located on Figure 1 modified from Lassere (1961) and Le Marechal and Vincent (1971).

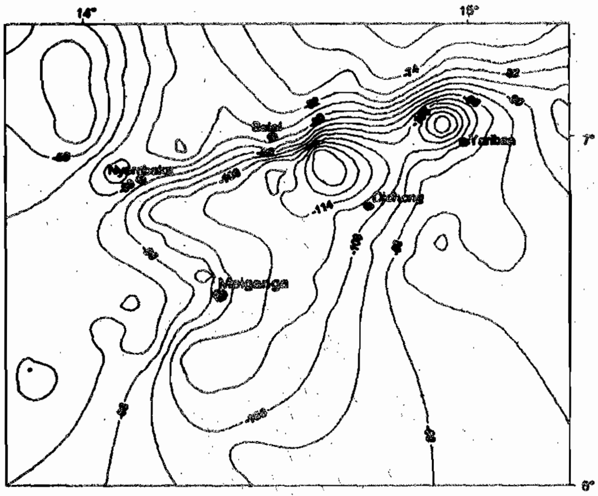

Figure 3. Bouguer anomaly map of the Mbere region from data by Legeley et al. (1996)

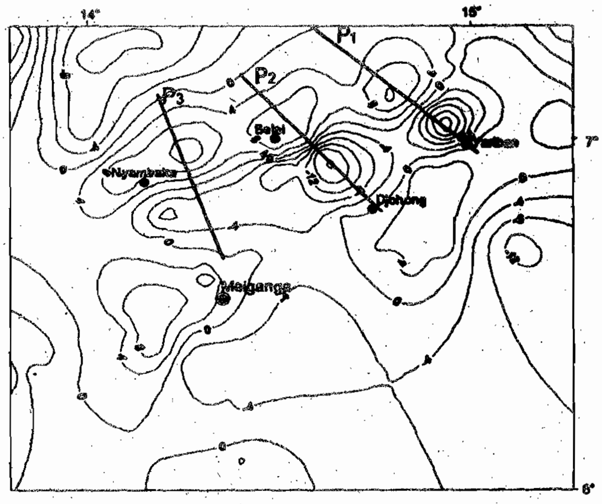

Figure 4. Third order residual anomaly map of the Mbere region from data by Legeley et al. (1996) with profiles

GRAVITY DATA

The gravity data used in this study are part of gravity survey carried out in Cameroon by ORSTOM (Legeley et al., 1996). The Bouguer anomaly map of the study area shown in Figure 3 is a compilation of the data obtained from IRD (Institut de Recherche pour le developpement). The map shows the structural feature of the Mbere region and a portion of Adamawa region. The region is characterised by a long wavelength negative Bouguer anomaly of about -122 mgals and two principal directions. One in the ENE direction which shows concentrated parallel isogals that are related to the Mbere trough and the other in the NNE to NE, which is the direction of the Adamawa plateau. The volcanic outflows c' served at Belel on the geologic map of the region have no effect on the Bouguer anomaly map. This might be due to their small thickness that does not cause much modification of the gravity field.

The gravity data were separated into regional and residual data up to the third order by the method of least squares using a Turbo Pascal 7.0 program (Njandjock et al., 2003). By correlating to the local geology, third order residual anomaly map was chosen for the interpretation of the near surface geological structures (Fig. 4). Three profiles were chosen according to the principal directions of the geologic structures. A spectral analysis using a Turbo Pascal 7.0 program (Njandjock, 2004) was carried out on these data to estimate the depth of structures responsible for the observed anomalies.

METHOD

Spectral analysis as described by Spector and Grant (1970) is an interpretation technique based on the study of power spectrum properties. From the study of the power spectrum logarithm as a function of the spacing frequency, the mean depth of bodies responsible for the observed gravity anomalies can be estimated. Gravity data vary as a function of distance along a profile. The power spectrum is the magnitude of the discrete Fourier transform gravity function. The depth h (km) to the approximate plane of density contrast can be calculated from the relation:

$$h = \Delta LogP/4\pi\Delta f$$

Where $\Delta LogP$ is the variation of the logarithm of the power spectrum for a frequency gap Δf (km^{-1}). This relation is deduce from the power spectrum logarithm curve versus the frequency. On this curve, two straight line segments can be identified and plotted by a least squares fitting on the data points. One in the high frequency range is caused by bodies at near surface, while the other in the low frequency range is caused by deep-seated bodies. Two planes of density contrasts are associated to these bodies and it is supposed that the gravity anomaly under study is mainly located between the two planes.

A 2.5D modelling of the data along the profiles was also carried out. The IGAO 2D1/2 modelling program by Chouteau and Bouchard (1993) was used. The initial depths of models

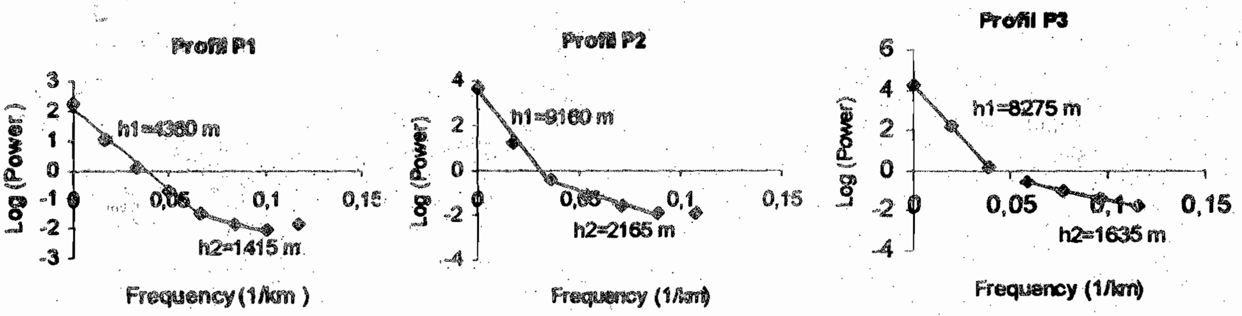

Figure 5. Plots of power spectrum versus the frequency for profiles P1, P2 and P3 . h1 - deep density contrast plane ; h2 - shallow densiy contrast plane.

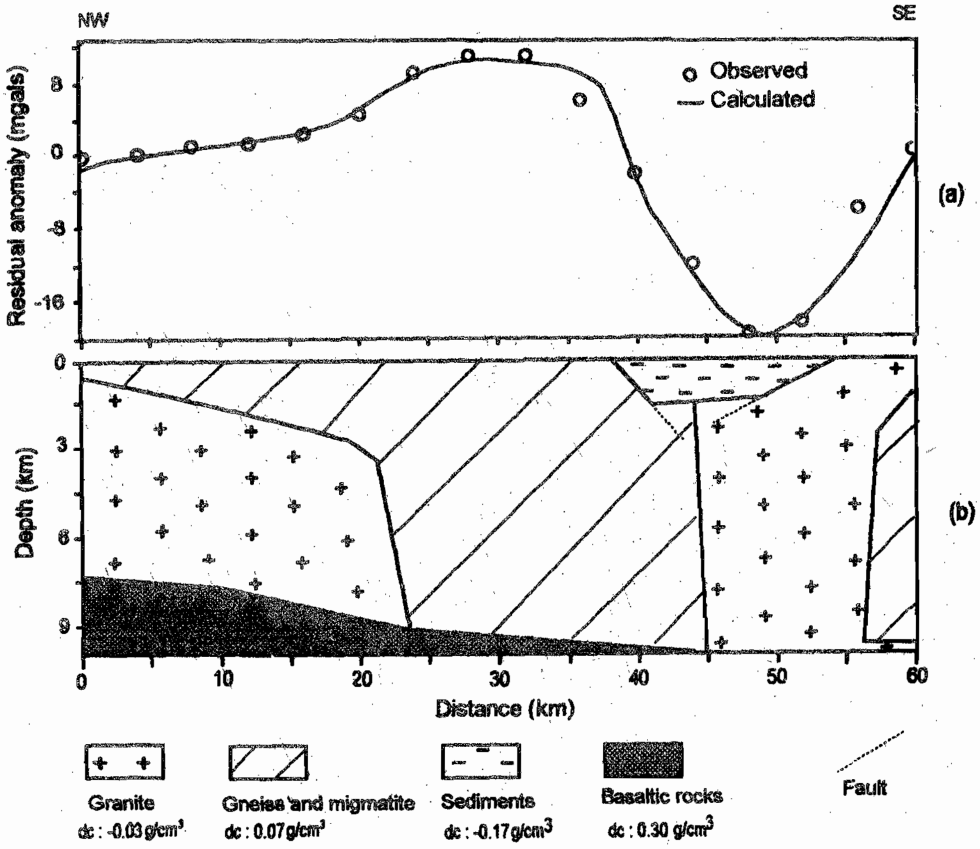

Figure 6. Profile P1 : (a) calculated anomaly ; (b) geological model. dc= density contrast

were chosen according to the results of spectral analysis. The density contrasts of rocks were calculated based on the difference with a mean density of the earth's crust taken as 2.67 g/cm^3. The mean densities of granite, sediments (sandstones and conglomerates), basaltic rocks and metamorphic rocks (gneiss and migmatite) are respectively 2.64, 2.35, 2.99 and 2.74 g/cm^3 (Telford et al, 1974). For the modelling, density contrasts of -0.03, -0.17, 0.30 and 0.07 g/cm^3 respectively were retained for the rocks named above.

RESULTS AND INTERPRETATION

Figure 5 shows the plots of the logarithm of the power spectrum versus the spacing frequency for the three profiles considered. The mean depth of density contrast plane is represented by h1 in the low frequency range and h2 in the high frequency range. Low depths were supposed to be caused by a contact between sediments and granites, and high depths by the contact between intruded basaltic rocks and gneiss (and granite). Values obtained show that the maximum depth of sediments is about 1415, 2165 and 1635 m for profiles P1, P2, and P3 respectively. The trough might be consequently deeper at Djohong than Yariban and Nyambaka. The intruded basaltic rocks might be located in the upper crust since the depths to the plane of density contrast are respectively 4360, 9160 and 8275 m for profiles P1, P2, and P3 in the low frequency range.

Models of NW-SE parallel profiles P1, P2 and P3 are represented on Figures 6, 7 and 8. Calculated anomaly curves have shapes that can be associated with third order polynomial, characteristic of fault or contact between two structures (Fig 6(a), 7(a), 8(a)) which shows that the shape of

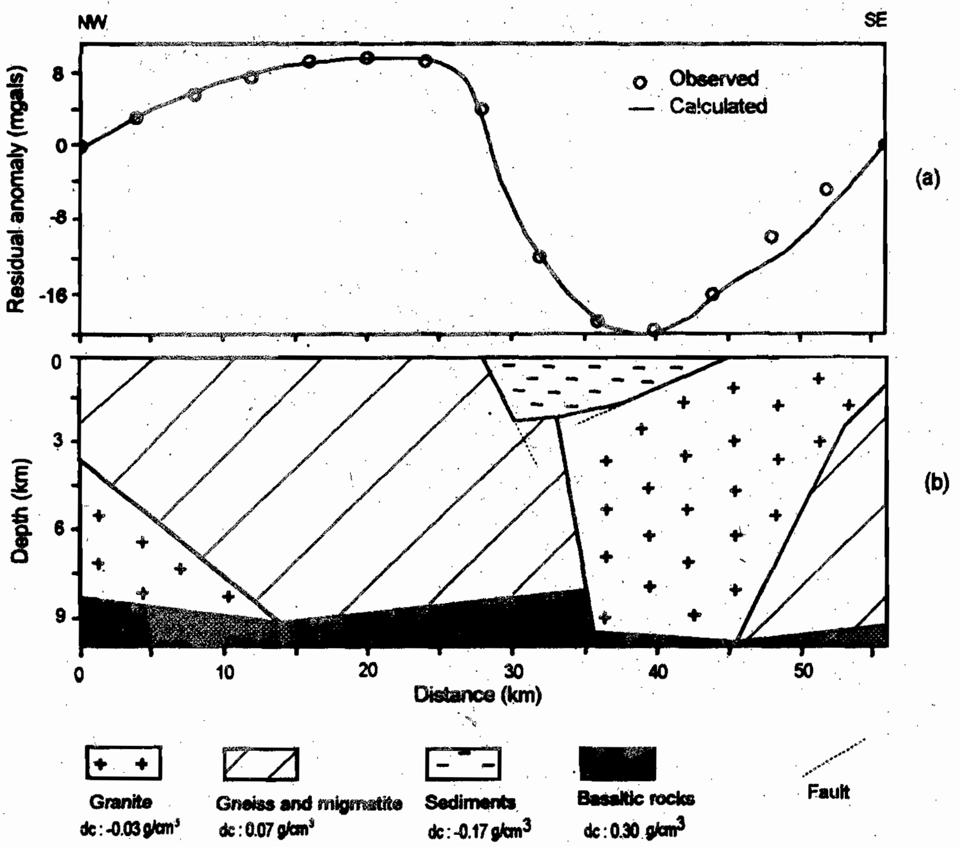

Figure 7. Profile P2 : (a) calculated anomaly ; (b) geological model. dc= density contrast

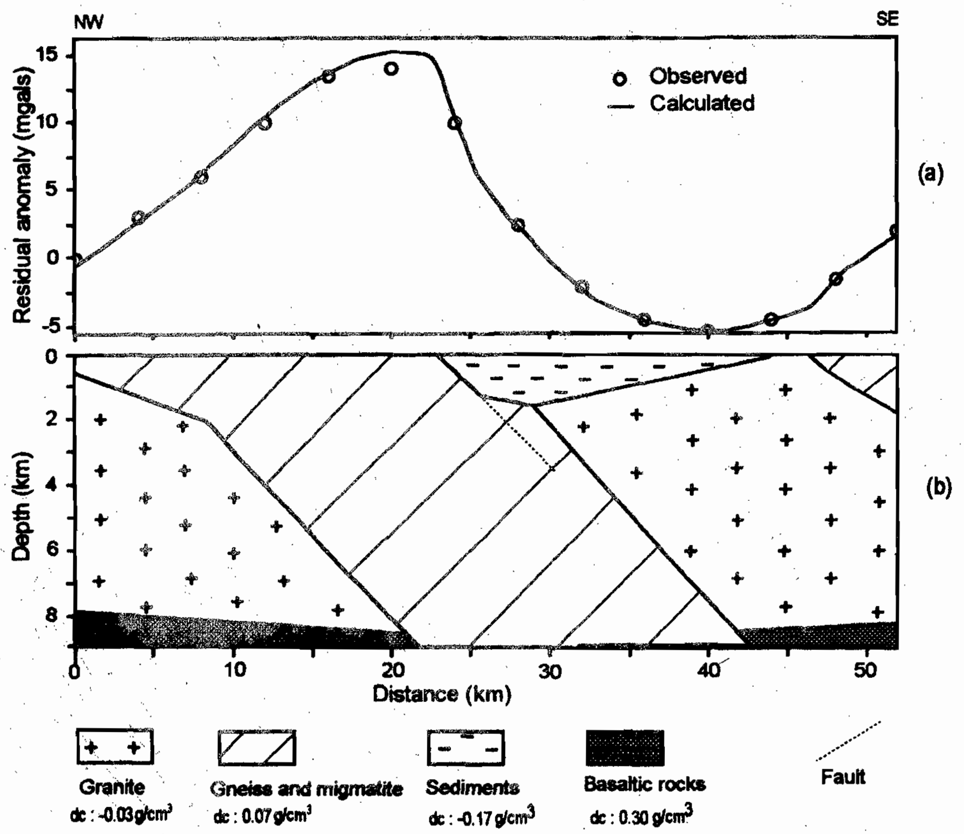

Figure 8. Profile P3 : (a) calculated anomaly ; (b) geological model. dc= density contrast

geologic models are almost similar and characterised by a major fault or a contact located around the centre of the models. The geologic models are represented on Figures 6(b), 7(b) and 8(b). For the spectral analysis, the depth of models chosen is 10 km for profiles P1 and P2, and 9 km for the profile P3. Models obtained show that the trough is less than 21 km wide with 2250 m maximum thickness of sediments observed at Djohong. For profiles passing through Yariban and Nyambaka, the thickness of sediments is respectively 1500 and 1600 m. The trough is bounded on its sides by normal faults whose slopes vary along the trough. Gneiss (and migmatite) observed along the NW extends to 9100 m maximum depth and is characterised in the South by a major contact with the granite. The one along the SE might belong to the south of Djohong as on (Fig 6(b), 7(b)) and to Meiganga as on Figure 8(b). The bottom of each model shows intruded basaltic rocks located at about 7200 km minimum depth.

DISCUSSION

The Mbere region is characterised by a line of fault in the NE-SW direction. Tectonic phenomena that affected the region during the Cretaceous are responsible for this structure. Models obtained show that metamorphic rocks are located in the upper crust. The depths agree with spectral analysis results of which the maximum depth to the density contrast plane is 9160 m. According to the spectral analysis of Fairhead and Okereke (1988) in different regions of Cameroon, the mean depth of the density contrast plane in the Adamawa region is 9 km for sources located in the upper crust. According to Noutchogwé (2004), when depths deeper than 10 km are considered while using third order modelling of residual anomaly of the Adamawa region, the values of density contrast got are lower and do not correspond to the calculated values.

The thickness of sediments varies between 1500 and 2250 m along the trough with a minimum at Yariban and a maximum at Djohong (Fig. 7(b)). The depths agree with the spectral analysis results for which the depths to the density contrast plane vary between 1415 and 2165 m along the trough. At Djohong, the thickness of sediments agrees with geomorphologic results by Chevassus-Agnes (1971), and more so according to the estimated values by Collignon (1970). Le Marechal and Vincent (1971) remarked that the estimated values by Collignon (1970) might be lower if it is considered that heavy masses under Djohong attenuate the anomaly magnitude due to the trough.

The contact between the granite and gneiss (and migmatite) under the trough can be observed on the geological section (Fig. 2). Border faults of the trough belong to the CASZ. Collignon (1968) earlier on indicated the existence of the northern fault on the gravity map. This constitutes the northern boundary of the trough (Ngangom, 1983). The gradient observed on the gravity map along the trough might not be due only to the northern fault but also to the contact between granite and gneiss (and migmatite) under the trough.

Intruded basaltic rocks observed on models might be due to the partial ascension of basaltic magma along the Panafrican basement fractures. Dorbath et al. (1986) observed that positive magnitude aeromagnetic data in the Adamawa region (Langel et al., 1982) might be located in the Lithosphere. The structural study by Ngako et al. (1991) have located the depth of basaltic rocks under the Tibati region at 5.5 km. Volcanic outflows observed on the geological map are related to the CVL and are not observed on models because of their low depth (Le Marechal and Vincent, 1971) that do not cause any modification of the magnitudes off observed anomalies.

CONCLUSION

The results obtained in this study reveal that the upper crust geological model along the Mbere trough does not vary much. Metamorphic rocks are constituted of gneiss and migmatite located mainly at the northern part of the trough with a 9 km mean depth. They are bounded in the South by an important contact with granite of which the slope varies along the trough. The thickness of sediments along the trough varies between 1500 and 2250 m with a minimum at Yariban and a maximum at Djohong. The depths of structures on the models agree with the spectral analysis results and other studies carried out in the region (Chevassus-agnes, 1971; Fairhead and Okereke, 1988). The trough is bounded on its sides by faults associated to the CASZ. The gradient observed on the gravity map along the trough might not be due only to the northern fault (Collignon, 1968) but also to the contact between granite and gneiss (and migmatite) under the trough. Intruded basaltic rocks in the region are related to the CVL and lie at 7200 m minimum depth. This depth corresponds to the location suspected by Dorbath et al. (1986) and is related to the depth of the basaltic rocks under the Tibati region in the SW of Adamawa (Ngako et al., 1991; Noutchogwé, 2004).

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