

EVIDENCE FOR UPPER MANTLE INTRUSION IN THE WEST AFRICAN COASTAL SEDIMENTARY BASINS FROM GRAVITY DATA: THE CASE OF THE SOUTHERN PART OF THE DOUALA BASIN, CAMEROON

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ABSTRACT

The Bouguer anomaly map of the region between latitudes 3°N and $3^{\circ}45'\text{N}$ and longitudes $9^{\circ}30'\text{E}$ and $10^{\circ}10'\text{E}$ and which forms the southern part of the Douala Basin, shows ring-like positive contour lines. The Bouguer gravity profiles obtained across the gravity anomaly contour lines in the region have been interpreted using $2\text{D}^{1/2}$ gravity modelling. The results reveal that in the southern part of the Douala Sedimentary Basin, two major structures exist: a half-dome of mantle material explained by isostatic compensation and a pillar of high density rocks probably representing an upper mantle intrusion down to a depth of about 14 km. The similarities of these results with those obtained in the coastal sedimentary basin of Mauritania-Senegal suggest a more extensive movement that would have affected the whole of West African coast.

KEYWORDS: Bouguer anomaly, dome, graben.

INTRODUCTION

The region under study lies between latitudes 3°N and $3^{\circ}45'\text{N}$ and longitudes $9^{\circ}30'\text{E}$ and $10^{\circ}10'\text{E}$ (Fig.1). It includes part of the Congo Craton to the East and the southern part of the Douala Sedimentary Basin to the West. The basin has the form of a half-graben (Njike, 1984). However, the detailed structure around the crust-mantle limit under this basin is poorly defined.

The Bouguer anomaly map produced by Legeley–Padovani et al. (1996) shows a group of isogals oriented NNW–SSE to N–S within the study area (Fig.2). A zone of positive anomalies reaching a

maximum value of 30 mgal is present in the region. The gravity anomaly contour lines are ring-like and present an E–W gradient of 2.2 mgal/km approximately. This could be due to an uplift of the dense material that forms a dome with a small diameter. However, this uplift of the mantle formation could have been expected to have the form of a half-dome since the basin has the form of a half-graben.

The aim of this study is to carry out gravity modelling along some profiles using the $2\text{D}^{1/2}$ IGAO modelling program (Chouteau et Bouchard, 1993) in order to better understand the cause of the Bouguer anomaly observed in this region.

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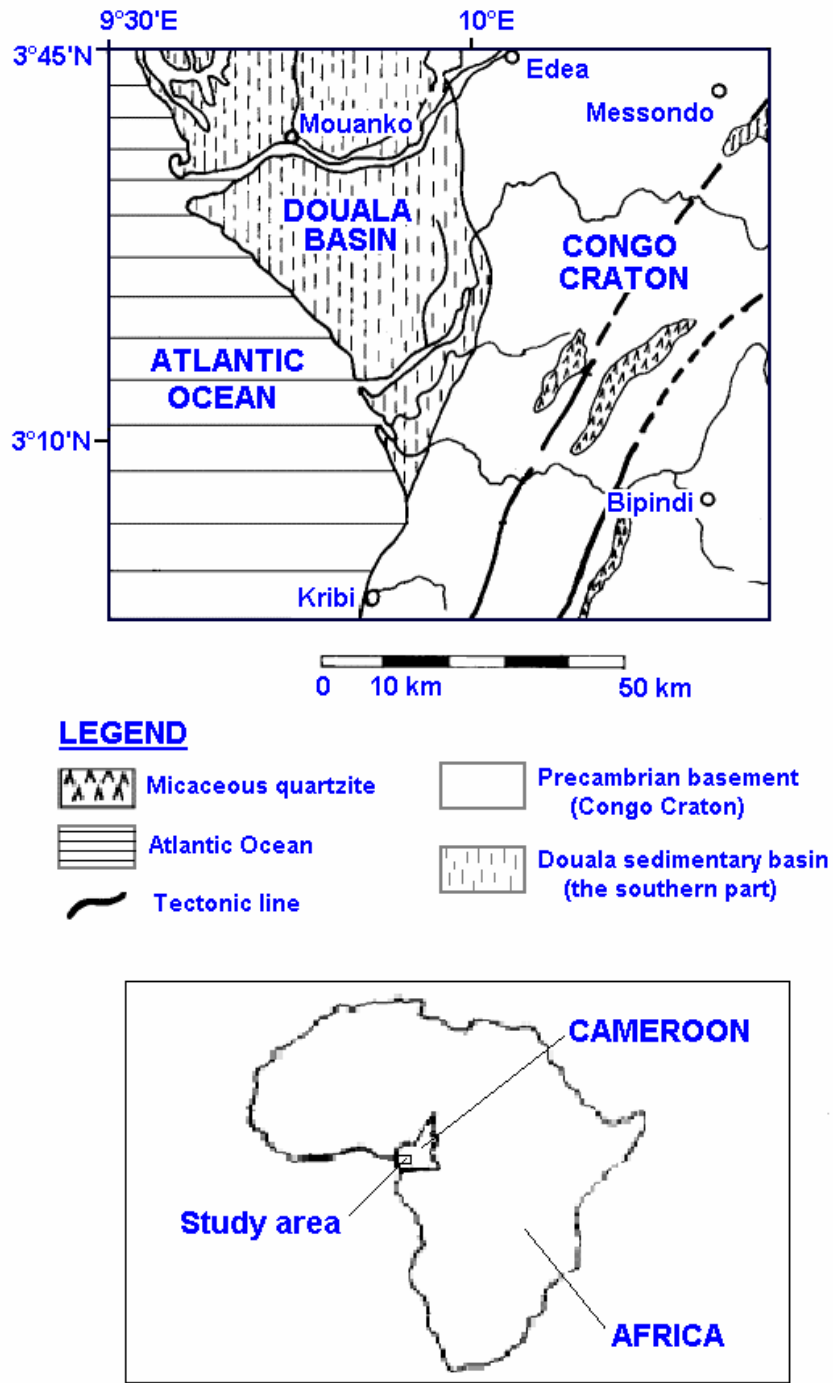


Figure 1: Location and simplified geological map of the region

GEOLOGY AND TECTONIC SETTING OF THE REGION

Outcrops over the part covered by the Congo Craton form a metamorphic Precambrian structure

(Fig.1). The basement is probably syenitic and shows an overall SSW-NNE orientation for the geological structures in the region (Koumetio et al., 2001; Koumetio, 2004).

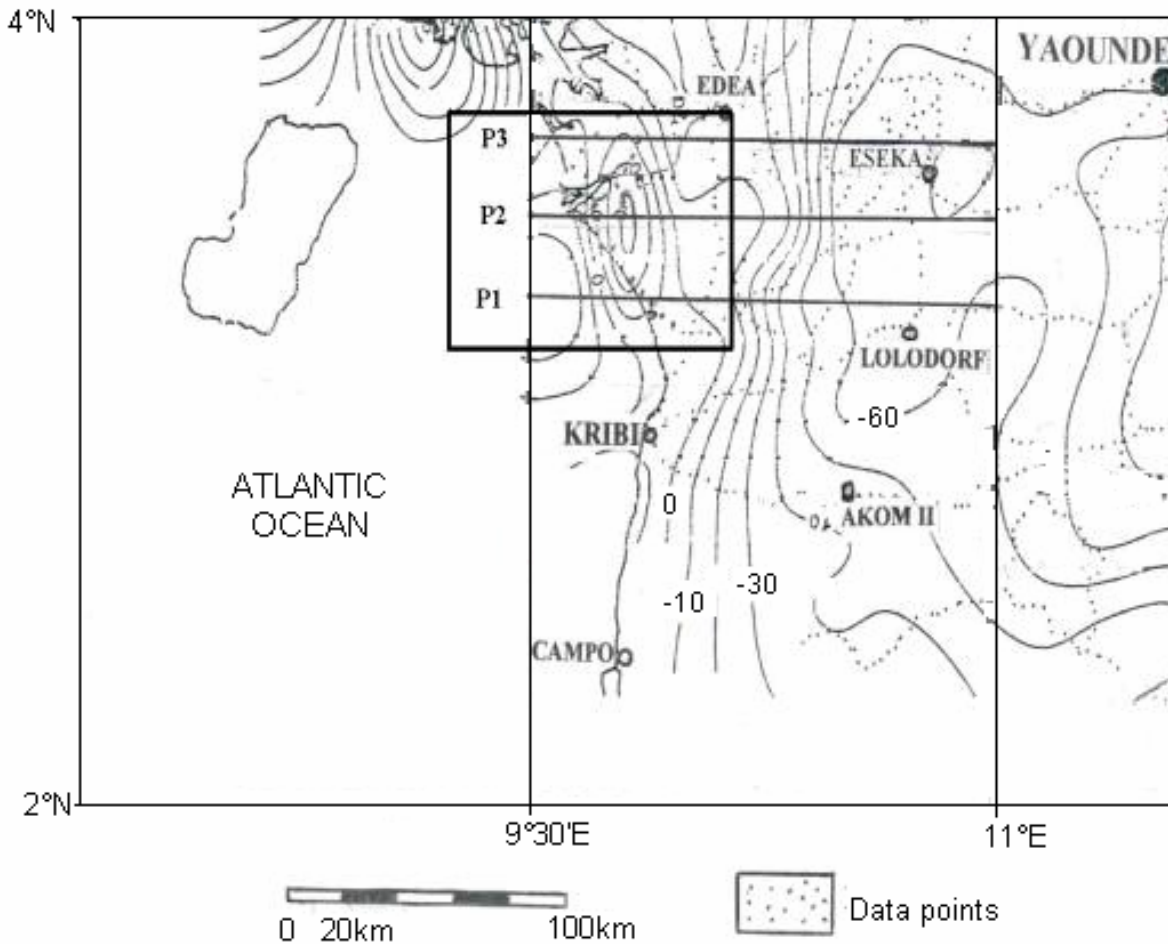


Figure 2: Bouguer anomaly map of the region (after Legeley-Padovani et al., 1996) showing the profiles: P₁, P₂, P₃.

According to Njike (1984) and Manguelle-Dicoum et al. (1993), the Douala Basin has a gneissic basement. The basin has the form of a half-graben presented as a distributive fault and there is a progressive uplift of the basin basement from the west to the east; going from depth of 8000m to 3000m approximately. The creation of the coastal Douala Basin could have been controlled by an E-W distension that could have provoked the complete rupture between the African and South American continents giving rise to the opening of the South Atlantic. This explains the half-graben form of the Douala Sedimentary Basin according to Reyre (1964), Hoffman (1971) and Njike (1984).

BOUGUER ANOMALY PROFILES AND THEIR INTERPRETATION

Three East–West gravity profiles P₁, P₂ and P₃ with their origins on longitude 9°30'E (Fig.2) have been interpreted using 2D^{1/2} gravity modelling. These profiles

run approximately along latitude 3°18'N, 3°30'N and 3°42'N for P₁, P₂ and P₃ respectively.

The 2D^{1/2} IGAO gravity and magnetic program by Chouteau and Bouchard (1993) was used to carry out the modelling. This program calculates the theoretical Bouguer anomaly created by proposed structures and plots a graph, which is then matched with the observed anomaly.

The models of the three profiles (Figs. 3i, 3ii and 3iii) present five formations of different densities: sediments (1), gneissic granite (2), syenite (3), gneiss (4) and upper mantle formation (5).

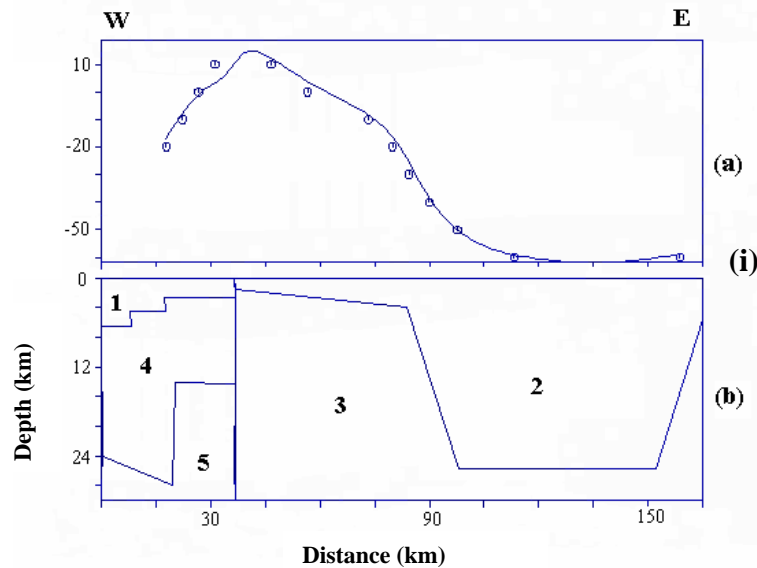
Through the modelling, an optimal density value was retained for each formation (Table 1) with the constraint that this density value lies within the range of possible density values given in the literature (Dobrin, 1976; Telford et al., 1981). Density contrasts for each formation were calculated relative to the reference density value of 2.67 g/cm³ for the crust. These density contrasts are given in Table 1.

Table 1: Range of densities used and their contrasts for various formations

Formation	Range of densities (g/cm ³)	Densities used (g/cm ³)	Density contrast (g/cm ³)
Syenite	2.60-2.95	2.82	0.15
Gneissic granite	2.59-2.63	2.62	-0.05
Sediments	2.17-2.70	2.60	-0.07
Gneiss	2.59-3.00	2.72	0.05
Upper mantle formation	3.20-3.65	3.50	0.85

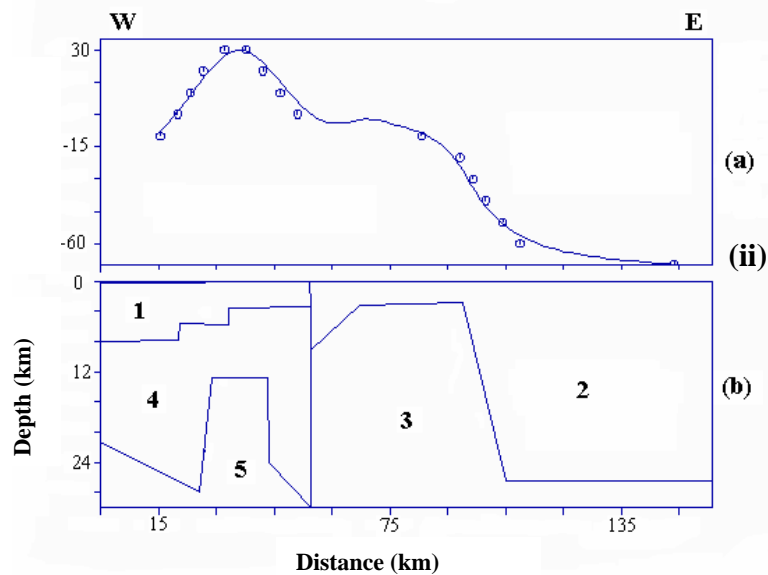
The models of the three profiles (Figs. 3i, 3ii and 3iii) show that the sediments extend from the Coast to the western margin of the Congo Craton which have syenitic basement. The depth of the sediments vary as one goes from west to east, from 6 to 3 km on profile P₁; from 8 to 3 km on P₂ and from 8 to 2 km on P₃. These

sediments lie on a gneissic basement. The top of this basement is presented as a distributive fault. The gneissic basement presents an uplift of the upper mantle formation. The top of this structure is at the depth of about 14 km on profile P₁, 13 km on P₂ and 15 km on P₃.



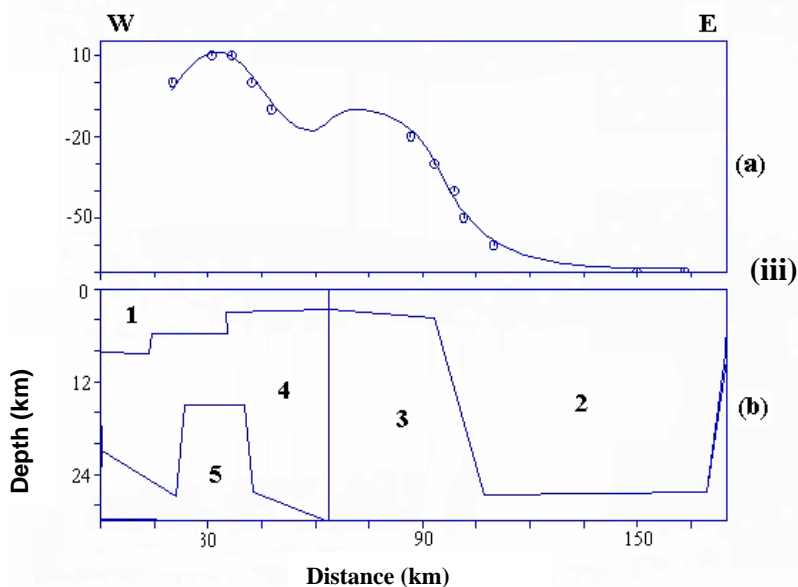
Legend of figure 3 : (a): Theoretical and experimental curve: observed anomaly calculated anomaly
 (b): Subsurface structure : 1: sediments; 2: gneissic granite; 3: syenite; 4: gneiss; 5: upper mantle formation

Figure 3(i): West-East gravity profile (P₁) running approximately along latitude 3°18'N



Legend of figure 3 : (a): Theoretical and experimental curve: | o o o observed anomaly
 | ——— calculated anomaly
 (b): Subsurface structure : 1: sediments; 2: gneissic granite; 3: syenite; 4: gneiss; 5: upper mantle formation

Figure 3(ii): West-East gravity profile (P₂) running approximately along latitude 3°30'N



Legend of figure 3 : (a): Theoretical and experimental curve: | o o o observed anomaly
 | ——— calculated anomaly
 (b): Subsurface structure : 1: sediments; 2: gneissic granite; 3: syenite; 4: gneiss; 5: upper mantle formation

Figure 3 (iii): West –East gravity profile (P₂) running approximately along latitude 3°30'N

DISCUSSION OF THE RESULTS

The upper mantle formation seen on our geophysical model could be the result of the association of two different geological structures. One is a half-dome of mantle formation in accordance with the half-graben structure of sediments in response to isostatic compensation. The other is a pillar of high density rocks (Fig.4). Considering the density value of this structure alone, it can represent a pillar of upper mantle formation, of gabbro or of eclogite, rocks whose density can be up to 3.5 g/cm³ (Telford et al., 1981). In accordance with the fact that the thickness of the crust is generally greater in stable zones (Craton) than in

mobile zones and considering the fact that the basement of the pillar of dense material merges with the limit between mantle and crust of the Congo Craton, this pillar of rocks may represent an upper mantle intrusion in the crust. The top of this pillar of upper mantle formation is at the average depth of 14 km.

The margin of the Congo Craton in our study region coincides with the eastern margin of the Douala Sedimentary Basin. This limit is associated with a seismic zone parallel to the volcanic line of Cameroon (Tabod et al., 1992). It could have been thought that the pillar of dense material is a consequence of volcanic activity but the absence of plumes observed at surface does not favour this explanation.

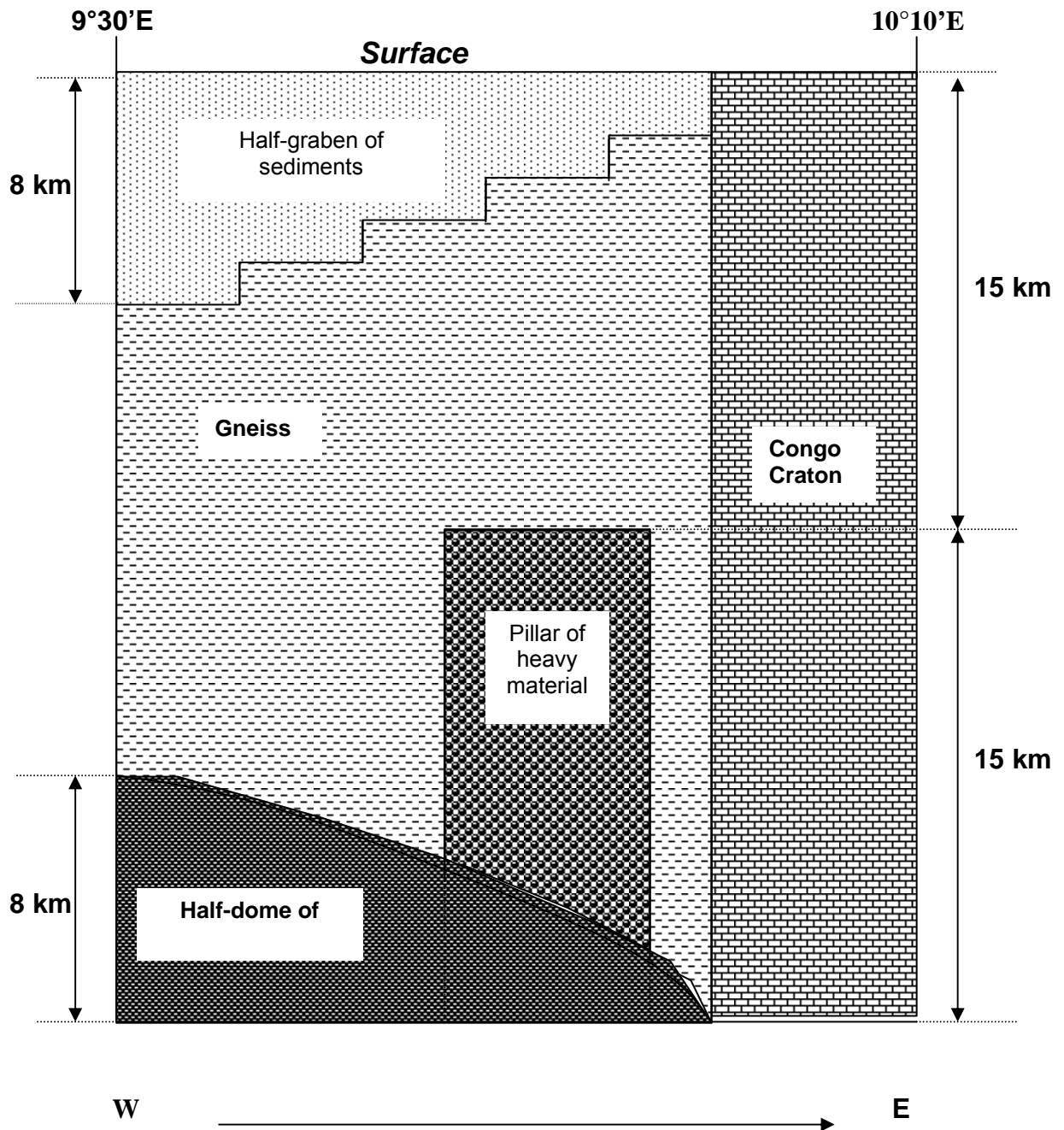


Figure 4: The half-dome of mantle formation and the pillar of heavy material

There are similarities between our study region and the one studied by Roussel and Lecorche (1983) in Mauritania. The latter has to the east, part of the West African Craton and to the west, part of the coastal sedimentary basin of Mauritania-Senegal which extends into the Atlantic Ocean. The Bouguer anomaly map in this region shows many ring-like positive gravity anomaly contour lines. Roussel and Lecorche (1983) have interpreted this gravity anomaly in the Senegal-Mauritania region as due to an uplifted block of mantle material down to a depth of about 15 km, a depth comparable to that found in this work. These similarities suggest a more extensive movement that would have affected the whole of West African coast or suggest that the uplift of dense material is recurrent around the margins of Craton-sedimentary basins. A study of the correlation between the high regional anomaly and the boundaries of the Craton and the sedimentary basin will bring more understanding to the modelled features.

CONCLUSION

The regional gravity anomaly data has revealed in the southern part of the Douala Sedimentary Basin, the existence of two major structures: a half-dome of mantle material probably explained by isostatic compensation and a pillar of high density rocks probably representing an upper mantle intrusion up to the depth of about 14 km. The similarities of these results with those obtained in the coastal sedimentary basin of Mauritania-Senegal suggest a more extensive movement that would have affected the whole of West African coast.

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