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Delineating Deep Basement Faults of South Cameroon Area

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Abstract: The present work is based on the analysis of the Bouguer gravity map of south Cameroon area to map deep faults. Our methodology consists of processing the data, so as to highlight the buried geological contacts and to reveal their dips. The study of the geological contacts is ensured by the upward continuation processing of the Bouguer gravity map at various altitudes, followed by the determination of the horizontal gradient maxima for each level. The progressive migration of these maxima while increasing the upward continuation altitude indicates the dip direction. These results allow the production of a structural map showing the fault systems for the survey area.

Key words: Bouguer anomaly · Horizontal derivative · Upward continuation · Structural map · South-Cameroon

INTRODUCTION

The study area lies in the southern Cameroon in the transition zone between the Pan-African belt and the Congo craton. The geodynamic evolution in this region is well constrained by the collision between the Congo craton and the Pan-African belt [1-3]. This collision yields to an overthrusting of the Pan-African units onto the craton of about 50 to 150 km [4, 5]. Due to the blanket of Pan-African units whose thickness can be considerable in places, the basement faults cannot be mapped directly using conventional field methods. In this circumstance, this study was aimed at utilizing an indirect method to map deep faults in the basement through the analysis of gravity data. Indeed, the gravimetry plays an important role in the identification of deep faults, their limits and their ramifications. The application of the upward continuation processing of the Bouguer gravity map at various altitudes, followed by the determination of the horizontal gradient maxima for each level allowed the localization of the deep faults in the study area and the determination of their dips [7].

Geological Setting: The area under study lies in southern Cameroon, located in the transition zone between the Congo craton (CC) and the Pan-African belt of West Africa (PAB). Two structural domains can be distinguished in this study area: the Ntem complex (CC) and the Yaoundé group (PAB). (Figure 1).

The Ntem complex represents the north-western part of the Congo craton in Central Africa and is very well exposed in Southern Cameroon [8]. The complex is composed dominantly by younger intrusive complexes and by banded series composed of gneisses. Intrusive complexes are primarily constituted of TTG suite rocks [9]. The TTG unit is made up of three rocks types: the tonalitic suite (known as "So'o granite"), the charnockitic suite and the granodioritic suite massifs [10]. The tonalitic suite is essentially exposed to the north and is strongly mylonitized and retrogressed along the fault boundary with formations of the Yaoundé Group.

The Yaoundé group is a huge allochtonous nappe thrusted southward onto the Congo craton. It comprises low-to high-grade garnet-bearing schist, gneisses and orthogneisses transformed under a medium-to high-pressure metamorphism reaching the granulite facies [11]. In the study area, Yaoundé group consists of the Mbalmayo-Bengbis series and the Yaoundé series known as "intermediate series". The Mbalmayo-Bengbis series are composed of schist and quartzites re-crystallized in the conditions of the greenschist facies [12]. The Yaoundé series consist of strongly deformed meta-sedimentary rocks and migmatites [13].

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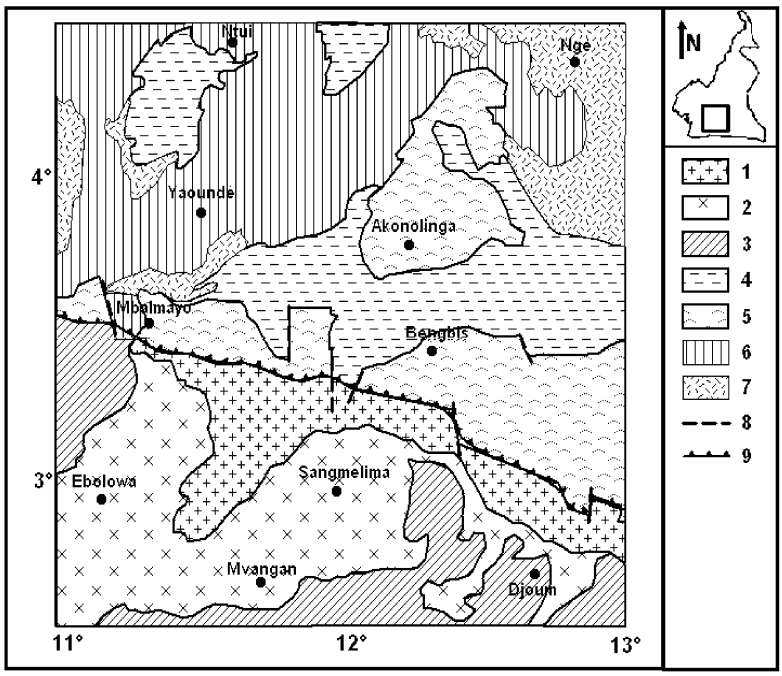

Fig. 1: Geological sketch map of the study area (modified after Feybesse, 1987) 1. Tonalitic suite (CC); 2. Charnockitic suite (CC); 3. Bonded series (CC); 4. Micashists (PAB); 5. Epischists (PAB); 6. Gneiss (PAB) ; 7. Granulites (PAB) ; 8. Fault; 9. Major thrust

The structural data show a definite deformation on the surface, which is characterized by flat structures gently sloping to the North with a generalized tilting towards the South or South-West, indicating a significant overlap of intermediate formations on the basement of the Ntem complex. This deformation is seen by the presence of folds sloping to the North. Generally, the region has a complex and uneven tectonic structure. The tectonic evolution of the region seems to have given rise to a vertical movement of the basement with subsidence to the North and uplift to the South [14]. This basement movement must have provoked irregularities in the formations at depth, giving rise to faults, horsts and grabens characteristic of the boundary between the Congo craton and the Pan-African fold belt.

MATERIALS AND METHODS

Gravity data consist of 617 Bouguer anomaly values coming from the database of the Institut Français de la recherche Scientifique pour le Développement en Coopération (ORSTOM). The Bouguer anomaly values are the result of the Free-air reduction referred to the ellipsoid, of the infinite plate reduction with a constant reduction density of 2.670 g/cm^3 and of the topographic reduction [15, 16]. The gravity survey accuracy is estimated to be about ± 0.5 mGal.

The analysis of gravity data makes use of the technique for locating the horizontal positions of magnetic contacts from gridded magnetic data [17]. This approach is based on the observations that the magnitude of the horizontal gradient of a gravity field peaks over vertical contacts [18]. In the automated method, a 3x3 window is passed over the horizontal gradient magnitude (HGM) grid and an attempt is made to fit parabolic peaks to the four 3-point scans passing through the center of the window. If a sufficient number of peaks or maxima is found (usually 2 to 4), the location of the largest peak is taken as the contact location. The technique has been applied to the grid of the computed horizontal gradient magnitude of the upward-continued data, along the three depth levels, 6, 8 and 10 kilometers, above the surface. The upward continuation processing of the Bouguer gravity map at various altitudes, followed by the determination of the horizontal gradient maxima for each level yields to the progressive migration of these maxima while increasing the upward continuation altitude indicating the dip direction. In map view, faults are presumed to produce a single alignment, or one "track" of prominent HGM maxima.

The amplitude of the horizontal gradient is expressed as:

$$HGM = \sqrt{\left(\frac{\partial g}{\partial x}\right) + \left(\frac{\partial g}{\partial y}\right)} \quad (1)$$

where $\frac{\partial g}{\partial x}$ and $\frac{\partial g}{\partial y}$ are the horizontal derivatives of the gravity field in the x and y directions.

RESULTS AND DISCUSSION

The Bouguer anomaly map of the study area (Figure 2) shows a predominant gravity low trending SW-NE to E-W and bounded by relatively steep gradients on the north and the south sides. The shape of this anomaly in the southern margin of the area on the Bouguer map is similar to that of the So'o granites in the geological map. In the north of this anomaly, a zone of small gravity highs, bounded by relatively steep gradients, occur over or near higher metamorphic formations (granulites, migmatites and micaschists) and other granitic plutons. The presence of high gravity gradients, which occur over these basic intrusive rocks, suggests the existence of a suture zone between two blocks of the crust [19]. The southern border of the area is by a relatively positive anomaly trending SW-NE, which seems to represent a signature of the dense rocks (charnockites) in this zone.

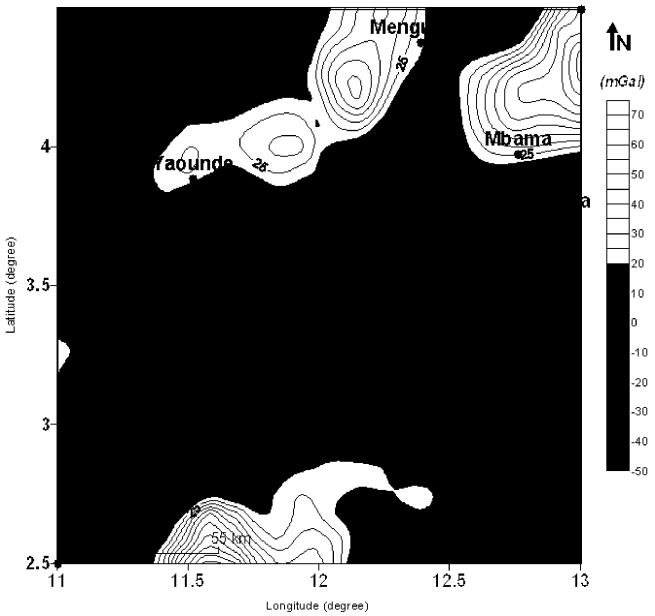

Fig. 2: Bouguer anomaly map of the study area.

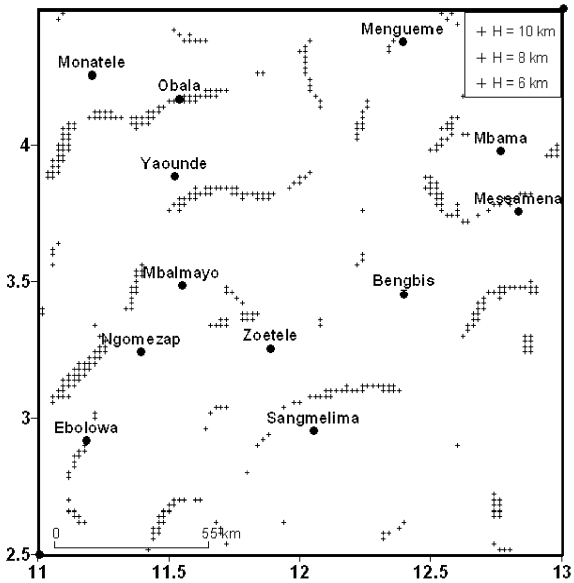

Fig. 3: Maxima of the horizontal gradient of the Bouguer anomaly and its upward continuation to different heights

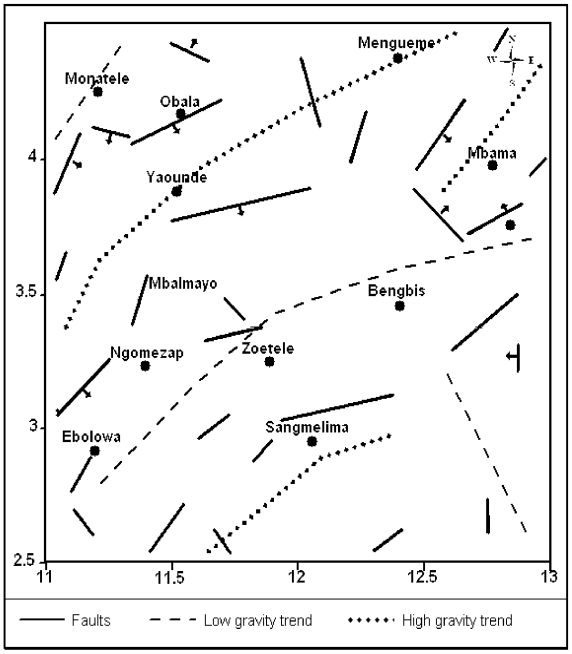

Fig. 4: Map showing the distribution of different interpreted gravity faults in the studied area. Arrows indicate dip direction.

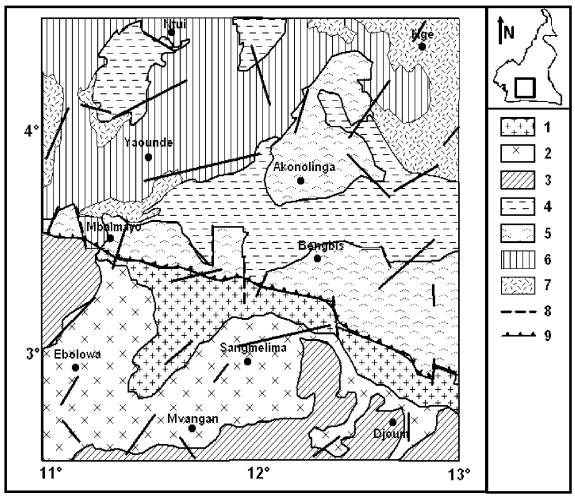

Fig. 5: Interpreted gravity faults superimposed on the geological sketch map of the study area

The results of horizontal gradient analysis at different altitude (4, 6, 10 km) are shown in Figure 3 and correspond to deep fractures in the study area. The predominant tectonic elements affecting the basement of the study area are constructed in Figure 4. The different gravity high and low trends are dissected by major and minor faults. It's seen that most of the faults put in evidence in the study area have a sub-vertical dips. The Figure 5 shows the mapped faults superimposed to the geological map of the South-Cameroon. The main fractures in the north and southwest of Sangmelima region lie in the southern margin of the granitic intrusion and are inferred to normal faults. It's observed a line of structure of general ENE-WSW direction extending from the south of Ebolowa to Mbalmayo area. The fault put in evidence in the Mbalmayo zone was already found using magneto-telluric method as an intra-granitic fault [20]. The positive anomalies in the northern part of the region are bounded by faults of different trend and dip direction. The general abundance of faults observed in the northern part of the area could be related to faulting associated with the put in place of deep-seated basement structures related to the inferred tectonic boundary separating the Craton and the Pan-African belt [21].

CONCLUSION

The main results obtained in this study bring new elements allowing improvement of our knowledge on the geological structures of the South – Cameroon region. The main faults that are responsible of the structuring of the studied area are put in evidence and are well localized by the multi-scale analysis of horizontal gravimetric gradient. In addition to the mapping of these faults, some indications have been obtained on their dip.

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