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Moho Discontinuity Depth Estimates for the Cameroon Volcanic Line from Gravity Data

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Abstract. In this work, the Moho depth in a part of the Cameroon Volcanic Line (CVL) between the latitudes 3°30′ to 6°33′N and the longitudes 8°50' to 11°27'E, has been estimated covering two distinct regions: the Mount Cameroon and the Bamenda by the use of polynomial separation of gravity data and spectral analysis along two profiles. The Moho is uplifted in the Mount Cameroon region, where the crust is thinned to about 24 km. In the Bamenda region, the crustal thickness is found to be normal at about 31 km. The high positive gravity anomalies of up to 100 m Gal observed in this area indicate the thinning of the crust in the Mount Cameroon region. Seismic and gravity data indicate a crustal thickness of 30-34 km along the continental parts of the Cameroon Volcanic Line, except in the Adamawa plateau, where the crust's thickness ranges between 20-23 km. The crustal thickness of about 31 km in the Bamenda region is an evidence of perfect isostatic compensation, which suggests a deep seated source for the negative anomaly, resulting in a general asthenospheric uplift along the Cameroon Volcanic Line.

Introduction

The study area is part of the Cameroon Volcanic Line (CVL) stretching from Limbe in the SW to the NE of Bamenda (Fig. 1, 2). This region is considered, in terms of gravity, as a transition zone between the oceanic and the continental parts of the CVL. This is because both positive Bouguer anomalies (which are generally found on oceanic areas) and negative Bouguer anomalies common on continents are observed in the study area. A highly negative Bouguer anomaly (down to -110 mGal) characterizes the Bamenda region, while in the Mount Cameroon area, the values are highly positive (up to 100 mGal). These two regions constitute two opposite poles: a positive pole in the Mount Cameroon region and a negative pole in the Bamenda region (Fig. 2).

Previous seismic studies by (Jayson and Bruce, 1991) in the oceanic part of the CVL have revealed asymmetric uplift of the Moho (thinning of the oceanic crust) associ-

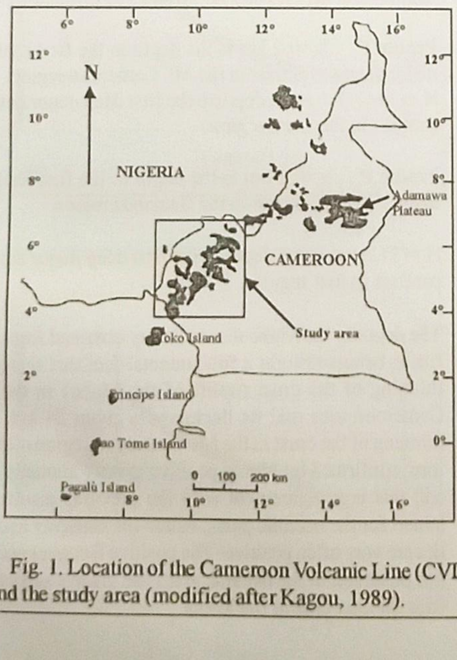


Fig. 1. Location of the Cameroon Volcanic Line (CVL) and the study area (modified after Kagou, 1989).

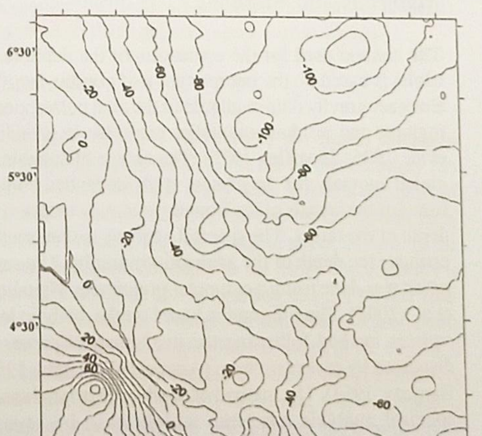


Fig. 2. Bouguer anomaly map of the study area, showing two poles: a positive pole in the Mt. Cameroon region and a negative pole in the Bamenda region (after Poudjom et al., 1996).

ated with extensive magmatism, particularly near some main volcanic centres. While seismic and gravity data have shown a crustal thickness of 30-34 km along the continental parts, except in the Adamawa plateau, where the crustal thickness is 20-23 km and this is due to an asthenospheric uplift in the upper mantle (Fairhead and Okereke,1987; Poudjom et al., 1995, 1997).

Present work aims to estimate the Moho depth in the study area as a contribution to the determination of the crustal thickness along the Cameroon Volcanic Line. This has been done in two stages. The determination of the influence of masses located at depth using regional yearly map anomalies.

The Cameroon Volcanic Line forms a part of the North Equatorial Pan-African chain, between the West African Craton and the Congo Craton. It is a zone of volcanic centers that trends N 30° and extends from Island of Pagalù in the Gulf of Guinea to Lake Chad (Deruelle et al., 1991). Thus, the Cameroon Volcanic Line has an oceanic part and a continental part. The basalts from both oceanic and continental sectors being geochemically and isotopically indistinguishable, suggest a similar mantle source.

The study area is a transitional zone between the oceanic and continental parts of the Cameroon Volcanic Line. The whole area is subject to many geological events, such as the deadly magmatic gas releases in Monoun and Nyos lakes in 1984 and 1986, respectively. The volcanic eruptions of Mt. Cameroon (which last erupted in the year 2000) and many seismic events have been regularly recorded in the area. The basement in this region is crystalline and marked by many huge volcanic mountains, as a result of important volcanic eruptions (Nzenti, 1987).

Materials and Methods

The method used for the estimation of the depth to the Moho is based on the interpretation of gravity data. The Bouguer gravity data available in the area correspond to regional and residual anomalies respectively (Poudjom et al., 1996; Shoeffler, 1975). The choice of suitable regional anomaly for the present study depended both on forms of the isogals of the Bouguer anomaly map and the depth of the target. The spectral analysis is then used to estimate the depth of the Moho discontinuity. The separation was done using a computer program by Njandjock et al. (2003). The program is based on the analytic least squares method following the mathematical processes discussed by earlier workers (Agocs, 1951; Grant, 1954; Baronov, 1954). The method of depth estimation through spectral analysis has been widely used by several authors with magnetic or gravity data (Spector and Grant, 1970; Spector and Parker, 1979; Ponsard, 1984).

The third order regional anomaly map of the study area more clearly indicates the two opposite gravity poles (positive in the Mt. Cameroon region and negative in the Bamenda region). While the forms of the isogals in two regions can be justified as resulting from deep structures.

Results and Discussion

Different types of geophysical studies have been carried out on the Cameroon Volcanic Line, both on the oceanic and the continental parts. Following results have been recorded for the continental part.

i). A thinning of both the crust and the lithosphere in the region of the Adamawa uplift, which is thought to be due to an asthenospheric rise in the upper mantle (Fairhead and Okereke,1987; Poudjom et al., 1995, 1997).

ii). An asthenospheric rise in the upper mantle (up to about 90 km of depth, with a lateral extension of about 100 km) beneath the area of Bamenda (Jean Marcel et al., 2003).

iii). The presence of near surface (1 to 2 km) magmatic gas pockets in the Lake Monoun and Lake Nyos regions (Kwende-Mbanwi and Dupis, 1993).

Two profile lines P_1 (in the Mt. Cameroon region) and P_2 (in the Bamenda region) were drawn on the third order regional anomaly map approximately perpendicular to the isogals. Figure 3 shows the variation of third order anomaly along profile P_1 (a) and profile P_2 (b), and the power spectrum versus frequency (in 1/km) on profile P_1 and profile P_2 (Fig. 3 c and Fig. 3 d, respectively).

Pal et al. (1979), Chakraborty and Agarwal (1992) and Njandjock (2004) have shown that to estimate the depth of the top and the bottom of a density contrast within the lithosphere, the slopes of the lines obtained should be divided by 4 p. This leads us to the Moho depth estimates (from the lines in Fig. 3 c and 3 d) given in Table 1.

Profile P_1: h_1=0.2 km is the depth to the first shallow major density contrast in the Mt. Cameroon region. H_1=(24±2) km is the depth to the first deep major density contrast in the same region.

Profile P_2: h_2=0.3 km is the depth to the first shallow major density contrast in the Bamenda region.

H_2=(312) km is the depth to the first deep major density contrast in that region.

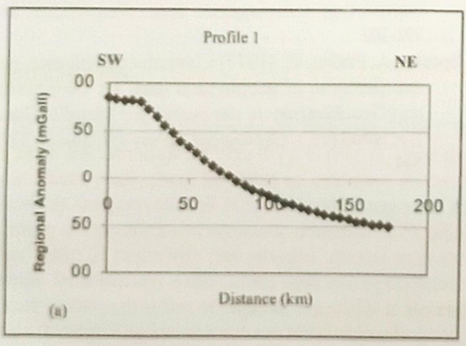
The depth to the Moho discontinuity obtained from profile P_1 brings to light a fundamental fact that there is a thinning of the crust (uplift of the Moho) in the Mt. Cameroon area and its thickness is about 24 km. The thinning of the crust in the Mt. Cameroon region is therefore, confirmed by highly positive gravity anomaly area and this is in agreement with the previous results obtained for the oceanic parts, where the Bouguer anomalies are very often positive. The positive Bouguer anomalies observed in the oceanic areas are always associated with thinned crustal thickness.

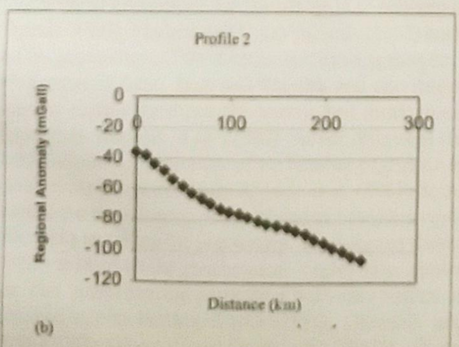
In other respects, the results of profile P_2 show that in the Bamenda region, the depth to the Moho discontinuity is normal (around 31 km) indicating perfect isostatic compensation. This agrees with previous results obtained in the continental parts of the CVL by Fairhead and Okereke (1987) and Poudjom et al. (1995; 1997), using seismic and gravity data.

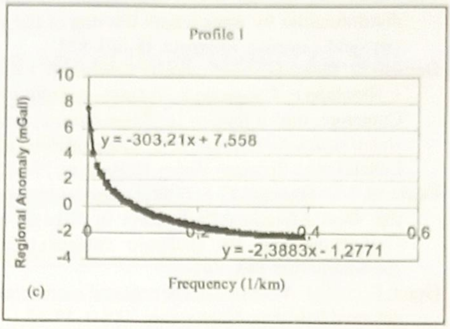
Table 1. Moho depth estimates along the two profiles

Profile	Length of profile (km)	Direction of profile	Moho depth estimate (km)
P1: Mt. Cameroon region	175	SW-NE	24±2
P2: Bamenda region	240	NNE-SSW	31±2

Thus, the analysis of different results obtained along the CVL has enabled us to show the variation of the depth to the Moho discontinuity. In both the oceanic and the continental parts of the CVL, crustal thickness varies alternately from thin (uplifted Moho) to normal (perfect isostatic compensation). It is also noticed that magma flows from the main volcanic centres, preferably near locations, where major fracture zones are thought to transect the CVL (Jayson and Bruce, 1991). These two assumptions suggest that both the oceanic and continental crusts along this line could have been formed by similar processes and there may be a general asthenospheric uplift along the CVL. Secondly, the highly positive Bouguer gravity anomalies observed in the Mt. Cameroon region, might be due to outflows of high density upper mantle magmatic material, forming most of the Mount Cameroon highlands (Fig. 2). The perfect isostatic compensation in the Bamenda region (a normal thickness of the crust) and the regional highly negative Bouguer anomaly (110 mGal) observed in that suggest a deep seated source.







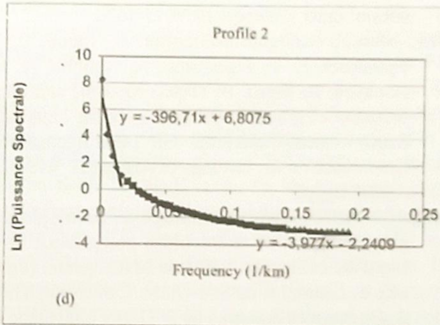


Fig .3. Variation of 3rd order profiles in (a), (b), (c) & (d).

Conclusion

In order to know the variation of the crustal thickness along the CVL, the depth to the Moho discontinuity has been estimated for the study area. There is an uplift of the Moho discontinuity in the Mount Cameroon area, where the crust is thinned down to about 24 km. In the Bamenda region, the depth to the Moho discontinuity is normal at about 31 km suggesting there is perfect isostatic compensation. Therefore, combining these results and those of previous geophysical work in the region, it can be noted that the crustal thickness varies alternately from thin (uplifted Moho) to normal (perfect isostatic compensation) along the line. Further, the crustal thickness along the CVL may be controlled by a general asthenospheric uplift.

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