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Structure of the Crust Beneath the South Western Cameroon, from Gravity Data Analysis

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Abstract

The study area is located in the south western Cameroon and includes part of the Cameroon Volcanic Line (CVL). Volcanic activity has been recorded in this area, precisely on the Mount Cameroon which recently erupted in 2002. In addition, deadly carbonic gas was emitted by crater lakes (Monoun and Nyos) in 1984 and 1986 respectively. Potential field model EGM2008 has been used to investigate the structure of the crust. A regional/residual separation is performed using upward continuation and polynomial separation methods. The results from this operation show a similarity between the regional anomalies resulting from both methods. The regional anomaly maps present an increasing gradient trending ENE-WSW above and below latitude 5˚N. Moreover, six nearly parallel profiles were drawn on the CVL in addition to two other profiles at the northern edge of Congo craton. These profiles were used to estimate the depths of the Moho discontinuity and some shallow sources by the means of the Bouguer and the residual anomalies respectively. The results show that the Moho discontinuity depths vary from 19 - 25 km (under Mount Cameroon) to 28 - 34 km (in Kumbo), while the southern neighbouring zone presents a Moho discontinuity depth ranging between 23 - 31 km (in Ngambe) and 22 - 32 km (in Eseka). These findings agree with the previous seismic and gravity researches lead in the area. EGM2008 is therefore a reliable tool to investigate the subsurface structures.

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Keywords

South Western Cameroon, EGM2008, Bouguer Anomaly, Spectral Analysis, Moho Discontinuity

1. Introduction

Gravity survey over Cameroon and its adjacent countries (Central African Republic, Chad and Nigeria) consists of local surveys collected in the 1960s and 1980s [1] [2]. The existing database shows a very good distribution in some specific areas like the Chad sedimentary basin because of petroleum investigation interest; unfortunately, other zones such as mountains, forests and those lake road infrastructures are less covered, making it difficult for the scientific studies. The part of the CVL belonging to the study area is covered by thick forest associated to highlands, with few carriageable roads. Hence, the available terrestrial gravity data distribution is highly uneven. Nevertheless, many important geophysical investigations based on terrestrial gravity data have been carried out along CVL, and important scientific results have been obtained by [3]-[7]. However, new generations of global models of gravity field such as EGM2008 ([8]) have the highest available spatial resolution in addition to their ability to provide precise and uniform gravity data. Moreover, they are freely available. Their compilation keeps the promise to overcome the sparseness of data, and can provide more information on the structure of the subsurface.

In this work, we use EGM2008 to reinforce the possibilities of applying this potential field model in regional mapping. Such works have previously been conducted by [9]-[13]. This proves its efficiency.

The present task aims to determine the structure of the crust beneath the study area through regional/residual separation of Bouguer anomalies. Residual anomalies are produced by shallow sources while regional anomalies are due to deeper ones. Therefore, this separation can enable us to estimate the depth to major discontinuities with an emphasis on the Moho discontinuity, as a contribution to the study of the subsurface along the CVL. The determination of the Moho discontinuity depth is very important for it firstly gives an insight about the isostatic compensation of the area and secondly; it shows the contribution of both shallow and deep seated features of the Bouguer anomalies. Several geophysical techniques have been used for the same purpose along the CVL, but the EGM2008 data provide better resolution than the ones used in the previous studies. This study also evaluates the efficiency of EGM2008 and its accuracy in recognising major tectonic and structural elements.

2. Geological Setting

The study area (**Figure 1**) includes part of the CVL and the northern edge of the Congo craton. The CVL belongs to the Pan-African Fold Belt, between the West African and the Congo cratons. It is made of volcanoes that trend N30˚E and extends from the Island of Pagalù in the gulf of Guinea to Lake Chad [14]: thus, the CVL is formed by an oceanic and a continental parts. It is underlain by Pan African basement rocks consisting mainly of schists and gneisses intruded by granites and diorites [14]-[16]. Cretaceous sediments, mostly sandstones and small amounts of limestone and shales are found in the coastal plain. Volcanic rocks that comprise the CVL range in composition from basalts to trachytes. For example, Mt. Manengouba (2420 m) consists of basalt, trachyte and rhyolite lavas, Mt. Cameroon (4095 m), the largest of the continental volcanoes, is mainly formed by alkaline basalts [17] and Mt. Etinde (1713 m), one of the older volcanoes, is made of nephelinitic lavas [18]. Other examples include Mt. Bamboutos (2670 m), which is characterized by the presence of alkali basalts and trachytes, and Mt. Oku (3011 m) where transitional basalt, quartz trachyte and rhyolite flows are found [19].

Previous deep-imaging multifold seismic shooting in the offshore part of the CVL, from [20], shows asymmetric uplift of the Moho discontinuity (thinning of the oceanic crust) which is associated with extensive magmatism, occuring near some main volcanic centres. [19] discovered that basalts from both oceanic and continental sectors are geochemically and isotopically indistinguishable, implying a similar mantle source. The geochemical and isotopic similarities between the CVL oceanic and continental basalts attest that the continental crust did not play any role in the magma genesis and that the source is not of lithospheric origin [16]. Along the CVL, mantle-derived (ultramafic) xenoliths have been found in several locations in basaltic lavas [14] [16] [21]. Despite the similarities in geochemical composition of volcanic lavas, no evidence has been found for a consistent migration of volcanic activity with time beneath the CVL.

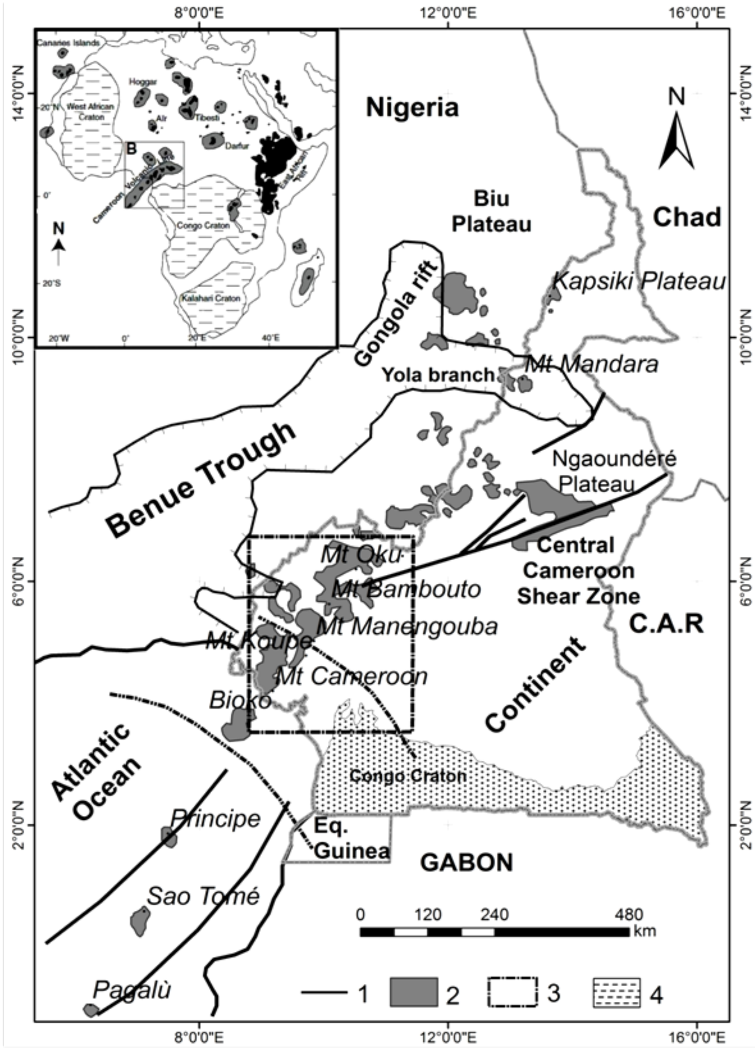

Figure 1. Location of the study area, modified from [32]. (1) Fault; (2) CVL; (3) Pan-African Fold Belt; (4) Congo craton.

Figure 2 represents the geological map of the study area, a compilation from [22]-[27]. This map shows two main geological domains, namely: the northern edge of the Congo craton, which is, according to [28], a set dominated by plutonic formations of the TTG suite (tonalites-trondhjemites-granodiorites); and the Pan-African Belt of Central Africa, marked by formations of the CVL.

The whole study area is subject of many geological events, such as the deadly magmatic gas releases in Lake Monoun (1984) and Lake Nyos (1986) [29], the volcanic eruptions of Mt. Cameroon which last erupted in the year 2000 ([30]), and also many seismic events which regularly recorded in the area. However, more in formations collected from the Cameroonian ministry in charge of mining affairs [31] indicate the presence of many mineral indices in the study area. Thus, all the previous findings show the importance of carrying more geophysical investigations in the area, for both scientific and socioeconomic (*i.e.*: civil protection, mineral resource prospection) purposes.

3. Data and Method

3.1. Data

Two different gravity databases are available for the study area: the terrestrial and the earth gravitational model EGM2008.

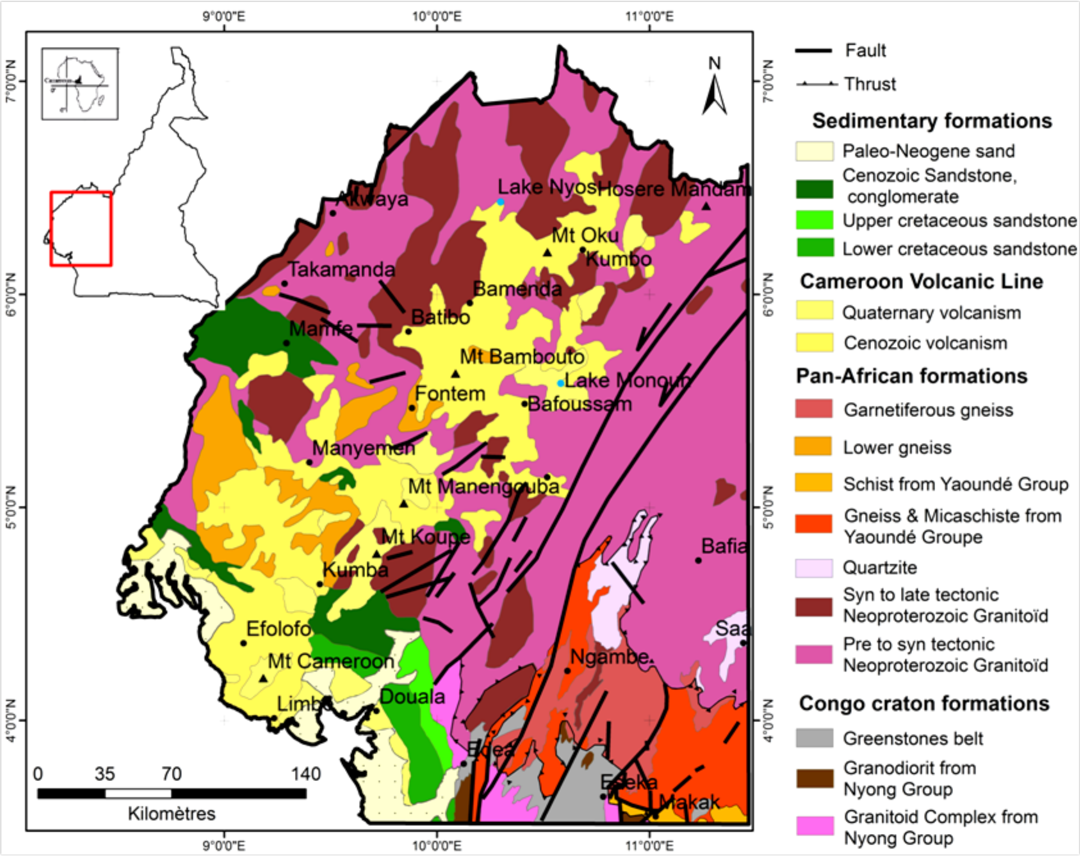

Figure 2. Geological map of the study area, compiled from [22]-[27].

3.1.1. The Terrestrial Data

The land gravity data available in the study area consist of about 670 observation points. The uneven distribution of measurements constitutes an unreliable basis of gravity analysis.

Figure 3 shows that the region of Kumbo including the localities of Bamenda and Bafoussam is characterized by negative Bouguer anomalies of high amplitude (down to −110 mGal), while in the Mount Cameroon, the values are positive (up to 100 mGal). Data are not available in the Ngambe, Fontem and Takamanda areas, which makes it diffucult the proper gravity investigations. Therefore, these data must undergo other processings such as an interpolation technique in order to fill the gaps.

3.1.2. The Earth Gravitational Model: EGM2008

The second database derives from the Earth Gravitational Model 2008 [8] [33]. The EGM2008 has been publicly released by the National Geospatial-Intelligence Agency (NGA) EGM Development Team of The United States of America. The data are first obtained as Free-Air Gravity Anomalies (**Figure 4**). The WGS 84 Geodetic Reference System (GRS) was used to define the geometry and the normal gravitational potential of the reference ellipsoid. The computed values refer to the surface of this reference ellipsoid. This gravitational model is complete to spherical harmonic degree and order 2159, and contains additional coefficients extending to degree 2190 and order 2159. The EGM2008 Bouguer anomalies are obtained after applying the topographic correction using the ETOPO 1 Digital Elevation Model [34], presented in **Figure 5**, and crust density contrast reduction of 2670 kg/m^3.

The EGM2008 presents a complete high resolution database, composed of previous land, marine, and airborne gravity data, and gravity anomalies from satellite observation. It therefore comprises data from inaccessible areas, contributing to overcome the problem of low resolution data.

Figure 6 shows values that spread from −255 to 198 mGal. This potential field signal has a deep correlation with former geological surveys in this area. In fact, around some volcanic mountains (Bafoussam, Bamenda,

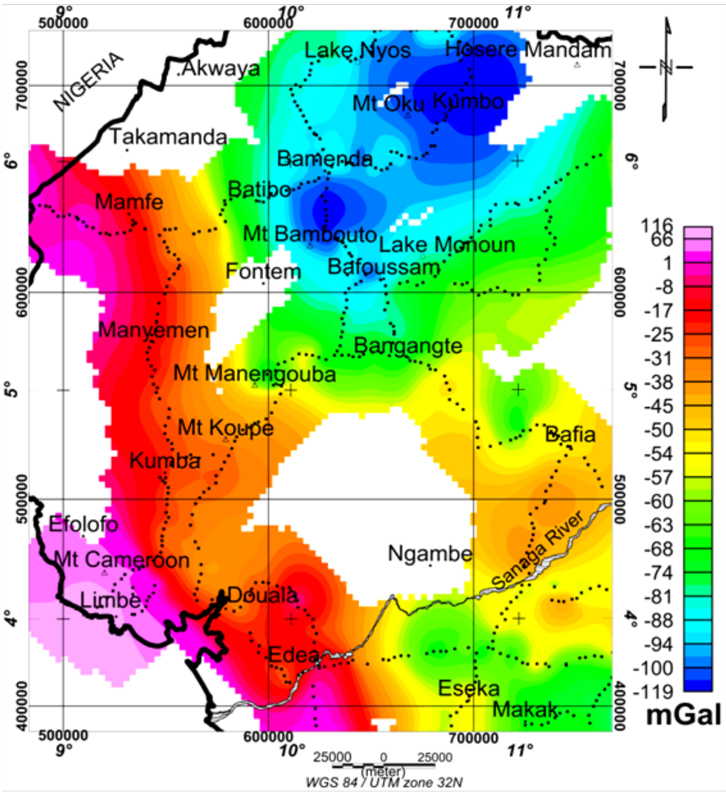

Figure 3. Bouguer anomaly map from existing land gravity data.

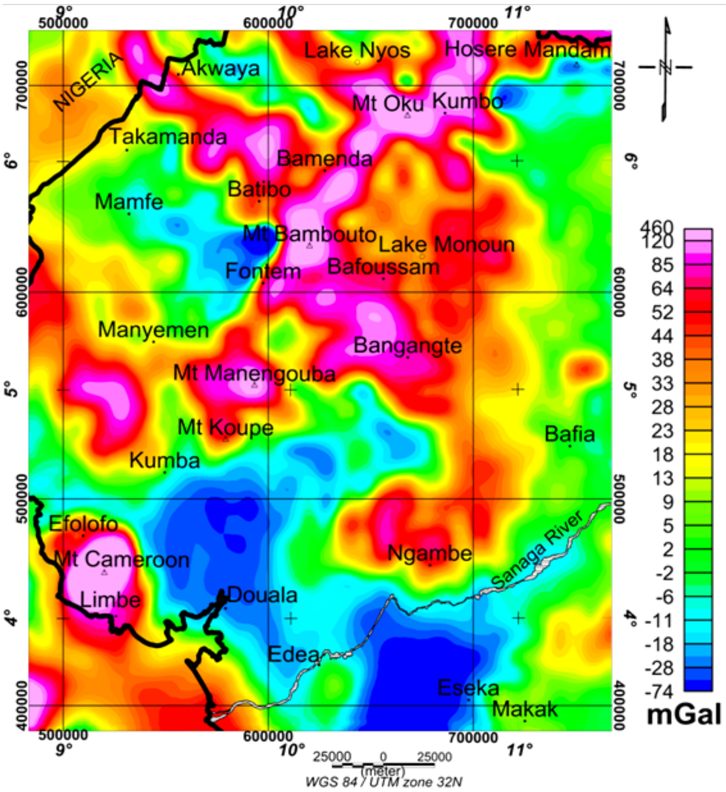

Figure 4. Free air anomaly map of the study area derived from EGM2008.

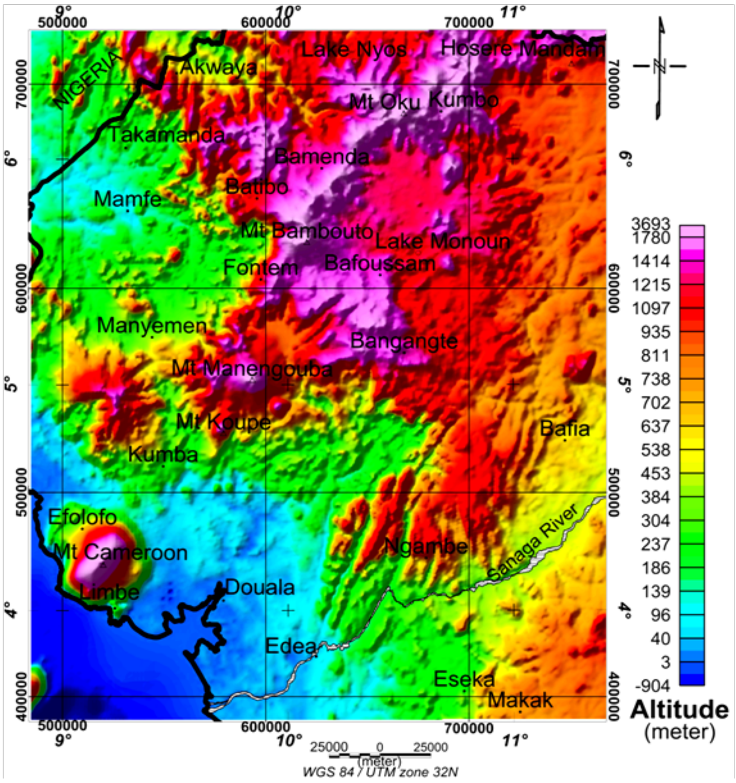

Figure 5. ETOPO 1 digital elevation model of the study area.

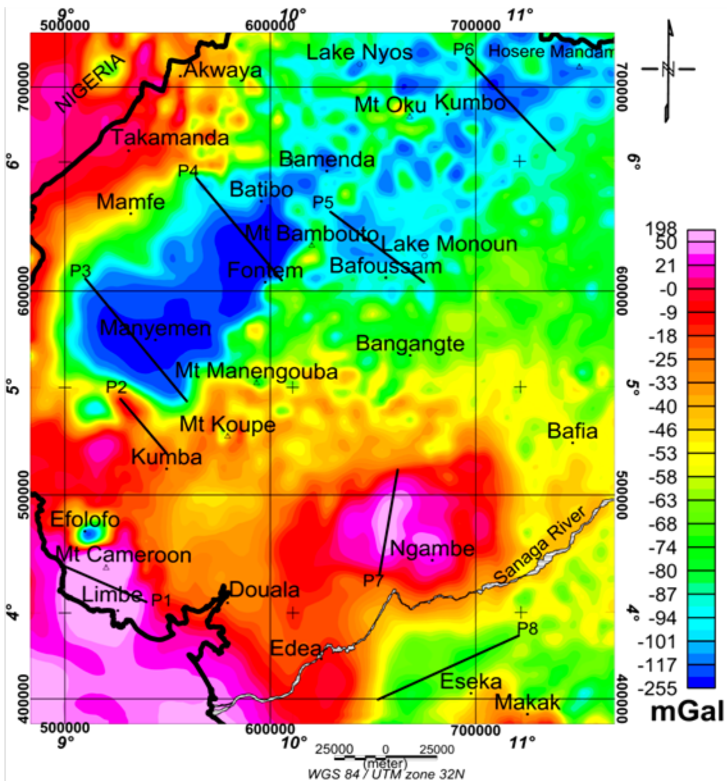

Figure 6. Bouguer anomaly map of the study area derived from EGM2008, dashed lines are profiles.

Mt Oku, until Hossere Mandam), there is a sequence of located negative anomalies that follow N30˚E trend. In the Mamfé basin, EGM2008 Bouguer anomaly indicates around the Manyemen and Fontem localities, an ellipsoid-shaped feature characterized by negative anomalies that extend from −255 to −90 mGal. This sedimentary basin is characterized by the lowest Bouguer anomaly values of the study area. Yet, Mt Cameroon which is the only active volcano of the CVL appears under a positive anomaly with values above 190 mGal, at the boundary ocean-continent. The oceanic zone presents positive anomalies ranging from 20 to 190 mGal. The North of Mt Cameroon is characterized by a very located negative anomaly that can be considered as a minor basin. Around Sanaga River, there are two circular positive anomalies: in Ngambe area it reaches 90 mGal whereas below Edea it is medium with 10 mGal average. The South-East of the map ends with a half circular anomaly around Eseka-Makak. The Lakes Monoun and Nyos that produced deadly gas in 1984 and 1986 respectively coincide with localized negative Bouguer anomalies. Globally, apart from the Mt Cameroon region characterized by positive Bouguer anomalies, all other mountains are located in zones of negative Bouguer anomalies.

3.2. Method

The Bouguer gravity anomalies are the sum of contributions from both superficial and deeper structures, corresponding respectively to the residual and regional anomalies [35]. According to [36], an optimal regional anomaly exists, and represents the contribution of the Moho discontinuity to the total Bouguer anomaly for an area. Based on this assumption, the depth of major discontinuities beneath the study area can be easily estimated. It consists of 1) the determination of the optimal regional anomaly map amenable for the study area, and 2) the depth estimation of the Moho discontinuity and some shallow located discontinuities using the spectral analysis technique.

3.2.1. Method of Determining the Optimal Regional Anomaly

The determination of the optimum regional anomaly map for the study area lies on the method of [37]. This method consists of two different stages:

The first stage is to determine a suitable altitude for the application of the upward continuation technique in the study area [38] [39]. The upward continuation technique is applied to the Bouguer anomalies at several altitudes (h_i), with the same sample point Δh ($h_2 = h_1 + \Delta h$). The extrema of each altitude of upward continuation are then counted. These are points where the gradient is null [40]. Further, a graph of extrema versus altitudes of upward continuation is plotted. Finally, the suitable altitude (H_{op}) necessary for the upward continuation technique is determined graphically. The authors show that for any other altitude $h > H_{op}$, the number of extrema is approximately constant. In this case, the upward continued anomaly maps are similar in form and design of isogals, and only the amplitudes of the anomalies differ.

The second stage is the determination of the optimal degree for the regional anomaly. [37] proposed a calculation technique summarized by the following expressions and formula:

Let us fit polynomials $p_d(x_i, y_i)$ given by the expression

$$f(x_i, y_i) = a_0 + a_1 x_i + a_2 y_i + \cdots + a_k y_i^n \quad (1)$$

$$p_d(x_i, y_i) = b_0 + b_1 x_i + b_2 y_i + \cdots + b_k y_i^d \quad (2)$$

where $k = \frac{(d+1)(d+2)}{2} - 1;\ d = 1, 2, \cdots, n-1, n-2, \cdots 1;\ i = 1, 2, \cdots, M$.

n is maximal degree of fitting and M is the number of data points according to the principle of minimum variance σ_d. Therefore, the variance σ_d is calculated through the following expression:

$$\sigma_d = \frac{1}{M} \sum_i^M \left[f(x_i, y_i) - p_d(x_i, y_i) \right]^2 \quad (3)$$

This technique is applied to the Bouguer anomalies for the H_{op} altitude. The H_{op} upward continued anomaly is fitted by polynomials of various degrees (1 to 12) with the analytic least-square method [41]-[46], and the variance of the data obtained for each degree is calculated [37]. Finally, the optimum degree of the polynomial evaluating this anomaly can be estimated from the point of discontinuity on a graph of variance against the degree of the polynomial.

To obtain the optimum regional anomaly of the study area, the Bouguer anomaly observed is fitted by a polynomial of the optimum degree determined previously, with the analytic least-squares method. Consequently, there must be some similarities between the optimum regional anomaly and the H_{op} upward continued maps.

3.2.2. Depth Determination from Spectral Analysis

Spectral analysis has been widely used by several authors to estimate the depth of various structures from gravity and magnetic data [7] [13] [47]-[55]. This analysis provides a quantitative technique for the study of large and complex aeromagnetic or gravity dataset. The logarithm of radial average of the energy spectrum (*i.e.* the square of the Fourier amplitude spectrum) is plotted versus the frequency. The slope of each segment provides information about the depth to the top of an ensemble of magnetic or gravity bodies [56]. This method does not require an a priori knowledge of the geometry and density contrasts of source bodies.

4. Results and Discussion

4.1. The Optimal Regional Anomaly Map of the Study Area

The third-order regional anomaly map (**Figure 9**) has been chosen for the present work after applying the method of [37]. Practically, the calculations made accordingly led us to plot the graph of the extrema versus the altitudes of upward continuation (**Figure 7**) and that of the variance against the degree of the polynomial (**Figure 8**).

According to [36], regional anomaly presents the contribution of the Moho discontinuity to the total Bouguer anomaly. Thus, it reflects the undulations of the Moho beneath the study area. The third-order regional anomaly map (**Figure 9**) and 30 km upward continuation (**Figure 10**) are similar. It confirms the reliability of the method proposed by [37]. For an easier interpretation, the study area has been divided into two main domains:

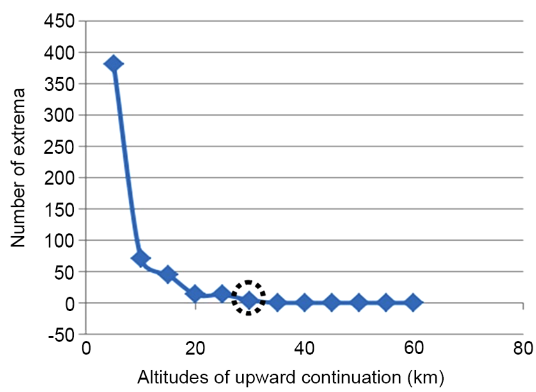

Figure 7. Graph of number of extrema point against upward continuation height.

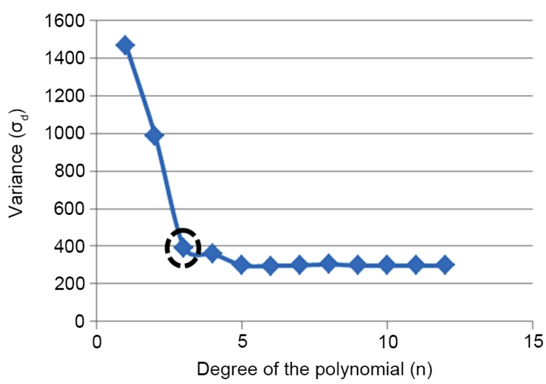

Figure 8. Graph of variance against degree of the polynomial.

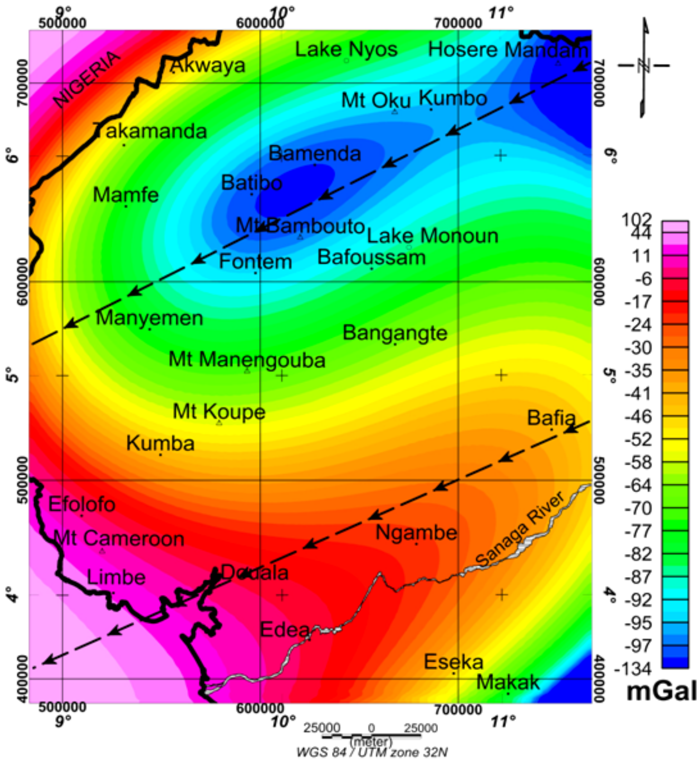

Figure 9. Third-order regional anomaly map from EGM2008, arrows representing the orientation of gradient.

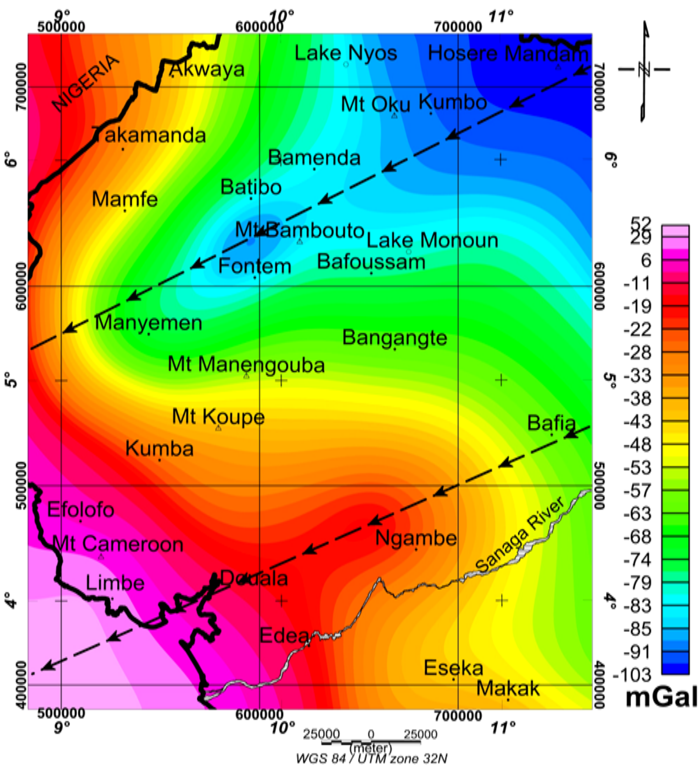

Figure 10. 30 km upward continued regional anomaly map from EGM2008, arrows representing the orientation of gradient.

- The first one is located above latitude 5˚N, characterized by negative regional anomalies orientated WSW-ENE. These anomalies extend from Manyemen in the Mamfé basin to the north-east of Kumbo mountainous region where the minimum of anomalies reaches approximately—130 mGal. It emerges on this field a strong gradient orientated in the NE-SW direction, suggesting an uplift of the Moho discontinuity in the Mamfé area and a thickening of the crust in the one of Kumbo;
- The second domain is located below latitude 5˚N. It shows positive regional anomaly in the Mount Cameroon region. The magnitude of the regional anomaly decreases from WSW to ENE. This domain is heavier than the first one in terms of the magnitudes of the observed regional anomaly, and also reveals a strong gradient orientated ENE-WSW. From this, it can be assumed that the Moho is uplifted in the Mount Cameroon region than in the Ngambe one.

In general, the qualitative interpretation of the regional anomaly leads to predict a thin crust in the Mount Cameroon region and thickened one in Kumbo and its surrounding areas.

Figure 7 and **Figure 8** represent the diagrams of extrema versus altitudes of upward continuation and variance against the degree of the polynomial respectively. They show the values of 30 km used for the upward continuation technique and 3 as the degree of the polynomial. These values are represented by dashed-circles.

4.2. The Residual Anomaly Map

The choice of the third-order regional anomaly for the present work influences that of the residual anomaly. Therefore, the third-order residual anomaly is obtained after subtracting the third-order regional anomaly from the total Bouguer anomaly. The third-order residual anomaly (**Figure 11**) has some similarities with that of Bouguer anomaly; this because the trend of positive and negative anomalies is still maintained. Nevertheless, above latitude 5˚N, the residual anomaly map shows the presence of many intrusions of dense materials along the CVL, and precisely in the areas of Bafoussam, Bamenda, Kumbo, etc. The study area may have been object of many mineralization processes that can predict economic potentialities [31], making the whole region interesting for both scientific and economic purposes.

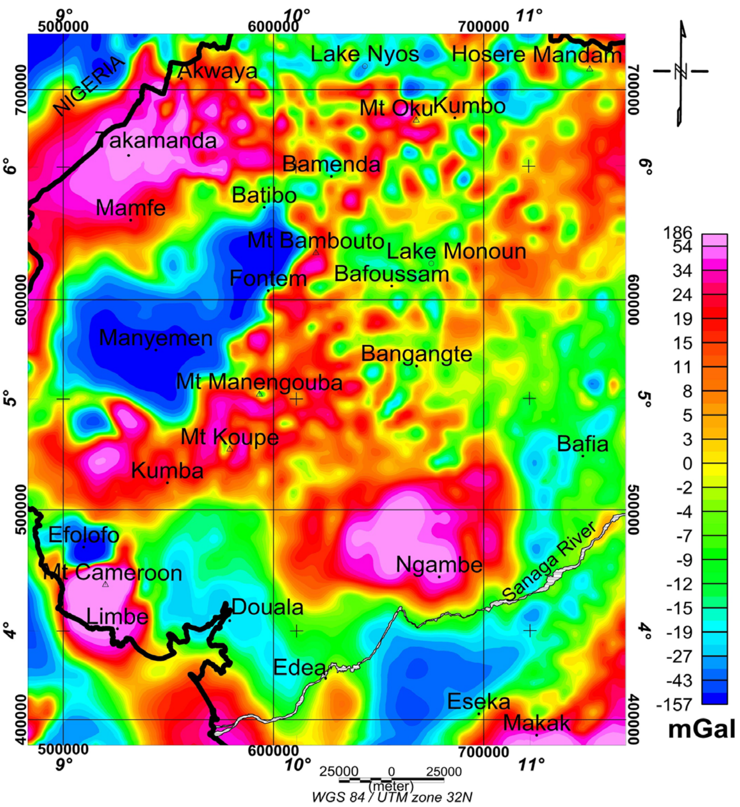

Figure 11. Third-order residual anomaly map from EGM2008.

4.3. Depth Estimation of Major Discontinuities

Table 1 presents the synthesis of the significant dense and less dense structures in the study area, from which we chose eight and drew profiles on the Bouguer anomalies map (**Figure 6**) for the depth calculations. **Figure 12** to **Figure 19** and **Table 2** and **Table 3** summarise all the results. They give in one hand the depth estimation of Moho discontinuity and on other hand the depth of some shallow structures.

4.3.1. Estimation of the Moho Discontinuity Depth

The present work shows that neither the positive Bouguer anomalies nor the negative ones are associated with a thickening of the crust:

- The Moho discontinuity beneath the Mt Cameroon is estimated around (22 ± 3) km. The previous studies conducted in the same region led to the following detphs: 19 to 21 km obtained by [5] using gravity data; 22 to 26 km by [7] from gravity data. [57] analysed seismic data and proposed a crustal depth of about 25.5 km;
- In the Kumbo area, the crustal depth is evaluated at (31 ± 3) km. [1] used gravity data to estimate the Moho depth in the same area to about 30 - 34 km. Seismic investigations conducted by [58] led to a depth estimate of approximately 33 km, whereas [7] used also the gravity data and got a depth between 29 and 33 km, compared to approximately 33 km from [57];
- In the Mamfe region, the thickness of the crust is about (27 ± 3) km in the locality of Manyemen and (29 ± 4) km around Fontem. These results agree well with the findings of [57] giving an estimation of about 31 in the same area;
- In Kumba graben, we got a depth of (22 ± 4) km. which result is not far from 28 km obtained by [57] from seismic analysis;
- In Ngambe and Eseka regions located at the transitional zone between the Congo craton and the Pan-African belt, we estimated a Moho depth of about (27 ± 4) and (27 ± 5) km respectively, while [59] found a depth of about 25 - 29 km in the same area.

The results obtained in this work (**Table 2**) highlight a fundamental fact: a general thinning of the crust (uplift of the Moho) along the CVL. For example, the results show that the positive Bouguer anomalies of high magnitude observed in the Mt. Cameroon region are associated to a thin crust, while in the Kumbo region where the

Table 1. Synthetic table of interesting Bouguer anomalies of the study area. Anomalies associated with P, are studied deeply according to the profiles dawn on Bouguer anomalies map.

Anomalies/location	Amplitude	Direction/trend	Causes/significance
Mount Cameroon, Limbe (P_1)	High amplitude positive anomalies	Quasi-circular	Cenozoic to actual volcanic formation, active volcano
Ngambe (P_7)	High amplitude positive anomalies	Quasi-circular	Transitional zone between the Congo craton and the Pan-African, mantle intrusion injected by Sanaga Fault
Takamanda, Cameroon-Nigeria boundary	High amplitude positive anomalies	Quasi-circular	Old granit and basement complex formation
Beneath Edéa	Relative positive anomalies	Quasi-circular	Transitional zone between the Congo craton and the Pan-African, mantle intrusion injected by Sanaga Fault
Eseka, Makak (P_8)	Relative negative anomalies	Located signature	Congo craton signature
Kumba (P_2)	Negative anomalies	Located signature	Cenozoic to actual volcanic formation
Manyemen-Fontem (P_3 and P_4)	High amplitude negative anomalies	CVL direction (N˚30E)	Sedimentary basin of Mamfe
Mt Bambouto-Mt Oku-Kumbo (P_5 and P_6)	Line of successive negative anomalies	CVL line direction (N˚30E)	Cenozoic to actual volcanoes from CVL
Lakes Nyos and Monoun	Negative anomalies	Located signature	Crater lakes associated with gas emission
Efolofo in the North of Mount Cameroon	Negative anomalies	Located signature	Minor basin

Table 2. Comparison of the Moho depth estimated from various studies.

Anomalies/location	Amplitude	Moho depth from the present work (km)	Moho depth from previous investigations (km)
Mount Cameroon, Limbe (P_1)	High amplitude positive anomalies	19 - 25	19 - 21 [5] 22 - 26 [7] ~25.5 [57]
Kumba, (P_2)	Negative anomalies	18 - 26	~28 [57]
Manyemen, (P_3)	High amplitude negative anomalies	25 - 33	~31 [57]
Fontem, (P_4)	High amplitude negative anomalies	24 - 30	~31 [57]
Bafoussam (NE Mt Cameroon), (P_5)	Line of successive negative anomalies	21 - 31	30 - 34 [1] ~33 [58] 28 - 32 [5] ~31 [57]
NE of Kumbo, (P_6)	Line of successive negative anomalies	28 - 34	30 - 34 [1] ~33 [58] 28 - 32 [5] 29 - 33 [7] ~33 [57]
Ngambe, (P_7)	High amplitude positive anomalies	23 - 31	
Eseka, Makak, (P_8)	Relatively negative anomalies	22 - 32	25 - 29 [59]

Table 3. Depth to interesting shallow structures in the study area.

Anomalies/location	Amplitude	Depth of shallow structures (km)	Shallow structure depth from previous studies (km)
Mount Cameroon, Limbe, (P_1)	High amplitude positive anomalies	8 - 12	7 - 9 [5]
Kumba, (P_2)	Negative anomalies	5 - 9	
Manyemen, (P_3)	High amplitude negative anomalies	4 - 8	4.5 - 7 [13]
Fontem, (P_4)	High amplitude negative anomalies	6 - 8	4.5 - 7 [13]
Bafoussam, (NE Mt Cameroon), (P_5)	Line of successive negative and positive superficial anomalies	5 - 9	
NE of Kumbo, (P_6)	Line of successive negative and positive superficial anomalies	3 - 7	
Ngambe, (P_7)	High amplitude positive anomalies	5 - 7	
Eseka, Makak, (P_8)	Relatively negative anomalies	6 - 8	

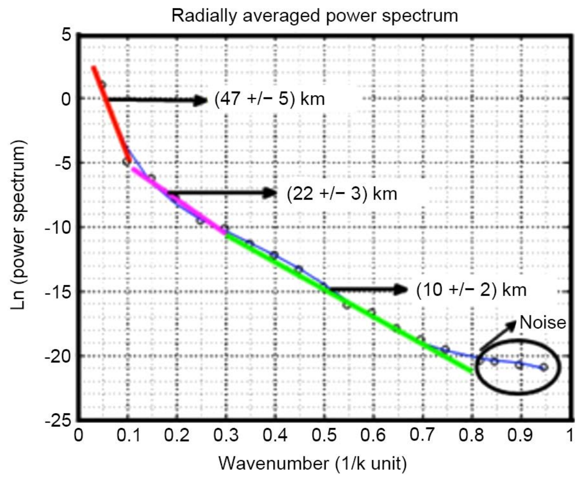

Figure 12. Power spectrum versus frequency for profile P_1 (Mount Cameroon).

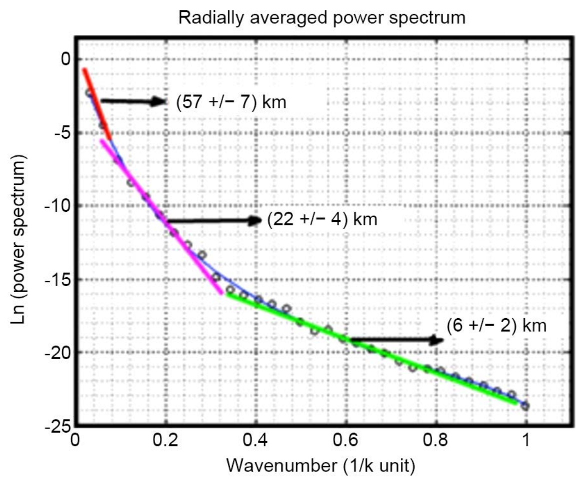

Figure 13. Power spectrum versus frequency for profile P_2 (Kumba region).

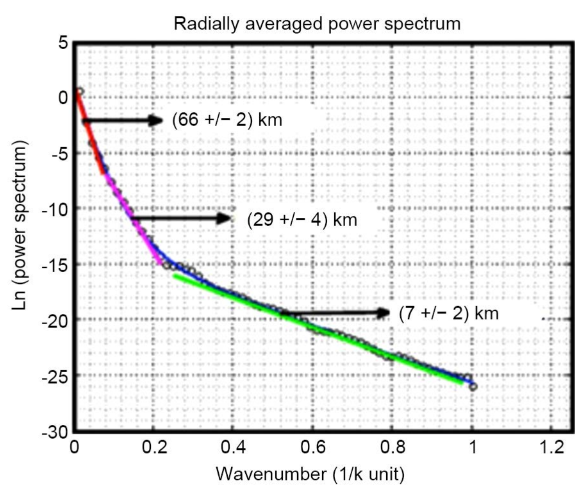

Figure 14. Power spectrum versus frequency for profile P_3 (Manyemen, Mamfe region).

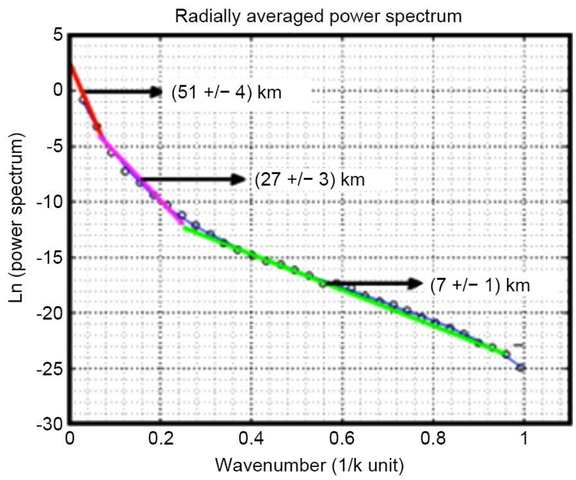

Figure 15. Power spectrum versus frequency for profile P_4 (Fontem, Mamfe region).

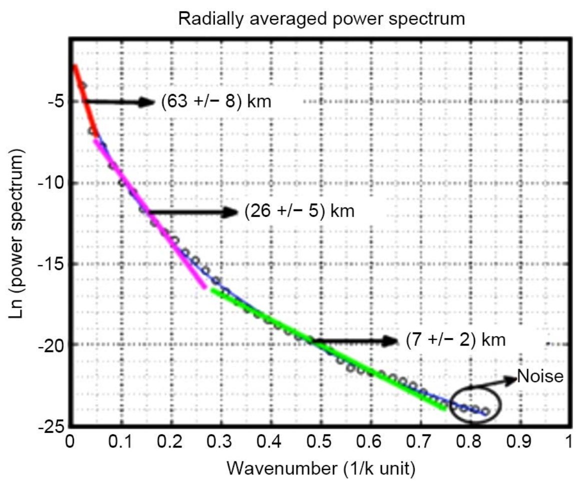

Figure 16. Power spectrum versus frequency for profile P_5 (Bafoussam region).

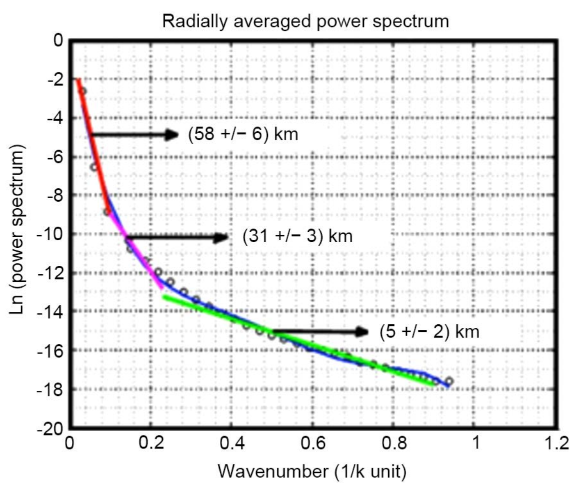

Figure 17. Power spectrum versus frequency for profile P_6 (Kumbo region).

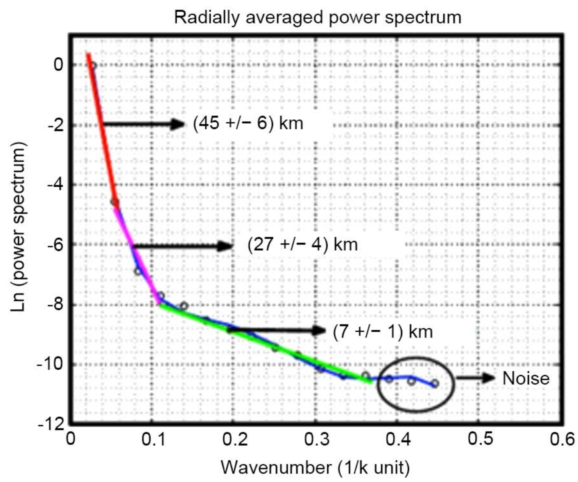

Figure 18. Power spectrum versus frequency for profile P_7 (Ngambe region).

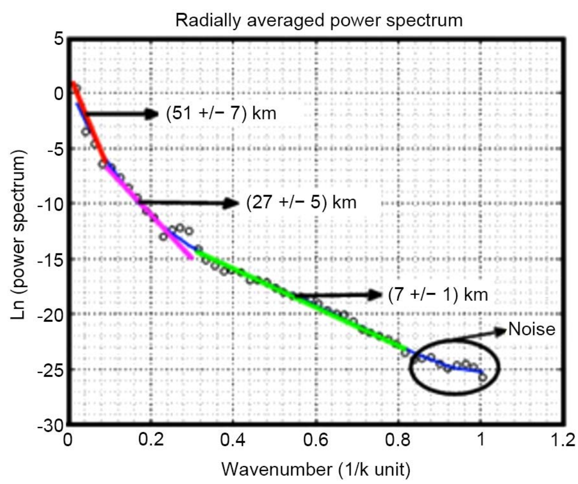

Figure 19. Power spectrum versus frequency for profile P_8 (Eseka region).

Bouguer anomalies are negative, the crust has a normal thiskness. The results can also suggest the fact that neither the Kumbo region nor the Mt Cameroon area is isostatically compensated. Another fact is that the northern edge of the Congo craton that constitutes a boundary with the Pan-african belt presents a relatively thin crust.

4.3.2. The Depth of Some Interesting Shallow Structures

Some interesting shallow structures have been identified on the Bouguer and the third-order residual anomaly maps (**Figure 6** and **Figure 11**). Based on the spectral analysis, the following depths have been obtained: (10 ± 2) km in the Mt Cameroon region compared to (7 ± 2) and (7 ± 1) km in Manyemen and Fontem respectively. In addition, (5 ± 2) km is estimated for the locality of Kumbo and (7 ± 2) km in Bafoussam. Finally, (6 ± 1) km and (7 ± 1) km were determined for Ngambe and Eseka regions respectively.

As mentioned before, the study area shows many dense and less dense intrusive structures due to volcanic activity, which may be related to the mineralization signs previously illustrated by [31]. Thus, the depths found in the present work predict many economic opportunities in the study area.

5. Conclusion

The present work shows new findings which prove the efficiency of the Earth Gravitational Model (EGM2008) in analyzing crustal structures beneath the south western Cameroon. It also shows that spectral analysis is an adequate technique to estimate the depths of either the Moho discontinuity using the Bouguer anomalies derived from EGM2008 or superficial discontinuities by the mean of the residual anomalies. The results obtained in the present work are in good agreement with many other findings of previous geophysical investigations. The EGM2008 geopotential field gravity model can be therefore used for further investigations in volcanic areas such as the oceanic part of the Cameroon Volcanic Line (CVL). These results illustrate a general thinning of the crust and also suggest that there is not isostatic compensation in the study area, especially in the Mount Cameroon and Kumbo regions. Furthermore, shallow structures with various densities are enlightened on residual anomaly map and can justify the scientific and socio-economic interests of the study area.

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