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Estimation of the Depth of Major Subsurface Discontinuities Beneath the Mount Cameroon Region, Central Africa, Based on New and Existing Gravity Data Analysis

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Abstract

The Mount Cameroon region is investigated using 2-D spectral analysis of the gravity data, in order to determine the depth of subsurface interfaces beneath the region. New gravity data are combined to existing ones to determine the depth of the major subsurface discontinuities throughout the region. Depths are established from the slope of the log-power radial spectrum et the lower end of the wave number band. Three major subsurface density discontinuities are determined beneath the Mount Cameroon: (1) 0.41 ± 0.02 km, (2) 1.26 ± 0.06 km, (3) 4.73 ± 0.24 km. This result has the best precision comparing with the those from the former Bouguer anomaly where the major subsurface discontinuities obtained are: (1) 0.48 ± 0.02 km for the first layer, 1.81 ± 0.09 km for the second and 6.87 ± 0.34 km for the third. This difference is probabely due to the densification of gravity data. The knowledge on the depth of different interfaces in the crust is very important in the reconstitution of the earth history. These results will the support of prospective investigations throughout this region.

Keywords: 2D Spectral analysis, Bouguer Anomaly, Major subsurface discontinuities, new gravity data

1. Introduction

The study area is situated at the Mount Cameroon which is the only active volcano in the Cameroon Volcanic Line (Déruelle et al.2000). Over the last 20 centuries, people living around this volcano have been victims of many natural disasters like volcanic eruptions, floods, landslides and mudslides that have each generated human casualty of which human and environmental damage (Thierry et al.2008). All these gives Mount Cameroon a special status that is worthy of scientific interest. Many geophysical surveys have been effectuated to study of the Mount Cameroon region. These include studies across the country, such as the work of Poudjom Djomani et al. (1995) with gravity data and those of Tokam et al. (2010) using seismic data. On a smaller scale, we can cite the work of Ateba et al. (2009) and that of Kenfack et al. (2011). The studies of Poudjom Djomani et al. (1995) were carried out in a regional framework, extended over several hundreds of kilometers, largely with evidence of deep structural contrasts, located in the upper mantle. The meaning attributed to gravity anomaly do not take into account the effect of gravitational density contrast due to the structure of the crust. The work of Kenfack et al. (2011) established the new gravity map and provides support for any interpretation of gravity anomalies in the region. Ateba et al. (2009), using the seismic method showed eruptive sites and directions of volcanic lava flows during the eruption of 2000. None of these works has focused on the major discontinuities of Mount Cameroon region. To solve the problem and have better understanding the structure of this Mountain, a new Bouguer anomaly map of the region that was presented in our previous article (Kenfack et al., 2011) study will be exploited.

The aim of this study is to define the depths of major subsurface discontinuities using 2-D spectral analysis technics. Determination of the power spectrum from Fourier coefficients to obtain the average depth to a disturbing surface, or the average depth to the top of a disturbing body have been used widely in geophysical studies (e.g., Spector and Grant, 1970). With this approach, we complete by the gravity method, the work of Tokam et al. (2010) which used the seismic data to determine the Crustal thickness in some localities in the Cameroon, specifically about the 25 km beneath the Mount Cameroon, but had not defined the depths of majors subsurface interfaces.

2. Geological Setting and Tectonics

Mount Cameroon is one of Africa's largest volcanoes, rise to 4060 m above sea level in the coast of west Cameroon. The massive steep-sided volcano of dominantly basaltic to trachybasaltic composition forms a volcanic horst constructed above a basement of Precambrian metamorphic rocks covered by Cretaceous to Quaternary sediments (Tsafack, 2009). More than 100 small cinder cones, often fissure-controlled parallel to the long axis of the massive 1400 km volcano, occur on the flanks and surrounding lowlands (Burke et Whiteman. 1973). During historical times, moderate explosive and effusive eruptions occurred from both summit and flank vents. A 1922 SW-flank eruption produced a lava flow that reached the Atlantic coast, and a lava flow from a 1999 south-flank eruption stopped only 200 m from the sea. Mount Cameroon is the most important volcano along the Cameroon Volcanic line (CVL), located at the boundary between the continental and oceanic lithosphere (Tsafack, 2009). The CVL tectonic structure (Figure 1) is the consequence of a series of parallel fissures oriented N30°E and transversal events (Burke and Whiteman. 1973). This line is made up of twelve main volcanic centres, with ages ranging from51.8 Ma to the present (Fitton and Dunlop., 1985, Moundi et al., 2007). Morphologicaly, Mount Cameroon is a stratovolcano, situated on a horst with boundary faults that are expressed by break of slopes (Deruelle et al., 1983). It is bounded by the Tombel graben to North and the Douala sedimentary basin to the South (Dumort, 1967). Its basement (Pan-African granite and gneiss) is covered by cretaceous to quaternary sediments, observable in the Bomana maar et the NW of the massif (Dumort, 1967).

The regional map of the cones shows three major tectonic axes that control the volcanic activity (Tsafack, 2009): The Debundsha axis (N60°-70°), the Limbe axix (N140°-150°) and the Batoke axis (N30°-40°)

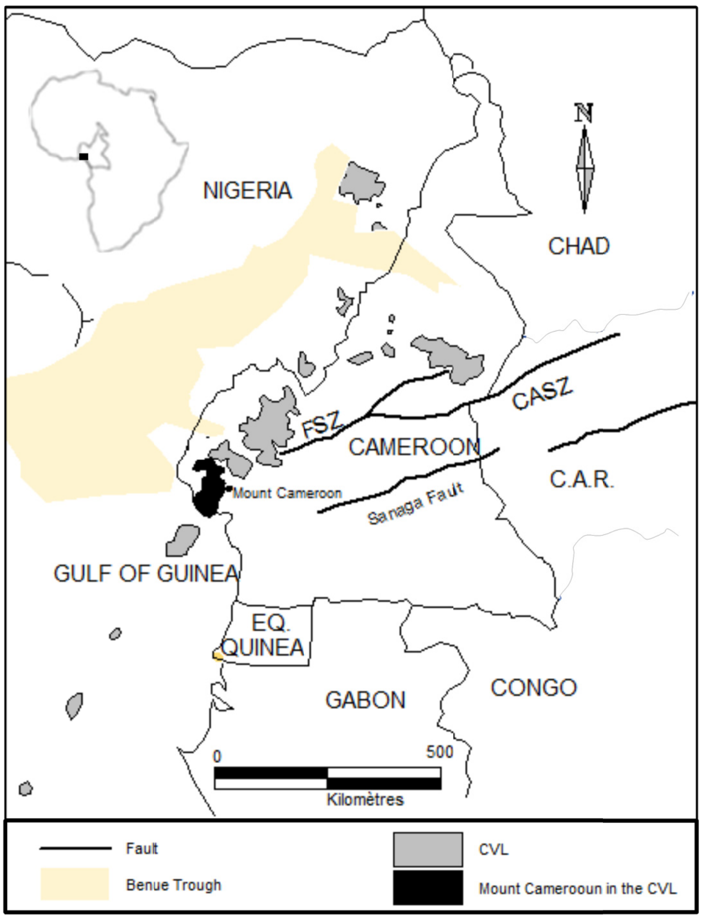


Figure 1. Location of the study area in the Cameroon Volcanic Line (CVL). Study area is shown in black. CASZ is Central African Shear Zone. FSZ is Foumban Shear Zone and C.A.R is Central African Republic

According to increasing altitudes, different zones of Mount Cameroon (Figure 2) can be characterized. From 0 to 1000 m altitude, we observe a tied structure, elongated in the direction SW-NE, characterizing the zone or cast lava from previous eruptions are also abundant and characterizes strength and speed with which products were ejected from the crater. From 1000 to 2000 m, there is a kind of uniformity of the structure in all directions. From 2000 to 3400 m, there is a very complex structure resulting from the last lava of the volcano on the northwest side of the hollow which are consequences of erosion, because rains are abundant in the area. From 3200 to 4055 m altitude, we are at the summit of Mount Cameroon also called Mount Fako.

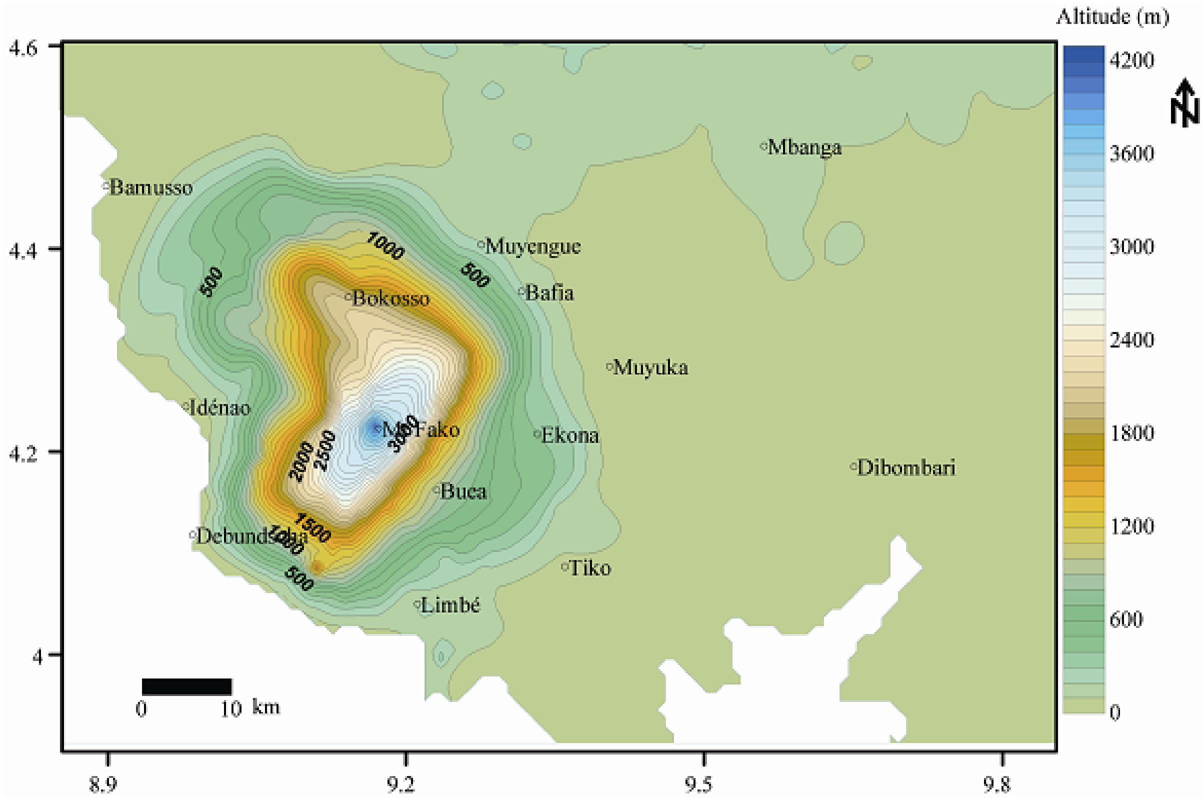


Figure 2. Relief map of the study area based on the Digital Elevation model (DEM) SRTM. The altitude in the area varied from 0 to 4060 m, which is the new altitude value of the Mount Cameroon based on GPS survey.

3. Gravity Data

Existing gravity data (Figure 3) were acquired firstly between 1963 and 1968, during a detailed gravity survey of Cameroon and Central Africa undertaken by the "Office de la Recherche Scientifique et Technique d'Outre-Mer" (ORSTOM) (Collignon, 1968; Louis, 1970), and secondly between 1970 and 1990, by Albouy et Godivier R., (1981) and Okereke, (1984). The gravity campaign was carried out on the Cameroon Mountain and its surroundings (Figure 3) in November 2008 for the mountain zone (between 2000 and 4055 m), and December 2009, around the mountain. The gravity was corrected in order to obtain the value of the Bouguer anomaly in each station. Gravity measurements were made with a Lacoste and Romberg Gravimeter having a calibration constant at 50°C. Observations were made with respect to the base station in Buea Up Station, which had earlier been tied to an international gravity station at the Douala airport, called "Reseau Matin". Drift corrections were applied. Relative station elevations along all traverses were measured with Global Positioning Système (GPS) and staff to an estimated accuracy of better than 0.3 m. The station elevations lie between 0 and 4060 m above mean sea level at Tiko and Debundsha.

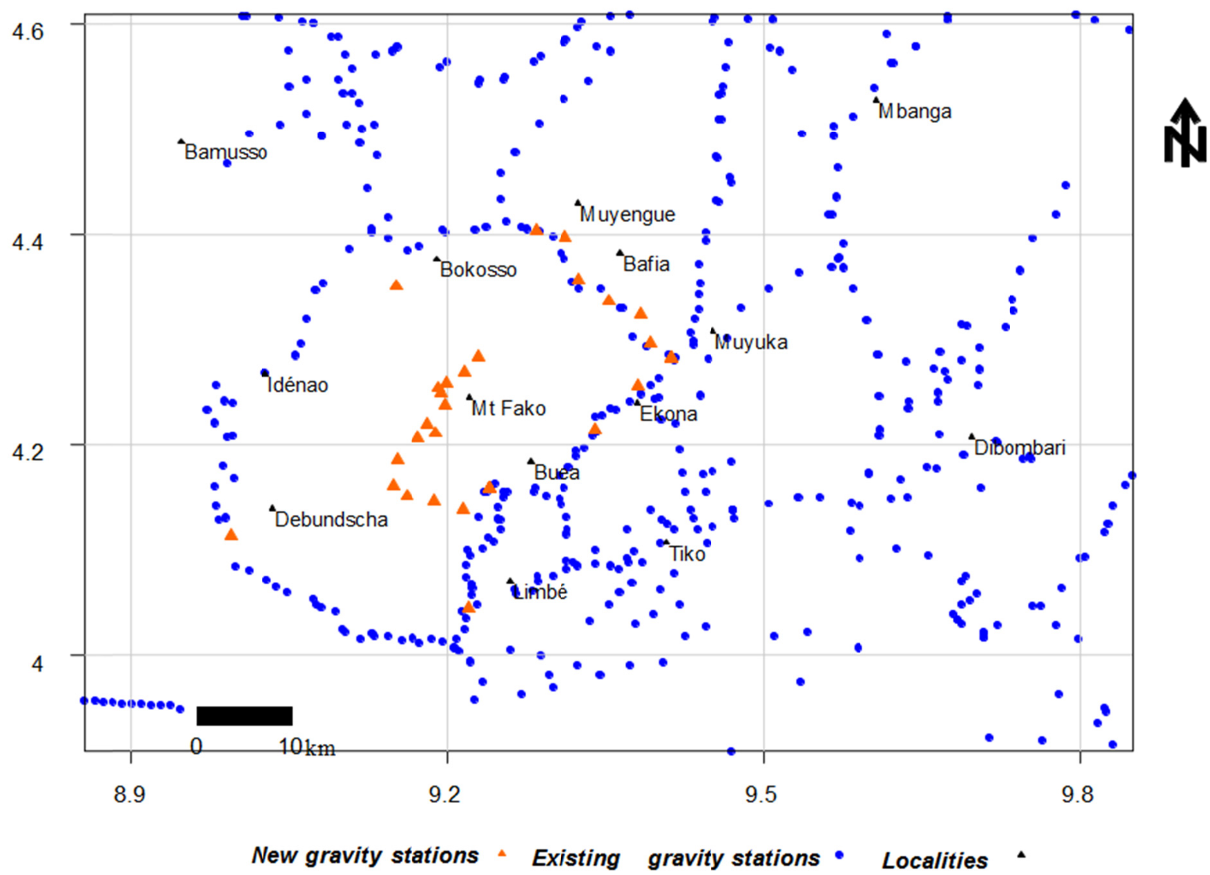


Figure 3. Distribution of the gravity data in the study area: The map consists of the new gravity data (red triangles) and the existing gravity data (blue dots)

4. Bouguer Anomaly Map

4.1 Bouguer Anomaly Map of the Existing Data

The Bouguer anomaly map of the existing data (Figure 4) shows four gravity domains: The first domain, which covers the mountain zone, is characterized by a large negative anomaly with a dominant N-S trend. This anomaly, with amplitude of -72 mGals, cannot be associated to any geaological formations, because the zone consists of basaltic dense rocks. This negative anomaly is due to the lack of gravity data in the area. The negative anomaly observed in the zone can be due to the effect of the neighboring formations observed in the northern part of the domain. The second domain, locatecd on the east and northeast of the study area is characterized by a large negative anomaly trending north-south to the east and east-west in the Northeastern part of study area. Contrary to the one observed in the middle part of the area, the amplitude of this anomaly is about -45 mGals. This anomaly can be interpreted to be due to the effect of large scale formations with low densities. The third domain, which is situated to the south and southwest of the study area, essentially covers the Atlantic Ocean and is marked by a positive anomaly with amplitude of 102 mGals. This positive anomaly with large wavelength and WNW-ESE trend are due to the effect of highly dense formations.

The presence of the Sea area can contribute to this positive anomaly. The fourth domain, which is situated in the northwestern part of the study area, is consisted of high isolated gravity anomaly with small wavelength. This positive anomaly, with amplitude of about 32 mGals can be interpreted to be due to high dense rocks in the area. The first domain and the third domain are separated by a steep NNW-SSE gradient, which is the effect of discontinuity between the two structures.

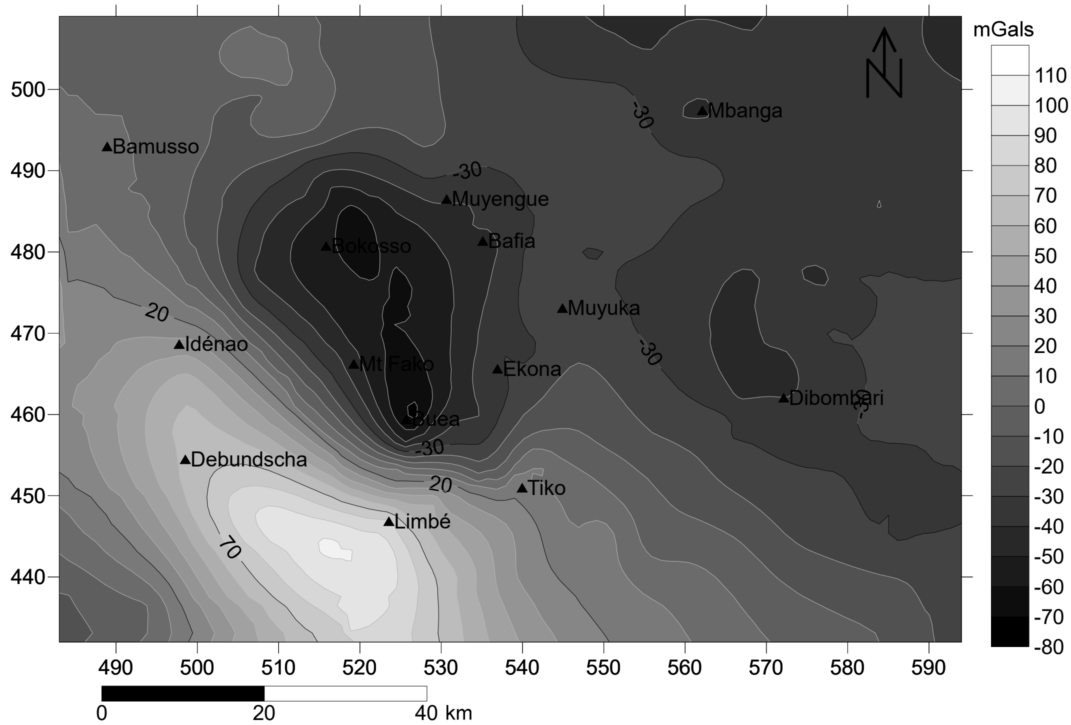


Figure 4. Existing Bouguer gravity map before densification

4.2 Bouguer Anomaly Map of the Existing and New Gravity Data

The Bouguer anomaly map (Figure 5) obtained by combination of both existing and new gravity data, shows a complex structure close to the mountain zone (between altitude 2000 and 3800 m). In the same case as the previous map, this Bouguer anomaly reveals four gravity domains. The first domain which covers a mountain zone, consists of both positive and negative anomalies. A closer look at the map shows that positive anomalies (10 to 32 mGals) appear in the central part of the mountain, closely around the altitude 2000 to 3800 m. These anomalies are interpreted as representing the existence of highly dense rocks in the mountain zone. The anomaly at the summit of altitude about 4060 m, is relatively negative (about -30 mGals), and can be interpreted to be related to the intrusion of low density formation in that zone. On the other hand, we find in the northern and the southern part of the area, low gravity anomalies that can be associated to low density formations. The presence of steep gravity gradients at the boundary of the anomalies can be associated to crustal discontinuity between juxtaposed formations in the study area. It is possible that the anomaly observed in the northern part of the study area originates from different sources. As observed in the previous anomaly map, the second domain, located on the East and northeast of the study area is characterized by a large negative anomaly with wavelength trending north-south to the East and east-west in the Northeastern part of study area. This anomaly can be interpreted to be due to the effect of large scale formations, with low densities. The third domain, which is situated at the south and southwest, is essentially covered by the Atlantic Ocean and marked by positive anomalies with amplitude of 110 mGals. These positive anomalies with a large wavelength and WNW-ESE trend are due to the effect of highly dense formations. The presence of the sea area can contribute to this positive anomaly. The fourth domain, which is situated in the northwestern part of the study area, consists of high isolated gravity anomaly with a small wavelength. This positive anomaly, with amplitude of about 32 mGals can be interpreted to be due to highly dense rocks in the area.

The first domain and the third domain are separated by a steep NNW-SSE gradient, which is the effect of discontinuity between the structures.

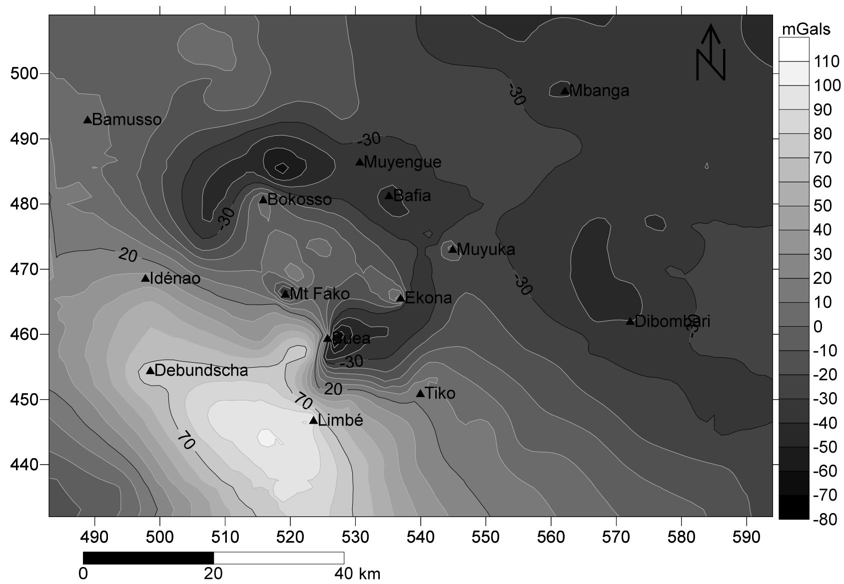


Figure 5. Bouguer gravity map after densification, map showing zone A, B, and D where depth to density discontinuities has been determined.

In general, the study area consists of high positive anomalies, especially in the area over the sea and the mountain area where there are mainly basaltic rocks. In addition to these positive anomalies, negative anomalies (down to -30 mgal) are also found in the mountain zone especially on the summit where the altitude is about 4060 m; this negative anomaly is interpreted as due to the collapsing of the crust in this zone. The negative anomalies found in the eastern, northern and northeastern parts of the study area are interpreted to be associated to the Douala sedimentary basin. The negative anomalies found on and around the mountain are most likely due to the collapsing of the crust in that area.

5. Method Review

With the goal to obtain mean depths to interfaces of significant density contrasts in the crust beneath the Mount Cameroon region, we used 2-D spectral analysis using FOURPOT software of Markku Pirttijärvi (2009). The FOURPOT program is designed for frequency domain processing and analysis of two dimensional (2D) potential field arising, in particular, from geophysical gravity and magnetic field measurements. The data can be irregularly or regularly sampled. The technics is based on transforming gravity data from the space domain to the frequency, or wave number. Considering discrete and 2D data, the governing equations are:

$$F_{nm} = \sum_{k=1}^{N} \sum_{l=1}^{M} e^{-2\pi i\left(\frac{nk}{N}+\frac{ml}{M}\right)} f_{kl} \tag{1}$$

And $$f_{kl} = \frac{1}{NM} \sum_{n=0}^{N-1} \sum_{m=0}^{M-1} e^{+2\pi i\left(\frac{nk}{N}+\frac{ml}{M}\right)} F_{nm} \tag{2}$$

Where N and M are the number of data values in x and y directions. The transform is complex which means that it has both amplitude and phase spectra.

FOURPOT computes the discrete 2D Fourier transform using the fast Fourier transform (FFT) algorithm. The Fourier transform represents a sum of sine and cosine terms with different spatial frequencies (kx and ky) that are defined by data sampling (dx and dy) in x and y directions. The highest spatial frequency is the so-called Nyquist frequency. The lowest frequency is based on the data coverage. Considering that the inverse of the spatial frequency represents wave length (λ x = 1/kx), zero frequency means infinite wave length, i.e. constant level of data. Because of the properties of the Fourier transform (symmetry, linearity, shift and derivate properties) several computational operations can be performed in Fourier transformed frequency (kx, ky) domain more efficiently than in the spatial (x, y) domain. The radial amplitude is the mean of the 2D Fourier amplitude spectrum (Blakely,1995).

$$A = |F| = \left[\mathrm{Re}(F)^2 + \mathrm{Im}(F)^2 \right]^{1/2} \tag{3}$$

along rings with radius

$$k_r = \left[k_x^{\ 2} + k_y^{\ 2} \right]^{1/2} \tag{4}$$

The amplitude spectrum has traditionally been used to estimate the depth to the bottom of potential field sources. This is established by fitting linear lines to the decaying amplitude curve on a semi-logarithmic scale (Markku Pirttijärvi, 2009).

In frequency domain, the Fourier transform of a potential field can be formulated as $F \approx Ce^{-hk}$

$$\text{giving } \log(F / C) = -h.k_r \tag{5}$$

Thus, the depth to the top of an anomaly source (h) is equal to the tangent or the slope of the linear parts of the amplitude spectrum. For general data type the coefficient C= 1 and the vertical axis is the logarithm of the amplitude spectrum, $\log|F|$. For gravity data the coefficient $C = -1/(k_x k_y k_r)$

6. Results and Discussion

The depths corresponding to the contrasts are estimated in four different areas (Figure 8) covering a total area of about 2858 km^2 on the combined existing and new gravity data. In the existing gravity data, and on the same total surface (Figure 6), the depths are estimated with the aim of comparing the result obtained using the new Bouguer anomaly map.

The power spectrum curves obtained are presented in Figures 7 and 9. On these curves, three straight line segments are identified and plotted by a least squares fitting on the data points. The mean depth of density contrast plane is represented by h1 in the high frequency range caused by bodies at near surface, h2 in the medium frequency range and h3 in the low frequency range associated to deep-seated bodies.

6.1 Depth Estimated on Bouguer Anomaly Map of the Existing Data

The area concerns the mountain zone where Bouguer anomalies is sometimes positive and negative.

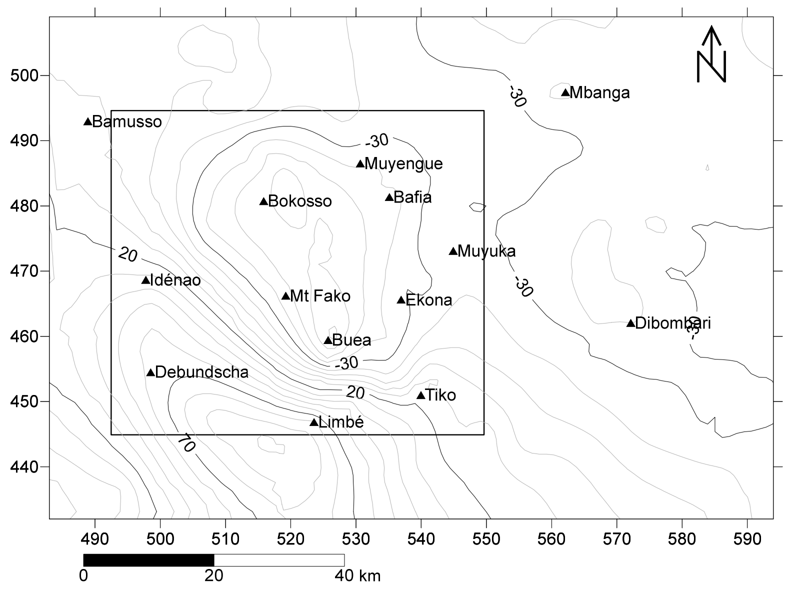


Figure 6. Existing Bouguer anomaly map showing the area where depths of major subsurface density discontinuities are determined.

Results of the power spectra analyses are shown in Figure 7 and summarized in Table 1. Each of linear segments is fitted by a least squares best fitting line. The choice of the endpoints for the linear regression is made by visual inspection.

The mean depth estimates for the deepest discontinuity obtained for existing gravity data is 6.87 km. The shallowest depth obtained for the area is 0.48 km and intermediate depth is 1.81 km. These depths cannot be interpreted as real mean depths of bodies responsible for the observed gravity anomalies in the area because these results are obtained without taking account of gravity data beyond the altitude of 2200 m. It is in agreement with the result of Nnange et al. (2000) obtained without densification of gravity data and which defined a discontinuity between 7 and 13 km in Adamawa Uplift region of Cameroon. The depth of some interesting shallow structures has been identified on the Bouguer and the third-order residual anomaly maps Beneath the South Western Cameroon (Jean Marcel et al. 2016). Based on the spectral analysis, the following depths have been obtained: (10 ± 2) km in the Mt Cameroun region compared to (7 ± 2) and (7 ± 1) km en Manyemen and Fontem respectively. In adition, (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. Due to the fact that the depth obtained by these authors in the mount Cameroon was not taking account of the lack of gravity data beyond the summit and to the fact that the spectral analysis was the 1D, the result obtained for this subsurface discontinuity remain uncertain. The difference between the present result (6.73km) and the result of Jean Marcel (10 km) is associated to the difference of the methods: 1D and 2D spectral analysis. To ameliorate these results, new gravity data are integrated in the existing.

The power spectrum versus the frequency (Figure 7) shows that the frequencies of up to 3.5 with Nyquist frequency about 2.75. The power spectrum up to 8 with a minimum of -4.

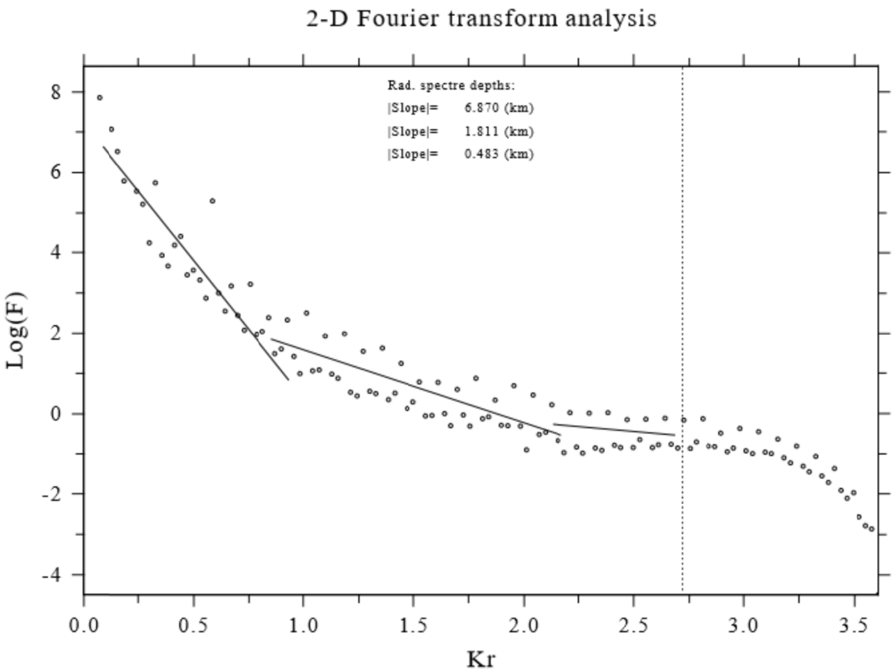


Figure 7. Plots of power spectrum versus the frequency for existing Bouguer anomaly data.

6.2 Depth Estimated on Bouguer Anomaly Map of the Combined Existing and New Gravity Data

The area concerns the same mountain zone where depths are estimated using combined and existing gravity data. Due to the fact that the values of gravity anomaly fluctuate enough, the domain was divided into four zones (A, B, C, D) presented in Figure 8 with the aim to have a good precision on the depth estimation.

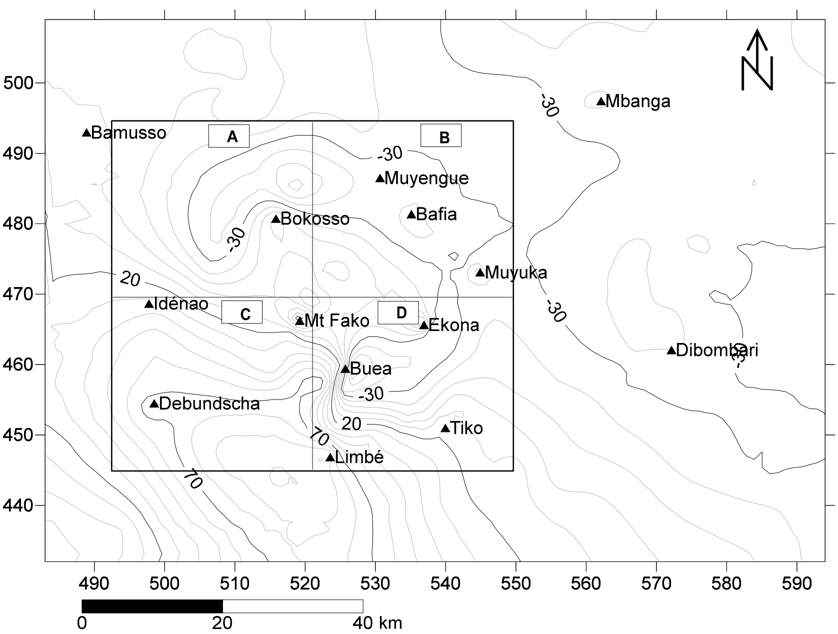


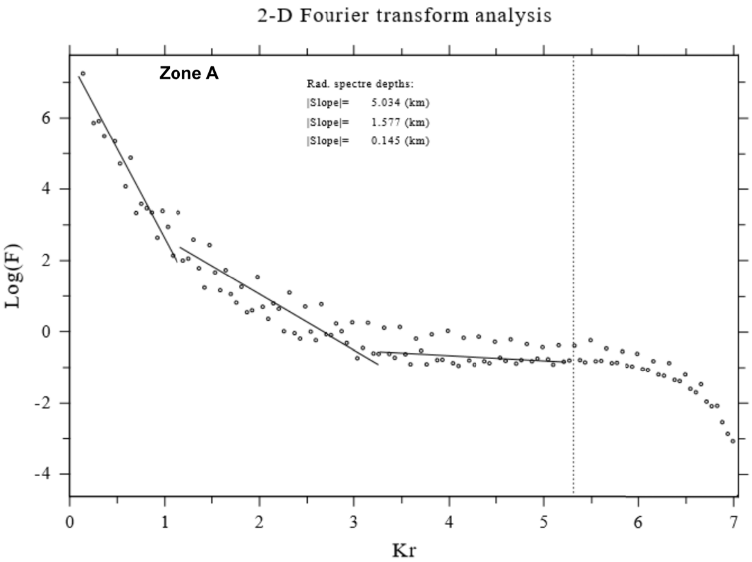
Figure 8. Bouguer anomaly map after densification showing zone A, B, C and D where depth of major subsurface density discontinuities has been determined.

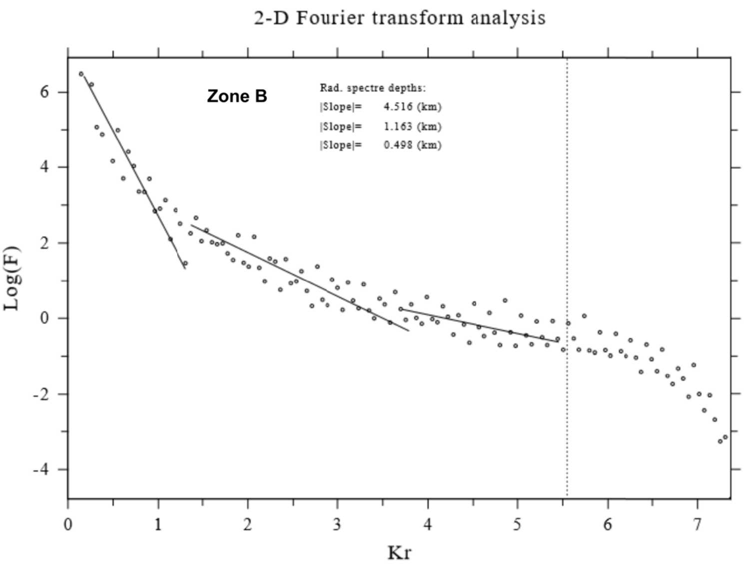
Results of the power spectra analyses are shown in Figure 9 and summarized in Table 1. The mean depth estimates for the deepest discontinuities obtained for zones A, B, C, D are 5.03 km, 4.52 km 5.62 km and 3.75 km respectively for a mean of 4.73 km. These depths might be interpreted as inter-basement density variation and gives a significant variation on the depth estimated comparing to result of Nnange et al. (2000) obtained without densification of gravity data, result of Jean Marcel et al. (2016) obtained in the same conditions. The mean depth is in agreement with the word of Shandini et al. (2010) which defined the shallowest depths obtained for the three profiles in the south Cameroon as 4.9 km, 4.7 km and 5.2 km respectively. This result was interpreted as mean depths of bodies responsible for the observed positive gravity anomalies in the northern part of the Congo Craton.

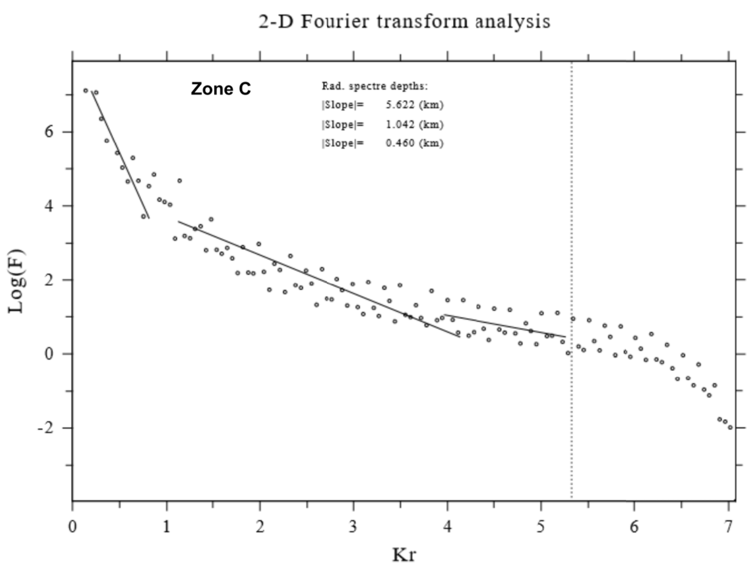
The shallowest depths obtained for the different area are 0.15 km, 0.50 km, 0.46 km and 0.51 km respectively with a mean of 0.41 km.

These depths can be interpreted as mean depths of bodies responsible for the observed negative gravity anomalies in the summit of the Mount. The intermediate discontinuities between the deepest and the shallowest are associated to the depth of 1.58 km, 1.16 km, 1.04 km and 1.25 with a mean of 1.26 km. The depths of 0.41 km, 1.26 km and 4.73 km are the new values of depths which might use for future subsurface investigation in Mount Cameroon. They might correspond to the mid-crustal density contrasts associated with volcanic intrusions.

The power spectrum versus the frequency (Figure 9) shows that the frequencies up to about 7 with Nyquist frequency about 5.5. The power spectrum up to about 8 for zone D and 7 for others with a minimum of -4.


2-D Fourier transform analysis
Zone A
Rad. spectre depths:
|Slope|= 5.034 (km)
|Slope|= 1.577 (km)
|Slope|= 0.145 (km)
Log(F)
Kr


2-D Fourier transform analysis
Zone B
Rad. spectre depths:
|Slope|= 4.516 (km)
|Slope|= 1.163 (km)
|Slope|= 0.498 (km)
Log(F)
Kr


2-D Fourier transform analysis
Zone C
Rad. spectre depths:
|Slope|= 5.622 (km)
|Slope|= 1.042 (km)
|Slope|= 0.460 (km)
Log(F)
Kr

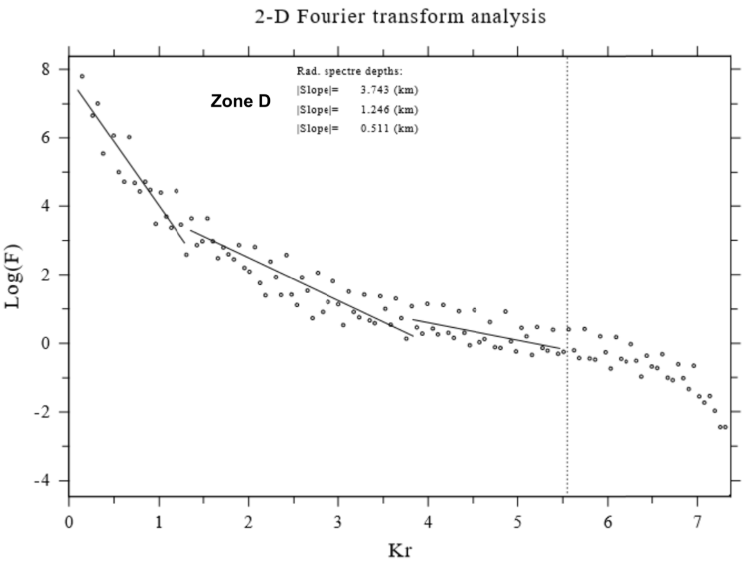


Figure 9. Plots of power spectrum versus the frequency for areas A, B, C and D

The average power spectrum was calculated by means of a Fast Fourier Transform (FFT). Three mean depths to crustal interfaces h_3, h_2 et h_1 in decreasing depth order are estimated from the slope of the corresponding segments. Results are summarized in Table 1.

Table 1. Maximum average depth estimates in kilometres beneath the region of the Mount Cameroon from the azimuthally average power spectra of Figure 7 and 9, starting from the shallowest discontinuity to the deepest.

Depth before densification				Depth after densification			
Zone	Layer 1 / h1 (km)	Layer 2 / h2 (km	Layer 3 / h3 (km)	Zone	Layer 1 / h1 (km)	Layer 2 / h2 (km	Layer 3 / h3 (km)
A	0.15	1.58	5.03				
B	0.50	1.16	4.52				
C	0.46	1.04	5.62	**Mountain**	**0.48**	**1.81**	**6.87**
D	0.51	1.25	3.74				
Average	**0.41**	**1.26**	**4.73**				

7. Conclusion

In order to determine the depth of major subsurface interfaces beneath the region, new and existing gravity data are used. These data are Fourier transformed into the wave number domain and used to determine the azimuthally power spectrum. The technics used is 2-D spectral analysis. Firstly, major subsurface discontinuities are estimated using existing gravity data and in the second position, new gravity data are combined to existing ones to determine the depth of the major subsurface discontinuities throughout the region. Depths are established from the slope of the log-power radial spectrum at the lower end of the wave number band. Three major subsurface density discontinuities are determined beneath the Mount Cameroon: (1) 0.41 ± 0.02 km, (2) 1.26 ± 0.06 km, (3) 4.73 ± 0.24 km. Due to the fact that these results are obtained after densification of the gravity data, they are judge more precise comparing with those from existing Bouguer anomaly. The structure of Mount Cameroon remains poorly known. The knowledge on the depth of different interfaces in the crust is very important in the reconstitution of the earth history. These results will the support of prospective investigations throughout the region.

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References

Albouy, Y., & Godivier R. (1981). Cartes gravimétriques de la République Centrafricaine: *ORSTOM, Paris, France.*

Ateba, B., Dorbath, C., Dorbath, L., Ntepe, N., Frogneux, M., Aka, F. T., … Manguelle, D. (2009). Eruptive and earthquake activities related to the 2000 eruption of Mount Cameroon volcano (West Africa): *Journal of Volcanology and Geothermal Research, 179,* 206-216. http://dx.doi.org/10.1016/j.jvolgeores.2008.11.021

Blakely, R. J. (1995). Potential theory in gravity and magnetic applications. *Cambridge Univ. Press,* 441 p.

Burke, K. C., & Whiteman, A. J. (1973). Uplift, rifting and the break-up of Africa. In: Tarling DH, Runcorn SK (Editors), Implications of Continental Drift to the Earth Sciences., *Academic press, London,* 735-755.

Collignon, (1968). Gravimétrie de Reconnaissance de la République Fédérale du Cameroun: *ORSTOM, Paris, France*, p. 35.

Déruelle, B., Bardintzeff, J. M., Cheminée, J. L., Ngounouno, I., Lissom, J., Nkombou, C., … Nkouathio, D. G. (2000). Eruption sumultanées de basaltes alcalins et de hawaïte au Monjt Cameroun (28 mars – 17 avril 1999). *C.R. Acad. Sci. Paris, Sér Iia, 331*(8), 525-531.

Deruelle, B., Moreau, C., & Nkonguin, E. N. (1983). Sur la récente éruption du mont Cameroun (16 octobre-12 novembre 1982): *C. R. Acad. Sri., Paris,* 807-812.

Dumort, J. C. (1967). Caractères chimiques des trois volcanismes du Cameroun: *Bulletin B.R.G.M., 21-75.*

Fitton, J. G., & Dunlop, H. M. (1985). The Cameroon line, West Africa, and its bearing on the origin of oceanic and continental alkali basalt: *Earth and Planetary Science Letters,* 23-38. http://dx.doi.org/:10.1016/0012-821X(85)90114-1

Jean, M., Abate, E., Nouck, P., Ngatchou, H., Oyoa, V., Tabod, C., & Manguelle-Dicoum, E. (2016). Structure of the Crust Beneath the South Western Cameroon, from Gravity Data Analysis. *International Journal of Geosciences, 7,* 991-1008. http://dx.doi.org/10.4236/ijg.2016.78075

Kenfack, J. V., Tadjou, J. M., Kamguia, J., Tabod, C. T., & Bekoa, A. (2011). Gravity Interpretation of the Cameroon Mountain (West Central Africa) Based based on the New and Existing Data: *International Journal of Geosciences, 2,* 513-522. http://dx.doi.org/10.4236/ijg.2011.24054

Louis, P. (1970). Contribution géophysique à la connaissance géologique du bassin du Lac Chad, *ORSTOM, mémoire, Paris, France,* p.311.

Markku Pirttijärvi, P. (2009). Processing and analysis of potential field data using 2-D Fourier transform. *User's guide to version 1.3. Geological Survey of Finland, 54 pp.*

Moundi, A., Wandji, P., Bardintzeff, J. M., Ménard, J. J., Okomo, L. C., Mouncherou, O. F., … Tchoua, F. M. (2007). Les basaltes éocènes à affinité transitionnelle du plateau Bamoun, témoins d'un réservoir mantellique enrichi sous la ligne volcanique du Cameroun, *Comptes Rendus Geoscience,* 396-406. http://dx.doi.org/ 10.1016/j.crte.2007.04.001

Nnange, J. M., Ngako, V., Fairhead, J. D., & Ebinger, C. J. (2000). Depths to Density Discontinuities Beneath the Adamawa Plateau Region, Central Africa, from Spectral Analyses of New and Existing Gravity Data. *Journal of African Earth Sciences, 30,* 887-901. http://dx.doi.org/10.1016/S0899-5362(00)00058-0

Okereke, C. (1984). A gravity study of the lithospheric structure beneath west Africa rift system in Nigeria and Cameroon (Unpublished doctoral dissertation). *University of Leeds, UK*. Pp. 272.

Poudjom-Djomani, Y. H., Nnange, J. M., Diamet, M., Ebinge, C. J., & Fairhead, J. D. (1995). Effective elastic thickness and crustal thickness variations in west central Africa inferred from gravity data: *Journal of Geophysical Research, solid Earth, 100,* 22047-22070. http://dx.doi.org/10.1029/95JB01149

Shandini, N. Y., Tadjou, J. M., Tabod, C. T., & Fairhead, J. D. (2010): Gravity data interpretation in the northern edge of the Congo craton, South-Cameroon. *Anuário do Instituto de Geociências, 33*(1), 73–82.

Spector, A., & Grant, F. S. (1970). Statistical models for interpreting aeromagnetic data. *Geophysics, 35*, 293–302. http://dx.doi.org/10.1190/1.1440092.

Thierry, P., Stieltjes, L., Kouokam, E., Nguéya, P., Salley, P. M. (2008). Multi-hazard risk mapping and assessment on an active volcano: the Grinp projet at Mount Cameroon. *Nat hazards, 45,* 429-456. http://dx.doi.org/10.1007/s11069-007-9177-3

Tokam, A. P., Tabod, C. T., Nyblade, A. A., Jordi, J., Wiens, D. A., & Pasyanos, M. E. (2010) Structure of the Crust Beneath Cameroon, West Africa, from the Joint Inversion of Rayleigh Wave Group Velocities and Receiver Functions. *Geophysical Journal International, 183,* 1061-1076. http://dx.doi.org/10.1111/j.1365-246X.2010.04776.x

Tsafack, J. P. F. (2009). Volcanisme plio-quaternaire du Mont Cameroun: pétrologie, minéralogie, géochimie isotopique, géochronologie et évolution de la bordure côtière (Unpublished doctoral dissertation). Université de Yaoundé I, Cameroun, 188p.

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