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Geometrical Configuration of the Garoua Basin, North Cameroon as Deduced from Earth Gravitational Model (EGM-2008)

Configuração Geométrica da Bacia de Garoua,
Norte do Cameroon como Deduzido do Earth Gravitational Model (EGM-2008)

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Abstract

Gravity data acquired from Earth Gravitational Model (EGM-2008) was analyzed to estimate the sedimentary thickness, extension and shape of the Garoua Basin, North Cameroon. Residual gravity field were obtained by bandpass filtering of Bouguer gravity anomalies using Geosoft Oasis Montaj. Two dimensional (2-D) forward modeling of the gravity data using Grav2dc v2.06, which uses the Talwini's algorithm was conducted along three profiles oriented NE--SW, NNE-SSW and WNW-ESE to verify the lateral variations of the sediment pile beneath these profiles. Accordingly,

the Garoua is made up of alternating succession of horsts and grabens bounded to the north and south by normal faults infilled with sedimentary rocks underlain by a rifted basement. The gravity models suggest an average thickness of sediments of 9km with a graben-shaped and extents over 80km. With this thickness of the sediment pile and considering the average temperature gradient, the subsurface of this basin offers adequate conditions for hydrocarbon generation if source rocks were to be found. The results obtained in this work corroborate those obtained from previous investigations.
Keywords: Earth Gravitational Model; Bouguer anomaly; structure; gravity; horst; graben; Garoua Basin

Resumo

Dados gravimétricos obtidos pelo Earth Gravitational Model (EGM-2008) foram analisados para se estimar a espessura sedimentar, extensão e forma da Bacia Garoua, Norte do Cameroon. O campo gravitacional residual foi obtido através da filtragem das anomalias gravitacionais Bouguer, utilizando-se o Geosoft Oasis Montaj. Obteve-se um modelo bidimensional (2-D) utilizando-se Grav2dc v2.06, o qual aplica o algoritimo Talwini, em três perfis orientados NE-SW, NNE-SSW e WNW-ESE para a verificação do empilhamento sedimentar. A Bacia de Garoua é composta por uma sucessão alternante de horsts e grabens limitados à norte e sul por falhas normais, num embasamento rifteado. Os modelos gravitacionais sugerem uma espessura de 9km de sedimentos, através de uma extensão de 80 km. Com esta espessura sedimentar e considerando-se o gradiente médio de temperatura, as condições em subsuperfície desta bacia são adequadas para a geração de hidrocarbonetos, caso sejam encontradas rochas geradoras. Os resultados obtidos neste estudo corroboram investigações prévias realizadas na região.
Palavras-chave: Modelo Gravitacional; Anomalia Bouguer; estrutural; gravidade; horst; graben; Bacia Garoua

1 Introduction

The Garoua Basin is the continuation of the Yola arm of the northern Benue Trough of Nigeria into the north Cameroon. This basin was formed over the Barremian Aptian age and it is the biggest of a series of basins formed in northern Cameroon and south-western Chad in this time (Maurin & Guiraud, 1990). It is bounded to the north by the Mokolo Plateau and to the south by the Adamawa Plateau. This basin as many other sedimentary basins that belonged to the West and Central African Rift System is believed to have potentials for hydrocarbons generation and accumulation (Eyike *et al.,* 2010; Uzoegbu, 2014). Previous gravity work done in the study area used ground gravity dataset carried out by the Office de la Recherche Scientifique et Technique Outre Mer (ORSTOM), collected between 1959 - 1979. The ground distribution of these data is highly uneven and concentrated along major roads and tracks with a station spacing of 2–5 km. Therefore, these data have a poor spatial coverage. These data were analysed by polynomial fitting then 2D forward modelling to deduce a geological model of the Garoua Basin with an estimate of the sedimentary pile thickness of 4km (Kamguia *et al*., 2005). Also, Mouzong *et al.* (2014) after applying bandpass filtering then horizontal gradient analyses determined sedimentary pile thickness average 8km. In this paper, a different set of gravity data will be used.

These are, gravity data derived from the Earth Gravitational Model 2008 (EGM2008).

These data will be processed and interpreted to determine the lateral extent, sediment pile thickness and the shape of the Garoua Basin. This dataset is a combination of many datasets and has a uniform coverage. With gravity data from EGM2008, inaccessible areas can be studied. Statistical analysis as to compare the gravity data from EGM2008 and land gravity data gives means of −38.25 and −38.21 mGal and a standard deviations of 12.30 and 12.42 respectively (Essi *et al.,* 2017). This statistical analyses indicates the slight differences that exist between the two sets of data. This work therefore, evaluates the EGM2008 in the Garoua Basin and the main objective is to determine whether the EGM2008 can aid to unravel the configuration of the Garoua Basin. The spectral analysis technique will be used to qualitatively and quantitatively provide a clear interpretation of the subsurface configuration of the basin.

2 Geologic and Structural Evolution of the Garoua Basin

The Garoua Basin is part of the northern segment of the Benue Trough in Nigeria. It is an Eastward continuation of the Yola Basin into the North Cameroon (Figure 1).

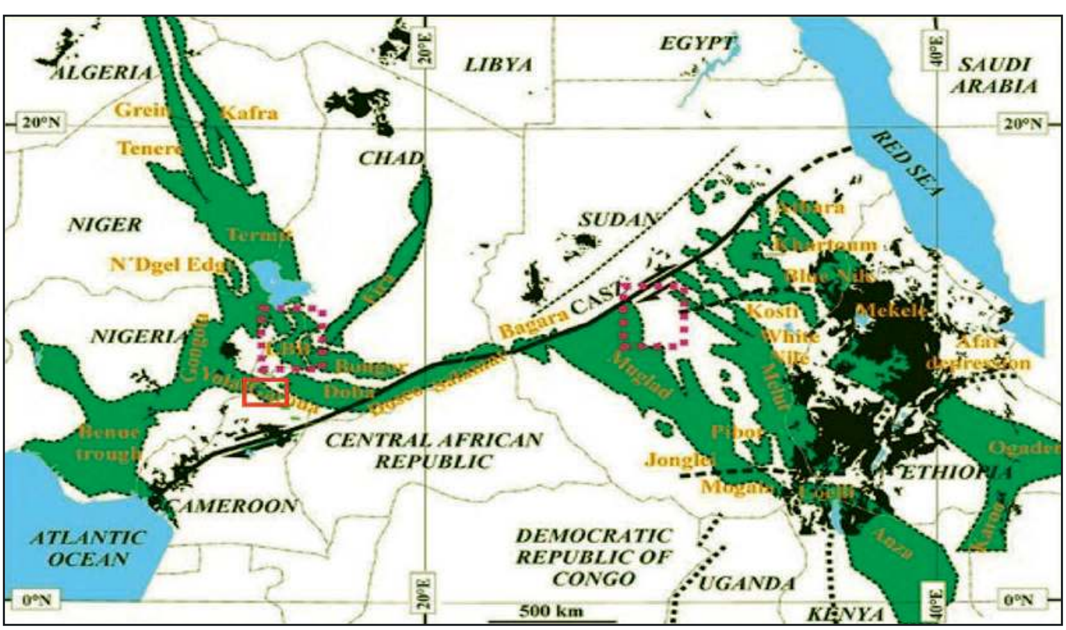

Figure 1 Geometry of the rift systems of West and Central Africa: 1-Volcanic areas, 2-Cretaceous Sedimentary Basins, Dashed line—interpreted hidden important rift boundaries, Dotted line—Tertiary active rifts. Red squares—area of interest (Vatrt *et al*., 2013)

The Benue Trough runs approximately NE--SW and is about 1000km long and 150km wide (Kamguia *et al.,* 2005). The Benue Trough is subdivided into three main structural and sedimentary domains (the Southern, Centre and Northern Benue); each domain has recorded a separate sedimentary and structural history (Benkhelil, 1988).

The trough bifurcates at its NE end to form the north trending Gongola and the east trending Yola arm that extend into Cameroon to form the Garoua Basin (Adekeye & Ntekim, 2007).

The Garoua Basin is infilled with Late Cretaceous marine and continental sediments (Cratchley *et al.,* 1984; Genik, 1992; Benkhelil *et al.,*1998). The dominant sedimentary facies are conglomerates and coarse grained alluvial sandstones. These sandstones are often rich in iron oxides and they crop out in the entire study area (Bessong *et al.,* 2015). The Precambrian gneisses, migmatite and schist crop out in the southern part of Garoua Basin with an extension of the gneisses to the northeast (Figure 2). The intrusive granites crop out extensively in the Garoua Basin in the northeast and southwest. These rock units form the basement complex below the sediments thus are termed the gneissic-granitic basement. Intrusive diorites also occur along the Poli--Lere axis (Poudjom *et al.,* 1992). Basaltic lavas in the Garoua Basin are akin to those of the Cameroon Volcanic Line (Poudjom *et al.,* 1997). The Garoua Basin is structurally bounded by early Cretaceous normal faults trending N100°E, and are intersected by younger strike-slip faults trending N10°-20°E with sinistral wrenching (Poudjom *et al.,* 1992).

The regional structural setting of the Garoua Basin is characterized by three major normal faults striking mainly in the NW-SE to NNE-SSW direction (Mouzong *et al.,* 2014). The continental crust underneath the basin (about 24 km) is thinner than the normal crust, but may be a little thicker to the east. This thinning of the crust is due to extensional regional stress and the uplift of the Asthenosphere is as a consequence and this result to an isostatic compensation. This lead to an average sedimentary pile thickness of about 6km from results obtained by Kamguia *et al.* (2005) and Mouzong *et al.* (2014).

3 Data Set and Methodology
3.1 Gravity Data

The gravity dataset used in this work is derived from the Earth Geopotential Model (EGM2008), (Palvis *et al.,* 2008). The study area falls within the coordinate system 8° and 9.8° N and 12.5° and 14.5° E. EGM2008 has been corrected for the long wa-

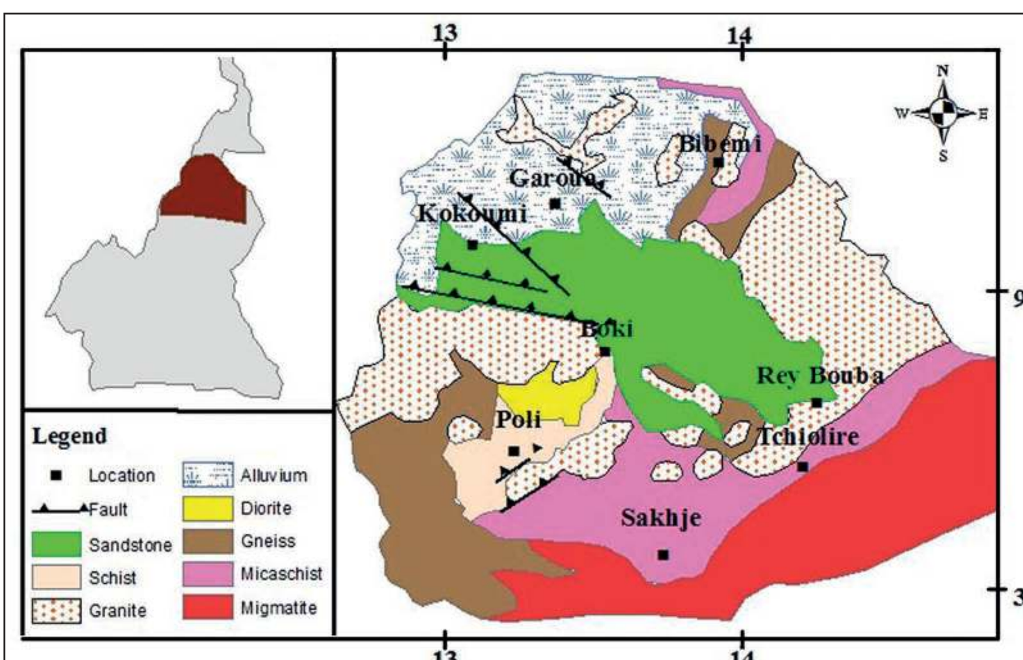

Figure 2 Location (Cameroon Map-Top left) and simplified geological map of the study area (right).

velength (≥300km) anomalies of satellite data (*e.g.* GRACE, CHAMP). The model provides Earth's external gravitational potential by a spherical harmonic model complete to degree and order 2160, with additional spherical harmonic coefficients extending up to degree 2190. This model provides gravity data with a 5' x 5' nominal resolution (Palvis *et al.,* 2008). This dataset was made available by the National Geospatial-Intelligence Agency (NGA) of USA. The topographic effect was calculated using the ETOPO1 elevation data (Amante & Eakins, 2008) and applying the Bouguer correction with a density of 2670 kg/m^3. The results of the corrections were used to produce the World Gravity Map (WGM) which is the first set of global gravity anomaly maps that take into account a realistic Earth model (Bonvalot *et al.,* 2012).

3.2 Spectral Analysis

The Bouguer anomaly value contains the effect of deep seated and near surface bodies which are as a result of regional and residual influences respectively.

Therefore, these two effects needed to be separated for a better interpretation.

Through the process of regional-residual separation the interpreter hopes to isolate features produced by near surface density variations (residual) from those produced by more deep-seated and therefore non-exposed geological features (regional). This separation was achieved by spectral analysis. Spectral analysis provides techniques for qualitative and quantitative studies of large and complex aeromagnetic or gravity data sets. This mathematical technique converts the data from the space domain to the frequency domain (Fast Fourier Transform). The logarithm of the radial average of the energy spectrum (the square of the Fourier amplitude spectrum) was plotted versus the radial frequency (Spector & Grant, 1970). The slopes of the linear segments of the spectrum determine the depth to both shallow (residual) and deep (regional) sources of the anomalies. These components were separated by bandpass filtering. By bandpass filtering of the power spectrum, gravity data are separated into low frequency signal corresponding to deep sources (basement) and high frequency signal corresponding to shallow or inter-basement sources (Figure 3). Very high frequency signal may also be present due to noise (beyond the Nyquist frequency). The bandpass filter was applied using Geosoft Oasis Montaj. The low wavenumber cutoff for low frequency wavelength was 5.49968 while high wavenumber cutoff for low frequency was 187. This interval of wavelengths was filtered out from the original data and corresponds to the regional anomaly while the result of the subtraction is the residual anomaly.

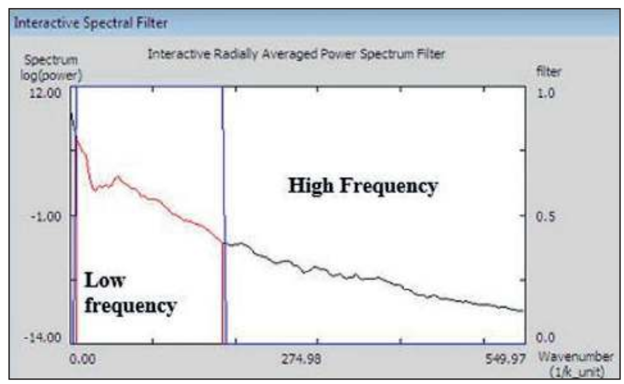

Figure 3 Bandpass filtering of gravity data: Low frequency represents signals from deep and broad Gravity sources. The High frequency corresponds to shallow source gravity signals

3.3 Modeling of Gravity Anomalies

The 2D forward modeling was applied along the constructed profiles (Figure 7), using Grav2dc 2.6 computer Program designed by Cooper and Cowan (2003a,b) which uses the Talwani algorithm. This algorithm combines the observed gravity field, a geologic model and the calculated field to relate them into a highly interactive interpretation frame work in order to understand the geologic structures of the basin. The forward modeling consisted of entering the shape of one or more geologic bodies to the Grav2dc 2.6 software and adjusting the shape, density contrast, width and depth until the calculated anomaly curve fitted the observed field curve. From the results of previous works carried in the study area, a relative depth of investigation was chosen for the modeling.

4 Results and Interpretation

4.1 Bouguer Anomaly Map

The Bouguer anomaly map obtained for this study was acquired from the already corrected gravity data of EGM2008. The Bouguer anomaly map (Figure 4) reveals several anomalies of various shapes and size, as well as trend directions of the geological features in the study area.

The map shows gravity values between +25 and +130mGal. Four relatively high anomalies were identified in the villages within the study area: the first in the south of the Nbouga locality, the second between Boki and Poli localities, the third is between Rey Boba and Sakhje localities and the fourth northeast of Bibemi locality. These positive anomalies can be interpreted as due to the shallowness of the basement rocks which are mainly made up of granite, gneiss, schist and micaschist. The relative gravity low anomalies are also observed; the anomalies run between Kokoumi and Rey Bouba localities in a NW-SE direction and northeast of Boili locality. This represents the sedimentary formations and are mostly composed of sandstones (Bessong *et al.,* 2015).

4.2 Regional and Residual Anomaly Map

The regional anomaly map obtained (Figure 5), is characterized by broad positive anomalies which are elongated with a maximum gravity reading of +102mGal and lies approximately in the NW–SE direction, corresponding to the axis of the Garoua Basin.

The gravity value of the regional decreases from the west towards the east by as much as 70mGal. Since the anomaly decreases from the west towards the east, the crust beneath the basin is thinner in the west. All these observations can be interpreted as due to uplift of the Asthenosphere in response to

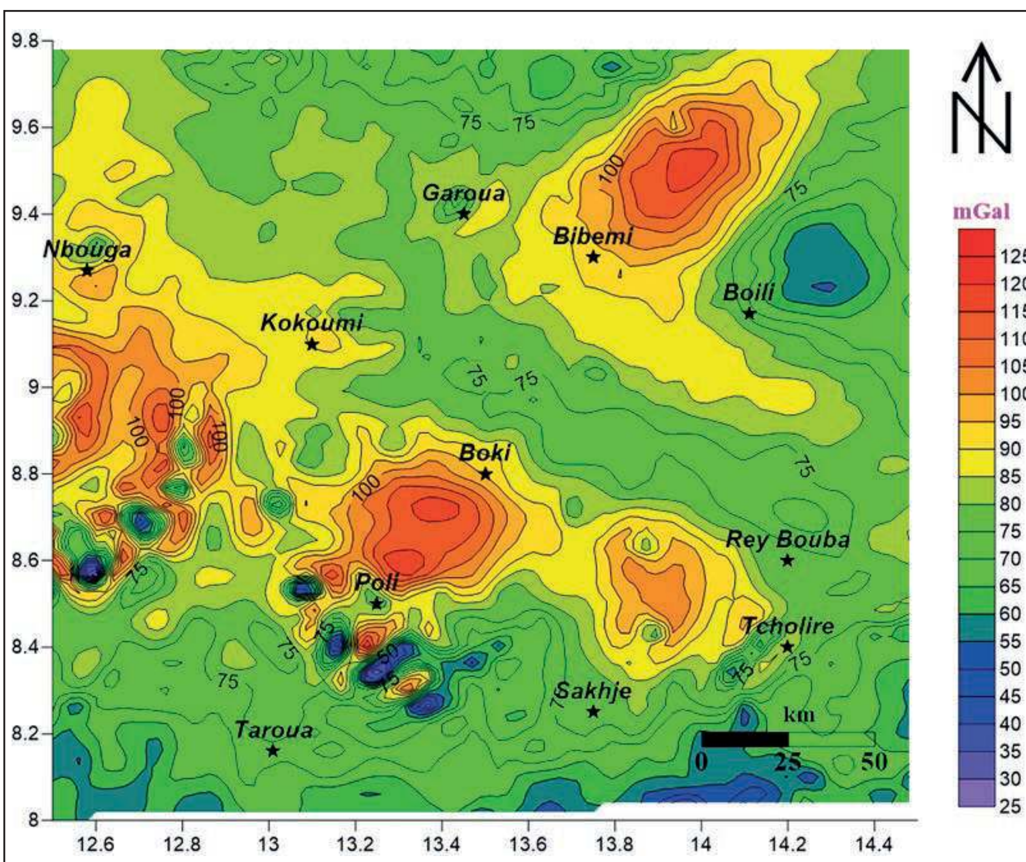

Figure 4 Bouguer Anomaly Map of the Garoua Basin: From the colour scale, yellow-red band represents high gravity corresponding to high density readings while green-purple band represents low gravity corresponding to low density readings. The X and Y axes are the geographical coordinates in the N and in the E Hemisphere as cropped from Figure 1.

isostatic compensation. The residual map (Figure 6) is the effect that remain when the regional anomaly is subtracted from the original data. The shape, size and orientation of residual anomalies are not very different from those of the Bouguer anomaly. The residual anomaly map shows clearly the extension of sedimentary deposits and reveal an elongated shape for the basin.

The residual anomaly indicates four gravity highs in the study area; the first positive anomaly south of Nbouga locality and second between Boki and Poli localities, interpreted to be the basement material (gneiss, schist migmatite) buried under a thin sedimentary cover that have cropped out. The third positive anomaly is between Rey Bouba and Sakhje localities and is a result of the intrusion of magmatic rocks (granite, diorite) into the basement complex. The fourth northeast of Bibemi locality and correspond to the Bibémi-Zalibi belt composed of volcano-sedimentary rocks and includes Mayo Kebbi greenstones, Zalibi-granitoids, as well as, volcanic venues (Essi *et al.,* 2017). The negative anomalies are located between Nbouga and Rey Bouba localities in a NW-SE direction north of the positive anomalies that runs south of the study area and the second negative anomaly is northeast of Boili. A comparison of these negative anomalies with the geological map (Figure 2) shows that these anomalies reflect Cretaceous sedimentary rocks along the Nbouga and Rey Bouba axis.

4.3 Gravity Models

Three profiles (Figure 7) were plotted on the residual anomaly obtained for a quantitative analysis, two across the basin (A-A'and B-B') and the third C-C' along the basin. The geometry of the basin is determined along these profiles. The low gravity anomaly expressions are related to the trough structures (Grabens) while the high gravity anomaly expression are related to the platform structure (Horsts). A relative depth of investigation of 10km was chosen for profiles A-A' and C-C' while profile B-B' depth of investigation was 15km for the modeling, the anomaly curves could well fits at these depths.

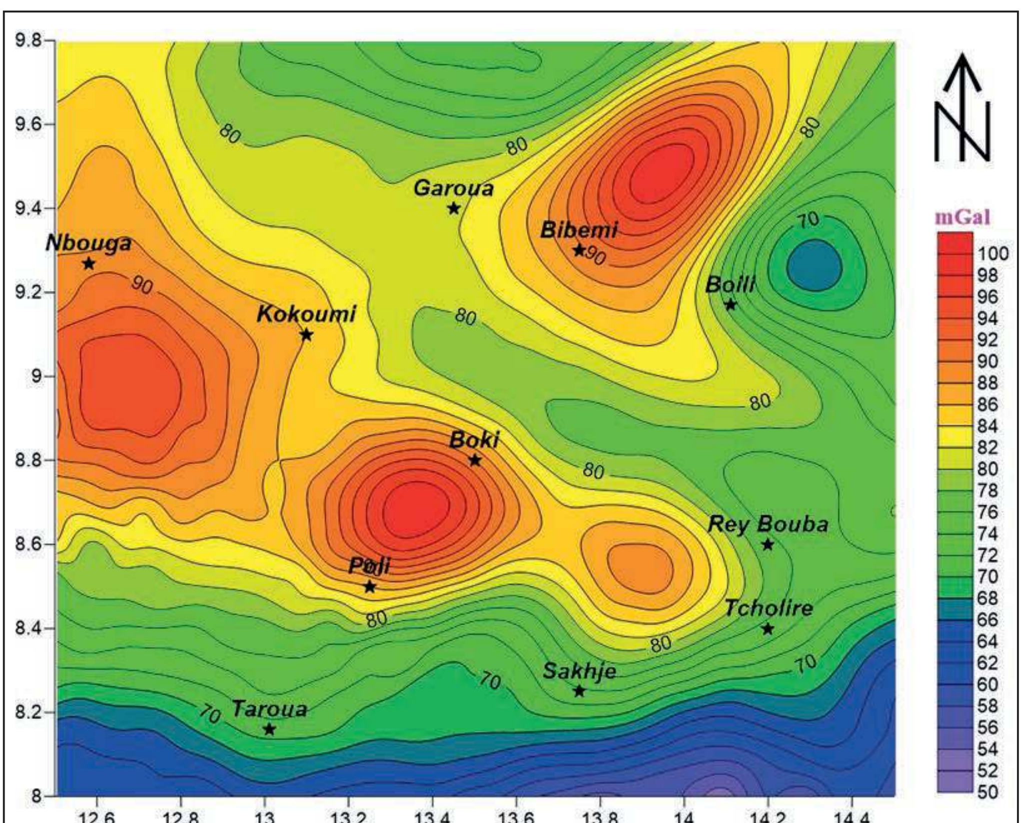

Figure 5 Regional anomaly map of the Garoua Basin: From the colour scale, yellow-red band represents high gravity corresponding to high density readings while green-purple band represents low gravity corresponding to low density readings. The X and Y axes are the geographical coordinates in the N and in the E Hemisphere as cropped from Figure. 1.

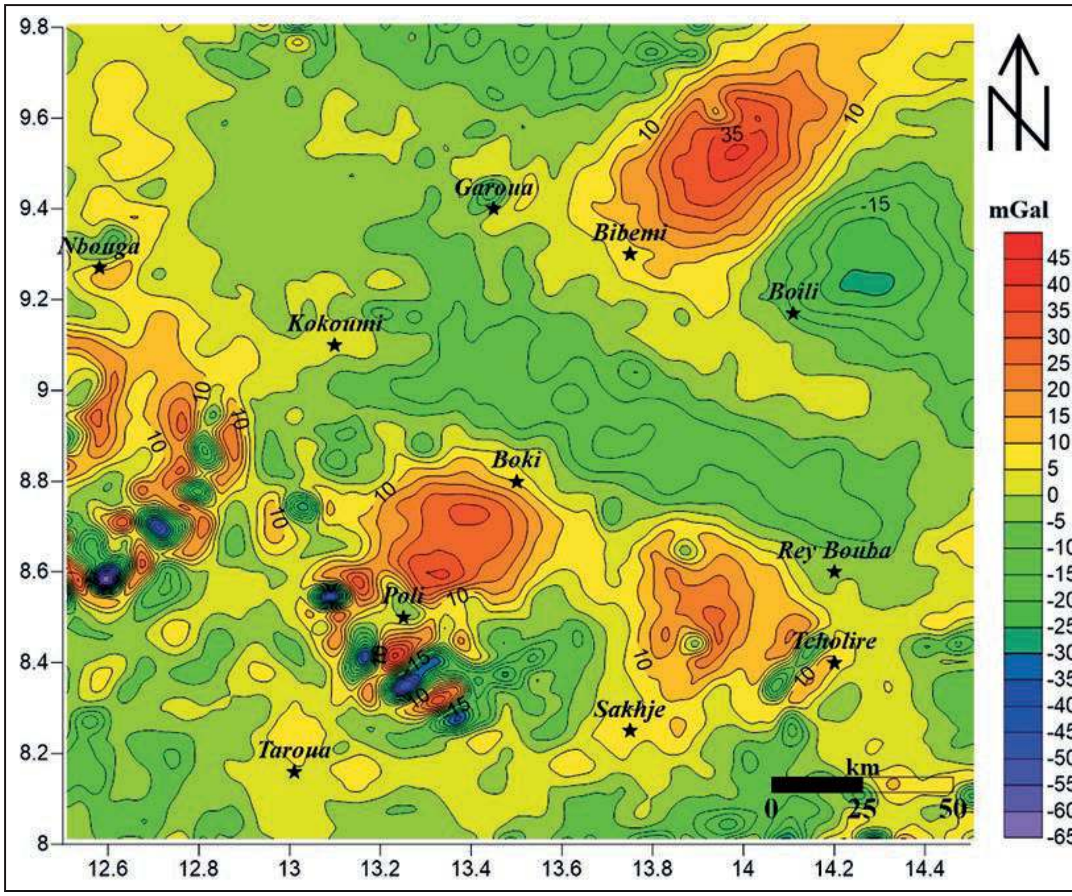

Figure 6 Residual anomaly map of the Garoua Basin: From the colour scale, yellow-red band represents high gravity corresponding to high density readings while green-purple band represents low gravity corresponding to low density readings. The X and Y axes are the geographical coordinates in the N and in the E Hemisphere as cropped from Figure 1.

4.4 Profile A-A'

Profile A-A' has a length of approximately 120 km (Figure 8) and passes through Boki and Bibemi localities. The observed anomaly curve presents a low gravity value of -12.4mGal indicating the presence of sediments. The model comprises two bodies. The first body has a density d_1= 2.59 g/cm^3 and corresponds to the sediment infill with a variable thickness reaching 9.0 km depth and a lateral extent of about 80km. The second body has a density of d_2= 2.8g/cm^3. The geologic map (Figure 2) shows some gneisses outcropping along this area of the profile. The model suggests a graben structure for the basin bounded to the north and south ends with normal fault, infilled with sedimentary materials.

4.5 Profile B-B'

Profile B-B' has a length of about 160km (Figure. 9) and passes through NE of Sakhje and NE Boili localities. The residual anomaly curve associated with the profile is characterized by a low gravity anomaly of approximately 21.6mGal, this also indicates the presence of sediments. To adjust the computed and the observed curves, two bodies were enough. The characteristics of the two bodies indicate the geometry of the superposition of the geological units in the subsurface with the Garoua Basin SSW of the profile present as a graben structure. The first body has a density of d_1= 2.57 g/cm^3 and corresponds to the sediment infilled with a variable thickness reaching about 9.5km in the SSW (Garoua Basin) and about 12.0km at the NNE (Pala-Lame Basin) of the profile. The second body with density d_2 = 2.77 g/cm^3 corresponds to the granite-gneissic basement.

4.6 Profile C-C'

Profile C-C' has a length of about 160km (Figure 10) and is plotted along the basin passing throu-

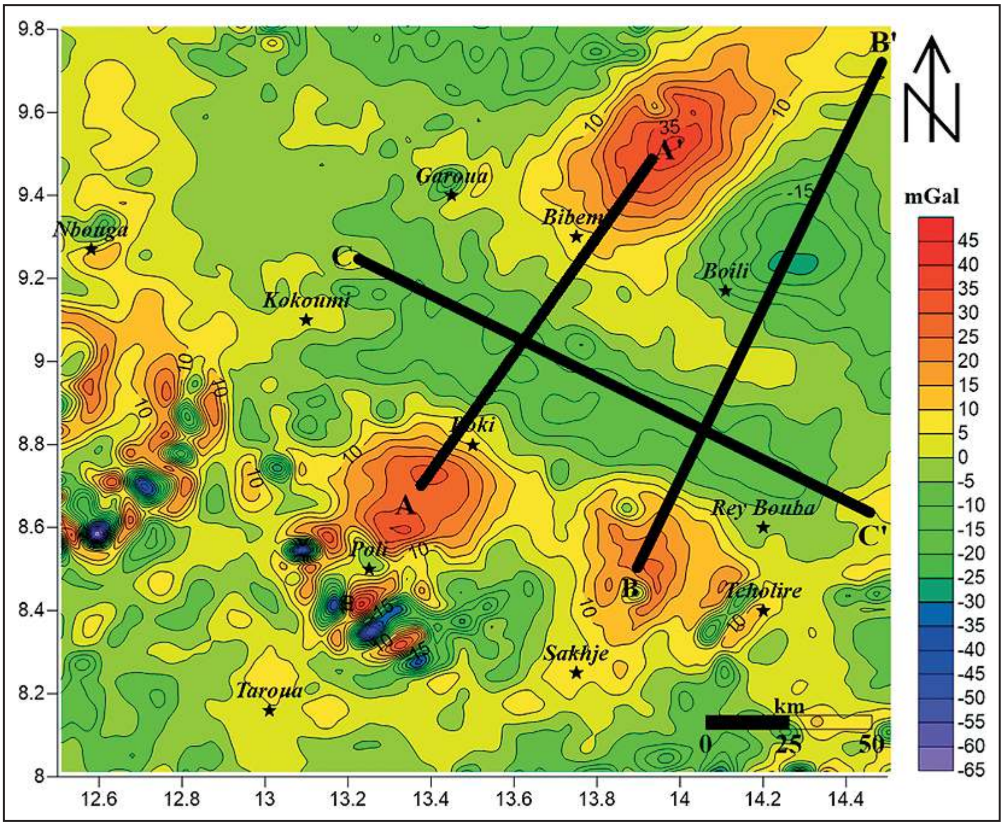

Figure 7 Gravity Profile: From the colour scale, yellow-red band represents high gravity corresponding to high density readings while green-purple band represents low gravity corresponding to low density readings. The X and Y axes are the geographical coordinates in the N and in the E Hemisphere as cropped from Figure. 1. The dark lines are the modeling profiles.

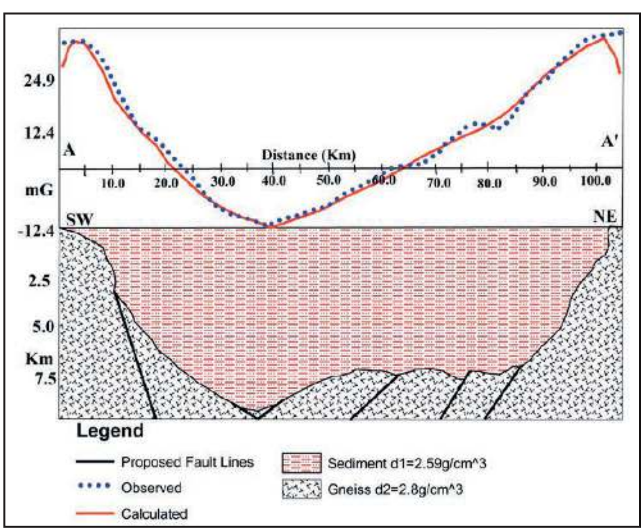

Figure 8 A 2D model of the Garoua Basin along Profile A-A': A-A' is the lengthof the modeling profile and it runs in a SW-NE direction in the study area map. Bottom-left is the investigation depth from 0-10km while top-left is the observed gravity value in mGal as indicated by the dotted blue curve, the red curve is the calculated gravity value obtained by estimating the effect of the density contrast, depth, size and shape of modelling bodies.

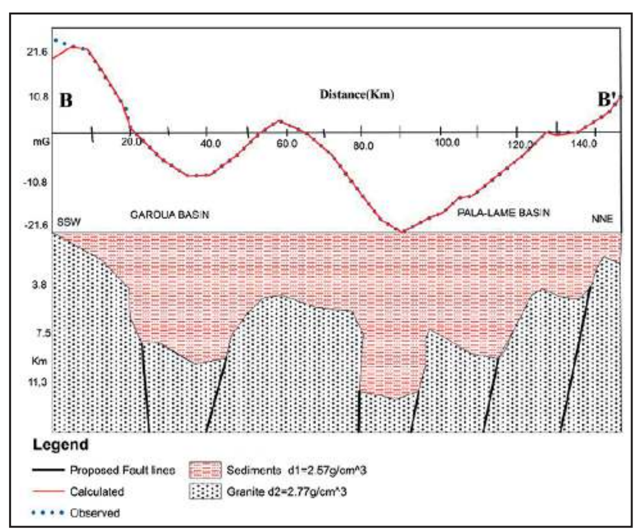

Figure 9 A 2D model of the Garoua Basin along Profile B-B': B-B' is the length of the modeling profile and it runs in a SSW--NNE direction on the study area map. Bottom-left is the investigation depth from 0-15km while top-left is the observed gravity value in mGal as indicated by the dotted blue curve, the red curve is the calculated gravity value obtained by estimating the effect of the density contrast, depth, size and shape of modelling bodies.

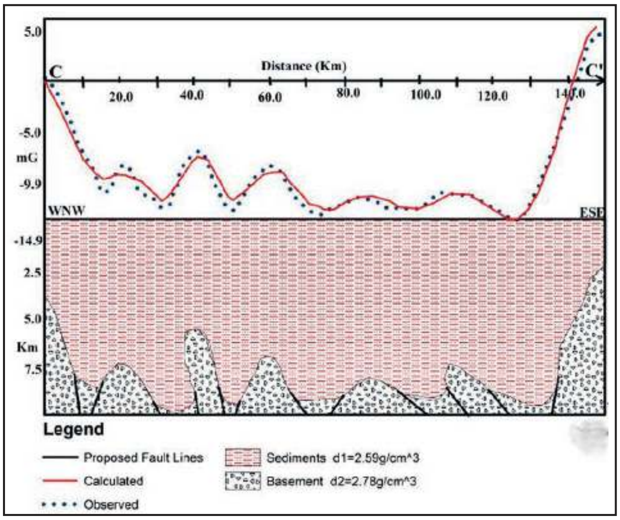

Figure 10 A 2D model of the Garoua Basin along Profile C-C': C-C' is the length of the modeling profile and it runs in a NW-SE direction on the study area map. Bottom-left is the investigation depth from 0-10km while top-left is the observed gravity value in mGal as indicated by the dotted blue curve, the red curve is the calculated gravity value obtained by estimating the effect of the density contrast, depth, size and shape of modelling bodies.

gh Kokoumi and Rey Bouba. The residual anomaly curve associated with the profile is characterized by a low gravity anomaly of approximately -14.9mGal, due to sediment infill. To adjust the computed and the observed curves, two bodies were also enough. The characteristics of the two bodies indicate the geometry of the superposition of the geological units in the subsurface. The first body has a density of d_1= 2.59 g/cm^3 and corresponds to the sediment infill with a variable thickness reaching 9.5km. The second body with a density of d_2 = 2.77 g/cm^3 corresponds to the granite-gneissic basement.

5 Discussion

The Bouguer anomaly map (Figure 4) of the Garoua Basin obtained from gravity data from EGM (2008) is characterized by positive anomalies south and northeast of the study area with the negative anomaly that correspond to the basin axis trending in the NW-SE direction. This map was previously analyzed by Kamguia *et al.* (2005) and Mouzong *et al.* (2014), using land-gravity data as well as by Essi *et al.* (2017) using gravity data from EGM2008. The results obtained in this work reveals the same position and trend of the anomalies as those obtained by those authors. From the results, the Garoua Basin axis is indicated by the negative anomaly running between Kokoumi and Rey Bouba localities. The different shapes of the anomalies obtained by different authors may be attributed to different separation techniques or the nature of the data. Statistical analysis by Essi *et al.* (2017) to compare the gravity data from EGM2008 and land gravity data gives means of −38.25 and −38.21 mGal and a standard deviations of 12.30 and 12.42 respectively. Generally, low gravity anomaly expressions are associated with structural features like grabens while high gravity anomaly are generally associated with structural features like horsts as in the case of the Garoua Basin.

The position of the faults are estimated from the horizontal gradients of the gravity anomaly (Telford *et al*., 2001) and these are reflected by the inflection points on the modeling profiles. The thicker the sedimentary piles, the more interesting the basin. This is because sedimentary piles provide the required temperature for petroleum generation. A sediment density contrast of –0.2g/cm^3 was derived in the model to obtain a sedimentary pile thickness of about 9.0km.

Kamguia *et al.* (2005) used the same density contrast and proposed a sedimentary pile thickness of about 4km. This substantial difference in sedimentary pile thickness may be due to the position of the modeling profiles, because Mouzong *et al.* (2014) calculated a sedimentary pile thickness of between 4 and 8.98km after applying spectral analysis on various negative anomalies. The spectral analysis Mouzong *et al.* (2014) applied on the negative anomaly N3 and N9 correspond to the profile B-B' in the present study and it shows a sediment pile thickness of 8.85km and 8.92km respectively. Seismic Refraction by Dorbath *et al.* (1986), reveals some crustal thinning within Central African shear zone including the Garoua Basin. Poudjom & Diament (1997) and Noutchogwe *et al.* (2006) also inferred, from gravity studies the uplift of the Asthenosphere associated with the abnormal thinning of the crust (24km). This crustal thinning is as a result of lithospheric extension, and the uplift of the Asthenosphere is in response to isostatic compensation (Kamguia *et al.,* 2005). This was also seen in the regional anomaly map of this work as the gravity value decreases from the west towards the east by as much as 70mGal (Figure 5). Although the EGM 2008 data set is of high quality as earlier described, it has limitations that is mainly due to omission errors. This means any gravity-field features with a resolution finer than EGM2008's spatial resolution is omitted and cannot be resolved. For this reason, many localized features in the basin may not be identified on the map. However, the results obtained in this study are compatible with previous findings within the basin by Kamguia *et al.* (2005), Mouzong *et al.* (2014) and Essi *et al.* (2017). The difference in the shape of the regional and residual anomalies may be due to the nature of the data or the separation technique.

EGM2008 data therefore, is recommended for gravity studies in other Cameroon basins which will help highlight possible target areas for seismic surveys.

6 Conclusion

The residual gravity anomaly map of the area shows alternating positive and negative anomaly values. This is associated with the density contrast which occurs between lithologic units. The density contrast when high indicates thehorsts and intrusions while low density contrast are grabens. The grabens are infilled with sedimentary materials. The sedimentary thickness obtained after modeling average 9.0km with a lateral extend of over 80km and the basin is grabe-shaped with a rifted basement.

7 Acknowledgement

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8 References

Adekeye, J.I.D. & Ntekim, E. E. 2007. The Geochemistry and Petrogenesis of Basaltic rocks of the Central part of Yola Basin, Upper Benue Trough, Nigeria. *Continental J. Earth Sciences, 1*(3): 1- 10.

Amante, C. & Eakins, B.W. 2008. *ETOPO1 1 Arc-Minute Global Relief Model: Procedures, Data Sources and Analysis*. National Geophysical Data Center, NESDIS, NOAA, U.S. Department of Commerce, Boulder,CO.

Benkhelil, J. 1988. The origin and evolution of the Cretaceous Benue Trough (Nigeria). *J. Afr. Earth Sci., 8*: 251–282.

Benkhelil, J.; Mascle J. & Guiraud, M. 1998. Sedimentary and structural characteristics of the Cretaceous along the Côte d'Ivoire--Ghana transform margin and in the Benue Trough: a comparison. *Proceedings of the Ocean Drilling Program, Scientific Results, 159*: 93-99.

Bessong, M.; Mbesse, C.O.; Ntsama, A.J.; Hell, J.V.; Abderrazack, E.L.A.; Fontaine, C.; Nolla, J.D.; Dissombo, E.A.N.; Eyong, J.T. & Mvondo, O.F. 2015. Mineralogy and clay minerals distribution in the Benue through, Northern Cameroon (W. Africa): Diagenetic Significance. *International Journal of Applied Research, 1*(11): 1-8.

Bonvalot, S.; Balmino, G.; Briais, A.; Kuhn, M.; Peyrefitte, A.; Vales, N.; Biancale, R. ; Gabalda, G. ; Moreaux, G. ; Reinquin, F. & Sarrailh, M. 2012. The *World gravity Map:* Bureau Gravimetric international.

Cooper, G.R.J. & Cowan, D.R. 2003a. The Shuttle Radar Topography Mission: A new source of near-global digital elevation data. *ASEG Preview, 107*:27–29.

Cooper, G.R.J. & Cowan, D.R. 2003b. The application of fractional calculus to potential field data. *Exploration Geophysics, 34*:51–56.

Cratchley, C.R.; Louis, P. & Ajakaiy, D.E. 1984. Geophysical and geological evidence for the Benue Chad Basin Cretaceous rift valley system and its tectonic implications. *Journal of African Earth Sciences*, *2*(2): 141-150.

Dorbath, L.; Dorbath, C.; Stuart, G.W. & Fairhead, J.D. 1986. A teleseismic delay time study across the central African shear zone in the Adamawa region of Cameroon West Africa. *Geophys. J. R. Astron, 86*: 752-766.

Eyike, A.; Werner, S.C.; Ebbing, J.E. & Dicoum, M. 2010. On the use of global potential field models for regional interpretation of the West and Central African Rift System, *Tectonophysics*, doi:10.1016/j.tecto.2010.04.026.

Essi, J.M.A.; Jean, M.; Atangana, J.Q.Y.; Ahmad, A.D.;,Dassou, E.F.; Mbossi, E.F.; Mvondo, O.J. & Penaye, J. 2017. Interpretation of gravity data derived from the Earth Gravitational Model EGM2008 in the Center-North Cameroon: structural and mining implications. *Arab J Geosci,, 10*: 130(1-13).

Genik,G.J. 1992. Regional framework, structural and petroleum aspects of rift basins in Niger, Chad and the Central African Republic (C.A.R.). *Tectonophysics, 213*: 169-185.

Kamguia, J.; Manguelle-Dicoum, E.; Tabod, C.T. & Tadjou, JM. 2005. Geological models deduced from gravity data in the Garoua basin, *Cameroon. J Geophys Eng, 2:* 147-152.

Maurin, J.C. & Guiraud, R. 1990. Relationships between tectonics and sedimentation in the Barremo Aptian intracontinental basins of Northern Cameroon. *J. Afr. Earth Sci., 10*: 331–40

Mouzong, M.P.; Kamguia, J.; Nguiya, S.; Shandini, Y. & Manguelle--Dicoum, E. 2014. geometrical and structural characterisation of Garoua sedimentary basin, Benue Trough, North Cameroon, using gravity data. *Journal of Biology and Earth Sciences,4*(1): E25-E33.

Noutchogwe, T.C.; Tabod, C.T. & Manguelle-Dicoum, E. 2006 A gravity study of the crust beneath the Adamawa fault zone, West Central Africa. *Journal of Geophysics & Engineering, 3*: 82-89.

Palvis, N.K.; Holmes, S.A.; Kenyon, S.C. & Factor, J.K. 2008. An Earth *Gravitational Model to degree 2160: EGM2008*. General Assembly of the European Geosciences Union,Vienna, Austria.

Poudjom, D.Y.H. & Diament, A. 1997. Lithospheric Lithospheric structure across the Adamawa plateau (Cameroon) from gravity studies. *Tectonophysics, 275*: 317-327

Poudjom, D.Y.H.; Diament, M. & Albouy Y. 1992. Mechanical behaviour f the lithosphere beneath the Adamawa Uplift (Cameroon, West Africa) based on gravity data. *J. Afr. Earth Sci., 15*: 81–90.

Spector, A. & Grant, F.S. 1970. Statistical models for interpreting aeromagnetic data. *Geophysics, 35*:293-302.

Telford, W.N.; Geldart, L.P. & Shriff, R.E. 2001. *Applied Geophysics*, 2nd Edition, Cambridge, 770p.

Uzoegbu, M.U. 2014. Litho-Biostratigraphy and Paleoenvironment of Synclinal Dukul Formation, NE Nigeria. International Journal of Technology Enhancements and Emerging Engineering Research, 2(6): 74-88.

Vatrt, V.; Lubomil, P. & Loule, J.P. 2013. New Technology Going Up from the GP Measurements, Known W_0 and Its Possible Utilization in Praxis. *Scientific Research, 4*(2): Article ID:31527