# Contribution of Satellite Gravity Data in the Geological Study of the Territories of Punia and Lubutu in the Province of Maniema (Democratic Republic of Congo)

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**Abstract:- This paper presents the use of satellite gravity measurements as a tool for the study of the subsurface structure of the province of Maniema, more precisely in the territories of Punia and Lubutu. To do this, we downloaded the satellite gravity data from the WGM2012 model measured by the GRACE (Gravity Recovery and Climate Experiment) satellites on the International Gravimetric Bureau (BGI) platform. Then, we applied the Bouguer correction which allowed us to transform the free-air anomalies that we had into Bouguer anomalies. Thanks to the Magmap extension of the Oasis Montaj software, we were able to extract the residual anomalies by applying a high-pass filter and then calculated the vertical and horizontal gradients. The high intensities of the anomalies throughout the northern and eastern part are probably due to the predominance of high-density granitic rocks while the low intensities of the anomalies in the south are associated with Ruzizian rocks which have a low density compared to the mafic intrusions located at this location. The rapid variations in the residual anomalies testify to an intense shear zone caused by the different tectonic episodes that this area has undergone. This type of anomaly indicates the presence of geological structures that may contain high density mineral substances such as most of the metallic ore deposits found in this area. The circular-shaped positive residual anomalies are also caused by the presence of mafic intrusions (high density substances) which are targets in mining exploration. Following the superposition of mining occurrences on our Bouguer anomaly map, we therefore noted that the majority of mining occurrences are located in areas of positive anomalies. The structural map produced at the end of this study highlighted multiple faults which are of significant mining interest and which will have to be the subject of more detailed geological exploration with the aim of discovering new mining deposits in this zone.**

***Keywords:-*** *Satellite Gravity, Geological Exploration, Maniema, DR Congo.*

## I. INTRODUCTION

The province of Maniema in DR Congo is full of immense mining and mineral resources. Economically, this province has significant mining potential with significant artisanal mining. It is essentially tin ore (cassiterite) and associated elements such as tungsten (wolframite), niobium also known as columbium and tantalum (coltan), located more towards the northern part of the province (UNICEF, 2021). These are the territories of Lubutu and Punia which will be the subject of this study. However, its geophysical database remains insufficient because the first exploration campaigns in the Congo Basin were concentrated in the center of the Basin (in the former provinces of Equateur and Bandundu). This situation is detrimental to the promotion of the said province with a view to exploiting its natural resources.

Faced with this state of affairs, we turned to the use of satellite gravity measurements as a mapping tool that could allow us to improve the geological knowledge of this region. With the help of computer software, we can easily scan, manipulate, analyze and interpret these satellite data in order to extract reliable geological information and provide good knowledge of the spatial distribution of these resources. Through this study, we are drawing up a first structural map of this area which can provide advice to other expertise in this area during the acquisition of much more detailed geoscience data.

## II. MATERIALS ET METHOD

- *The Method used to Carry out this Study can be Summarized in Three Steps:*

- *Literature Review:*

We consulted books and documents relating to satellite geophysical imagery as well as the geological and tectonic aspects of our study area;

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- *Data Processing:*

At this stage, we transformed the free-air anomalies into Bouguer anomalies by applying the Bouguer correction. We also applied transformation operators such as regional-residual separation, as well as horizontal and vertical derivatives. This is with the aim of better understanding the spatial variations in rock density in order to improve knowledge of the structural geology of the study area;

- *Interpretation of the Results:*

Here, using the maps developed, we proceeded to identify multiple gravity signatures which can be associated with geological structures of economic interest. In other words, it was a question of giving a geological meaning to the anomalies detected on the geophysical maps produced.

As part of this work, the downloading, the processing and the mapping of data as well as interpretation of the results were carried out using software such as ArcGIS 10.8, Surfer 21, Oasis Montaj 8.4.

## III. GENERAL OVERVIEW OF THE STUDY AREA

➢ *Presentation of the Province of Maniema*

Located almost in the center of the DR Congo, the province of Maniema covers an area of 132,250 km² or 5.6% of the total area of the country. It is limited to the north by the Orientale Province, to the south by Katanga, to the east by South Kivu and North Kivu and to the west by Kasaï Oriental. In 2005, it had nearly 1.6 million inhabitants, or 2.9% of the national population. Its urban population represents 1.1% of the urban area of the DR Congo. The density is low (12 inhabitants/km²) compared to the national average (24 inhabitants/km²).

Maniema is characterized by a hot and humid climate which evolves from the equatorial type in the North to the Sudanian type in the South, passing through a transition zone in the Center. The average temperature is 25°C. Two large plant formations cover Maniema: the dense humid forest in the North which occupies three quarters of the province and the savannah in the South. The province of Maniema is very rich in rivers. It is crossed from South to North by the Congo River which drains the waters of several tributaries. Administratively, the province of Maniema includes 1 city subdivided into 3 communes and 7 territories subdivided into 21 sectors and chiefdoms. Finally, the Maniema Province is populated only by Bantu people made up of three ethnic groups (UNDP, 2009 [1]).

This province is three quarters occupied by forest and contains enormous potential for the development of the population. Forest products are numerous and varied. In particular, forest species are well identified but until now have been exploited in an artisanal manner. Maniema also contains 24 natural forest reserves, some of which have already been invaded by the population. The province has a National Park (Lomami), nature reserves and tourist sites. But tourism is very little developed due to lack of infrastructure. Agriculture remains the main activity of the province. Despite the favorable conditions for intensive and diversified agriculture, the population mainly practices traditional cultivation of staple foods such as rice, plantains, corn and cassava. Finally, in recent years, the working population has become increasingly interested in commerce, which is experiencing strong expansion.

➢ *Description of the Study Area*

Located in the north of the province of Maniema precisely in the territories of Punia in the South and Lubutu in the North, our study area is located on the eastern edge of the Congo Basin. The area is approximately 1,613 km². Figure 1 below shows the location of the study area.

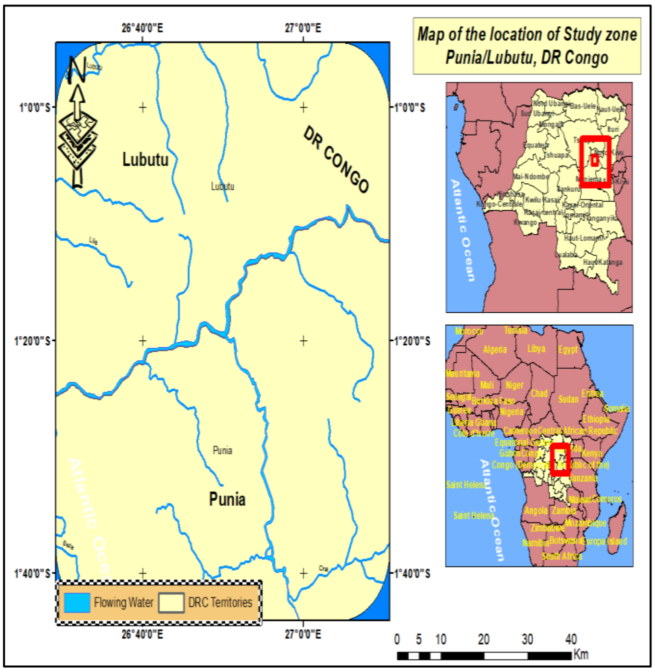



Fig 1 Location Map of the Study Area

This region is entirely watered by the Lowa River which divides our study area into two parts: the northern part in the territory of Lubutu and the southern part located in the territory of Punia. The area is also watered by numerous rivers constituting tributaries of the large Lowa River.

- *The Geographical Coordinates of the Tops of the Zone are Shown in Table 1 Below.*

Table 1 Geographic Coordinates of the Tops of the Study Area

| Sommets | Longitude (D°M'S'') | Latitude (D°M'S'') |
|---|---|---|
| Upper Left | 26°39'11"E | 01°08'08"S |
| Upper Right | 27°00'35"E | 01°08'08"S |
| Lower Right | 27°00'35"E | 01°30'04"S |
| Lower Left | 26°39'11"E | 01°30'04"S |

The area is located south of the equator and has a humid tropical climate with alternating seasons. Regarding vegetation, the area is dominated by dense humid forest as shown in the satellite image (fig. 2) below.

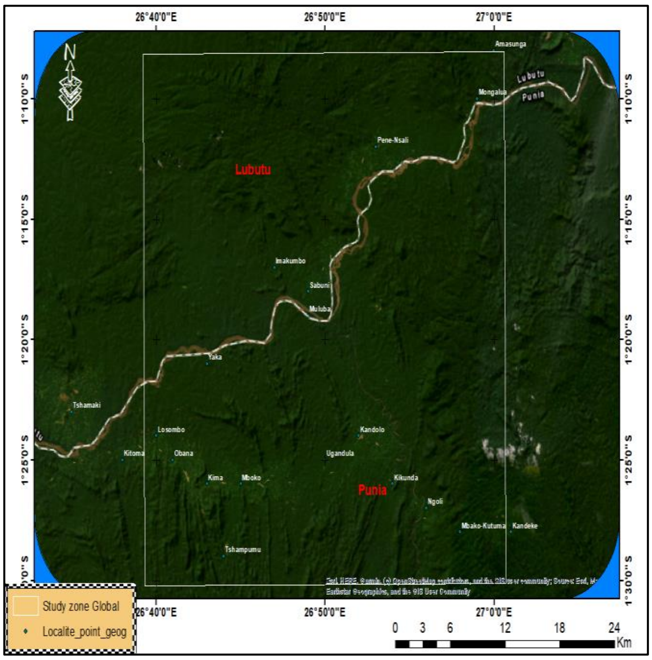



Fig 2 Aerial View of the Study Area

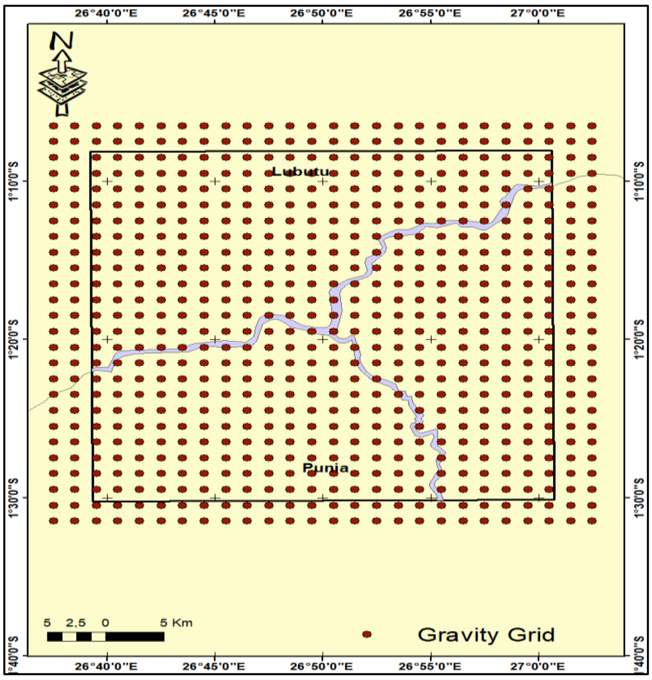



Fig 3 Grid Map of Downloaded Satellite Gravity Data

Economically, the province of Maniema has significant mining potential with significant artisanal mining east of the Congo River. It is essentially tin ore (cassiterite) and associated elements such as tungsten (wolframite), niobium also known as columbium and tantalum (coltan), located more towards the northern part of the province (Lubutu, Punia, Kasese, Kailo, Kalima), as well as gold in sites located mainly in the southern part (Kama, Bikenge, Salamabila/Namoya, Kabambare). Some diamond mining is reported west of the Congo River, in Phanerozoic terrains in the Bahina chiefdom in Kibombo, as well as in Amilulu north of Lubutu (UNICEF, 2021 [2]).

## IV. PRESENTATION OF SATELLITE GRAVITY DATA

Between 1952 and 1956 the 'Société de Recherche Minière en Afrique' (REMINA) carried out a combined gravity and magnetic campaign in the Congo Basin. However, the high density of these data is concentrated in the former provinces of Equateur and Bandundu. In our study area, we note an absence of terrestrial or airborne gravity or magnetic data. This is how we downloaded the satellite gravity data from the International Gravimetric Bureau (BGI) platform. The latter is a service of the Council of Astronomical and Geophysical Services (CAGS) directly dependent on the ICSU (International Council of Scientific Unions) and UNESCO. Installed since its creation (1951) in France, it has been hosted by the Midi-pyrénées Observatory / Mixed Research Unit 5562 (OMP/UMR), since 1981. The BGI's mission is to store and make available the international scientific community all the gravimetric data acquired throughout the world (Boualem BOUYAHIAOUI, 2010 [3]).

The satellite gravity data downloaded are defined by Word Gravity Model (WGM) 2012 to have a regular grid covering entirely the study area (fig. 3).

The WGM2012 gravity anomalies are derived from the available terrestrial global gravity models EGM2008 and DTU10 and include 1'x1' resolution terrain corrections derived from the ETOPO1 model which take into account the contribution of most surface masses (atmosphere, land, oceans, inland seas, lakes, ice sheets) and ice shelves) (BGI, 2020 [4]).

The official Earth Gravitational Models (EGM2008) has been released publicly by the EGM development team at the National Geospatial-Intelligence Agency (NGA). Among other new data sources, the GRACE satellite mission provided a very high-resolution model of global gravity.

- *Characteristics of GRACE (Gravity Recovery and Climate Experiment) Satellites*

GRACE is a cooperative mission between USA and Germany to better the earth's gravity over time. According to NASA this the mission was carried to better understand the oceanic mass changes, monitor how snow and other resources of water changed with time and most importantly to obtain the gravity data with better accuracy for a long period of time. This mission was led by Dr. Byron Tapley from The University of Texas Center for Space Research (UTCSR) as principal investigator and Frank Flechtner as a co-principal investigator from Jet Propulsion Laboratory.

GRACE mission consists of two satellites that work based on GPS and microwave ranging system. They appear to come close together when there is no change in the gravity field on the surface of the earth but far away when there is a sudden change in the gravity field. This mechanism gives GRACE a lot of precise measurements about the gravity field of the earth (Ashish Pandey, 2021 [5]). These satellites were designed to be in space and collecting data for about five years which was launched in

2002 but they are expected to continue for a long period of time. These data would help visualize the change in the mass system on the earth which would give changes in the earth's gravity due to mass difference. Now there has been a lot of applications and analysis based on the data this mission acquired (fig. 4).

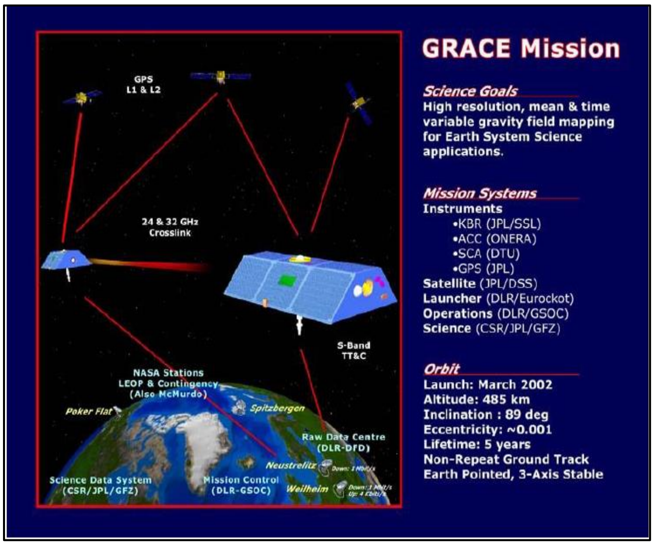


Fig 4 Flight Configuration GRACE Mission
(Image Credit: The University of Texas Center for Space Research (UTCSR)).

## V. DATA PROCESSING

The geological interpretation of satellite gravity anomalies is facilitated by the application of mathematical corrections and filters. The various operations that we used to carry out this study are detailed in the following points.

➤ *Calculation of Bouguer Anomalies*

We applied the Bouguer correction which allowed us to transform the free-air anomalies that we have into Bouguer anomalies. This correction aims to remove for the continents the effect of the rock masses located above the ellipsoid due to their density being much greater than that of the air. In the calculation of the free-air anomalies, the material which constitutes the relief is not taken into account; the Bouguer correction aims to correct this situation and assumes that this space is, in the continental domains, replaced by air in place of a material with density $\rho = 2.67\ g/cm^3$ (representing the average densities for rocks of this type of crust) (Pierre P., Dunod. 2008 [6]).

By definition, the free-air anomaly $A_{al}$ is the difference between the measured value $g_m$ at a given altitude $h$ (counted positively upwards) and the theoretical value $g_0$ modified taking into account the free-air correction $(\Delta h)$ :

$$A_{al} = g_m - g_0 + \Delta h = g_m - g_0 + 0.3086h\# \quad (1)$$

With $\Delta h = 0.3086h\ mgal/m$ and $h$ = the altitude of the measurement point. So $\Delta h$ is positive if we are above the reference level and negative if we are below it (Michel Chouteau, 2002 [7]).

By definition, the complete Bouguer anomaly $A_{BC}$ will be the difference between the measured value $g_m$ at a given altitude $h$ and the theoretical value $g_0$ modified to take into account the free-air correction $(\Delta h)$, the Bouguer correction $(\Delta p)$ and Terrain corrections $(\Delta T)$:

$$A_{BC} = g_m - g_0 + \Delta h - \Delta p + \Delta T = g_m - g_0 + 0.3086h - 0.0419\rho h + \Delta T\# \quad (2)$$

With $\Delta p = -0.0419\rho h\ mgal/m$, $\rho = 2.67\ g/cm^3$. Note that the Terrain corrections $(\Delta T)$ are always positive (J. Dubois et al., 2011 [8]).

The Oasis Montaj software allowed us to automatically calculate the Bouguer anomalies via its "GX - Gravity" extension (fig. 5).

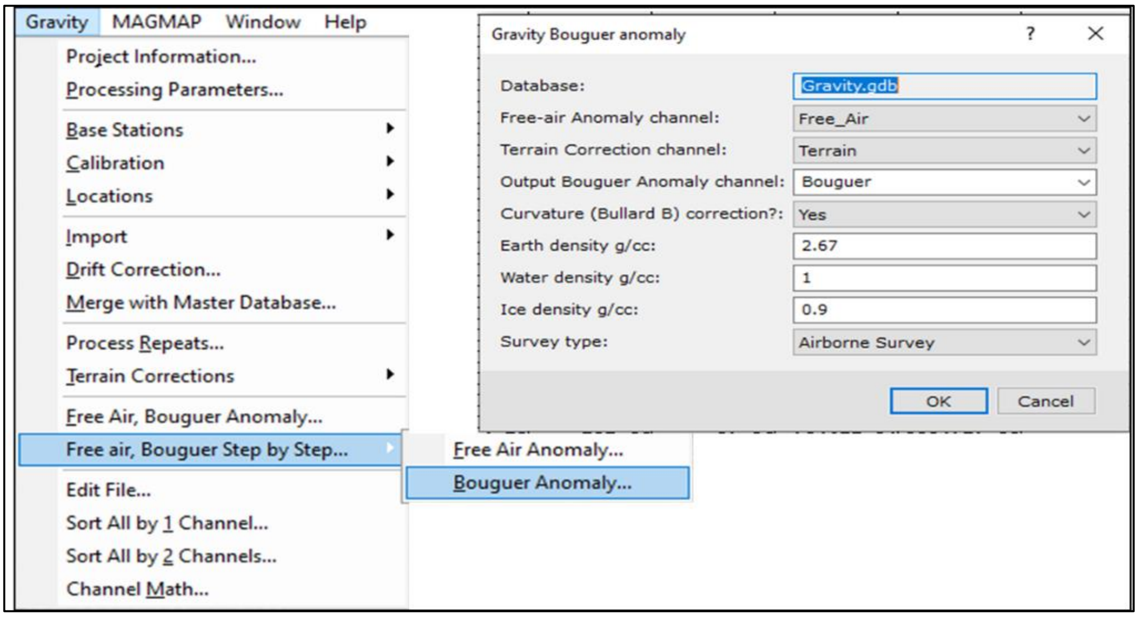
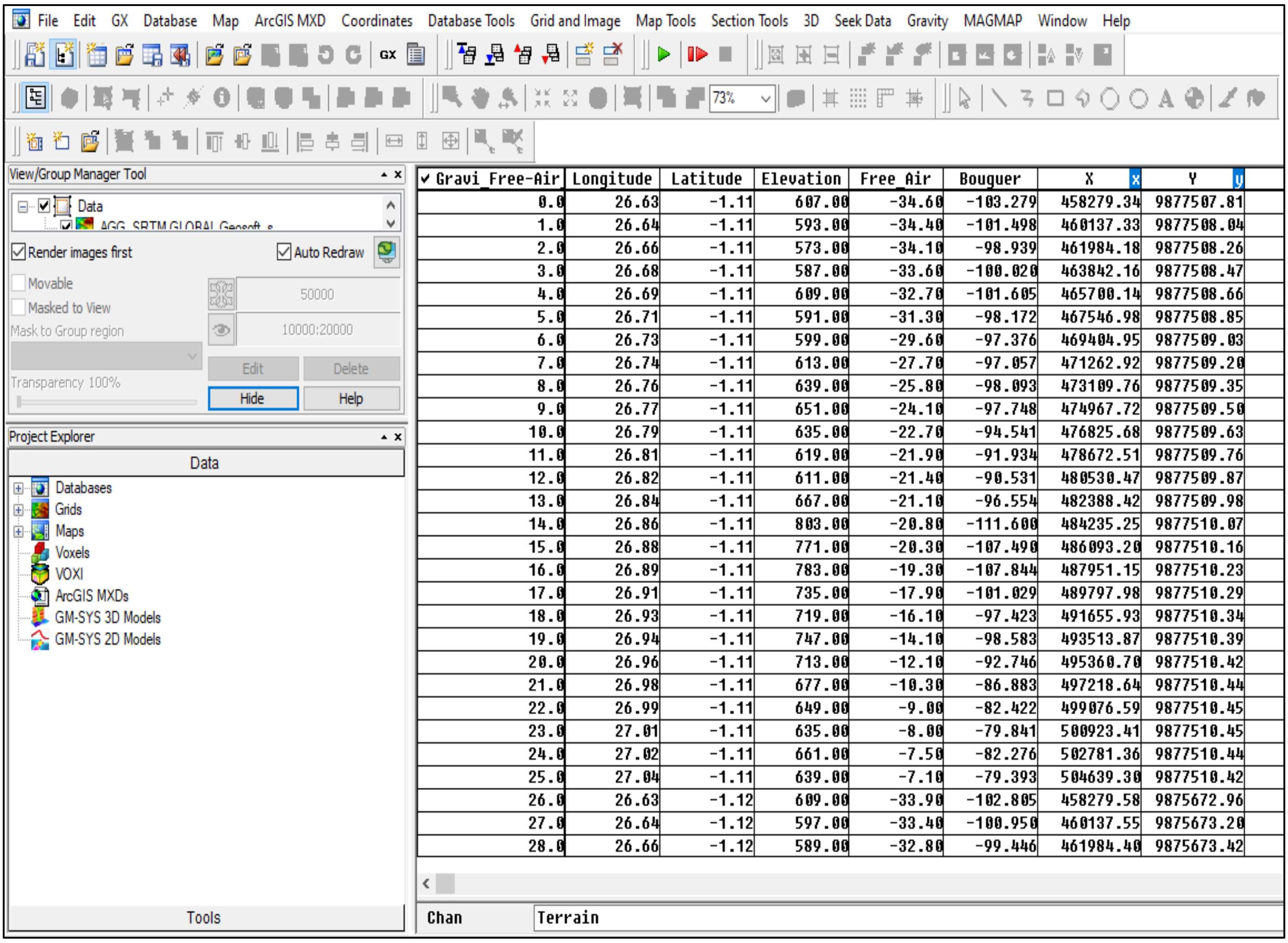


Fig 5 Calculation of the Bouguer Anomaly with the "GX - Gravity" Extension of the Oasis Montaj Software

- *Figure 6 below Shows us Visualization of the Results (Bouguer Anomalies) Obtained after Applying the above Operation.*



| ✓ Gravi_Free-Air | Longitude | Latitude | Elevation | Free_Air | Bouguer | X | Y |
|---|---|---|---|---|---|---|---|
| 0.0 | 26.63 | -1.11 | 607.00 | -34.60 | -103.279 | 458279.34 | 9877507.81 |
| 1.0 | 26.64 | -1.11 | 593.00 | -34.40 | -101.498 | 460137.33 | 9877508.04 |
| 2.0 | 26.66 | -1.11 | 573.00 | -34.10 | -98.939 | 461984.18 | 9877508.26 |
| 3.0 | 26.68 | -1.11 | 587.00 | -33.60 | -100.020 | 463842.16 | 9877508.47 |
| 4.0 | 26.69 | -1.11 | 609.00 | -32.70 | -101.605 | 465700.14 | 9877508.66 |
| 5.0 | 26.71 | -1.11 | 591.00 | -31.30 | -98.172 | 467546.98 | 9877508.85 |
| 6.0 | 26.73 | -1.11 | 599.00 | -29.60 | -97.376 | 469404.95 | 9877509.03 |
| 7.0 | 26.74 | -1.11 | 613.00 | -27.70 | -97.057 | 471262.92 | 9877509.20 |
| 8.0 | 26.76 | -1.11 | 639.00 | -25.80 | -98.093 | 473109.76 | 9877509.35 |
| 9.0 | 26.77 | -1.11 | 651.00 | -24.10 | -97.748 | 474967.72 | 9877509.50 |
| 10.0 | 26.79 | -1.11 | 635.00 | -22.70 | -94.541 | 476825.68 | 9877509.63 |
| 11.0 | 26.81 | -1.11 | 619.00 | -21.90 | -91.934 | 478672.51 | 9877509.76 |
| 12.0 | 26.82 | -1.11 | 611.00 | -21.40 | -90.531 | 480530.47 | 9877509.87 |
| 13.0 | 26.84 | -1.11 | 667.00 | -21.10 | -96.554 | 482388.42 | 9877509.98 |
| 14.0 | 26.86 | -1.11 | 803.00 | -20.80 | -111.600 | 484235.25 | 9877510.07 |
| 15.0 | 26.88 | -1.11 | 771.00 | -20.30 | -107.490 | 486093.20 | 9877510.16 |
| 16.0 | 26.89 | -1.11 | 783.00 | -19.30 | -107.844 | 487951.15 | 9877510.23 |
| 17.0 | 26.91 | -1.11 | 735.00 | -17.90 | -101.029 | 489797.98 | 9877510.29 |
| 18.0 | 26.93 | -1.11 | 719.00 | -16.10 | -97.423 | 491655.93 | 9877510.34 |
| 19.0 | 26.94 | -1.11 | 747.00 | -14.10 | -98.583 | 493513.87 | 9877510.39 |
| 20.0 | 26.96 | -1.11 | 713.00 | -12.10 | -92.746 | 495360.70 | 9877510.42 |
| 21.0 | 26.98 | -1.11 | 677.00 | -10.30 | -86.883 | 497218.64 | 9877510.44 |
| 22.0 | 26.99 | -1.11 | 649.00 | -9.00 | -82.422 | 499076.59 | 9877510.45 |
| 23.0 | 27.01 | -1.11 | 635.00 | -8.00 | -79.841 | 500923.41 | 9877510.45 |
| 24.0 | 27.02 | -1.11 | 661.00 | -7.50 | -82.276 | 502781.36 | 9877510.44 |
| 25.0 | 27.04 | -1.11 | 639.00 | -7.10 | -79.393 | 504639.30 | 9877510.42 |
| 26.0 | 26.63 | -1.12 | 609.00 | -33.90 | -102.805 | 458279.58 | 9875672.96 |
| 27.0 | 26.64 | -1.12 | 597.00 | -33.40 | -100.950 | 460137.55 | 9875673.20 |
| 28.0 | 26.66 | -1.12 | 589.00 | -32.80 | -99.446 | 461984.40 | 9875673.42 |

Chan Terrain

Fig 6 Results Obtained after Calculating the Bouguer Anomaly in the Oasis Montaj Software

➢ *Regional-Residual Separation Method*

For this procedure, frequency filters were applied to the Bouguer anomaly data. The high-pass filter attenuated low-frequency anomalies and enhanced high-frequency anomalies. This operation was made possible thanks to the MAGMAP filtering extension of the Oasis Montaj software.

➢ *Vertical And Horizontal Derivatives*

These mathematical filters, which are also found in the MAGMAP filtering extension of the Oasis Montaj software, respectively make it possible to identify lineaments (faults or contacts) and to better understand the position of the bodies which create the anomalies located near the surface.

## VI. RESULTS AND DISCUSSIONS

In gravity prospecting, as in any other geophysical investigation, it is obligatory to present the results obtained in the form of maps. This is to facilitate the visualization and interpretation of the variation of the calculated and/or measured geophysical parameter. It is with this in mind that we have presented the results of the processing mentioned above clearly on maps. It was therefore essential for us to convert the downloaded satellite gravity data into a grid by choosing the appropriate interpolation method to better map them. The interpolation method chosen is kriging because it allows the exact interpolation of the data (point estimation) and the smoothing property which implies that the estimated values are less dispersed than the known true values.

The Bouguer Anomaly map was drawn automatically, using the interpolation method, with a choice of an average density equal to 2.67 g/cm$^3$ (average density of the crust). This map is shown with a contour equidistance of 0.5 mGals. Depending on the intensity of the anomalies, we see on the Bouguer anomaly map (fig. 7) that the south of our study area is dominated by low anomaly intensities varying between -104 mGals and -76 mGals (blue color) precisely in the territory of Punia. However, we note that the northeastern part of this zone is characterized by high values of Bouguer anomalies (-94 to -76 mGals).

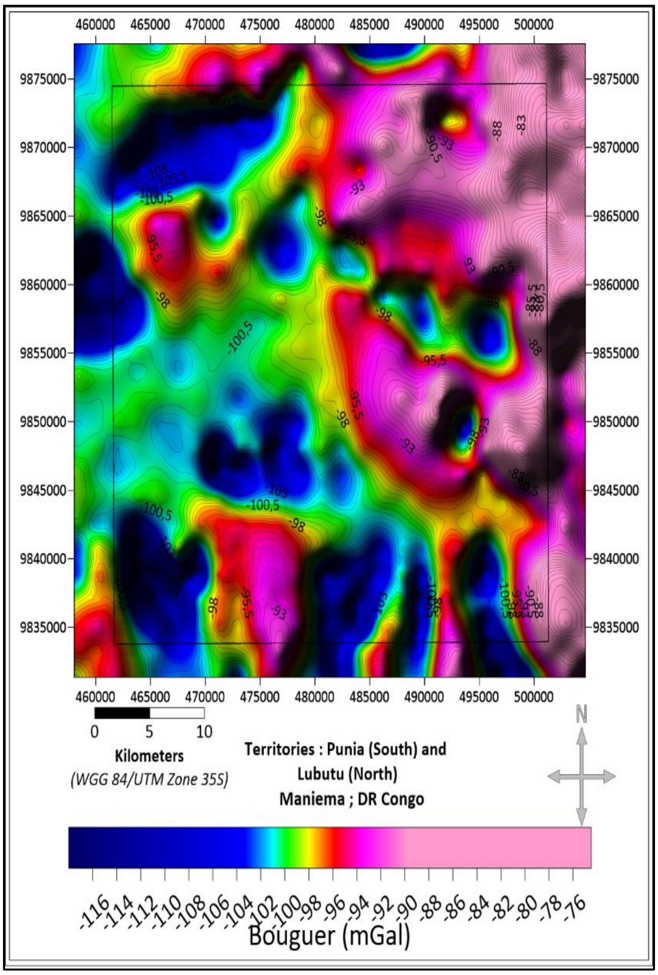



Fig 7 Bouguer Anomaly Map

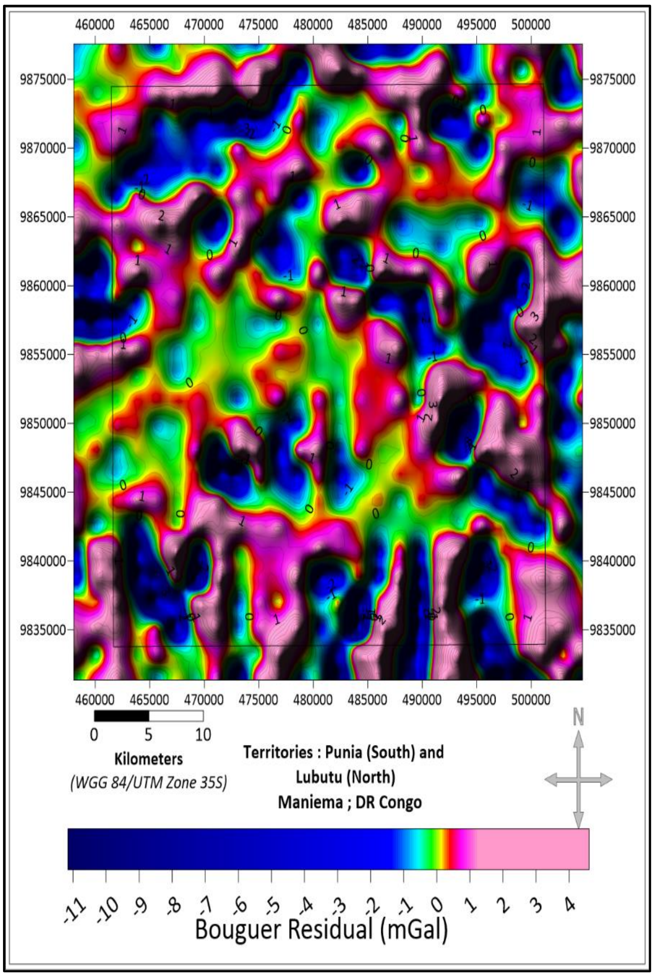



Fig 8 Residual Bouguer Anomaly Map

➢ *The Bouguer Anomaly Map above Reveals the Following Geological Information:*

- The high intensities of the anomalies throughout the northern and eastern parts are probably due to the predominance of high density granitic magmatic rocks;
- The low intensities of the anomalies in the South are associated with the predominance of Ruzizian rocks which certainly have a low density compared to the mafic intrusions found at this location;
- This map also highlights areas of tightening of the iso-anomaly curves which can be interpreted as being contacts between materials of different densities or faults.

Remember that the sources generating residual low wavelength anomalies are generally superficial geological structures. The residual anomaly map was therefore obtained by differentiating between the Bouguer anomaly and the regional anomaly. Depending on the intensity of the anomalies, we observe low amplitude anomalies with rapid lateral variation (fig. 7).

This area of the Maniema province is full of important mineral resources such as gold, tin, tungsten, etc. (MRAC, 2005 [9]). Variations in anomalies result from the difference in density, or density contrast, between a rock body and its surroundings. The sign of the density contrast determines the sign of the gravity anomaly (Philip Kearey, 2002 [10]). On this map we note the presence of abrupt variations in residual anomalies, a phenomenon which testifies to an intense shear zone caused by the different tectonic episodes that this area has undergone. Note also the attenuation of the vast anomalies observed on the Bouguer anomaly map. This type of positive anomalies indicates the presence of geological structures containing high density mineral substances such as most of the metallic ore deposits found in this area. The orientation of these structures is NW-SE, NE-SW and N-S. Note also that the high intensities of the quasi-circular shaped anomalies in this area are probably due to the predominance of mafic intrusions (high density substances) which are good targets in mining exploration. Negative anomalies, for their part, reveal the presence of synclinal structures, uplifts of low-density sedimentary rocks which create a negative contrast with the magmatic rocks of the environment.

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The vertical derivatives of the gravity anomalies accentuate the effects of superficial sources compared to deep sources. The map of the first vertical derivative (fig. 9) makes it possible to highlight the tectonic accidents and contacts in the superficial part of the earth's crust. We observe on this map, a series of positive and negative axes in an essentially N-S direction in the southern part.

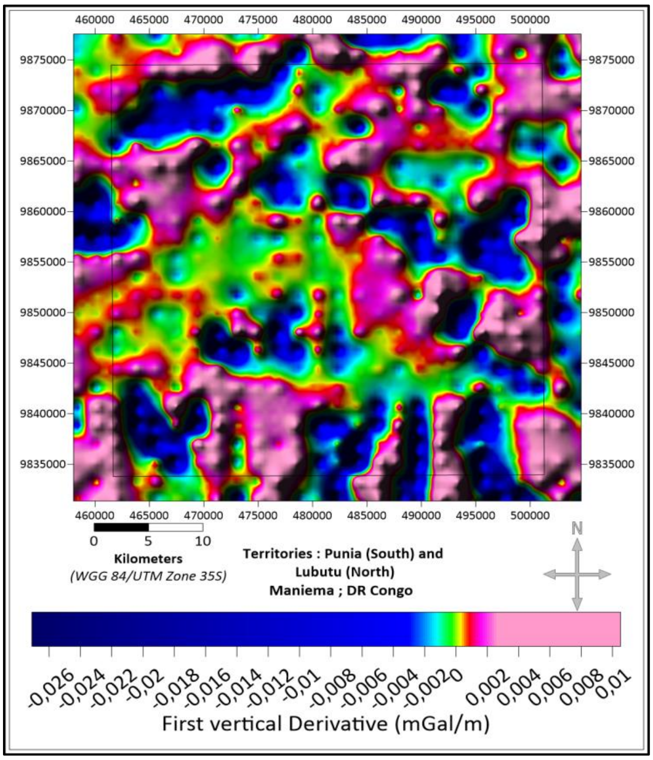


Fig 9 First Vertical Derivative Map

Calculating vertical derivatives helps attenuate long wavelengths and significantly improves the resolution of smaller anomalies located near the surface. The application of this filter on the Bouguer anomaly map amplified the effect of superficial sources by attenuating the effect of deep sources and made it possible to better identify the geometric limits of the bodies. The vertical derivative map shows us small local disturbances of the gravitational field which are secondary in size but essential in the study of geological structures. The sources generating this type of anomalies are generally shallow geological structures (mineral deposits, superficial faults, folds, salt domes, cavities, magmatic intrusions, etc.).

The maps of the horizontal derivatives as a function of x and of y make it possible to better identify contacts between two environments of different densities, hence the importance of the application of these horizontal derivatives in the detection of faults in our study area (fig. 10 a and b).

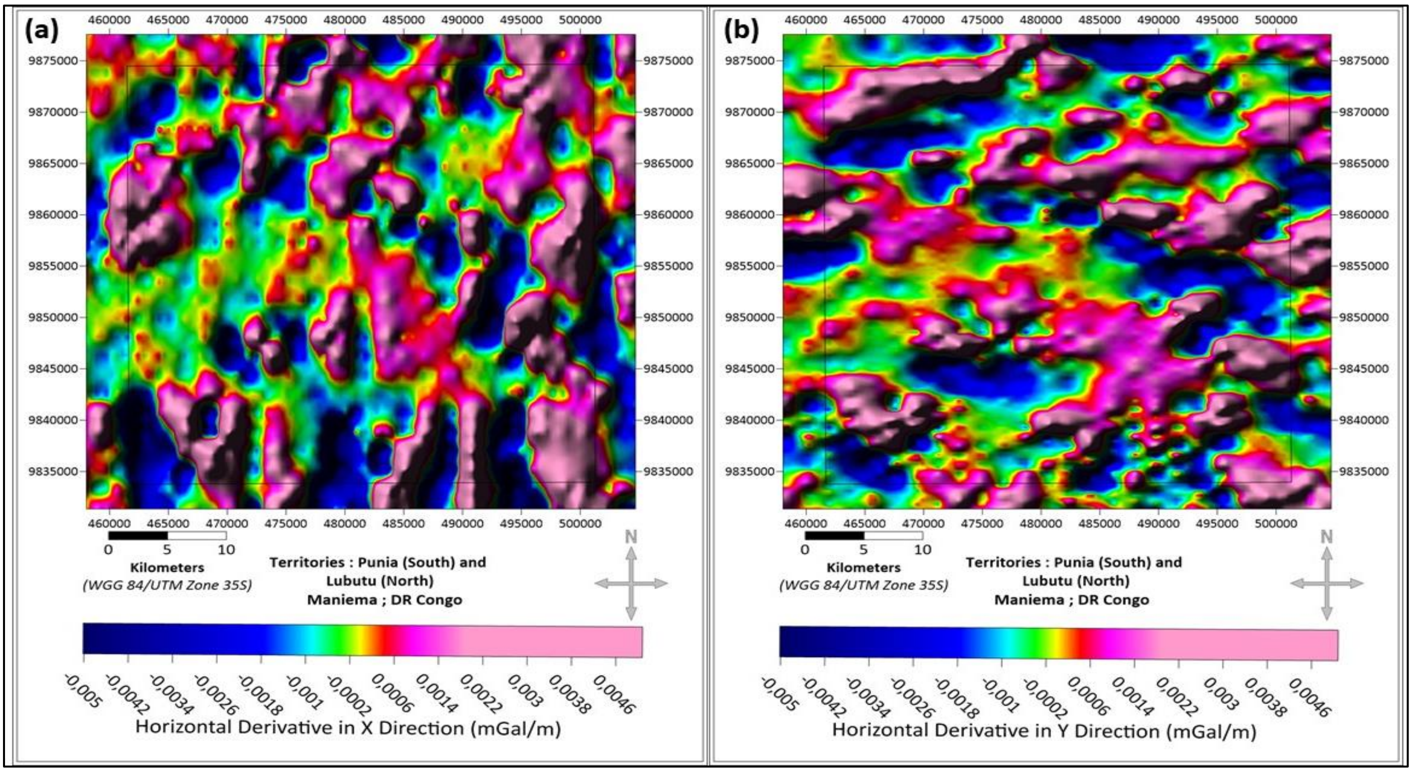


Fig 10 (a) Horizontal Derivative in X Direction; (b) Horizontal Derivative in Y Direction

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On these two maps we note that, although the application of a filter in a given direction makes it possible to locate faults or contacts oriented in all directions, we must point out that their preferential direction very often remains perpendicular to the direction of the filter applied: the horizontal derivative as a function of X (90°; E-W) will detect faults or contacts preferably oriented in the direction of Y (0°; N-S) and vice versa. The maxima and minima of the anomalies identified on the two horizontal derivative maps are areas of density contrast that can be considered as faults or contacts. The visual analysis of the maps above allows us to vectorize the gravity axes revealing the presence of several major tectonic accidents such as faults or lateral lithological contacts.

Our study area is located in the eastern edge of the Congo Basin, more precisely in the province of Maniema which is known for its mineralization indices of gold, cassiterite, amblygonite, clays, copper, diamond, iron, kaolin, manganese, columbo-tantalite, lead, talc, wolfram, copper and cobalt according to the Cellule Technique de Coordination et de Planification Minière (CTCPM, 2003 [11]). We have superimposed these mining occurrences on our Bouguer anomaly map (fig. 11).

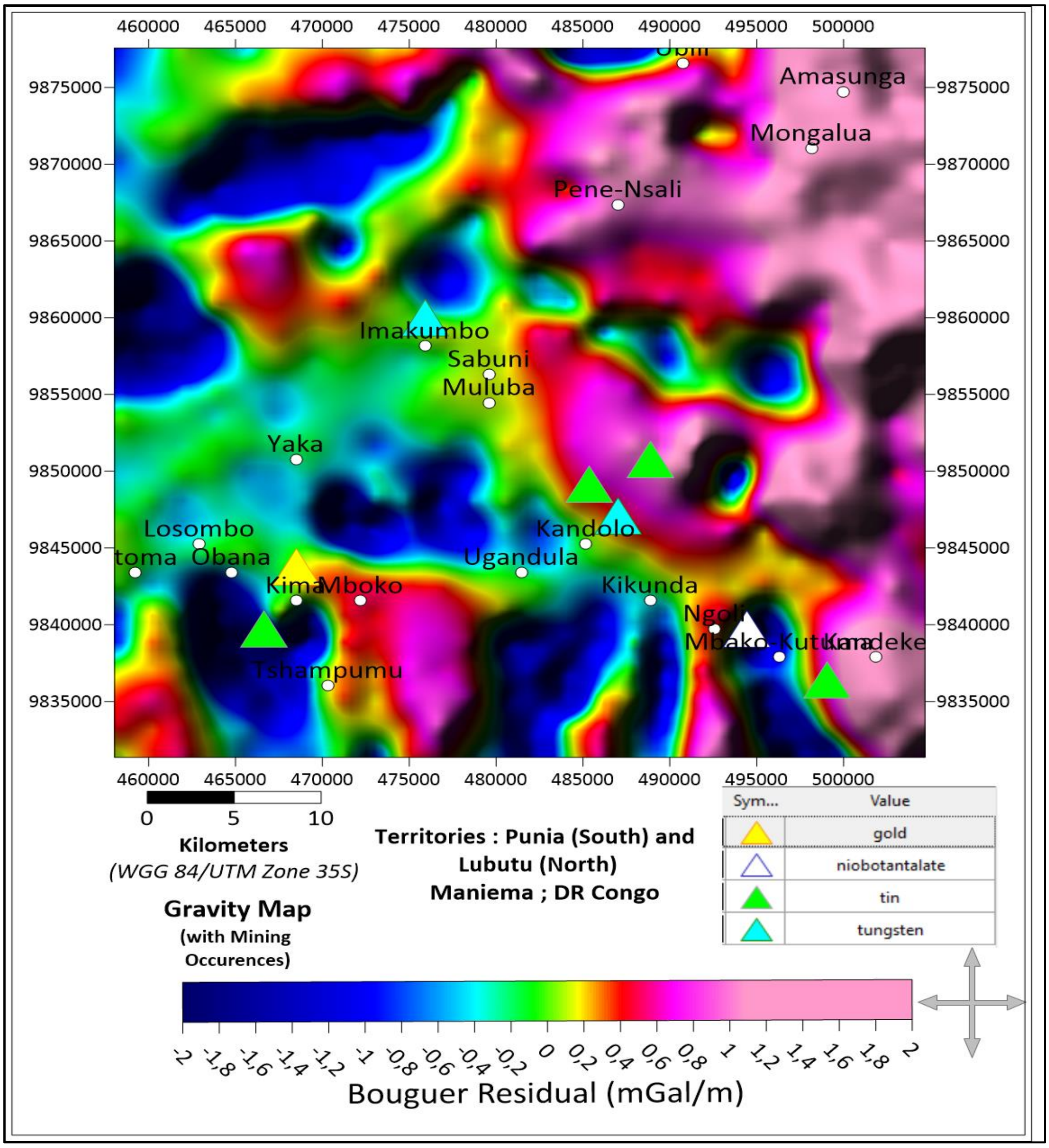


Fig 11 Mining Occurrences Superimposed the Bouguer Anomaly Map

The Bouguer anomaly map represents the variation in densities of geological formations. Igneous and/or metamorphic rocks being much denser than the sedimentary rocks, we often consider that the density contrasts are therefore due to the presence of these crystalline rocks. Sedimentary formations can also induce variations in density which must be taken into account during interpretation. We therefore note that the majority of mining occurrences are located in areas of positive anomalies.

The interpretation of gravity maps, in particular those of the vertical and horizontal gradients, allowed us to establish a structural map on which all the lineaments highlighted by the different processing methods were represented (fig. 12).

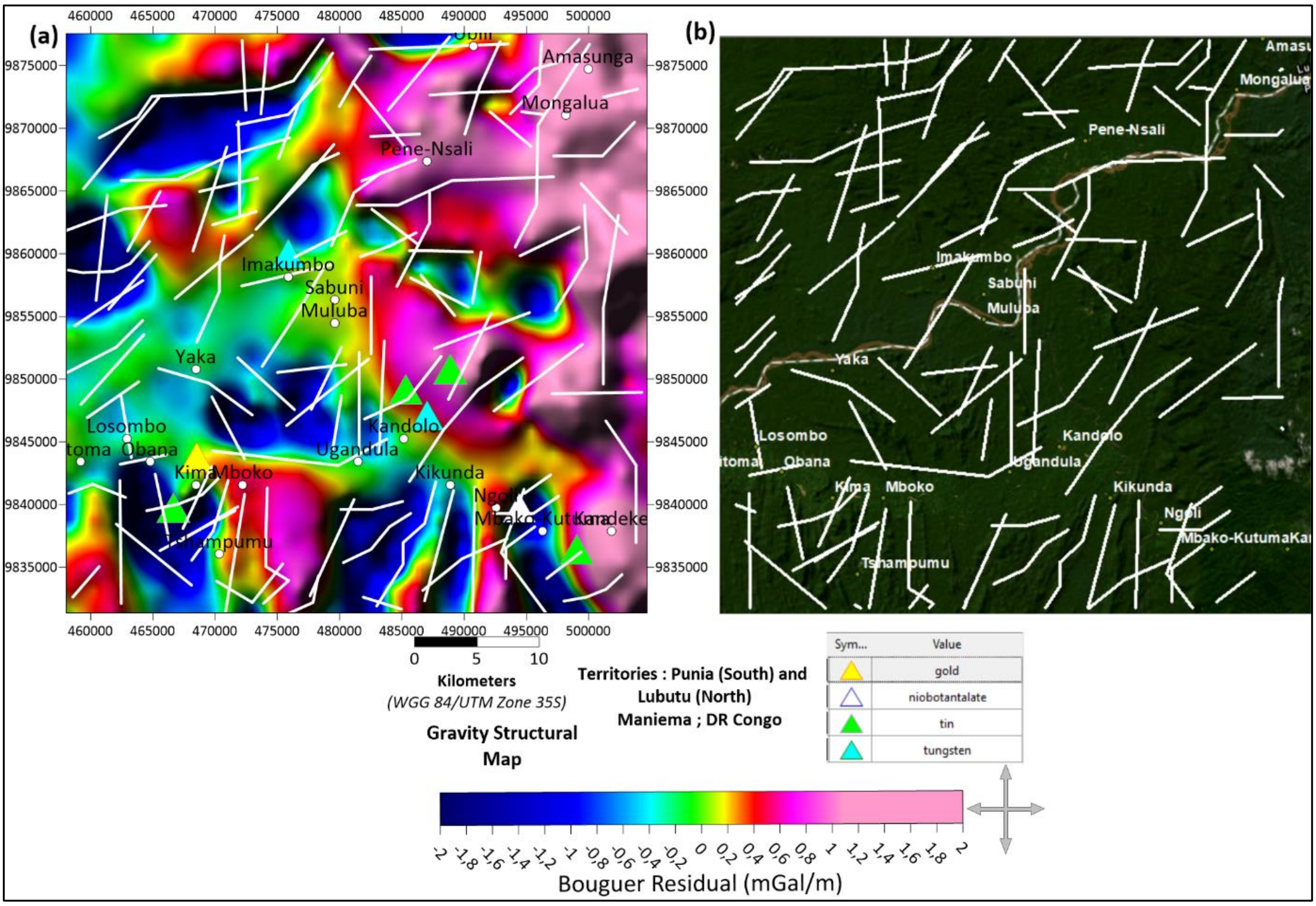

Fig 12 Structural Map of our Study Area. (a) on Bouguer Anomalies; (b) on the Satellite Image

On these maps we manually traced the faults on the areas of strong gradient of Bouguer anomalies enhanced on the vertical and horizontal derivative maps. The application of these filters made it possible to highlight several faults in our study area, the latter falling within the tectonic and structural framework of the Ruzizi Supergroup (RU). The Ruzizian geological formations are considered the NW extension of the Ubendian range of Tanzania. These formations have undergone high degree metamorphism and are formed of micaschists, paragneisses, quartzites and amphibolites with a preferential NW-SE orientation with moderately steep dips towards the NE.

The phases of early compression and deformation being characterized by major NW-SE dextral shear zones as well as that of the Neoproterozoic marked by the development of sinistral brittle-ductile strike-slip faults (Mashauri NDABAGA, 2017 [12]) largely contributed to the generation of several faults in our study area, which explains the presence of multiple faults enhanced by the directional filtering of anomalies.

We saw above that the sign of the density contrast determines the sign of the gravity anomaly. Most metallic ores have very high densities compared to other geological substances in their environment (H.O Seigel, 1995 [13]), gravity method is therefore very often used to detect geological structures that may contain this type of ore. Thus, the identified faults in this area are of significant mining interest and will need to be the subject of detailed geological exploration with the aim of discovering new ore deposits in this area.

## VII. CONCLUSION

The use of satellite gravity data as a mapping tool can allow us to improve the geological knowledge of this region. The Bouguer anomaly maps associated with vertical and horizontal derivatives maps produced reveal the following geological information:

- The high intensities of the anomalies throughout the northern and eastern part are probably due to the predominance of high-density igneous rocks while the low intensities of the anomalies in the south are associated with Ruzizian rocks which have a low density compared to the mafic intrusions found at this location;
- The abrupt variations in the residual anomalies testify to an intense shear zone caused by the different tectonic episodes that this area has undergone. These anomalies indicate the presence of geological structures that may contain high density mineral substances such as most of the metallic ore deposits found in this area;
- The circular-shaped positive residual anomalies are also caused by the presence of mafic intrusions (high density substances) which are good targets in mining

exploration. Note also that the high intensities of the quasi-circular shaped anomalies in this area are probably due to the predominance of mafic volcanic intrusions (high density substances) which are good targets for mining exploration;

- The analysis of the spatial variation of Bouguer anomalies associated with mining occurrences in this region shows us that the majority of these mining indices are located in areas of positive anomalies.

The phases of early compression and deformation being characterized by major NW-SE dextral shear zones as well as that of the Neoproterozoic marked by the development of sinistral brittle-ductile strike-slip faults have largely contributed to the generation of several faults in our study area, which explains the presence of multiple faults enhanced by the directional filtering of anomalies. Thus, the mapped faults in this area are of significant mining interest and will require detailed geological exploration with the aim of discovering new ore deposits in this area.

In order to have much more reliable geological, structural but also geomorphological information, we recommend that a remote sensing study using multispectral or hyperspectral satellite images (Landsat, SPOT, etc.) as well as radar satellite images (SRTM, ASTER) precedes a field campaign. For risk mitigation, we believe that by multiplying field campaigns (geological and geochemical surveys) and by reducing the grid size of aerogravity and aeromagnetic investigations in areas of interest, we would be able to properly locate prospects and make their ranking.

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