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Mineral Exploration of the Former Province of Kasaï-Occidental through the Analysis of Land and Satellite Gravity Data

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Abstract:- This paper is based on the application of terrestrial and satellite gravimetry in mining and petroleum research in the former province of Kasai-Occidental in the Democratic Republic of Congo. This former province was split into two new provinces: Kasaï and Kasaï-Central. From a geological point of view, this area is dominated by Mesozoic and Cenozoic rocks in its northern part and by Precambrian rocks very rich in minerals in its southern part. Due to the insufficiency of terrestrial gravity data from pre-existing campaigns, we had access to satellite data from the International Gravimetric Bureau platform in order to have better resolution in the mapping of the subsurface of this region. The data processing methodology consisted of background noise attenuation as well as regional-residual separation. The gravity sets detected on the Bouguer anomaly map were grouped into high and low intensity zones. The structural map on which we have traced the faults and fold axes shows a preferential orientation of these structures in the NW-SE direction. The superposition of mineral occurrences and geological structures highlighted allowed us to split this zone into two parts: The southern part whose gravity highs concentrate the majority of diamond and iron occurrences and the gravity depressions which concentrate the indices of Lead, Nickel, Manganese; as well as the northern part located in the center of the Central Cuvette which contains a great thickness of sediments constituting, therefore, a favorable place for the maturation of the source rocks.

Keywords:- *Exploration, Mineral Resources, Gravimetry, Western Kasai.*

I. INTRODUCTION

The Democratic Republic of Congo is a country immensely rich in mineral resources. The oil potential of its sedimentary basins as well as the large mineral reserves in its subsurface have given it a place of choice in the eyes of investors. However, certain provinces of major mining and petroleum interest have only been poorly explored, thus limiting knowledge of their geology and the possible types of mineral resources to be discovered within them. This is the case of the former Kasaï-Occidental province of the DR Congo, which has been subdivided into two new provinces since 2015: Kasaï and Kasaï-Central. The Technical Cell of Coordination and Mining Planning (CTCPM) noted the ores such as diamond (in abundance), iron, gold, chromium, nickel, cobalt, platinum, copper, kaolin and lead present in this region. In consideration of the problem linked to the insufficiency of data facing this region, we consider that a geophysical study based on the interpretation of satellite gravity data is necessary to improve knowledge of its geological framework and for orientation future mining and oil exploration.

II. PRESENTATION OF THE STUDY AREA

A. Geographical Framework

The area extends into the provinces of Kasaï and Kasaï-Central. Almost all of this area is located in the former province of Kasaï-Occidental. It crosses the territories of Dekese, Mweka, Ilebo, Luebo, Demba, Dimbelenge, Dibaya, Kazumba, Tshikapa and Luiza. Note that the area entirely covers oil blocks 17b and 18 and partially blocks 2b, 8, 9, 10 and 17a of the Congo sedimentary basin in the Bushimay sub-basin. Its surface area is approximately 174,125 km² (fig. 1).

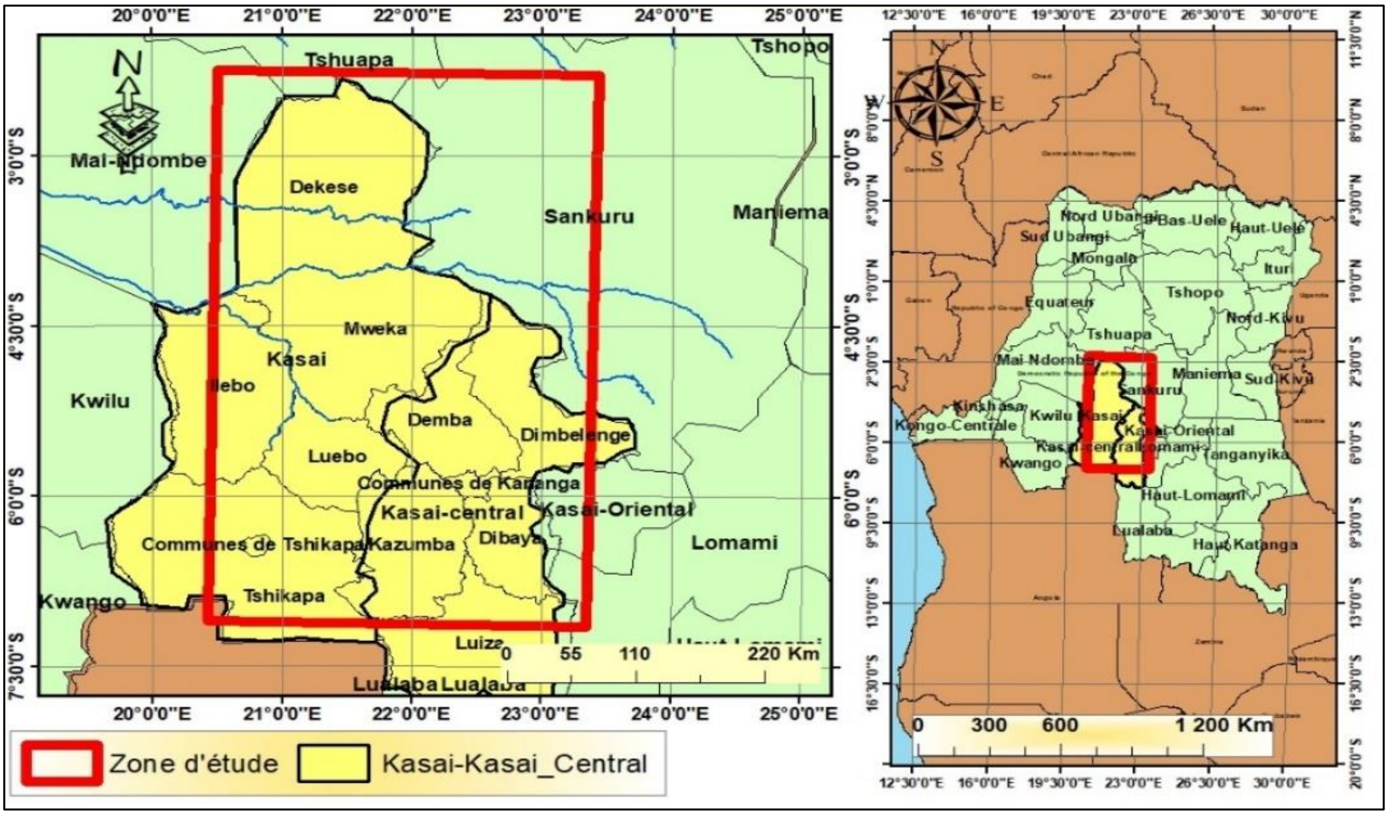

Fig 1: Location of the Study Area (Kasaï-Occidental).

In 2005, the province of Kasaï-Occidental had nearly 4.3 million inhabitants, or 7.6% of the national population in DR Congo. With a heterogeneous distribution, the average density (28 inhabitants/km²) is slightly higher than the national average (24 inhabitants/km²). It experiences an equatorial tropical climate in the north and a Sudanese-type climate in the south. There are two seasons: the rainy season (mid-August – mid-January and mid-February – mid-May) and the dry season (mid–January – mid-February and mid-May – mid-August). The average temperature varies from 16°C to 32°C. Lush and varied vegetation covers the province and is essentially characterized by three plant formations: the dense humid (or equatorial) forest in the north, the subequatorial forest and the savannah. The population of Kasaï-Occidental is mainly composed of three ethnic groups, the Luba-Kasaï, the Kuba and the Lunda Tshokwe (UNDP, 2009).

Its altitude varies between 360 m to 680 m. The hydrography is mainly composed of the Kasaï river, itself fed by several tributaries. The area therefore includes an important network of watercourses, the most important of which are the Lukenie, Lulua, Lubefu, Sankuru and Kasaï rivers (fig. 2).

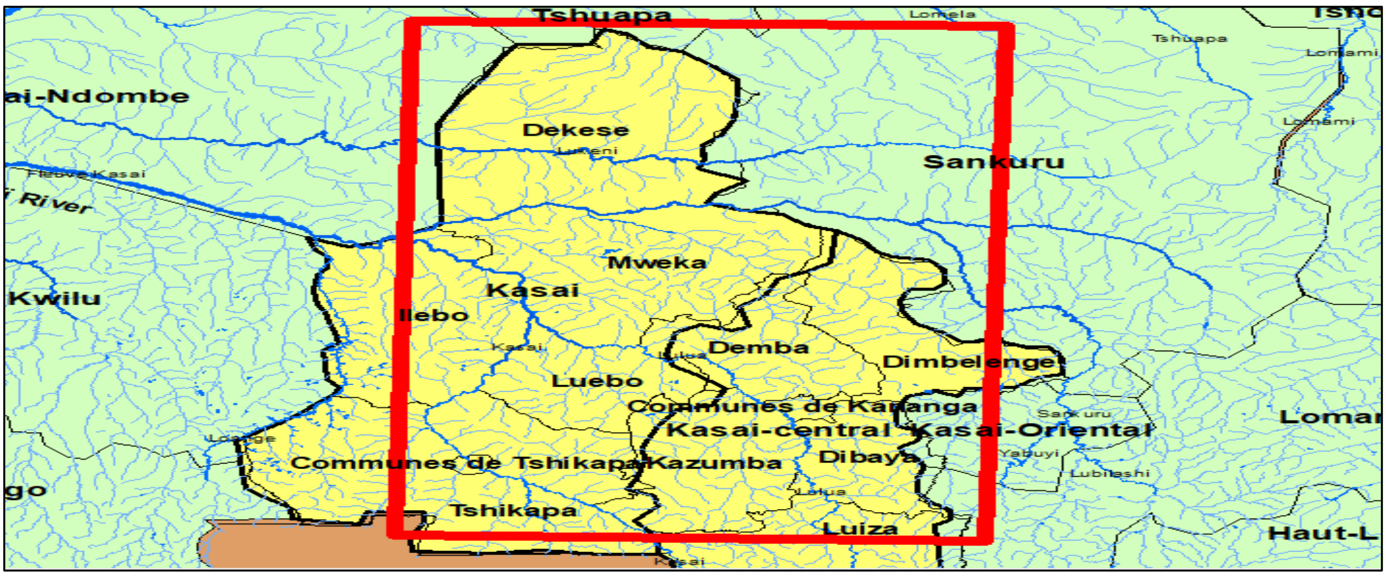

Fig 2: Hydrographic Network of the Study Area

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B. Geological Framework of the Study Area

The Sankuru-Mbuji-Mayi-Lomami-Lovoy (SMLL) basin, DRC, located between the Archean-Paleoproterozoic Kasai Craton and the Mesoproterozoic Kibaran Belt, includes the Mbuji-Mayi Supergroup, a sedimentary sequence unaffected by regional metamorphism and containing a large diversity of well-preserved acritarchs.

The Mbuji-Mayi Supergroup crops out in its type region in eastern Kasai and northwest Katanga. In Katanga, this Supergroup rests discordantly on the Mesoproterozoic Supergroup of the Kibara Mountains while in Kasai, it rests on the Archaean Kasai craton. To the north, the Mbuji-Mayi supergroup is covered by the Mesozoic sedimentary sequences of the Cuvette Centrale. The Roan Group, lower unit of the Katanga Supergroup, is considered to be the stratigraphic equivalent of the Mbuji-Mayi Supergroup (Cahen, 1982; Baudet, 1987). The work carried out by the Royal Museum of Central Africa led to the production of the geological map of the study area (Fernandez and al., 2015) (fig. 3).

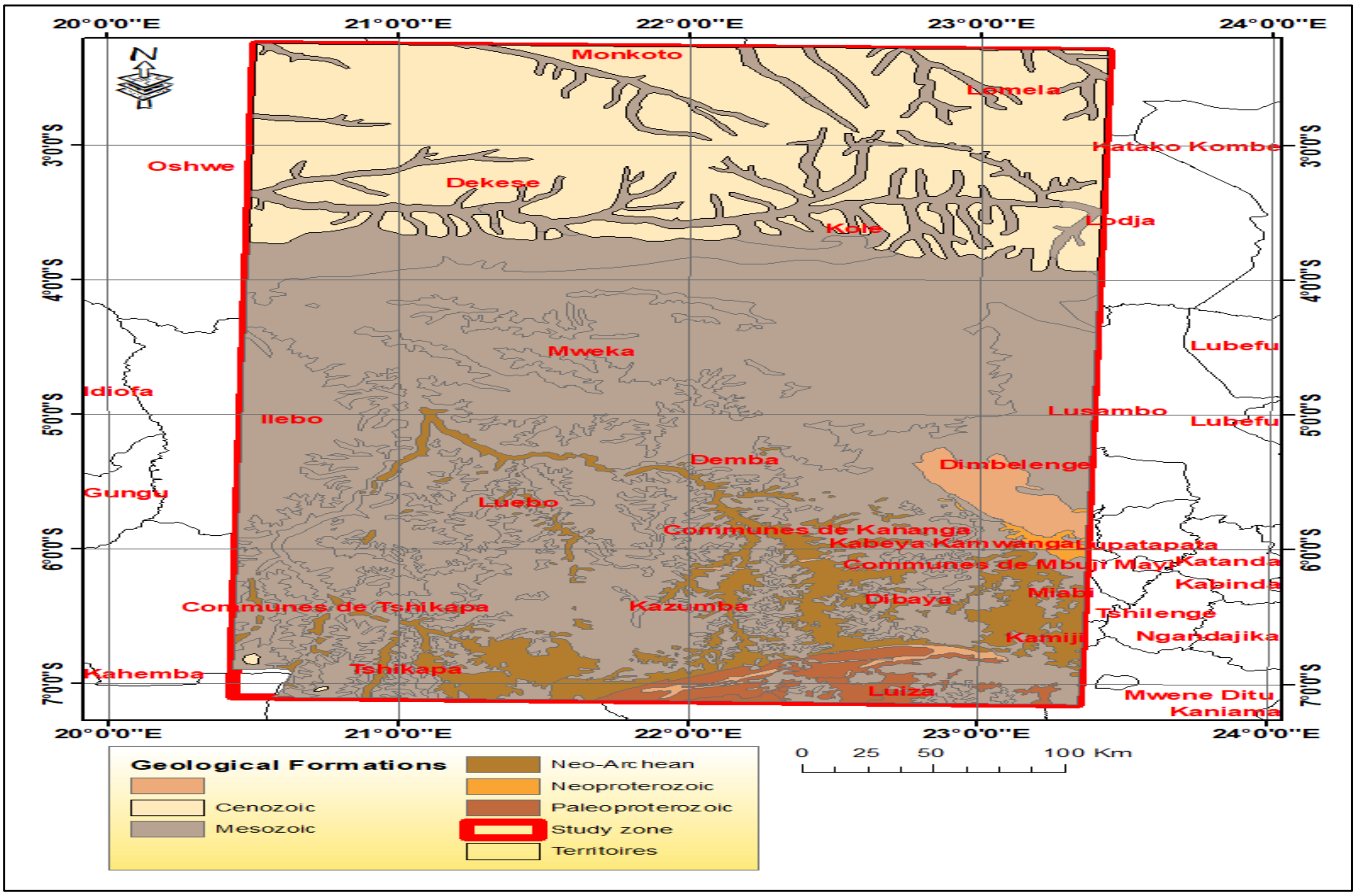

Fig 3: Geological Map of the Study Area

Lithostratigraphically, this Supergroup is composed of two distinct successions (i) a lowersiliciclastic sequence of BI Group (ca. 1175 Myr to ca. ca. 1050 Myr, certainly older than 885 Myr) unconformably overlying the northern ca. 3.0-2.6 Gyr granitoid Dibaya Complex and overlain by (ii) a poorly constrained upper carbonate sequence with sparse shales of the BII Group. Basaltic pillow lavas overlying the Mbuji-Mayi Supergroup were dated at 948 ± 20 Ma (C. François and al., 2015).

III. DATA ACQUISITION AND PROCESSING

A. Data Acquisition

The terrestrial gravity data collected at this location during the REMINA campaign (1952-56) are distributed randomly. In order to have better resolution in the mapping of the subsurface of this region, we had access to satellite data from the International Gravimetric Bureau (B.G.I) platform defined by Word Gravity Model (WGM) from 2012. Both the following figures show us the difference between the scattered data from the REMINA survey (1952-1956) (fig. 4) and the WGM 2012 satellite data (fig. 5).

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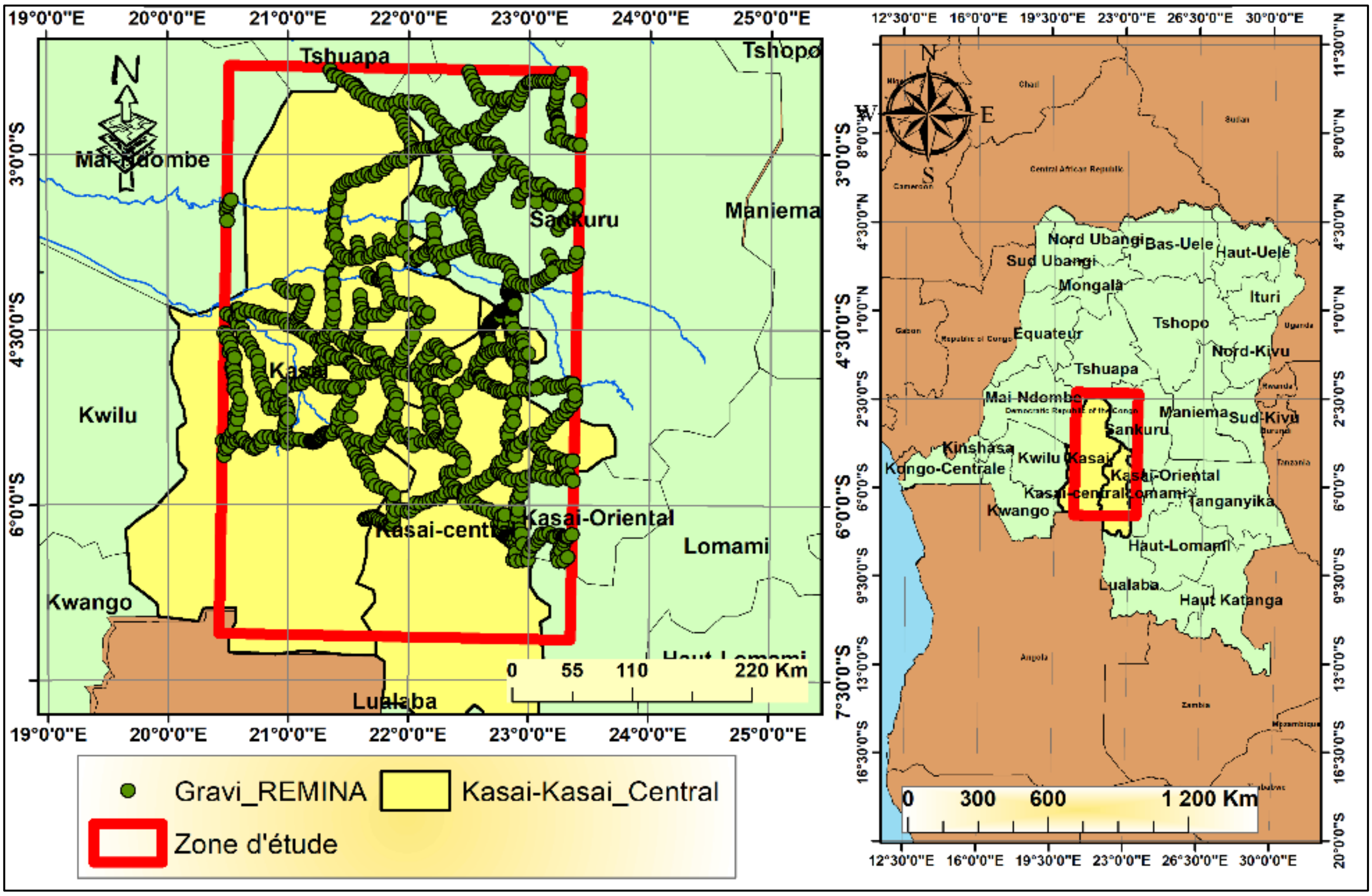

Fig 4: Map of the REMINA 1952-1956 Terrestrial Gravity Survey

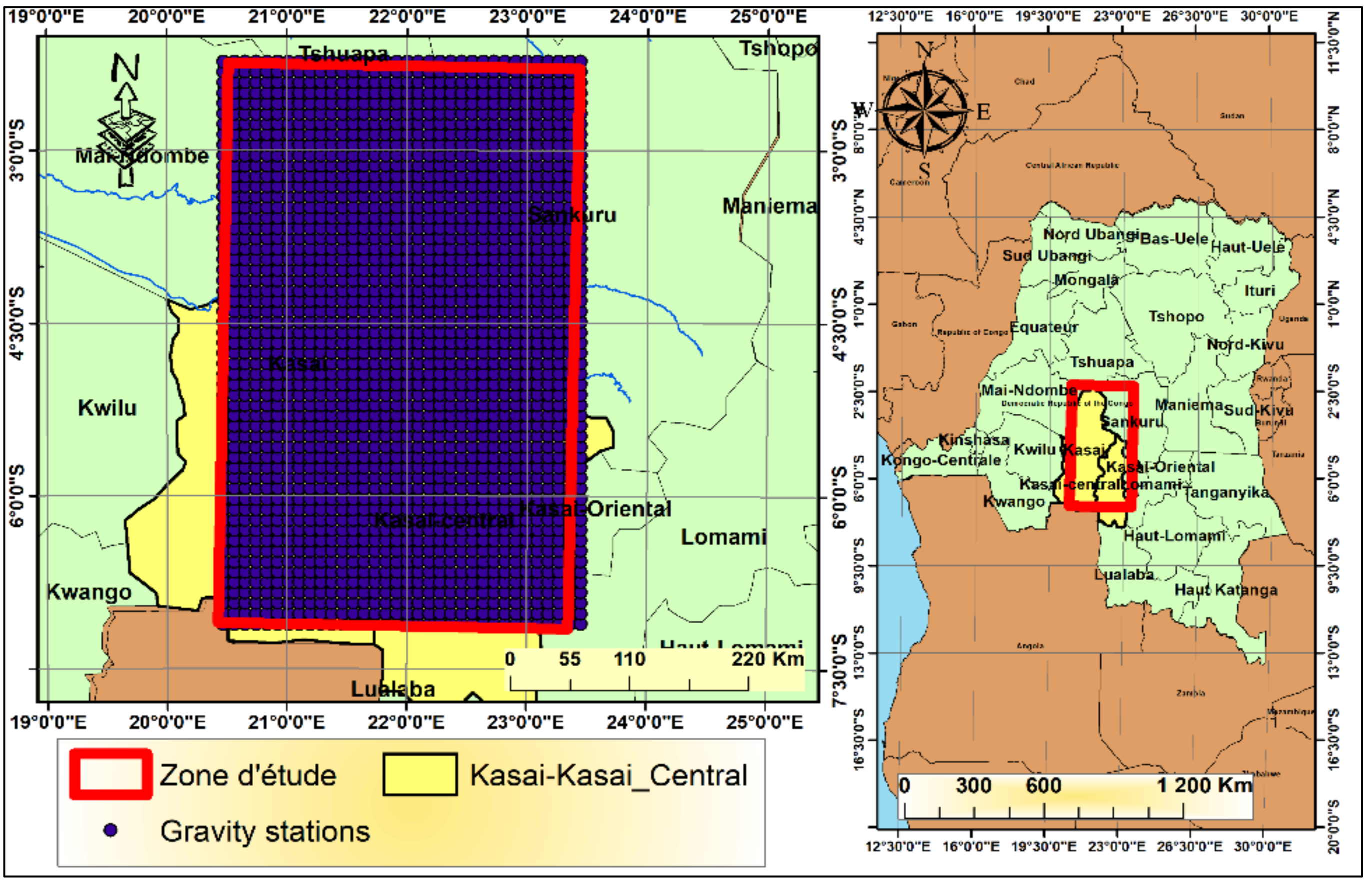

Fig 5: Map of WGM 2012 Satellite Gravity Data

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B. Data Processing

➢ *Filtering and Attenuation of Background Noise*

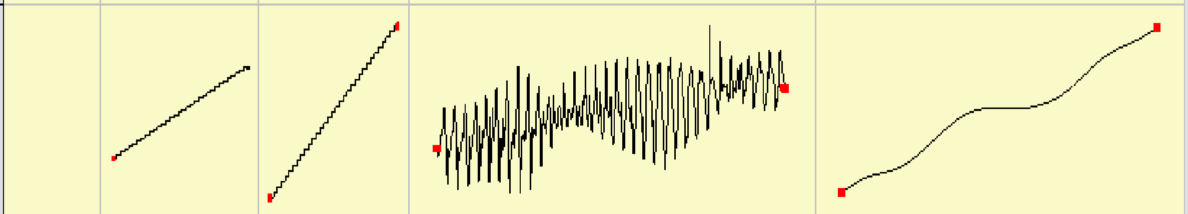
The origins of background noise are multiple, we distinguish:

- ✓ **Background noise of geological origin:** caused by various minerals in the soil or in the bedrock near the surface and which affect the measurements;
- ✓ **Background noise of natural or environmental origin:** this is the case of ground vibrations caused by the movement of trees in the wind;
- ✓ **Background noise of artificial origin:** this is the case of ground vibrations which occur when a terrestrial geophysical survey is carried out near an urban and/or industrialized area;
- ✓ **Background noise of instrumental origin:** coming from errors in execution or correction of measurements.

Indeed, the sources of background noise differ depending on the type of survey, its objectives and the spacing between measurements. To attenuate this background noise, which appears as high frequency peaks, we applied filtering in the frequency domain (low pass filter) appropriate to our measurements. This allowed us to separate the amplitudes of the noisy signal from the Bouguer anomalies. This is how, using its analysis tools, the OriginLab software allows us to choose the "Signal Processing" extension to achieve the operation with the "Smoothing" tool. A dialog window opens and allows you to directly choose the column of data concerned by the smoothing (Bouguer Anomalies). The appropriate method is the Low-pass FFT (Fast Fourier Transform). The results are shown in Figure 6 below.

GravXYZ - GravXYZ.xls *

	A(X)	B	C	D(Y)	E(Y)
Long Name	N° Station	Longitude	Latitude	Bouguer	Bouguer Filtré
Units		(°)	(°)	(mGal)	(mGal)
Sparklines					
1	1	22,8	-6,55	-124,735	-124,37074
2	2	22,85	-6,55	-127,71	-124,32976
3	3	22,9	-6,55	-128,765	-124,28877
4	4	22,95	-6,55	-128,928	-124,24777
5	5	23	-6,55	-128,378	-124,20678
6	6	23,05	-6,55	-127,687	-124,16579
7	7	23,1	-6,55	-127,16	-124,12481
8	8	23,15	-6,55	-126,576	-124,08386
9	9	23,2	-6,55	-125,358	-124,04292
10	10	23,25	-6,55	-123,708	-124,00201
11	11	23,3	-6,55	-122,288	-123,96113
12	12	23,35	-6,55	-120,986	-123,92028
13	13	23,4	-6,55	-119,645	-123,87948
14	14	23,45	-6,55	-118,629	-123,83873
15	15	23,5	-6,55	-117,607	-123,79802
16	16	23,55	-6,55	-116,766	-123,75737
17	17	23,6	-6,55	-117,377	-123,71678
18	18	23,65	-6,55	-117,568	-123,67626
19	19	23,7	-6,55	-116,827	-123,63581
20	20	23,75	-6,55	-115,087	-123,59544



GravXYZ

Fig 6: Visualization of the Amplitudes of the Noisy and Filtered Signal on the Original Lab Software

➢ *Regional – Residual Separation*

This method consists of separating Bouguer anomalies into regional and residual anomalies. To do this, the application of a powerful low-pass filter was useful for enhancing regional anomalies and the application of a high-pass filter for obtaining residual anomalies. The difference between the total signal (Bouguer), the low-pass filtered signal (Regional) and the high-pass filtered signal (Residual) is shown in the graph below (fig. 7).

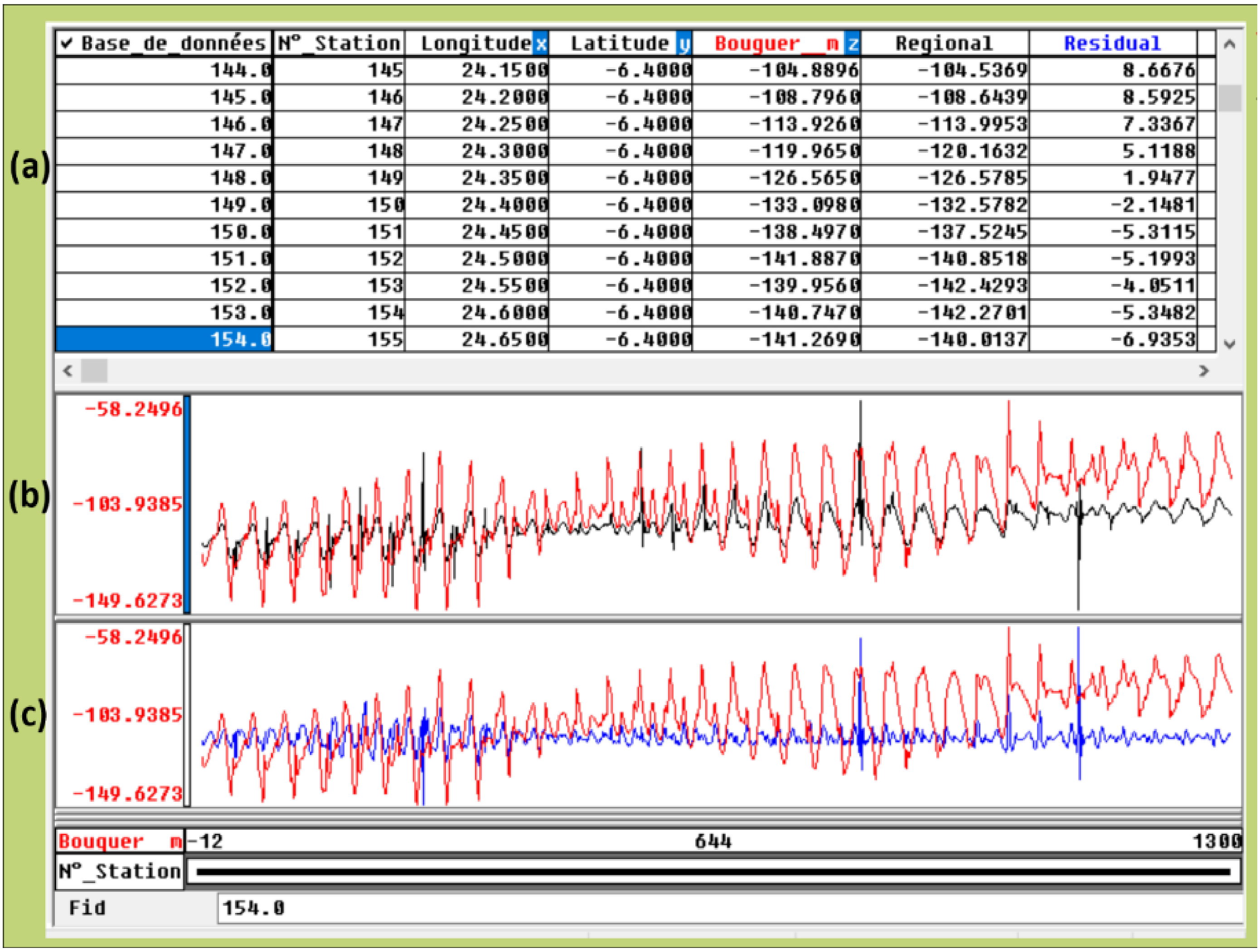


Fig 7:(a) Database; (b)Total Signal (Bouguer; Red Curve) VS Low-Pass Filtered Signal (Regional; Black Curve); (c) Total Signal (Bouguer; Red Curve) VS High-Pass Filtered Signal (Residual; Blue Curve).

In the figure above, we see that the curve of the total signal (in red) includes several roughness linked to the high frequencies still present in the signal while the curve of the low-pass filtered signal (in black) is smoother. This smoothing proves that the disturbing high frequency noises have been extracted from the total signal. We also note that the curve of the high-pass filtered signal (in blue) only retained the anomalies of small extension by attenuating the large regional variations.

IV. DATA STATISTICS

➢ *The Statistical Processing (tab. 1) of Gravity Data Shows us the Following:*

- For Free-Air anomalies, the lowest value is -66.1 mGal, the highest is 23.8 mGal and the average is -23.12 mGal;
- For Bouguer anomalies, the lowest value is -135 mGal, the largest is -26.2 mGal and the average is -87.38 mGal;
- For measured gravity (g), the minimum value is 977793.7 mGal, the maximum value is 977954.5 mGal, and its average is 977865.54 mGal.

Table 1: Data Statistics

	Measured Gravity (mGal)	**Free-Air Anomalies (mGal)**	**Bouguer Anomalies (mGal)**
Count	1209	1209	1209
Minimum	977793.7	-66.1	-135
Maximum	977954.5	23.8	-26.2
Mean	977865.54	-23.12	-87.38
Std. Dev.	25.13	17.53	17.35

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V. INTERPRETATION OF RESULTS AND DISCUSSIONS

At the end of the data processing, we generated the Bouguer anomaly map with the aim of observing the spatial variations in density of geological formations and detecting the different gravity signatures which will give us first ideas on the type of geological structures present within the subsurface of our study area (fig. 8).

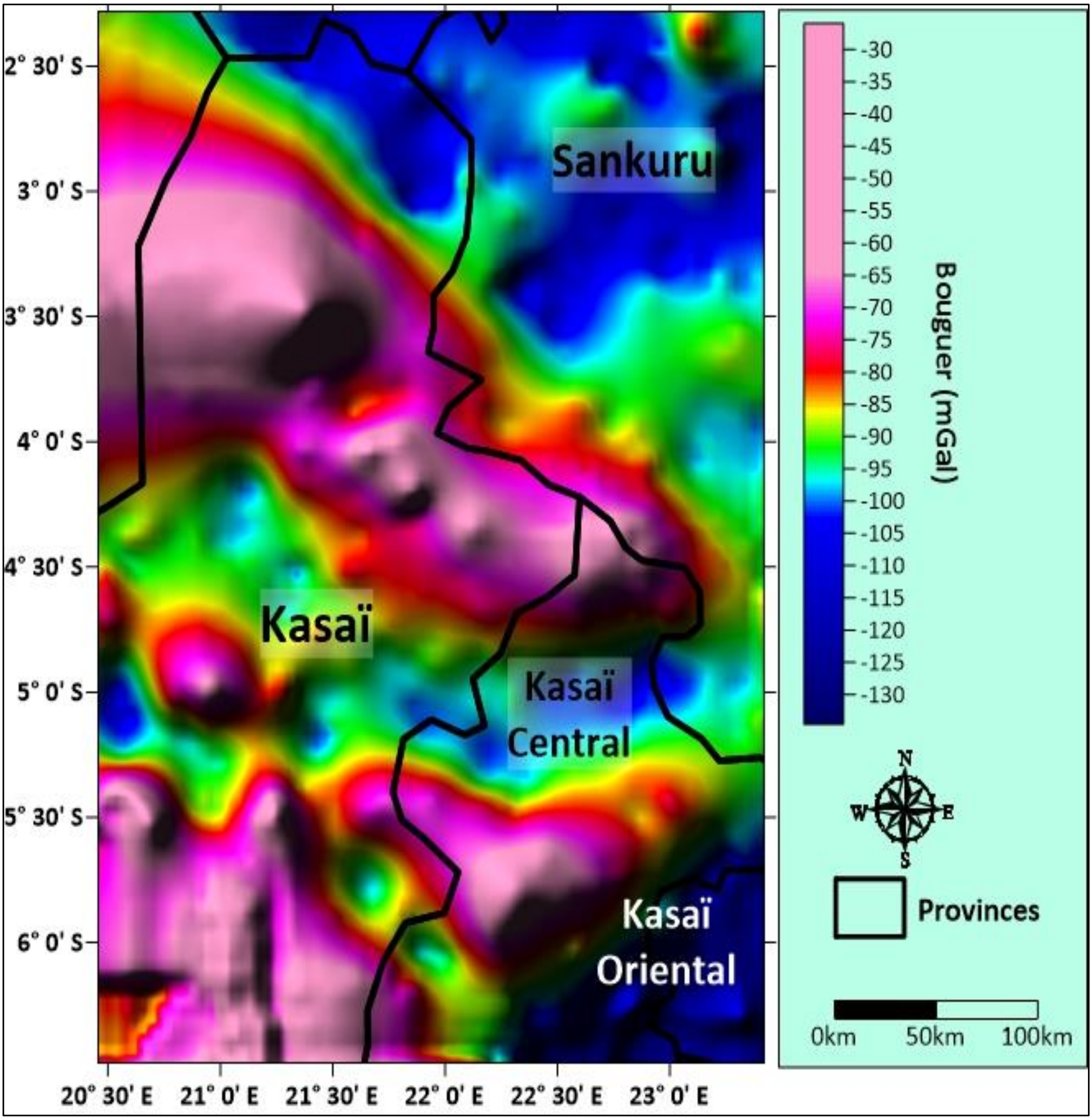

Fig 8: Bouguer Anomaly Map

The Bouguer anomaly map above represents the variation in density of geological formations. The basement being made up of rocks much denser than the sedimentary cover, it is often considered that the density contrasts are therefore due to the crystalline basement. However, the ancient carbonate sedimentary formations of the Mbuji-Mayi supergroup can also induce positive density contrasts which must be taken into account during interpretation.

Several gravity sets were detected on the Bouguer anomaly map, which allowed us to group them into high intensity zones: A1, A2, A3 and A4 and low intensity zones: B1, B2 and B3 (fig. 9).

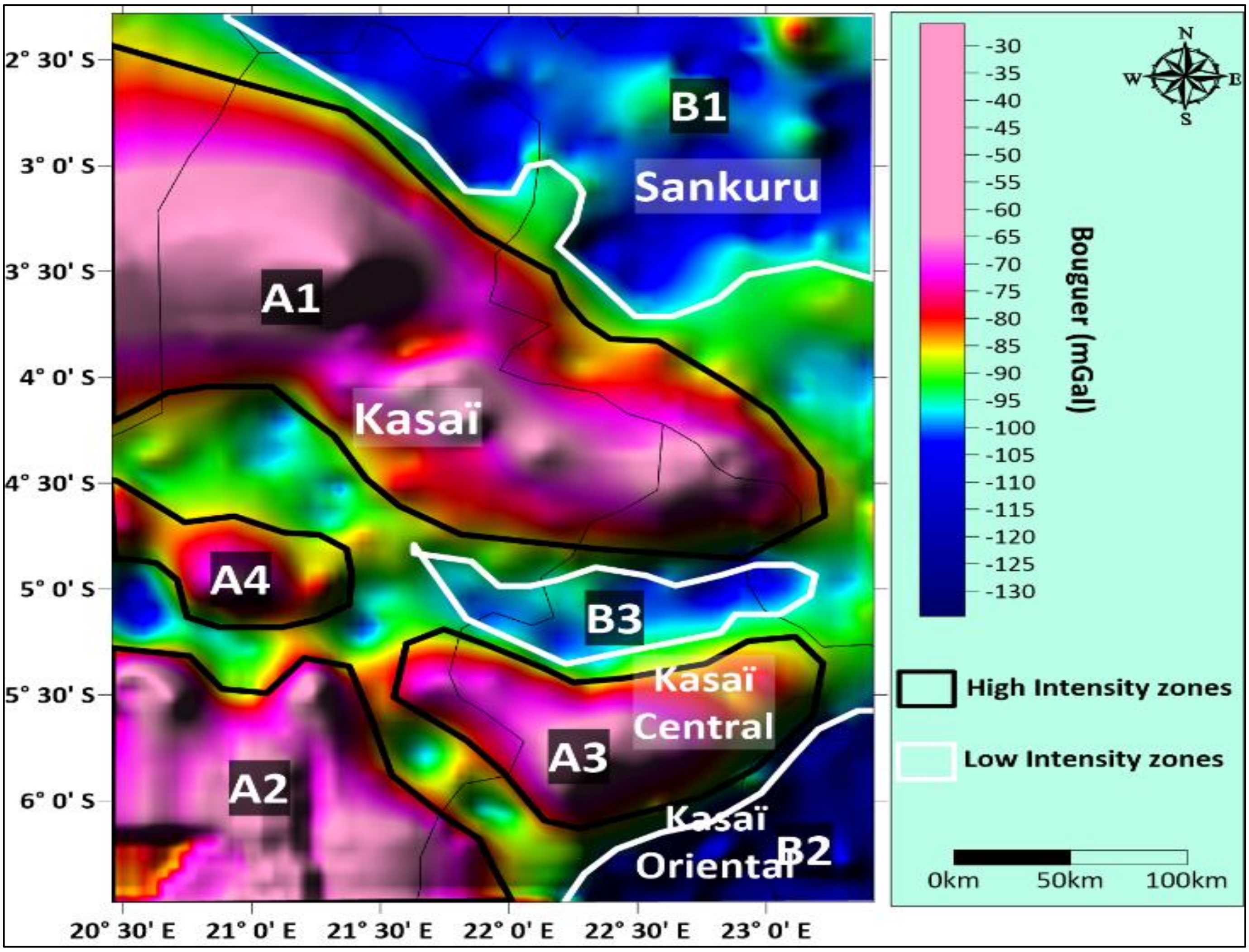

Fig 9: Map of Classified Bouguer Anomalies

These areas were digitized and saved in shapefile format. Table 2 below summarizes the characteristics of each zone.

Table 2: Characteristics of the Anomaly Zones Identified on the Map

Zones	Area (Km^2)	Intensity (mGal)	Orientation
A1	42,862	(-26 to -65) High	NW-SE
A2	16,366	(-30 to -60) High	NW-SE
A3	11,389	(-40 to -80) High	E-W
A4	4,580	(-60 to -85) High	NW-SE
B1	27,012	(-95 to -110) Low	NW-SE
B2	7,354	(-120 to -135) Low	NE-SW
B3	5,125	(-100 to -110) Low	E-W

Zone A1 represents a gravity high oriented in the NW-SE direction and could indicate regional basement uplift. It covers the central part of the Kasai province and the north of Kasai-Central. This uprising would have led to the formation of antiform structures: this is the large Dekese dome already identified in several pre-existing studies (E. Manwana and al., 2022). Another high intensity zone A2 varies in the same direction and tends to indicate the presence of a large extension of the basement which covers the entire south-western part in the Kasai province. This area is located around the Archean rocks of the Kasaïan craton in which several ores such as diamondiferous Kimberlite as well as iron have been discovered. Zone A3 also indicates a basement uplift which covers the entire central part of the Kasai-central province. The presence of very high-density magmatic rocks would be the cause of this gravity high. The A4 anomaly tends to indicate the presence of a basement uplift of low amplitude and extension in the Kasai province. These structures (shoals, antiforms, etc.) caused mainly by tectonic compression factors are of capital importance in terms of petroleum and mining: They could constitute hydrocarbon traps or concentrations of high-density metallic ores.

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Zone B1 is located to the northeast of our study area. This is a very negative anomaly (of the order of -95 to -110 mGal), this indicates that the density of geological formations is very low at this location in the Sankuru province. Anomalies B2 and B3 located respectively in the southeast and in the center of the area indicate significant subsidence which represent depressions in the basement. Geologically speaking, these series of negative anomalies indicate collapse ditches where we can identify the presence of mature source rocks but also formations such as salt domes. However, the B2 anomaly is located in the magmatic and metamorphic rocks of Kasai in which we can find kimberlites which often generate negative gravity anomalies.

Our study area would have undergone episodes of extension and compression. Extension would have created ditches and compression would have created basement uplifts, antiforms and salt domes. This assumption is further supported by the fact that said uplifts and ditches are surrounded by a gradient of anomaly value. These anomaly gradient zones are due to density contrasts that generally occur along faults separating ditches and uplift zones. This is how we produced a map on which we identified all the areas of gradient and peaks/troughs of the anomalies and we traced the faults and fold axes using the visual analysis of the Bouguer anomalies (fig. 10)

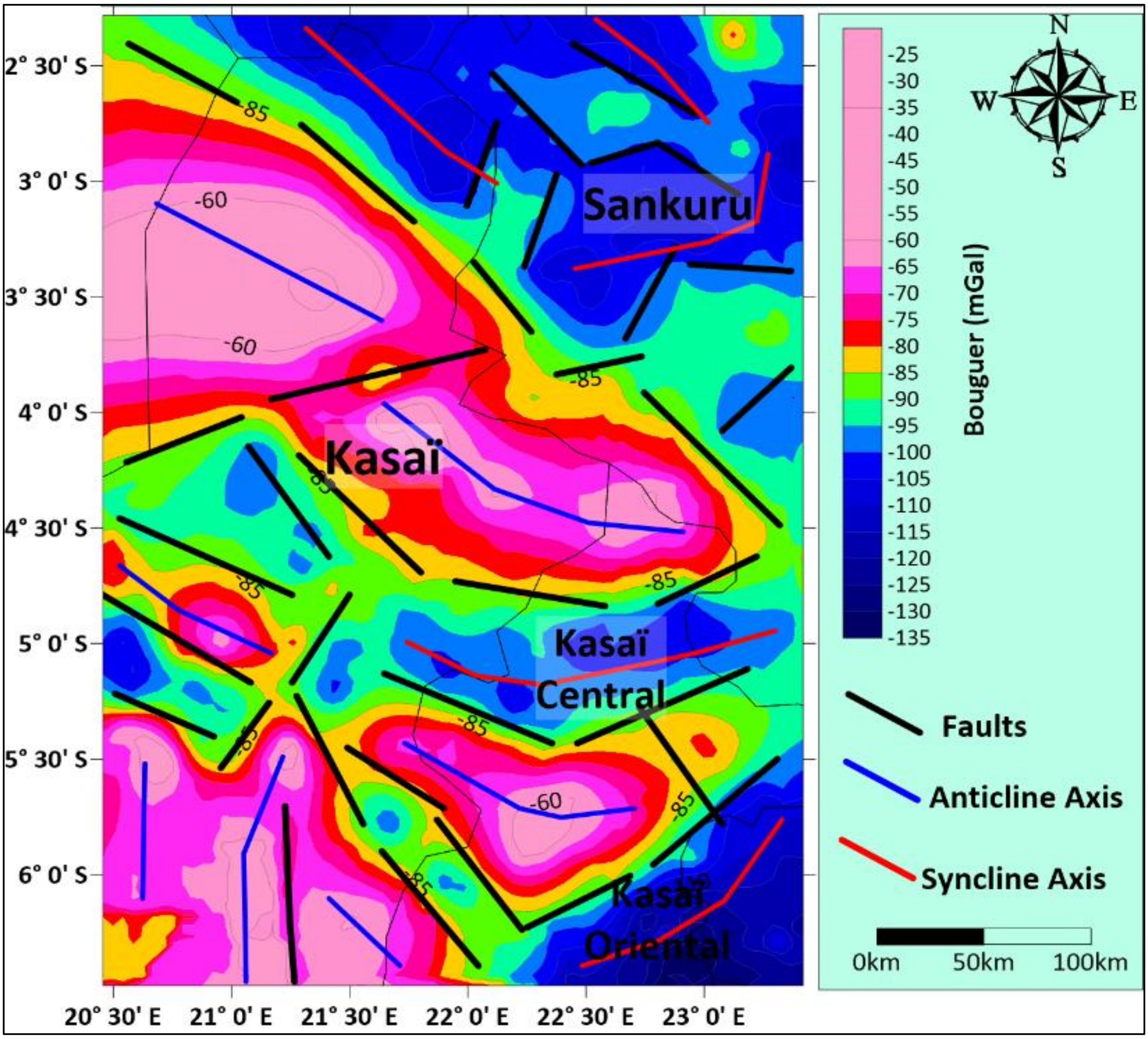

Fig 10: Map of the Bouguer Anomaly: Identification of Faults and Fold Axes.

On this map we have manually traced the faults and fold axes respectively on the contrast zones and anomaly peaks/troughs. The general trend of these structures shows us a preferential orientation in the NW-SE direction. The involvement of these structures in the search for mineral resources is better represented on the composite map below (fig. 11).

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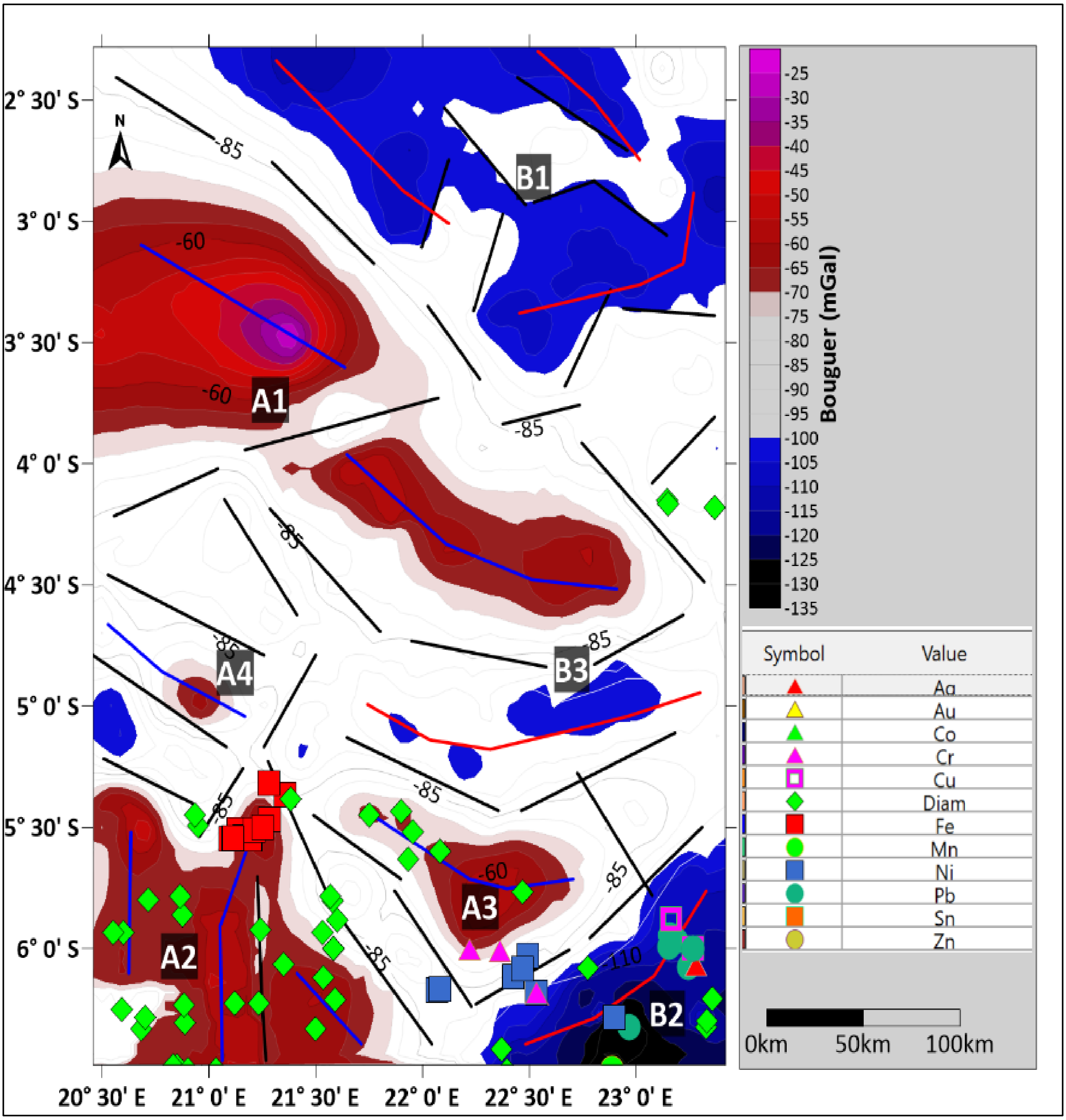

Fig 11: Composite Structural Map of the Study Area.

We superimposed mining occurrences and geological structures on Bouguer anomalies. The latter were selected on the basis of their intensity: High intensities ≥ -70 mGal and Low intensities ≤ -100 mGal. We therefore see that this area is split into two parts. The southern part, composed mainly of Proterozoic and Archean rocks, is very rich in diamond (Michiel C.J. de Wit et al., 2015; Maarten J. de Wit et al, 2015) as well as other minerals such as nickel, gold, chromium, platinum, silver, copper, zinc, manganese, kaolin and lead as shown on the map above. The Lead, Nickel and Manganese indices are mainly concentrated in the negative anomalies (zone B2) while the high gravity A2 and A3 concentrate the majority of Diamond and Iron occurrences. As for the northern part, dominated by much more recent geological formations (Mesozoic and Cenozoic), it contains only very few diamond indices in the east. However, it is an area of great thickness of sediment located in the center of the Central Basin which constitutes a favorable place for good burial of organic matter and excellent maturation of the source rocks. Table 3 below groups together the anomaly zones and their economic interest.

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Table 3: Anomaly Zones and their Economic Interest

Zones	Area (Km2)	Provinces	Territories	Mineral Occurrences	Economic Interest
A1	42,862	Kasaï	Dekese - Mueka	-	Large oil interest in blocks 17 and 18.
A2	16,366	Kasaï	Luebo - Tshikapa	Diam - Fe	Great mining interest for diamond and iron exploitation.
A3	11,389	Kasaï-Central	Demba	Diam - Cr	Great mining interest for the exploitation of diamonds and metallic ores.
A4	4,580	Kasaï	Ilebo - Mueka	-	Oil interest in blocks 17a and 17b. Possibility of maturation of source rocks
B1	27,012	Sankuru	Lomela - Kole-Lodja	-	Great oil interest in blocks 8, 9 and 10. The deepest zone, favoring maturation of the source rocks.
B2	7,354	Kasaï-Oriental – Kasaï-Central	Dibaya - Kabeya Kamuanga	Ni - Pb – Diam - Mn -Arg - Cu	Great mining interest for the exploitation of diamonds and metallic ores.
B3	5,125	Kasaï – Kasaï-Central	Mueka - Demba	-	Oil interest south of blocks 17b and 18.

VI. CONCLUSION

The analysis and interpretation of gravity data allowed us to confirm the great economic interest of the provinces of Kasaï and Kasaï-Central. The filtering and attenuation of background noise, which has multiple origins, was made possible by the application of a low-pass filter using the “Signal Processing” extension of the OriginLab software. With the Oasis Montaj software, we carried out the regional-residual separation by applying a low-pass filter to enhance the regional anomalies and a high-pass filter to obtain the residual anomalies. The Bouguer anomaly map produced at the end of data processing allowed us to establish two groups of anomalies according to intensity: high intensity zones (from -30 to -85 mGal) and low intensity zones (from -95 to -135 mGal). Thanks to the composite structural map in which we have superimposed the mineral occurrences and geological structures on the Bouguer anomalies, we have produced a document which improves knowledge of the geological framework of this area. This document could serve as a basis for future mining and oil exploration.

REFERENCES

[1]. UNDP (2009), Province du Kasaï-Occidental Profil Résume : Pauvreté et Conditions de vie des Ménages.

[2]. Cahen, L. (1982) – Geochronological correlation of the late Precambrian sequences on and around the stable zones of equatorial Africa. – In: Geochronological correlation of Precambrian sediments and volcanics in stable zones (Bonhomme, Michel-G. Ed.). Precambrian Research.

[3]. Baudet D. (1987) – Implications of a palynological study in the Upper Precambrian from estern Kasai and northwestern Shaba, Zaire. – Geol. Journ. 22, Thematic Issue, 121-137.

[4]. Fernandez Alonzo and al., (2015), Carte Géologique de la République Démocratique du Congo au 1/2.500.000 : Notice explicative, Ministère des Mines, République Démocratique du Congo.

[5]. C. François, B. K. Baludikay, J. Y.Storme, D. Baudet And E. J. Javaux (2015), Geochronological constraints on the diagenesis of the Mbuji-Mayi Supergroup, Democratic Republic of Congo (DRC).

[6]. Eli-Achille Manwana Mfumukani, Franck Tondozi Keto, Robert Muanda Ngimbi, Emmanuel Bahati Wenda, Anscaire Mukange Besa, Reagan Lotutala Tazi, Olivier Muhingy Sawa-Sawa (2022), Interpretation of Gravity Data and Contribution in the Structural Study of the Southern Part of the Congo Basin: Case of the Kasaï Region in D.R. Congo; Volume 7, Issue 9, September – 2022 International Journal of Innovative Science and Research Technology; ISSN No: -2456-2165.

[7]. Michiel C.J. de Wit and Hielke A. Jelsma (2015), A Review of the Kimberlites of the Democratic Republic of Congo, Geology and Resource Potential of the Congo Basin, Springer.

[8]. Maarten J. de Wit and Bastien Linol (2015), Precambrian Basement of the Congo Basin and Its Flanking Terrains, Geology and Resource Potential of the Congo Basin, Springer.

[9]. Pierre Evrard (1957), Les recherches géophysiques et géologiques et les travaux de sondage dans la Cuvette congolaise. L'académie royale des sciences coloniales.

[10]. G. R. Foulger and C. Peirce (2002), Geophysical methods in geology.

[11]. Brahimi Sonia, Munschy Marc, Bourmatte Amar (2008), Apport de la gravimétrie et du magnétisme à l’étude de la structure du bassin d’Illizi (Algérie).