Gravity Investigations Applied to the Geological Framework Study of the Mambasa Territory in Democratic Republic of Congo

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Abstract:- This study concerns the gravity survey carried out in the territory of Mambasa in the province of Ituri in DR Congo, with the aim of studying its subsurface framework. We applied Free-Air and Bouguer corrections to the gravity measurements in order to eliminate gravity variations of non-geological origin. As for the graphical representation of the results, the spatial interpolation tools were useful to us in the elaboration of Bouguer anomaly maps. Then, we classified the study zone into Bouguer anomaly zones based on intensity. Gravity highs could indicate basement uplifts due to compressional movements. These uplifts would have led to the formation of granite domes which could be associated with mineralization. The enormous gravity depression would, for its part, be synonymous with a ditch or the presence of very low-density geological formations. The gravity profiles drawn support the analyzes of the maps: the anomaly curves are very fluctuating and uneven, highlighting several gravity highs and depressions. These fluctuations are probably induced by the presence of faults which separate the different anomaly zones.

Keywords:- *Gravity, Interpretation, Structure, Geology, Ituri.*

I. INTRODUCTION

The Democratic Republic of Congo is recognized worldwide as a country with immense natural resources. To date, it owes this reputation, apart from its magnificent biodiversity, its august plant cover and its immeasurable water potential, to the plurality of its mining resources all equally essential to the various industries, whether technological, energy or even jewelry. However, its real potential in natural resources of its territory does not manage to move from the status of simple potential to that of obvious reserves. As part of this work, we were mainly interested in gravity prospecting which is a method of natural geophysical investigation based on the measurement and analysis of variations in the gravitational field. Its multiple advantages, notably its implementation by land or airborne route as well as the rapid processing of data acquired in the field using the high-performance software currently produced, have made it one of the most used methods in geophysical prospecting. It is with this in mind that a gravity survey was carried out in the province of Ituri, more precisely in the territory of Mambasa, with the aim of acquiring data which will allow us to improve knowledge on the geological and structural aspect of this region.

II. METHOD AND MATERIALS

Data processing is an essential step in gravity prospecting. It is essential in the calculation of the Bouguer anomaly, in its mapping and in its interpretation. This is how we used two types of gravity data processing:

- Processing useful for Bouguer anomaly calculations;
- Processing useful for mapping and interpreting results.

In the first, we essentially find corrections or reductions of data acquired in the field while the second include regional-residual separation methods, calculations of vertical and horizontal gradients of the Bouguer anomaly, derivatives and continuations. The kriging interpolation method was necessary for us to map the results. A host of computer software allowed us to accomplish this work. These include: Geosoft Oasis montaj, ArcGis, Golden Surfer, etc.

III. DESCRIPTION OF THE STUDY ZONE

A. Geographical and Administrative Situation

➢ *Location*

The territory of Mambasa is located in the province of Ituri in Democratic Republic of Congo. With an area of 36,783 km2, this administrative entity covers almost 55% of the extent of the province of Ituri. The territory has 7 chiefdom communities, namely: Rabombi, Rakwanza, Randaka, Bombo, Walese Dese and Walese Karo. It is limited to the east by the territory of Irumu and Djugu, to the west by the province of Tshopo, to the north by the province of Haut-Uélé and to the south by the province of North Kivu. The city of Mambasa is the capital of the territory which bears the same name. Below is the location map of the study area (Fig. 1).

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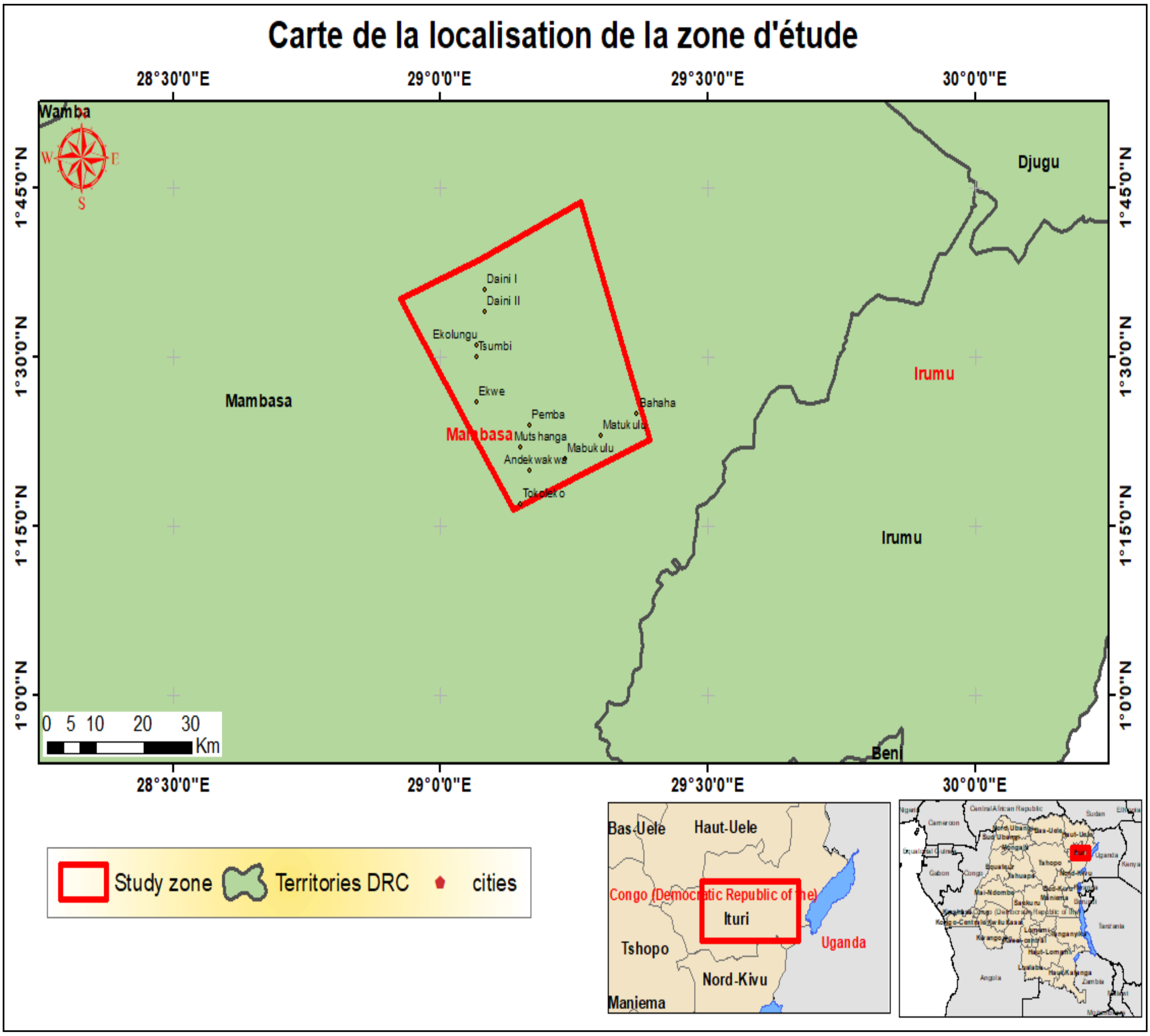

Fig 1: Location Map of the Study Area

➢ *Relief and Soil*

Mambasa is located at an altitude of 650 to 1000 m. Its relief is not very rugged. The soils are generally acidic, derived mainly from the underlying granites and quartzites, often composed of sandy clays (Benedito Bhanya, 2006).

➢ *Climate and Vegetation*

The Mambasa region benefits from an equatorial climate with alternating rainy and dry seasons during which evaporation is intense. The driest month is January with rainfall less than 50 mm in some parts. During the dry season, the sky is absolutely cloudless, evaporation is very high, the average daily temperature is between 27 and 28°C. Rainfall is bimodal with rainy seasons centered on the equinoxes and dry periods centered on the solstices. Its average is 1600 to 2000 mm.

Most of the Mambasa landscape is covered in dense semi-evergreen forest with a closed canopy. It is a very rich ecosystem in both plant and animal species.

B. Geological Framework

In 2015, a team composed of geologists from the Ministry of Mines (Secretariat General, CTCPM, CAMI) and the Ministry of Scientific Research and Technology (CRGM) worked jointly with the Royal Museum of Central Africa (RMCA) to update geological knowledge relating to the DR Congo. These studies led to the development of the geological map of the Democratic Republic of Congo at 1:2,500,000 (Fernandez and al., 2015). These are the same results that allowed us to map the main geological units of our study area (fig. 2).

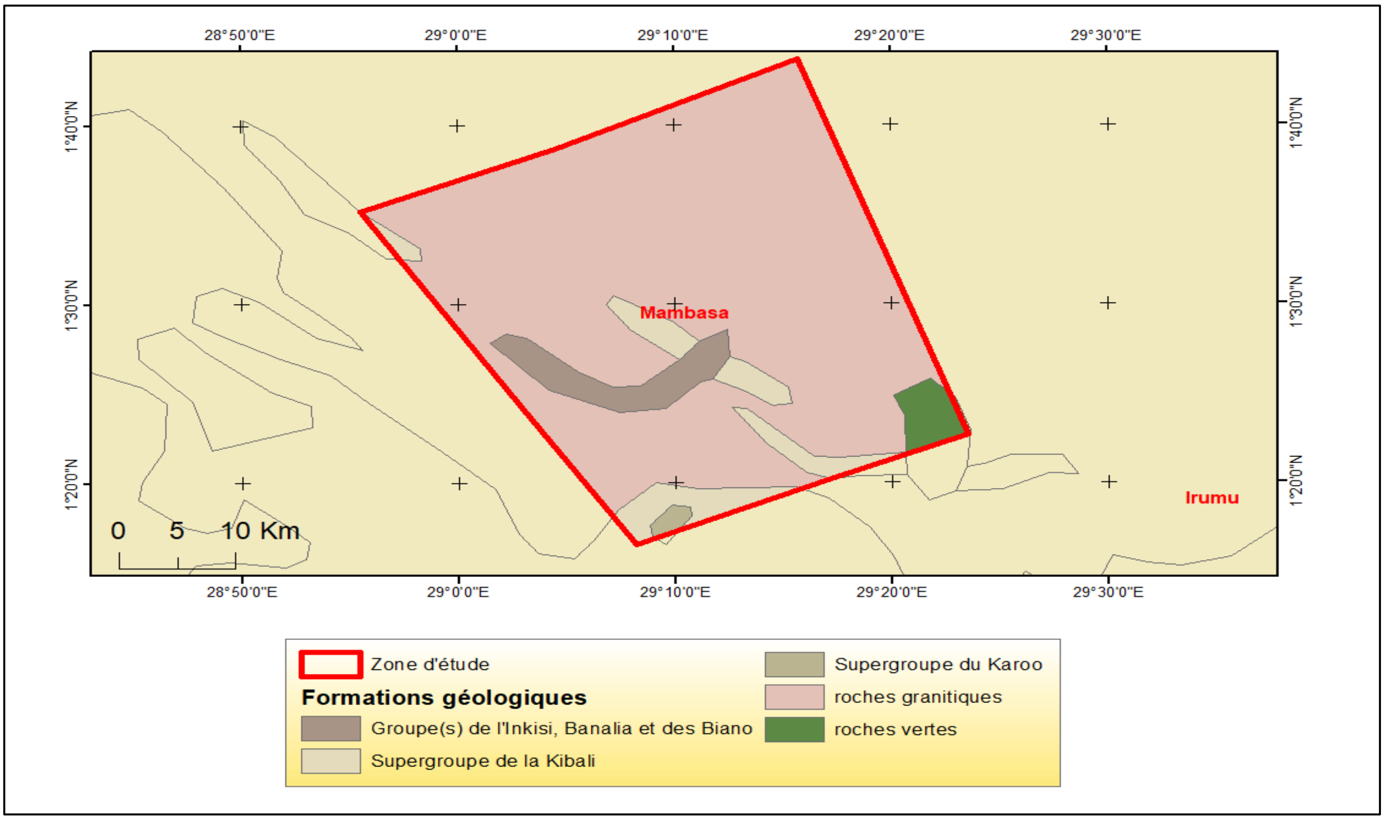

Fig 2: Geological Map of the Study Area

The entire area is dominated by granite-type magmatic rocks, while we find the Banalia group which intersects the Kibali supergroup in the center. The presence of green rocks is reported in the South-East.

IV. GRAVITY DATA PRESENTATION

Measuring relative gravity values, that is, differences in gravity between locations, is simpler and is the standard procedure in gravity surveying. Absolute gravity values at survey stations can be obtained by reference to the International Gravity Standardization Network (IGSN) of 1971 (Morelli et al. 1971), a network of stations in which absolute gravity values were determined by reference to sites of absolute gravity. By using a relative reading instrument to determine the difference in gravity between an IGSN station and a field location, the absolute value of gravity at that location can be determined (Philip Kearey, 2002). The gravity data acquired in the Mambasa Territory is presented as follows (Tab.1).

Table 1: Data Statistics of the Gravity Data

Bouguer Anomalies	
number of values	100
sum	-15477,32
minimum	-169,12
maximum	-129,57
mean	-154,77
standard deviation	9,022

Gravity measurement was carried out for 100 stations. A sample of the first 10 stations has been represented, for illustrative purposes (Tab. 2).

Table 2: Presentation of the gravity data

N°	**Longitude (°)**	**Latitude (°)**	**Bouguer (mGal)**
01	29,23	1,69	-154,88
02	29,23	1,68	-154,82
03	29,23	1,67	-155,48
04	29,22	1,67	-156,02
05	29,22	1,67	-158,95
06	29,2	1,67	-164,19
07	29,2	1,65	-164,5
08	29,2	1,65	-164,7
09	29,19	1,65	-166,43
10	29,18	1,64	-166,72

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V. DATA PROCESSING AND MAPPING

The main processing steps for mapping gravity data are the calculation of the Bouguer anomaly and its graphical representation. Calculating the Bouguer anomaly is the step that directly follows the field data acquisition phase. Indeed, during the data acquisition phase in the field, several factors influence the gravity measurements. These factors are the latitude and altitude of the measuring station, the drift of the measuring device (gravimeter), the topography and the surrounding environment (constructions), the effect of the masses of the surrounding reliefs (especially in the mountainous regions), tides, etc. This is why all these disturbing effects must be removed so that the mapped anomaly corresponds to the density variation in the subsurface. This anomaly is called "Bouguer Anomaly". Using the GX-Gravity extension of the Oasis Montaj software (fig. 3), we carried out the Free-Air and Bouguer corrections.

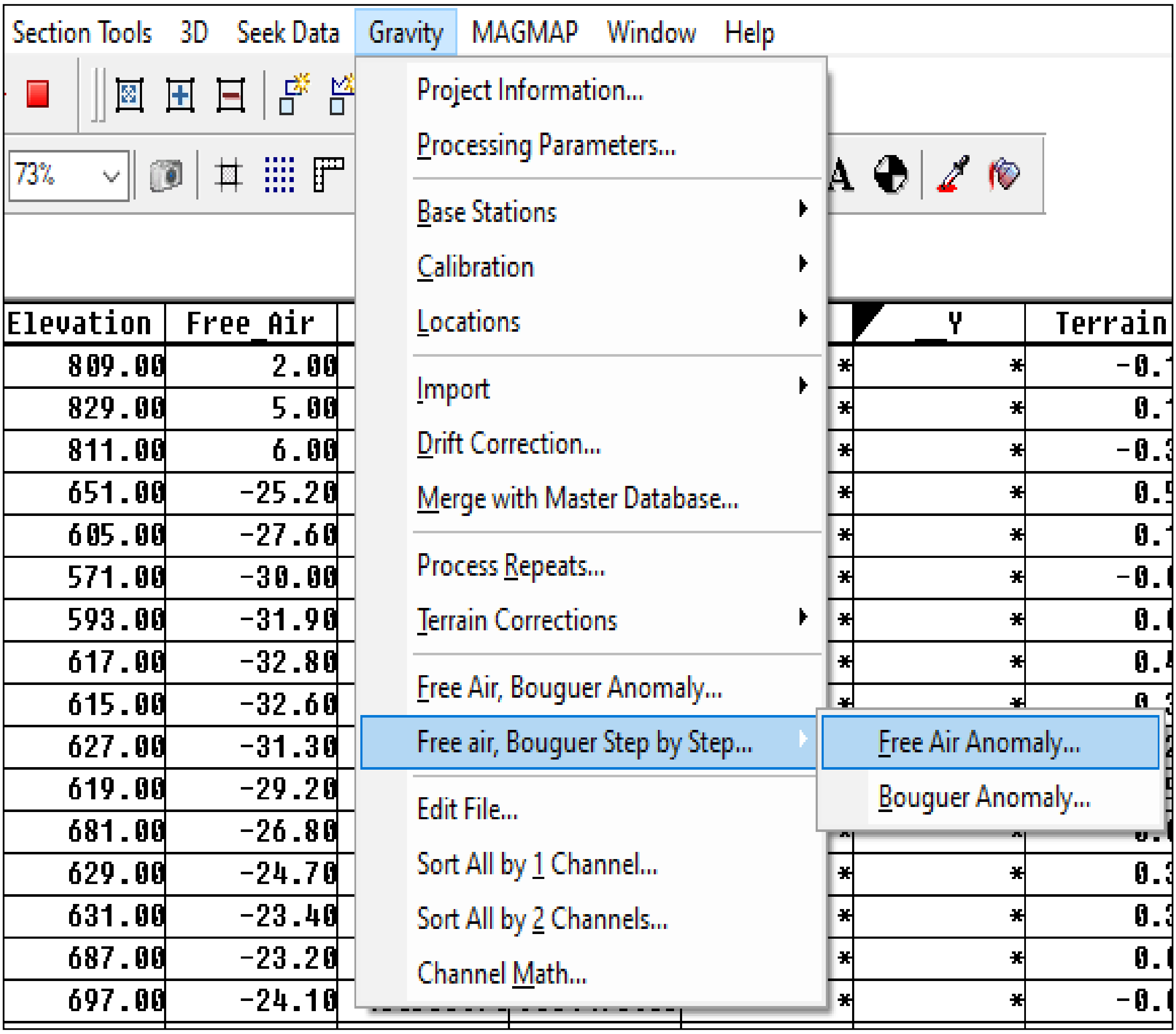

Fig 3: Tabs for Applying the Free-Air and Bouguer Corrections with the "GX - Gravity" Extension of the Oasis Montaj Software

As for the graphic representation of the Bouguer anomaly, this involves drawing the map of isolines produced automatically with the help of the computer, which requires knowing the values of the anomaly at the nodes of a regular grid. Then use digital methods of approximations and interpolations to trace the isolines following a mesh deduced from the profiles established on the background of a topographic map at the desired scale. The spatial interpolation tool integrated into the Golden Surfer software (fig. 4) was useful to us in carrying out this task.

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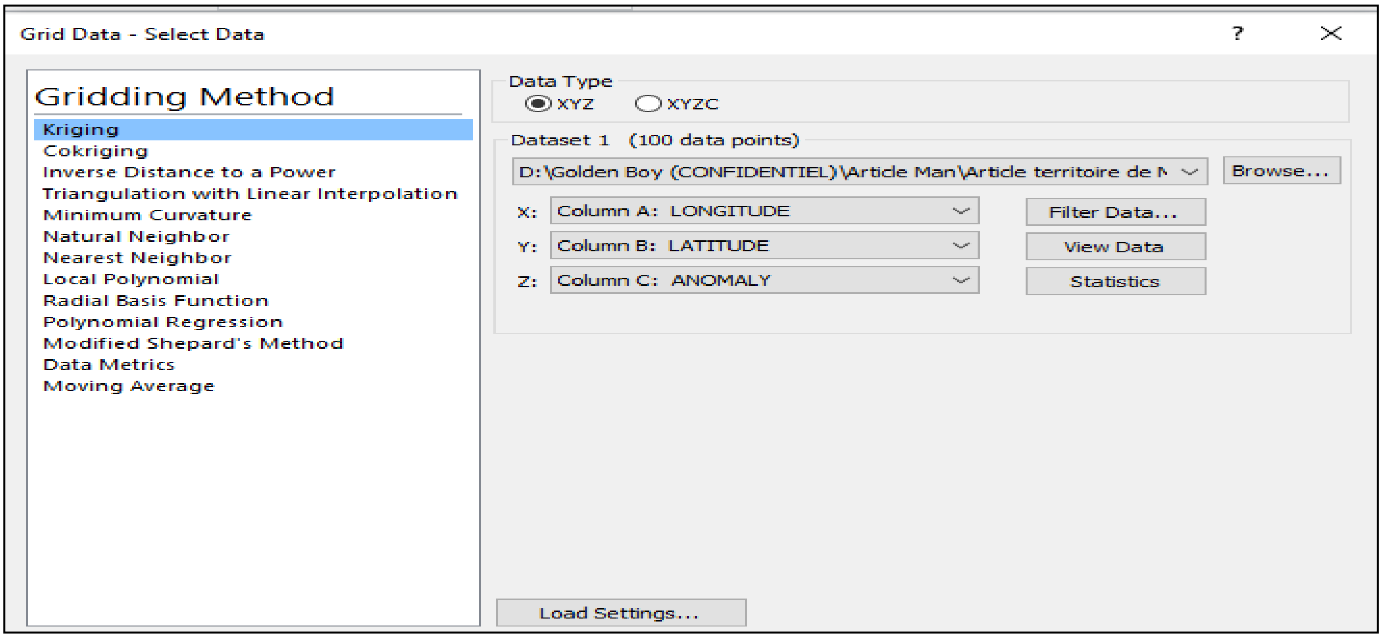

Fig 4: Window for Spatial Interpolation of Gravity Data from Golden Surfer Software

In the figure above, you will notice that we used Kriging as an interpolation method. Indeed, kriging is a stochastic spatial interpolation method which predicts the value of a natural phenomenon on unsampled sites. In this method, the mean is assumed to be unknown but uses the invariant on the neighborhood of the estimated point. This method only uses the assumption of intrinsic stationarity (Lamamra Abdessattar and al., 2019).

VI. RESULTS AND DISCUSSIONS

A. Bouguer Anomaly Map

Gravity anomaly maps are the basic documents for any interpretation in gravity prospecting. Thus, the goal of interpreting gravity anomalies is to find the distribution of sources: density contrasts and geometries which create the anomalies observed on the surface (Yvette Hermine, 1994). We see on the Bouguer anomaly map (fig. 5) that the center of this zone is dominated by low anomalies varying between -160 mGals and -170 mGals (dark blue color). However, we note that the eastern and western parts of this zone are occupied by high intensities between -156 to -142 mGal.

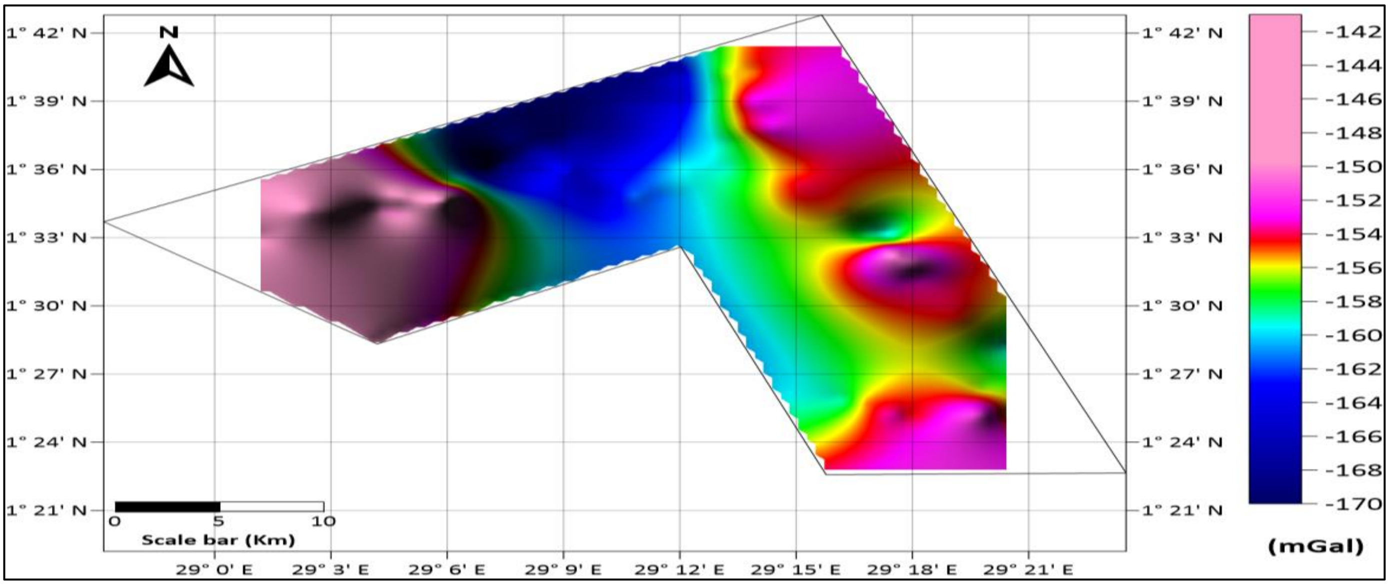

Fig 5: Bouguer Intensity Map

Depending on the shape of the iso-anomaly contours, the map below highlights concentric quasi-circular anomalies and linear anomalies. The predominant shape of iso-anomaly contours is the quasi-circular shape. These concentric quasi-circular anomalies perfectly match the intensity values of the anomalies (fig. 6).

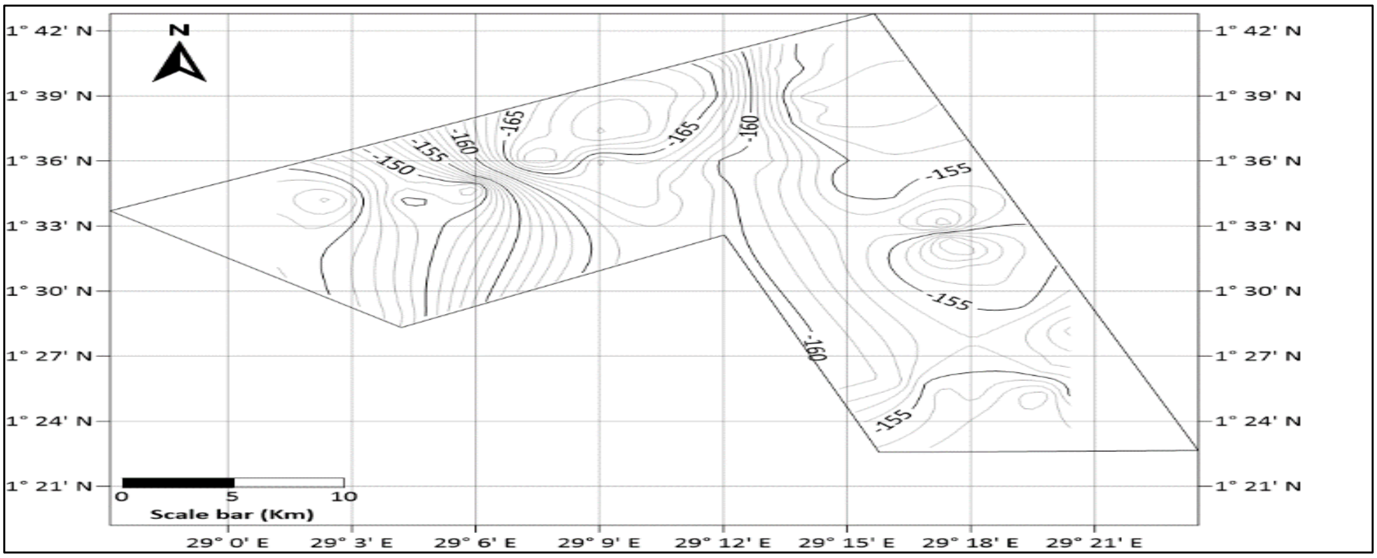

Fig 6: Bouguer Contour Map

The quasi-circular contours are observed towards the East, center, West and South of the study area. This map also highlights areas of contours tightening which can be interpreted as being contacts between rocks of different densities or faults.

- *In This Study, we Classified the Area into Five Zones Based On Intensity:*

- Four high intensity areas (from -156 to -142 mGal) named Zones A, B, C and D;
- One low intensity area (from -170 to -160 mGal) designated by Zone E (fig. 7).

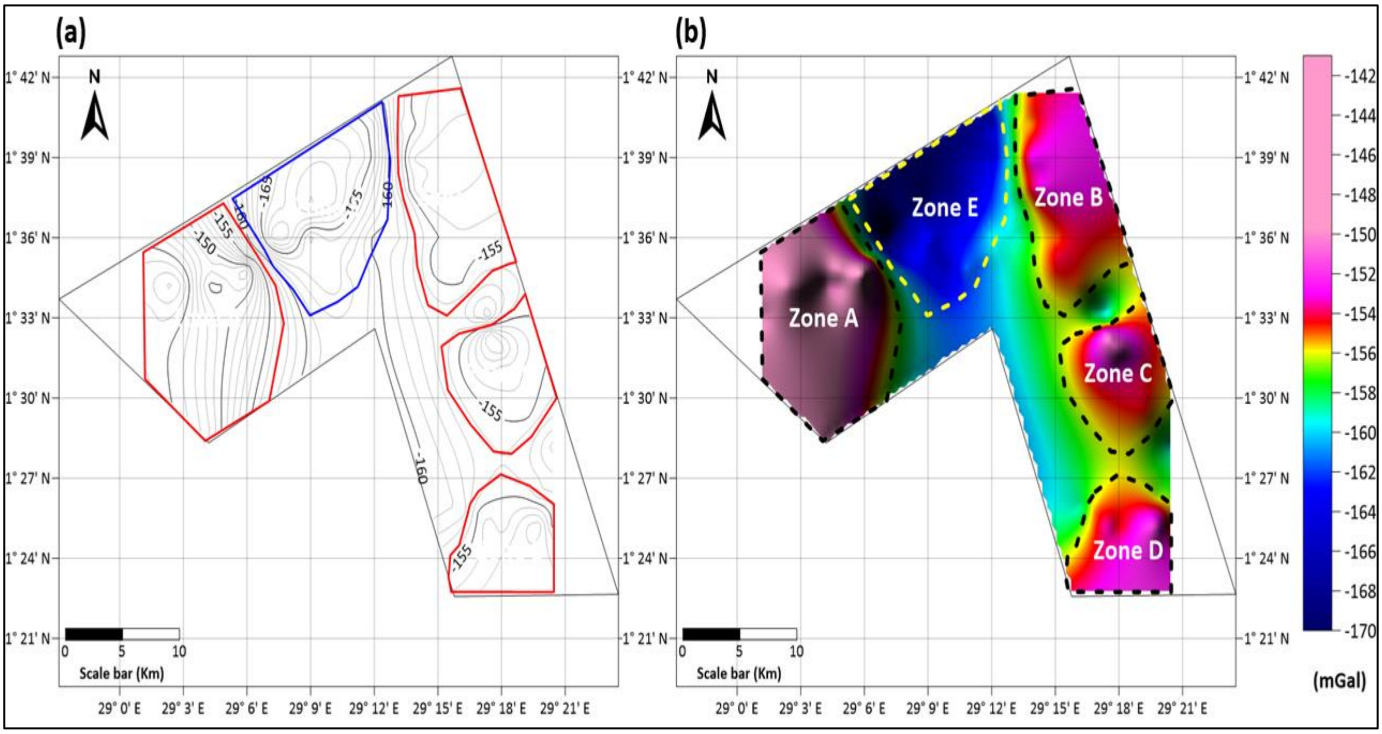

Fig 7: Classification of Anomaly Zones: a) Contour Map; b) Intensity Map

Zones A, B, C and D represent high intensities of anomalies. Being located in the zone of granitic rocks which have a density between 2.50 and 2.81 g/cm^3 (H.O Seigel, 1995), these zones could indicate basement uplifts due to compressional movements. These uplifts would have led to the formation of granite domes which could be associated with mineralization. The latter could come in particular from the leaching of the basement which was made up of igneous and metamorphic rocks. Zone E indicates a significant depression of the basement or the presence of geological formations of very low density but which have not been shown on the geological map in Figure 2.

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B. Gravity Profiles

Gravity profiles are very important in monitoring the gravity signatures of several structural models. Thus, in order to intersect all the anomaly zones and to better study the structural aspect of the granitic rocks of this region, we have drawn two long gravity profiles on our Bouguer anomaly map: Profiles AB and BD.

Profile AB below (fig. 8), having a SW-NE orientation, mainly intersects the three zones (zones A, E and B) present in the northern part of our study area.

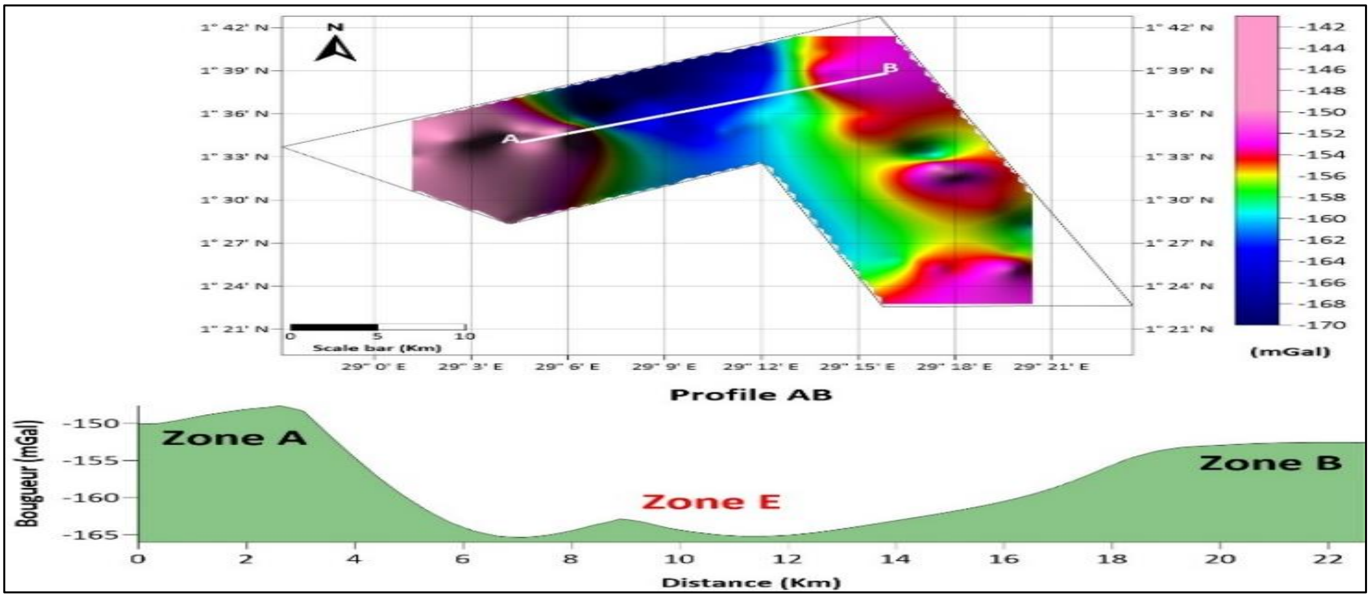

Fig 8: AB Profile

In the middle of the profile, we observe a depression of the anomaly curve in zone E. In the absence of geological field or drilling informations at this location, the extent of this depression of the anomaly values of Bouguer allows us to make two hypotheses:

- The disturbing body would be a gigantic mass of low density. Which would then reveal a lateral variation in lithology responsible for this enormous depression;
- This area is a very large depression of dense granitic rocks, which would be filled by much less dense recent formations.

On the other hand, we notice very high anomaly values at the ends of the profile (zones A and B). These areas concentrate the highest anomaly values in the study area.

The BD profile below (fig. 9), having a NNW-SSE orientation, is drawn in the eastern part of the study area. It mainly cuts across the three zones (zones B, C and D).

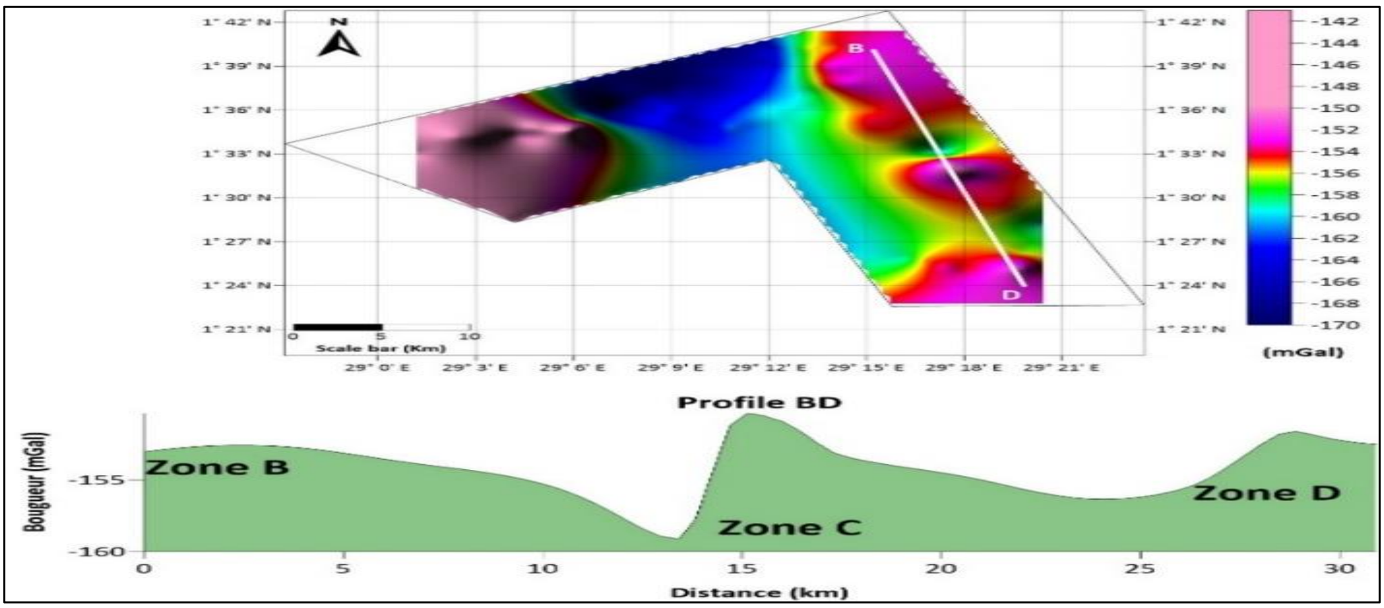

Fig 9: BD Profile.

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We observe a very fluctuating and rugged anomaly curve highlighting several gravity highs and depressions. These fluctuations are probably induced by the presence of faults which separate the different anomaly zones. We also notice a very large density contrast highlighted by the inflection of the curve over the distance between 13 and 14 km. This zone where the anomaly contrast is very strong (-142 and -158 mGal respectively for the elevated part and sagging part) reveals the gravity signature of a major regional fault.

C. Horizontal Derivative Maps

The horizontal derivative filters in a given direction are very useful to highlight all the lineaments of said zone in a direction almost perpendicular to that of the applied filter. In order to analyze the major structural trends in our study area, the horizontal derivatives of the Bouguer anomalies in the East-West (Dx) and North-South (Dy) azimuths were applied (fig. 10 a and B).

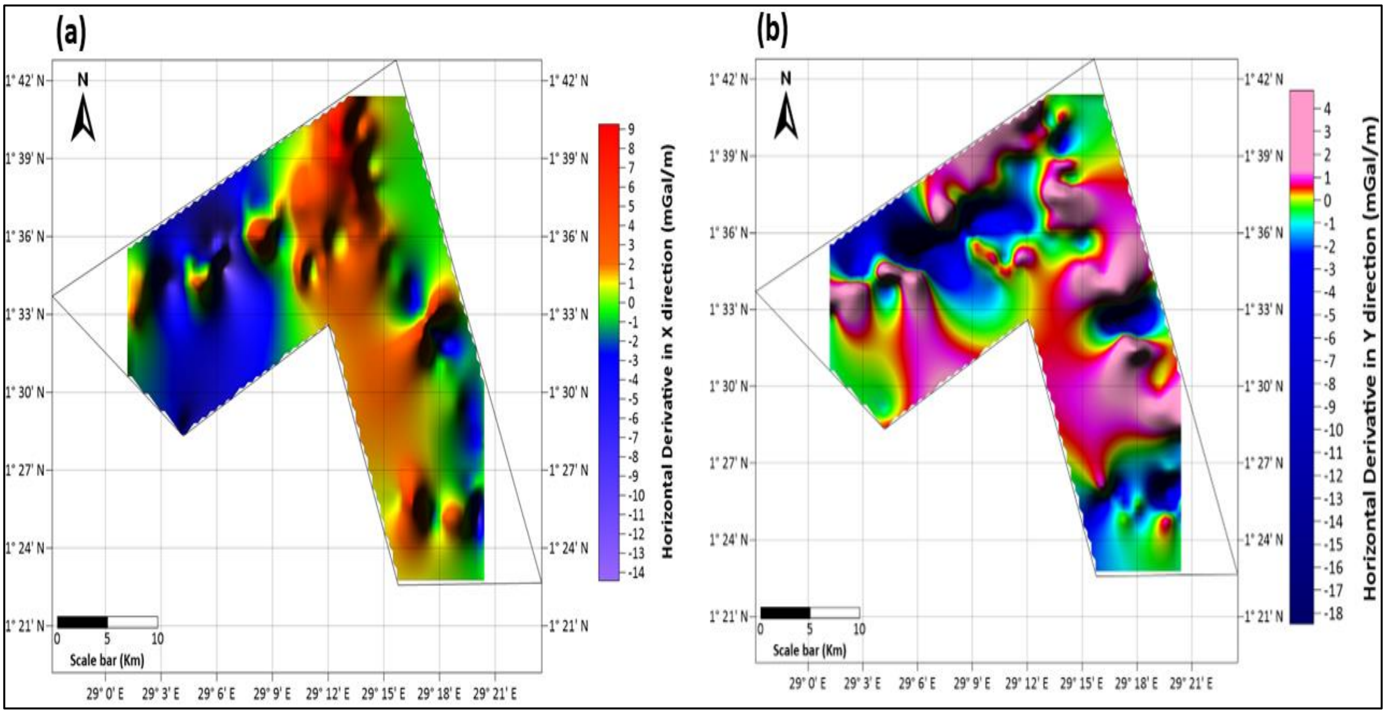

Fig 10: (a) Horizontal Derivative in X Direction (Dx); (b) Horizontal Derivative in Y Direction (Dy).

The anomaly pics (maxima) highlighted in the Dx and Dy maps could be associated with geological structures such as faults or lateral lithological contacts.

VII. CONCLUSION

In conclusion, we say that the interpretation of the gravity data helped us to improve our knowledge of the structural framework of the different geological formations present in our study zone. The center of this zone is dominated by a very low anomaly while the eastern and western parts of this zone are occupied by high values of Bouguer anomalies. Being located in the zone of granitic rocks which have a density between 2.50 and 2.81 g/cm^3, the gravity highs indicate basement uplifts due to compressional movements. The gravity depression represents a ditch or even the presence of very low-density geological formations but which have not been reported on the geological map. Note that the presence of granite domes can be associated with mineralization. The latter could come in particular from the leaching of the basement which was made up of igneous and metamorphic rocks. A new acquisition of fine-grained gravity and magnetic data will certainly make a major contribution to the mineral exploration of this area.

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