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DETERMINATION OF AREAS SUITABLE FOR THE DETECTION OF GEOLOGICAL STRUCTURES IN THE LOKORO SUB-BASIN USING THE MAGNETIC METHOD

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ABSTRACT

This work focuses on identifying potential areas in the Lokoro sub-basin, a strategic region located in the south-western part of the central Congolese basin. Covering an area of 51,759 km², this sub-basin encompasses the Mai-Ndombe province. Mapping the geological structures of this area is essential for highlighting hydrocarbon potential, a crucial aspect for future tenders. The study is based on the processing and analysis of magnetic data collected in the Lokoro sub-basin. The magnetic method, which evaluates the distortions of rocks buried in the earth's crust, enables the interpretation of magnetic anomalies linked to subsoil susceptibility. This approach provides clues to geological formations likely to accumulate hydrocarbons, offering valuable insight to prospectors. The anomalies detected may indicate the presence of geological structures favorable for hydrocarbon accumulation. By deepening our understanding of the geological structures of the Lokoro sub-basin, this research facilitates the exploration and exploitation of petroleum resources in this promising region. In sum, this study is a crucial step in revealing the hidden potential of the Lokoro sub-basin and in guiding petroleum exploration efforts in this resource-rich area.

Keywords: susceptible zones, magnetic data, geological formations, hydrocarbon accumulation, petroleum resources

INTRODUCTION

In addition to Triassic, Paleozoic (including Cambrian and Ordovician), and Vendian strata that show significant tectonic deformations, the Lokoro sub-basin's geological formations are distinguished by nearly tabular Mesozoic horizons [1], [10]. Gravimetry, magnetometry, seismic, and electromagnetic are some of the geophysical techniques used in this area to look for hydrocarbons [11]. Finding geological formations that are likely to be hydrocarbon traps is the goal of these methods [18], [21]. The distribution of the subsurface's physical characteristics can be learning using the many geophysical prospecting techniques [7]. Magnetometry and gravimetry are particularly complementary: magnetometry analyzes the shape of the geological container, while gravimetry assesses the shape of the contents [23], [24]. It should be noted that the gravitational field is always directed towards the center of the Earth, whereas the magnetic field can vary in all directions, except at the poles (*g* = *B*) [11], [23], [24].

The main objective of this study is to identify geological structures of major petroleum interest, likely to form hydrocarbon traps. To achieve this, we will process magnetic data by visualizing magnetic anomaly maps and examining profiles highlighting interesting geological structures. Our study area (Figure 1) is located in the south-west of the Democratic Republic of Congo, entirely in the new Mai-Ndombe province [3], [4].

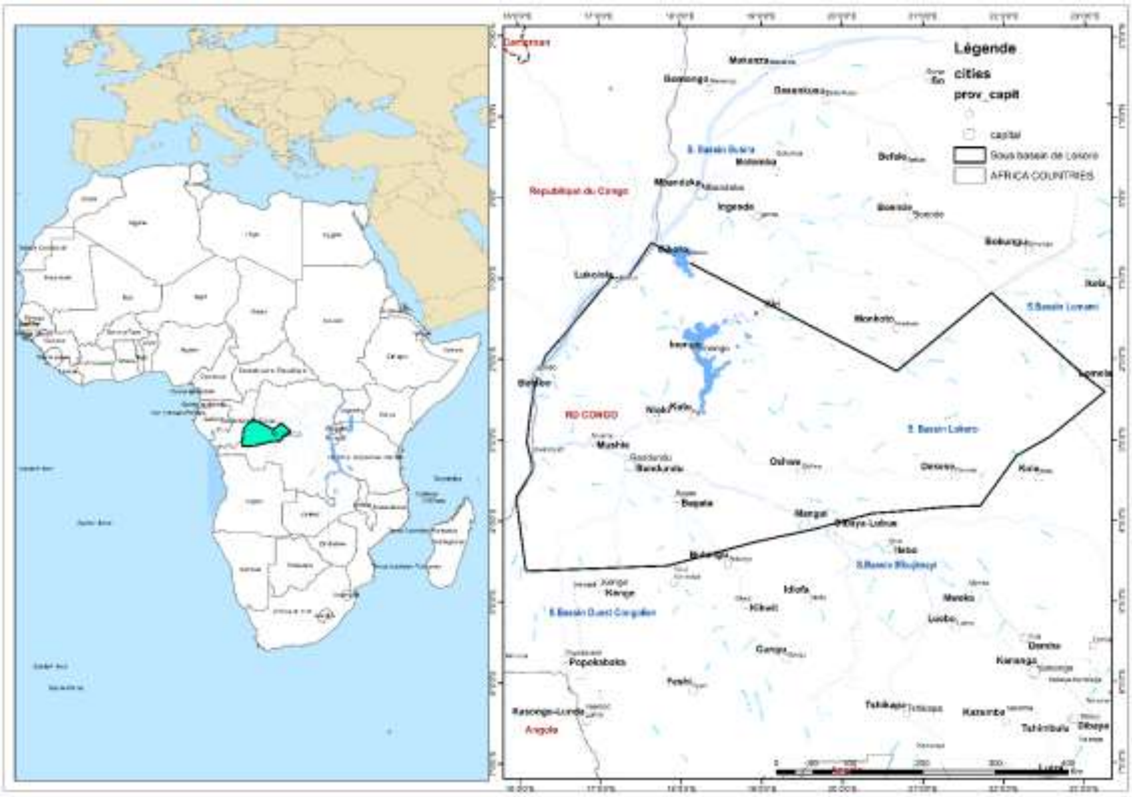

***Figure 1**. Location of the Lokoro sub-basin.*

MATERIALS AND METHODS

The aim of this work is to identify and characterize potential geological structures in the Lokoro sub-basin, located in the central basin of the Democratic Republic of Congo, through the interpretation of magnetic data. Magnetic data, which measure the distortions of rocks buried underground, are crucial for detecting anomalies associated with underlying geological formations [23], [24].

The study is based on the processing and analysis of magnetic data collected in the sub-basin. The magnetic method measures the distortion of rocks buried in the earth's crust

[8], providing information on magnetic anomalies that may indicate the presence of geological formations favorable for hydrocarbon accumulation [17]. These anomalies are essential for the prospector, as they indicate potential sources of hydrocarbons at different depths in the earth's crust [13], [15]. The gravimetric data presented in the Table 1 are essential to guide geological investigations in the Lokoro sub-basin, identifying areas where geological structures can be detected using geophysical methods.

***Table 1**. Presentation of gravimetric data for the study area* [22]

Longitude (degrees)	*Latitude (degrees)*	*Bouguer anomaly (mGal)*
21,65	-4,35	-81,2275
21,55	-4,30	-80,1163
21,60	-4,30	-78,5673
21,65	-4,30	-78,0397
21,70	-4,30	-76,6646
21,50	-4,25	-79,6448
21,55	-4,25	-78,2586
21,60	-4,25	-76,2886
21,65	-4,25	-74,6049
21,70	-4,25	-72,2476
21,75	-4,25	-69,2562
21,40	-4,20	-79,3193

RESULTS AND DISCUSSION

An airborne survey was carried out by CGG, ESSO TEXACO in collaboration with the Congolese state structures responsible for hydrocarbons between 1973 and 1987, financed by the central government. The aim of this campaign was to highlight the possibility of finding a petroleum system in the Cuvette Centrale, since the latter is a vast subsidence zone and abounds with several seeps across its surface, Lokoro sub-basin was entirely covered by magnetometric prospecting. The flight plan consists of North-South lines spaced 25 km apart, with East-West crossings every 18 km. But in the Oshwe territories, this spacing was halved, so it dropped from 18 km to 9 km; this is to highlight the seepage discovered in this area [3], [4].

TREATMENT OF MAGNETIC ANOMALIES

MAGNETIC ANOMALIES

The Total Magnetic Field anomaly shown in the Figure 2 varies from -100 to 122.7 nT. The northern part going north-east and north-west shows that they are dominated by the presence of high total magnetic field anomalies ranging from 32.5 to 122.7 nT. Negative or light anomalies are present in the central part to the south, south-east and south-west. As magnetometry allows us to highlight the bedrock trend [9], as for the Lokoro sub-basin, the map of the total magnetic field distribution shows that the bedrock is oriented East-West.

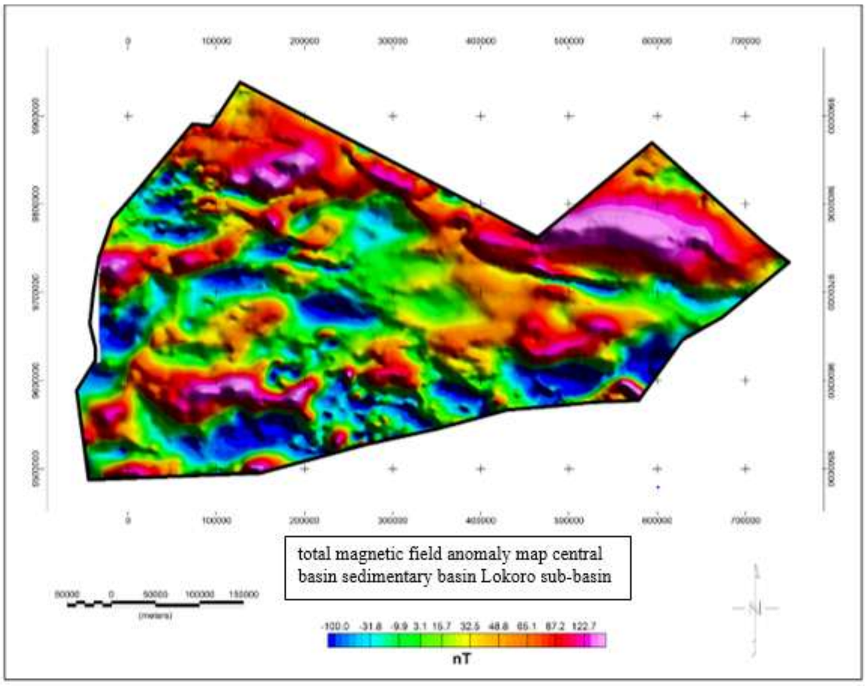

Figure 2. *Total magnetic field anomaly map.*

MAGNETIC INCLINATION

The mean value of the magnetic inclination allows us to map the reduced magnetic field at the pole, as it is used in the formula for the vertical component [23]. For this reason, a map showing the tilt distribution in the Lokoro sub-basin and a histogram have been drawn up to highlight the statistical parameters, in particular the mean value, which must be included in the calculation (Figure 4). The map showing the distribution of inclination varies from -38.1 to -30.5 degrees. It varies and increases from north to south, with a difference of -1.5 degrees according to the color scale. A map showing the distribution of magnetic inclination in the study area is shown in the Figure 4.

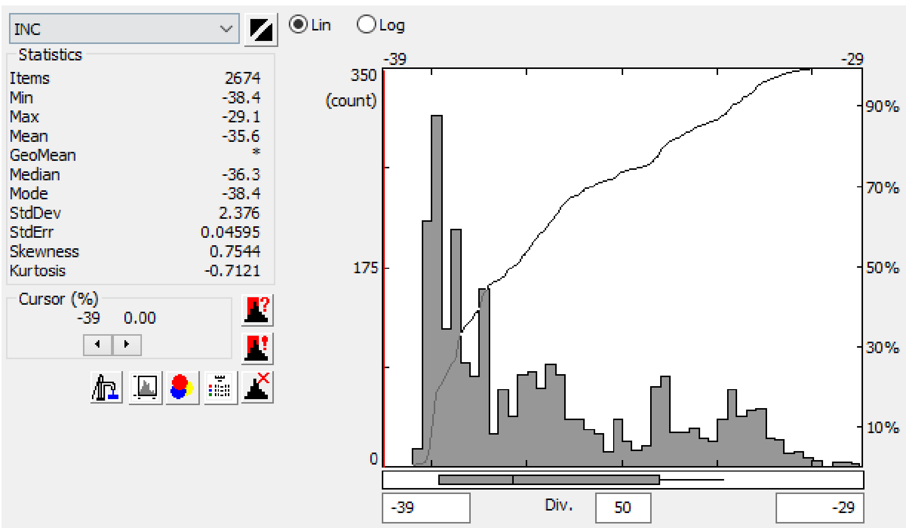

Figure 3. *Tilt histogram using Grapher*

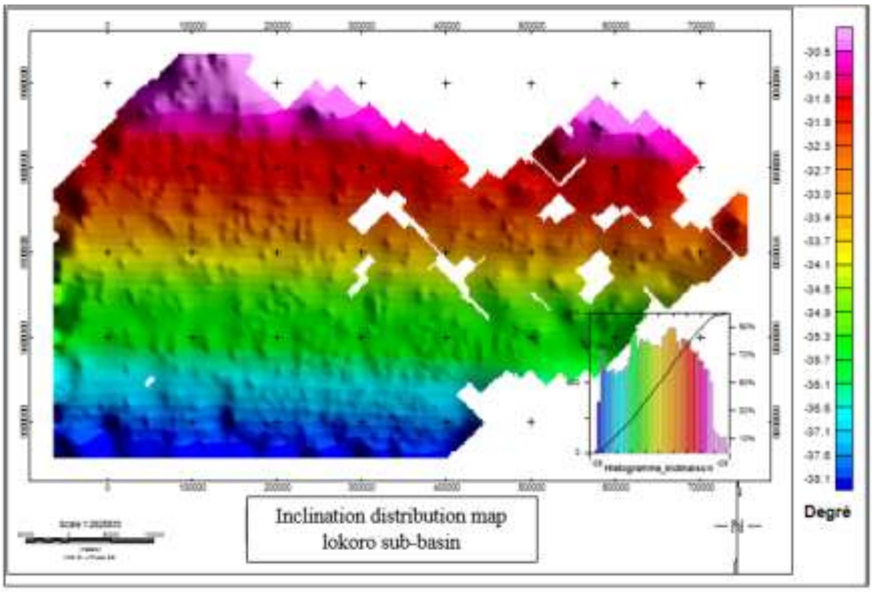

Figure 4. *Evolution of magnetic inclination in the Lokoro sub-basin.*

MAGNETIC DECLINATION

Magnetic declination shows values ranging from -4.7 to -2.4 degrees. It varies by -0.2 degrees from NE-SW. Declination increases from SW-NE. The distribution of magnetic declination is illustrated on the map shown in Figure 5. The mean value of the declination we will use to calculate the Magnetic Field to find the vertical component is -3.8 degrees (Figure 6).

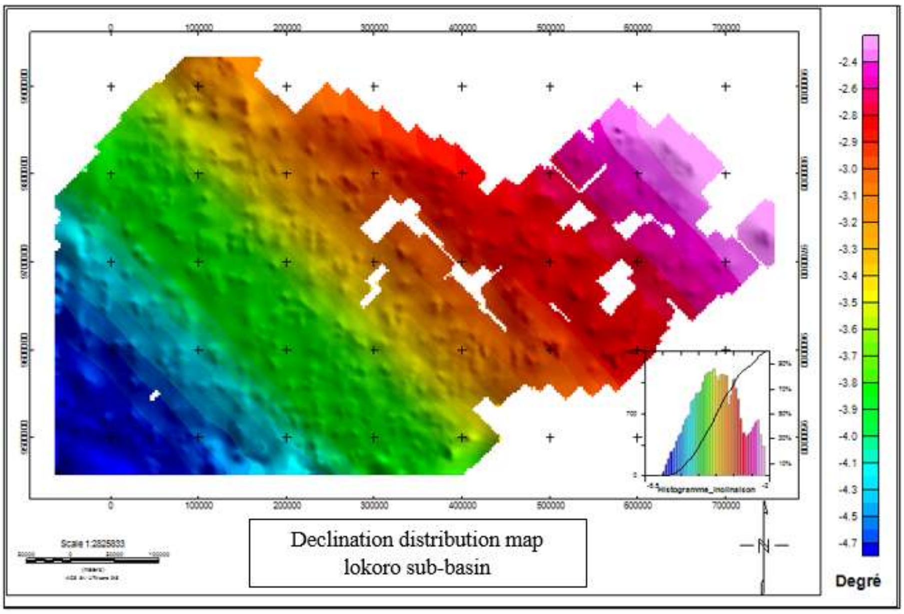

Figure 5. *Evolution of magnetic declination in the Lokoro sub-basin.*

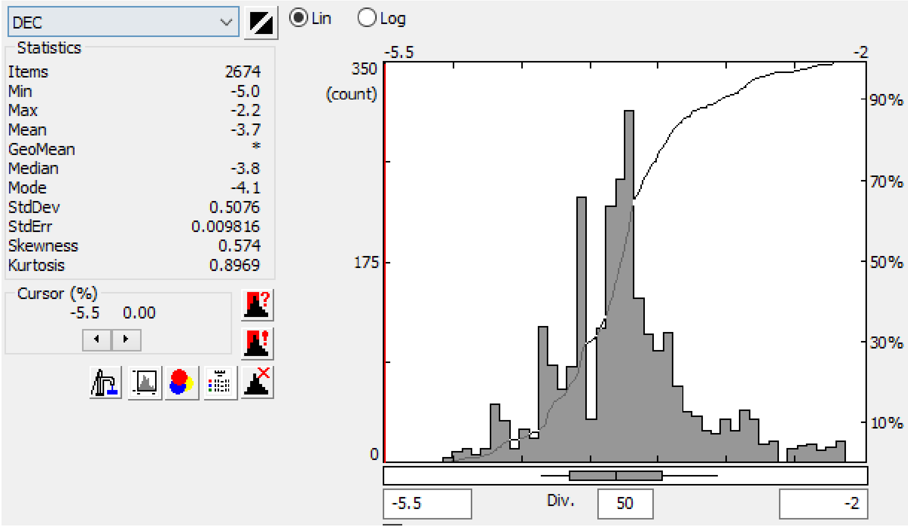

Figure 6. *Declination histogram using Grapher*

POLE REDUCTION

Modern methods for processing magnetic anomalies come before modeling [2]. Pole reduction is the process of transforming all observed anomalies at a given location into pole-reduced anomalies [11], [12].

The new anomalies are those that would be observed if the field were vertical in the study zone [24]. This then simplifies the modelling, as the situation is identical to that encountered in gravimetry.

To find the magnetic anomalies of the reduced total field at the Pole, we need to know the magnetic inclination and declination [22]. To find them, you need to know the average altitude, the Total Magnetic Field of the study area, the year of the magnetic survey and the geographical coordinates [20].

The map of magnetic anomalies reduced to the pole (Figure 7) shows us that their intensity ranges from 133.2 to 197.9 nT. These anomalies are distributed as follows:

- Positive or heavy anomalies in the range 12.6 to 197.9 nT are located to the west, northwest and part to the southwest;
- Negative or light anomalies are therefore located in the center going south and west, and part in the northeast. These anomalies lie in the lower intensity range of 12.6 nT.

Generally speaking, the magnetic anomalies reduced at the pole present East-West and other North-West to South-East trends.

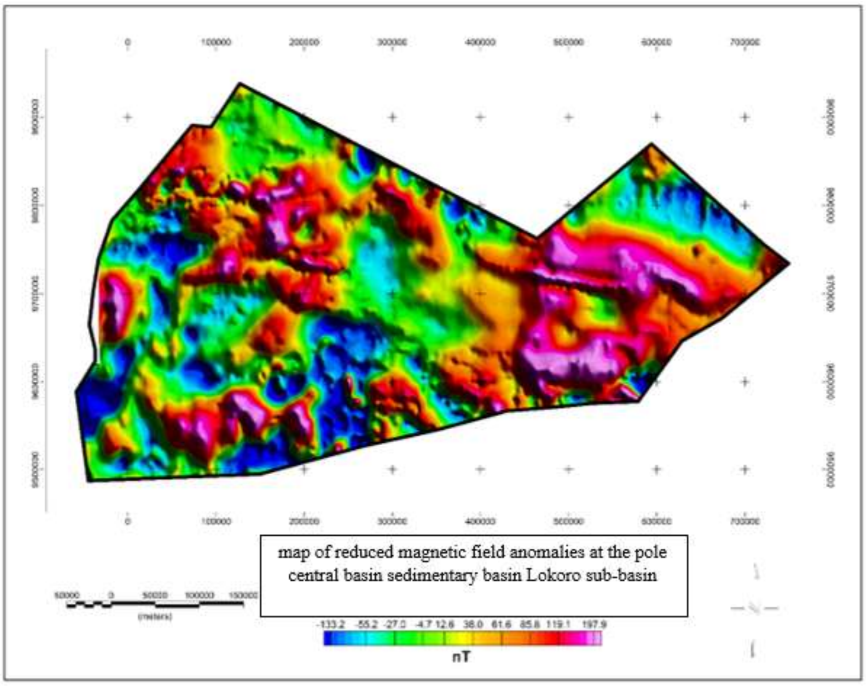

***Figure 7**. Map of reduced magnetic anomalies at the pole.*

DERIVATIVE WITH RESPECT TO X

The derivative map with respect to X shows magnetic lineaments in the direction perpendicular to the derivation [25]. We observe magnetic lineaments-oriented North-South. These are not distributed throughout the Lokoro sub-basin. However, they are prominent in the western part, south towards the south-west and part towards the east (Figure 8).

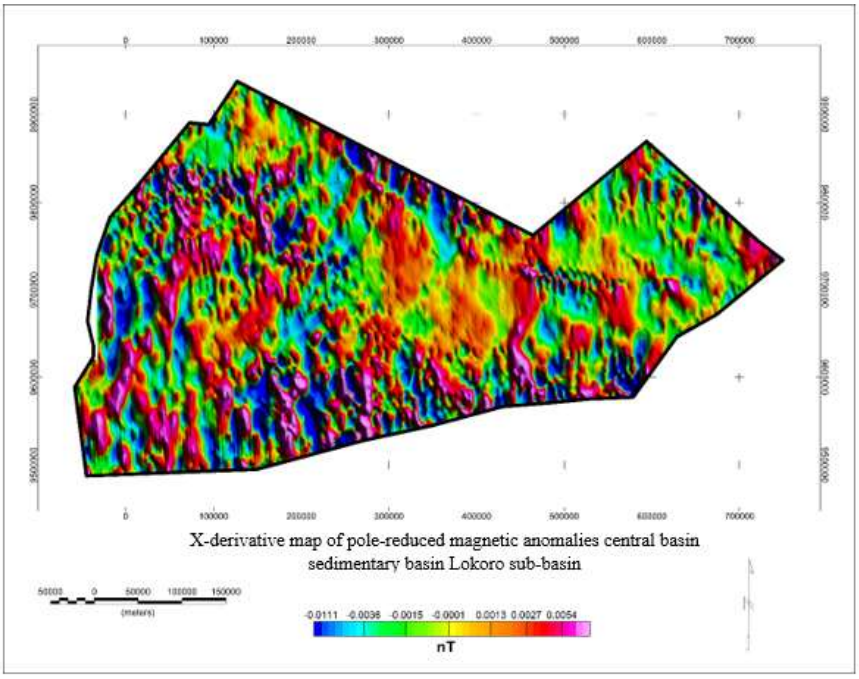

***Figure 8**. Derivative map with respect to X.*

DERIVATIVE WITH RESPECT TO Y

The map of the horizontal derivative with respect to Y shown in the Figure 9 shows many magnetic lineaments oriented in the East-West direction, perpendicular to the derivative. This map highlights significant magnetic lineaments to the west, south and south-west and south-east.

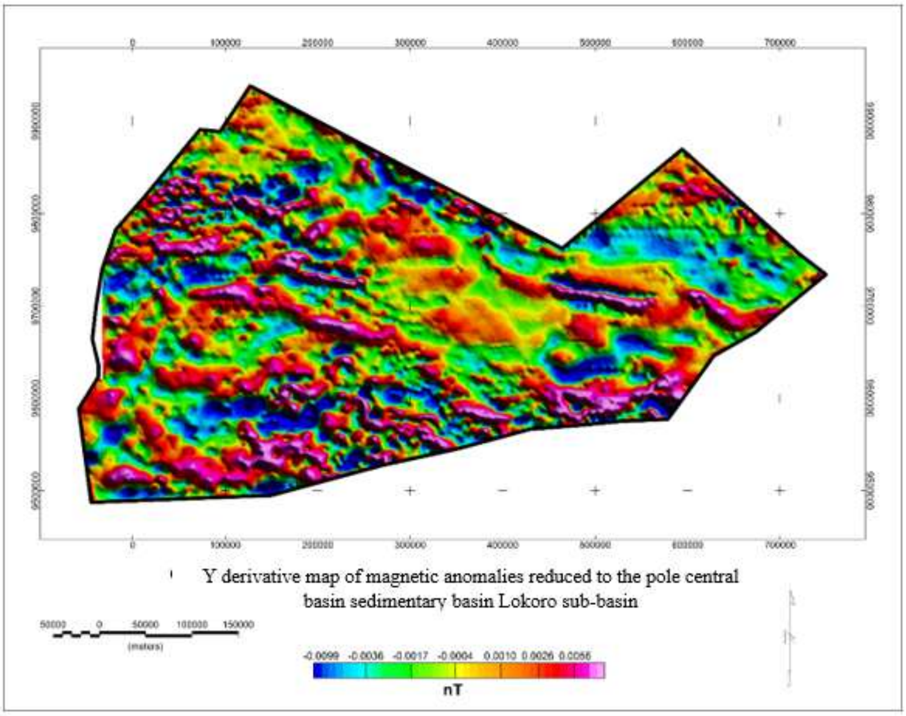

Figure 9. *Y derivative map*

45-DEGREE DERIVATIVE

This filter was used to highlight magnetic lineaments in the direction perpendicular to 45 degrees [16]. We observe magnetic lineaments running north-west to south-east, or at 135 degrees. These lineaments (Figure 10) are most abundant in the southern and western parts, descending towards the south-west. Magnetic lineaments can correspond to either faults or lithological contacts [6], [19]. These lineaments enable us to identify at least those zones where tectonics have revealed faults [15], [16]. A map illustrating the magnetic lineaments shown in the Figure 11 was therefore presented, with a view to locating areas with a strong presence of magnetic lineaments. Observation of the map below shows lineaments covering almost the entire Lokoro sub-basin, except for the central part and a section to the east. The parts not covered or with weak magnetic lineaments can be explained by the presence of a significant sedimentary thickness.

APPLICATION OF THE EULER DECONVOLUTION FILTER

This filter was used to highlight hydrocarbon traps such as anticlines. To do this, we used Bouguer anomaly data with a structural index of 0 to highlight dykes. Their circular shapes and variations in depth allow us to identify the geological structures that may underlie them (Figure 12).

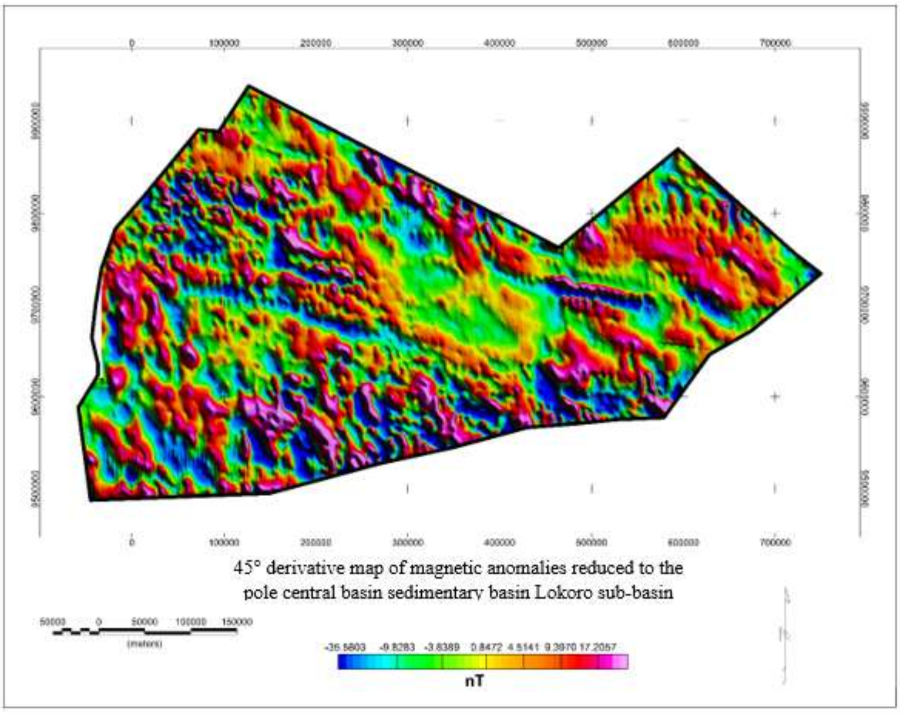

***Figure 10**. 45-degree derivative map.*

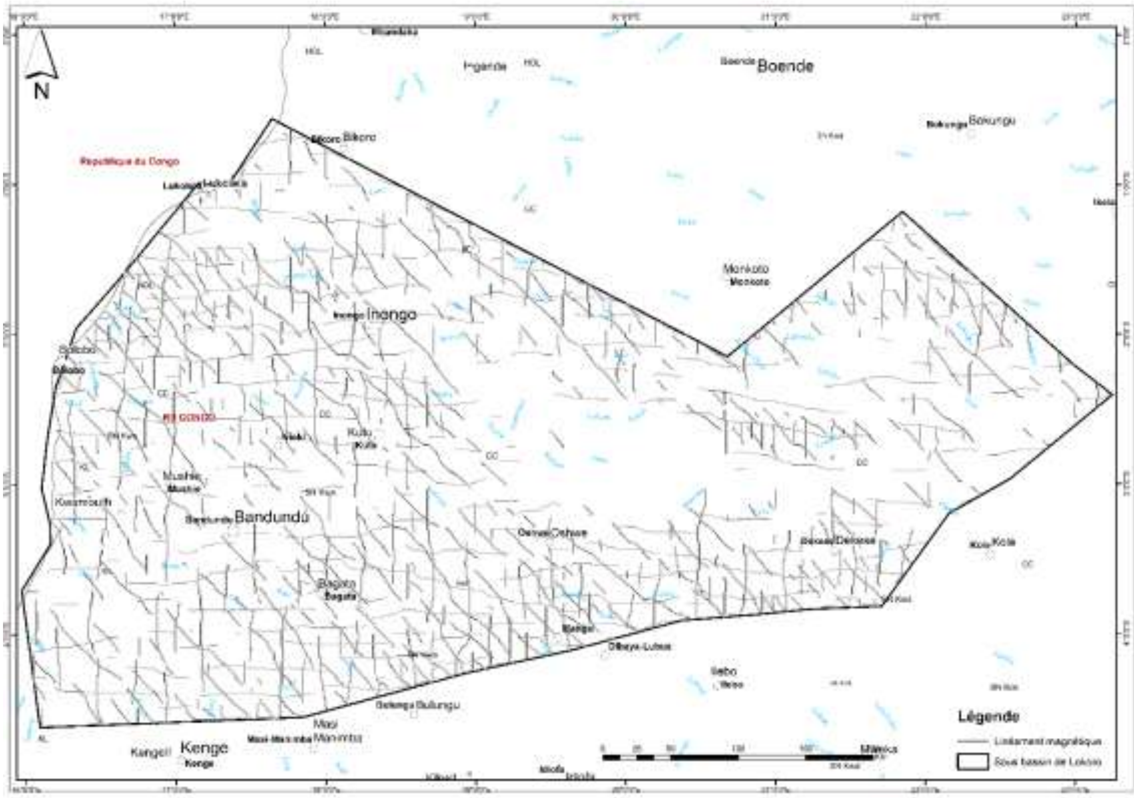

***Figure 11**. Map of magnetic lineaments in the Lokoro sub-basin.*

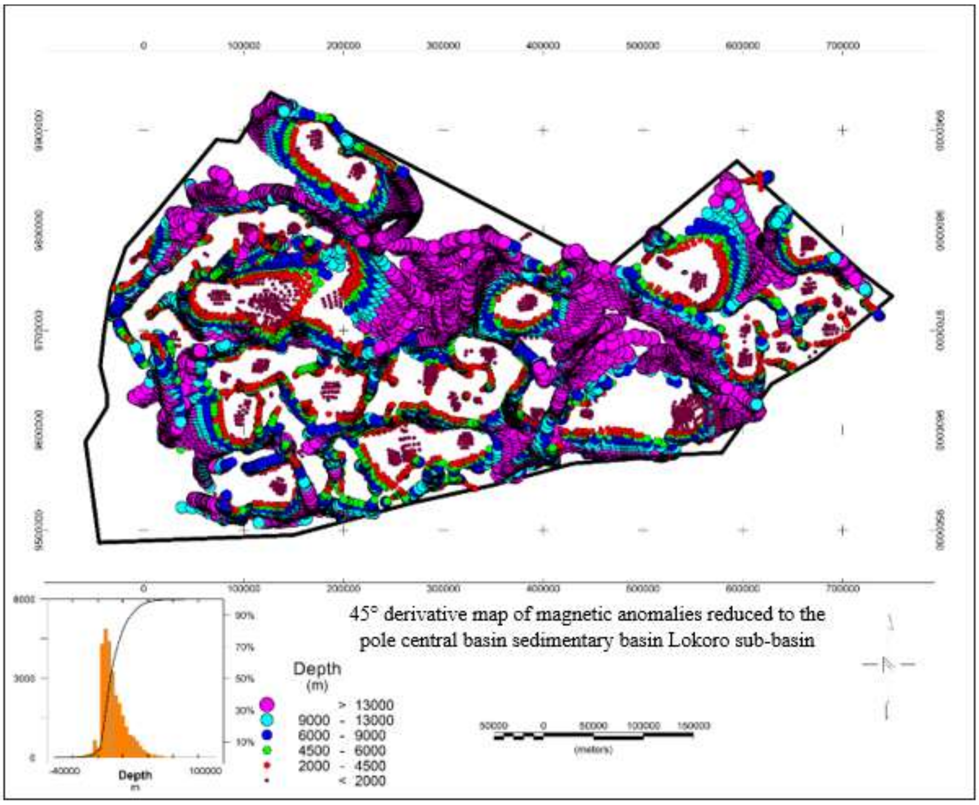

Figure 12*. Dyke depth map in the Lokoro sub-basin.*

DISCUSSIONS

- ✓ Structural analysis of magnetic surveys: This involves studying variations in the Earth's magnetic field to understand the underlying geology, such as faults and rock layers.
- ✓ Correlations with stratigraphy: Anomalies observed in magnetic surveys coincide with geological formations identified by seismic data. A lack of correlation may indicate the need for other exploration methods.
- ✓ Local anomalies and oilfields: Some magnetic anomalies are indicative of oil or gas resources, which can guide exploration efforts.
- ✓ Source rocks and reservoirs: Magnetic anomalies can indicate changes in rock types, which are relevant for identifying likely to contain hydrocarbons.

CONCLUSIONS

Magnetometry is an effective method for exploring the magnetic susceptibility distribution of rocks, revealing crucial information about their composition and structure. When a rock has a high magnetic susceptibility, it is more apt to be traversed by a magnetic field, unlike low-susceptibility rocks, which interact differently with these fields. This technique is particularly valuable in oil exploration, where it can be used to identify geological structures likely to contain hydrocarbons.

Map interpretations resulting from the processing of magnetic anomalies have led to significant discoveries:

- ✓ Euler deconvolution filter: By applying this method, it was possible to determine the depths of geological structures. The structural index used for the gravity and magnetic data revealed that the depth of the dykes exceeds 500 meters, providing a solid basis for geological studies.
- ✓ Dyke geometry: In the Lokoro sub-basin, analyses showed that the dykes are circular or ellipsoidal in shape. The extremities of these structures are characterized by significant depths, while the center displays shallower depths, which could indicate zones favorable for hydrocarbon accumulation.
- ✓ The use of magnetometers in petroleum exploration is essential. Not only does it measure the intensity and direction of the magnetic field, it can also detect magnetic anomalies that may indicate the presence of underground resources. Thanks to technological advances, modern magnetometer models now incorporate features such as GPS, which considerably improve the accuracy of readings and facilitate geological mapping.

In short, magnetometry is an indispensable tool in petroleum exploration, providing an in-depth understanding of the underlying geological structures. Its application not only allows us to identify possible hydrocarbon-rich zones, but also to better understand our planet's geological dynamics. Thanks to these advanced techniques, researchers can continue to explore and discover the riches hidden beneath our feet.

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