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CONTRIBUTION TO THE GRAVIMETRIC AND MAGNETOMETRIC STUDY FOR THE IDENTIFICATION OF ZONES WITH OIL POTENTIAL IN THE CENTRAL BASIN: CASE OF BLOCKS 1 AND 24 IN THE DRC

César Tambashie Okitafumba [1*]

Ravely Nsieto Lusakueno [1]

Michel Ndete [2, 3]

Osée Mayinga Mayinga [1]

Bob Mayemba Kisaka [1, 3]

Franklein Muamba Kanangila [1]

[1] Exploration-Production Department, Faculty of Oil, Gas and Renewable Energies, University of Kinshasa, D.R. Congo
[2] Geoscience Department, Faculty of Science and Technologies, University of Kinshasa, D.R. Congo
[3] Center for Geological and Mining Research (CRGM), Democratic Republic of Congo
[4] Mining Cadastre, D.R. Congo
email (corresponding author): cesar.tambashie@unikin.ac.cd; cesarokita64@gmail.com

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ABSTRACT

In the search for hydrocarbons, geologists, geochemists and geophysicists work together on the scale of a sedimentary basin. They seek to identify a petroleum system in order to maximise the chances of finding an accumulation of hydrocarbons in a specific part of the subsoil. The exploration campaign in the Cuvette Centrale began in the 1950s with geological, geophysical, geochemical and drilling campaigns carried out by several foreign organisations, including the Belgian firm Remina. These campaigns provided key information about the petroleum systems. These include the presence of hydrocarbon showings and geological structures that may favour the formation, migration and trapping of hydrocarbons.

The main aim of this work is to highlight the geological structures of major petroleum interest, while identifying the geological structures found in our study area, particularly in Blocks 1 and 24 in the central basin of the Democratic Republic of Congo, and their petroleum interest, based on the processing and interpretation of magnetic and gravity data. To better study our sedimentary basin, we used the method of regional-residual separation and variation of the Magnetic Field, we had to highlight the faults in different directions North-West towards the South-East, the collapse trenches localised in the North-East, the zones of uplift of Socle which today constitute the top of Inongo.

As never done before, this study develops a structural reference model by integrating the analysis of Bouguer and magnetic anomalies. It aims to locate zones of source rock maturation, identify possible hydrocarbon migration paths and pinpoint geological structures conducive to hydrocarbon accumulation. The results, presented in map form, are a strategic tool for petroleum exploration and the analysis of regional tectonic dynamics. In particular, it provides an unprecedented and detailed geophysical record for Blocks 1 and 24 of the Cuvette Centrale, enabling a targeted and efficient assessment of petroleum potential.

Keywords: petroleum potential, magnetic fields, geological structures, anomaly, fault, geological contact

INTRODUCTION

The Democratic Republic of Congo is a country with enormous potential in terms of hydrocarbons and metallic and non-metallic mineral resources. Certain untapped resources in the Democratic Republic of Congo, such as hydrocarbons, remain a challenge today, as they represent a shortfall in revenue. The exploration campaign in the Cuvette Centrale began in the 1950s with geological, geophysical, geochemical and drilling campaigns carried out by several foreign organisations, including the Belgian firm REMINA. These campaigns provided key information about the petroleum systems. These include the presence of hydrocarbon showings, geological structures that may favour the formation, migration and trapping of hydrocarbons. [1],[2]

We are well aware that the central basin underwent extension in the Upper Proterozoic and was reactivated in the Mesozoic (Karroo) by the dynamics of stretching. During this period, tectonic faults developed in the Congo craton, leading to the formation of several horsts and grabens. A new rejection occurred in the Upper Jurassic. It was during this movement that the oil shales of the Kisangani stage were deposited. Another rejection occurred in the Cretaceous, in connection with the system of trenches that led to the break-up of the Congo Craton and the opening of the South Atlantic. It was during this period that the Kipala bituminous layers were deposited [2],[3].

The stratigraphy of the central basin shows polymorphous sandstones and ochre sands of Cenozoic fluvial and eolian origin at the base. The Upper Palaeozoic includes Carboniferous and Permian formations. From the Upper Proterozoic to the Paleozoic (Devonian), three groups have been identified [4],[26]:

- The Proterozoic age group, made up of lagoonal marginal marine sediments.
- The Cambrian age group, with alluvial deposits (Bobwamboli arkoses) and deltaic Mamungi and Kolé shales.
- The Ordovician, Silurian and Devonian age group contains the Galamboge quartzites (marine dunes), the Alolo shales (fluvial) and the Banalia arkoses (deltaic).

Our aim is to contribute to the development of a structural model of inestimable interest, as it will enable us to locate the areas of maturation of the source rocks; to gain an idea of the possible migration routes of hydrocarbons; to identify and locate geological structures likely to contain oil (oil traps) based on the interpretation of Bouguer and magnetic anomalies. The results are presented in map form.

This research contributes to the development of a structural reference model, based on the joint interpretation of Bouguer and magnetic anomalies. The aim is to locate areas of source rock maturation, identify potential hydrocarbon migration pathways, and highlight structures conducive to hydrocarbon accumulation (structural traps). The results, presented in map form, offer strategic support for oil exploration and understanding regional tectonic dynamics.

It should be emphasized that this study provides Blocks 1 and 24 of the Cuvette Centrale with a geophysical record that is sufficiently detailed to enable in-depth analysis. This analytical framework thus provides a solid basis for directing exploration towards the most promising zones, with a view to a more targeted and efficient assessment of oil potential. No previous studies along these lines have been carried out in these two blocks in the past.

MATERIALS AND METHODS

Any scientific study relies on a number of methods and techniques. The methods and techniques used in this work include the following:

To carry out this work, we used a computer with software for analysis, processing, 2D and 3D visualisation, profile plotting and data modelling, including: Golden Surfer, Geosoft Oasis_montaj and ArcGIS.

Gravimetry is one of the methods used in geophysical prospecting. It is used to study the subsurface by analysing variations in the gravity field. Spatial variations in the gravity field reflect the contrasting densities of rocks in the Earth's crust. Gravimetry therefore makes it possible to probe at a distance for bodies of interest to the prospector [5],[6],[7]. Like any geophysical prospecting campaign, a gravimetric campaign generally comprises three stages: data acquisition, which is carried out by surveying with a gravimeter, data processing and data interpretation [8],[9],[10].

Magnetic methods have been used in applied geophysics for a long time and are still the first of the other geophysical techniques to be used in mineral exploration and often in oil exploration. [28]. By definition, a magnetic anomaly is the difference between the value of the measured field and the theoretical one; these anomalies are due to changes in the structure or geological nature of the subsoil**.** [10],[13],[14].

A raw anomaly cannot give precise information because of the influence of several parameters on the measurements, and therefore, before moving on to the interpretation stage, we will have to introduce the necessary processing to the data taken in the field. [10],[13],[14].

Proper interpretation requires knowledge of a number of details that only become apparent when these processes are applied to the raw data. The aim of these operations is to better position the magnetic and spectrometric anomalies, to separate their sources and to remove the noise that affects the measurements. [10],[13],[28].

In magnetic prospecting, we are interested in the anomalous field of crustal origin. The residual (anomalous) field is the difference between the total field and the regional (local) field. [10],[13].

RESULTS

Localisation

Our study area is located in the western part of the DRC (Figure 1), covering nine territories: Mbandaka, Bikoro, Ngende, Kiri, Lukolela, Monkolo, Bomongo and Bolomba. It is located between longitudes 17 and 20° East and latitudes 1 North and 1 South. [11],[12],[24],[25]

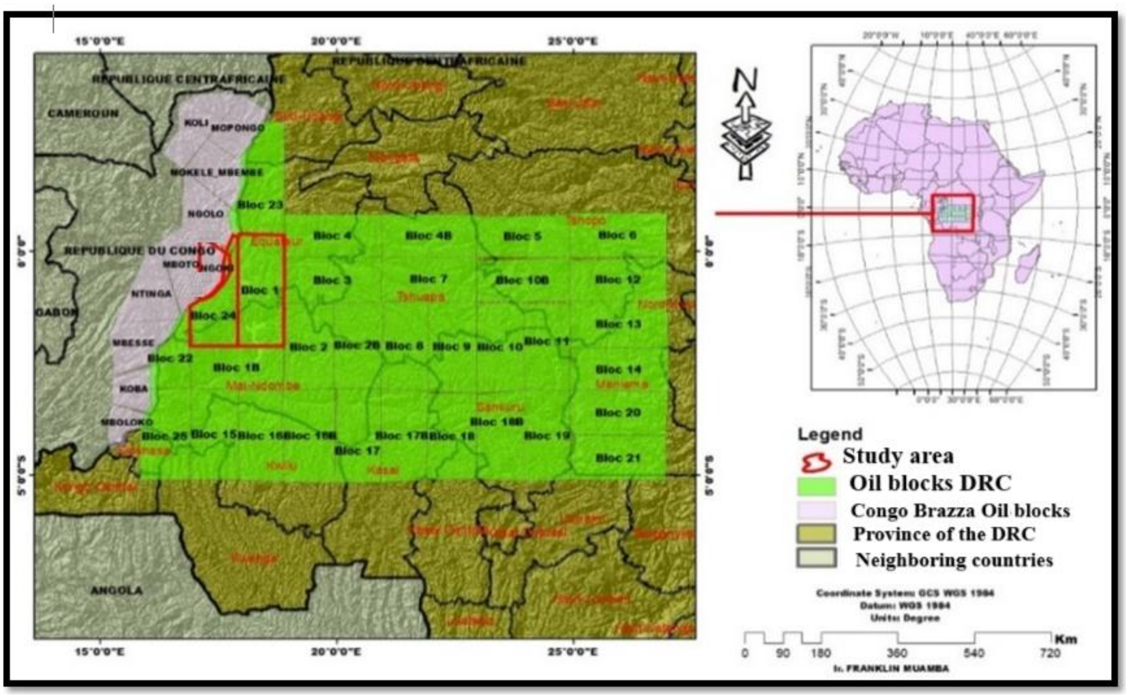

***Figure 1**. Map showing the location of the study area*

Presentation of the geophysical data

The gravimetric and magnetic data used in this work come from an airborne survey carried out in the Cuvette Centrale in 1987 by CGG on behalf of the Ministry of Hydrocarbons. [12]

Here, we define the spatial variations of the acceleration of gravity by the values of Bouguer and the variation of the Magnetic Field; this means that we have used data that have already been corrected for external causes (effects of: lunisolar attraction, latitude, topography, etc.) that may influence them. [13],[14]

In addition, these measurements were taken at 900 m above ground level on a global grid made up of 82,203 lines separated by at least 30 km in length and 20 km in width, with a maximum spacing of 80 m between reading stations.

It is not easy in this work to give a list of all the measurements, given their multitude. This is why, for illustrative purposes, we have chosen 10 stations. For each measurement station shown in Table 1, we give the geographical coordinates: longitude, latitude and the Bouguer and Magnetic Field values. [11],[24]

***Table 1**. Representation and structure of the gravimetric and magnetic data used*

X longitude	Y latitude	Anomaly Bouguer	Anomaly magnetic field	X	Y
21,25	-3,8	-67,3592	29,84964561	22,39999909	-2,649999967
21,3	-3,8	-69,1776	29,02624321	22,40999909	-2,649999967
21,35	-3,8	-70,9063	28,40869141	22,41999909	-2,649999967
21,15	-3,75	-62,2575	28,30576706	22,42999909	-2,649999967
21,2	-3,75	-62,5157	27,94552803	22,43999909	-2,649999967
21,25	-3,75	-63,7673	27,94552803	22,44999909	-2,649999967
21,3	-3,75	-65,7877	27,94552803	22,45999909	-2,649999967
21,35	-3,75	-68,0664	28,15137863	22,46999909	-2,649999967
21,4	-3,75	-70,4348	28,61454201	22,47999909	-2,649999967
21,1	-3,7	-58,1267	29,12916756	22,48999909	-2,649999967

PROCESSING AND INTERPRETATION OF DATA

Total Magnetic Field anomaly maps

The map on the Figure 2 showing the distribution of the Magnetic Field in our study area delimits the heavy anomalies in red colour located in the centre going East and North-East. It also appears in the South-Western part and to the North towards the West. There are also several small circular heavy anomalies on the map. [10],[15],[16]

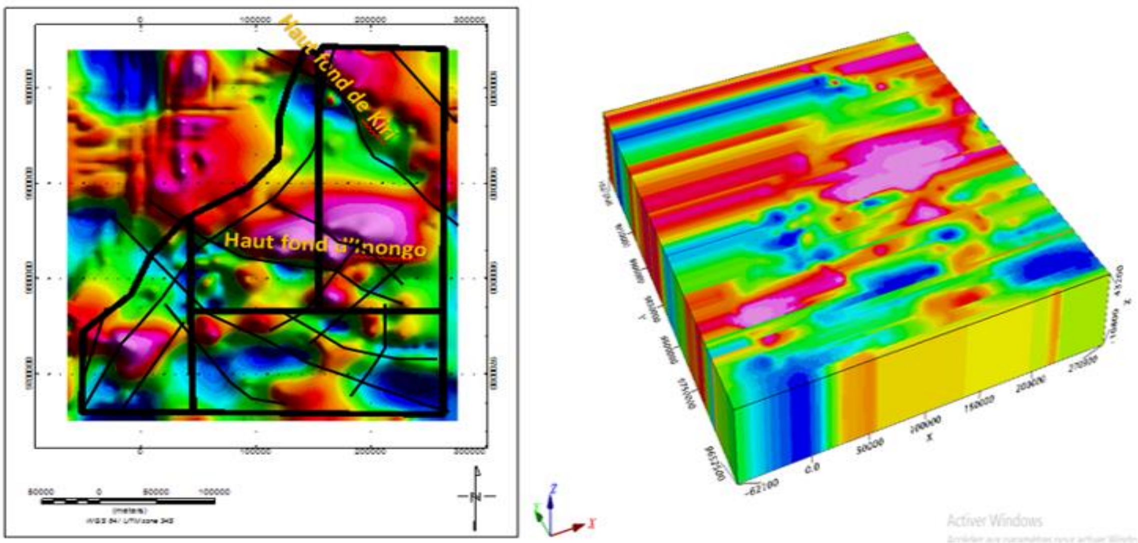

***Figure 2.** Map of total magnetic field anomalies*

As for the light anomalies, they are found in the North-West, West, South and part towards the North-East and South-East. Medium anomalies are located alongside heavy and light anomalies. If we look at the behaviour of these anomalies, we see a range of heavy, light and medium circular anomalies, especially towards the south and north-east.

Generally speaking, the areas of heavy anomalies are attributed to the uplift of the bedrock, and the areas of light anomalies to the thickness of the sediments. Thus, based on this structural interpretation, the southern and north-eastern parts are configured as a horst and a graben following a disjunction between light and heavy anomalies. [10],[16],[17]

As the magnetic method gives us information on the shape of the Base, for our study area the shape of the latter is from North-East to South-West and others are oriented from North-West to South-East. We note the presence of large faults on the map of magnetic anomalies oriented more from North-West to South-East. [13],[18]

Horizontal derivate relative to X

The horizontal derivative with respect to X (Figure 3) has enabled us to highlight information on lithological contacts or faults in the direction perpendicular to X. [17]. We can see faults or lithological contacts running more in a north-west to south-west direction. Other faults run north-east-south-west and north-south.

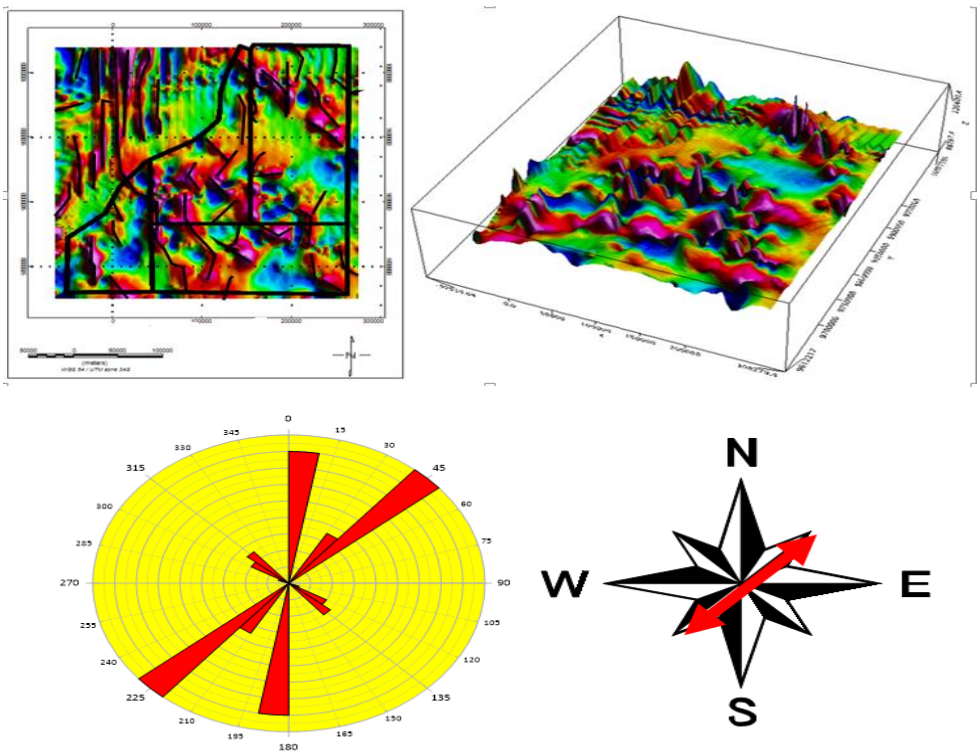

Figure 3. *Map of the horizontal derivative with respect to X and identification of faults*

Horizontal Derivative Relative to Y

The map of the horizontal derivative with respect to Y (Figure 4) highlights faults or lithological contacts in the direction perpendicular to Y. The geological structures identified, in this case faults, run from east to west. Some faults run from north-east to south-west [10],[17]. These faults favour the migration and trapping of hydrocarbons in the Central Cuvette of the DRC.

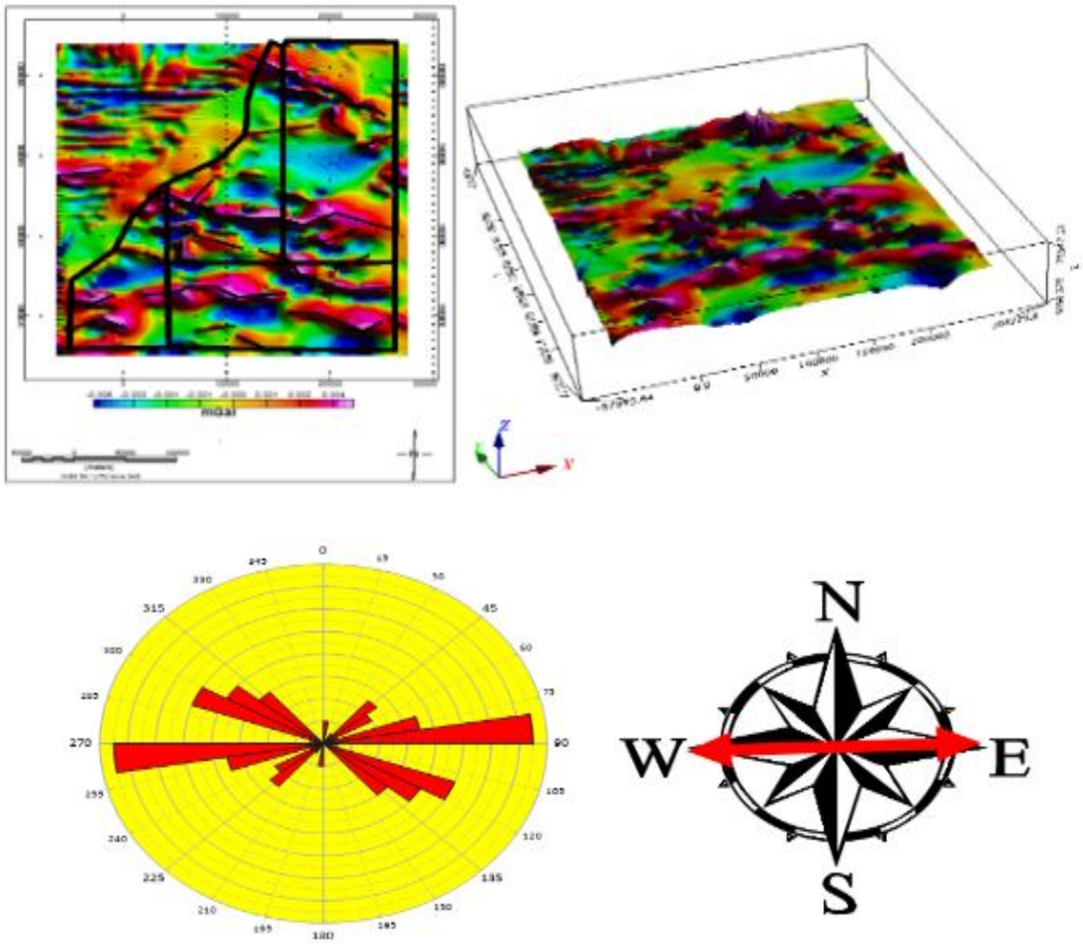

Figure 4. *Map of the horizontal derivative with respect to Y of the Total Magnetic Field, identification of faults and preferential direction.*

Vertical Derivative

The vertical derivative of the total magnetic field in our study area shows the peaks of heavy anomalies located more in the central, southern and north-eastern parts. The faults identified in the vertical derivative map (Figure 5) of the total magnetic field are located at the edges of the heavy anomalies corresponding to the maximum gradients. These faults are of the brittle type and some are lineamentary, located at the edges. [19],[20]

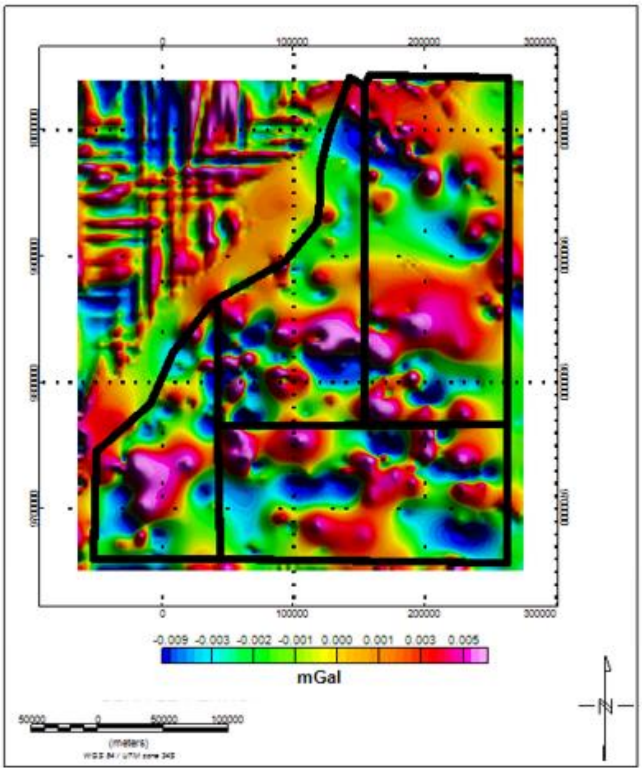

Figure 5. *Vertical drift map, location of faults and diagram of preferential fault directions*

Map of Bouguer Anomalies

The Bouguer anomaly map (Figure 6) shows heavy anomalies to the north-east and south. The one located towards the North-East shows an elongated and therefore linear shape which goes from North-West to South-East.

The anomalies to the south are east-west and north-east to south-west. These heavy anomalies are assimilated to magmatic intrusions or basement uplift. There are 3 basement uplift structures identified on the Bouguer anomaly map. [21],[22]

Deep zones that we consider to be collapse trenches. These zones contain great sedimentary thicknesses and there are two of them. One is located to the south-west of Fond 1, oriented north-west to south-east, and the other to the south of Fond 2.

A number of faults are present, running north-west to south-east. The major faults are located at the edges of the heavy anomalies, i.e. at the shoals. There are also some brittle faults located above the latter. These faults are more oriented North-East to South-West. [23]

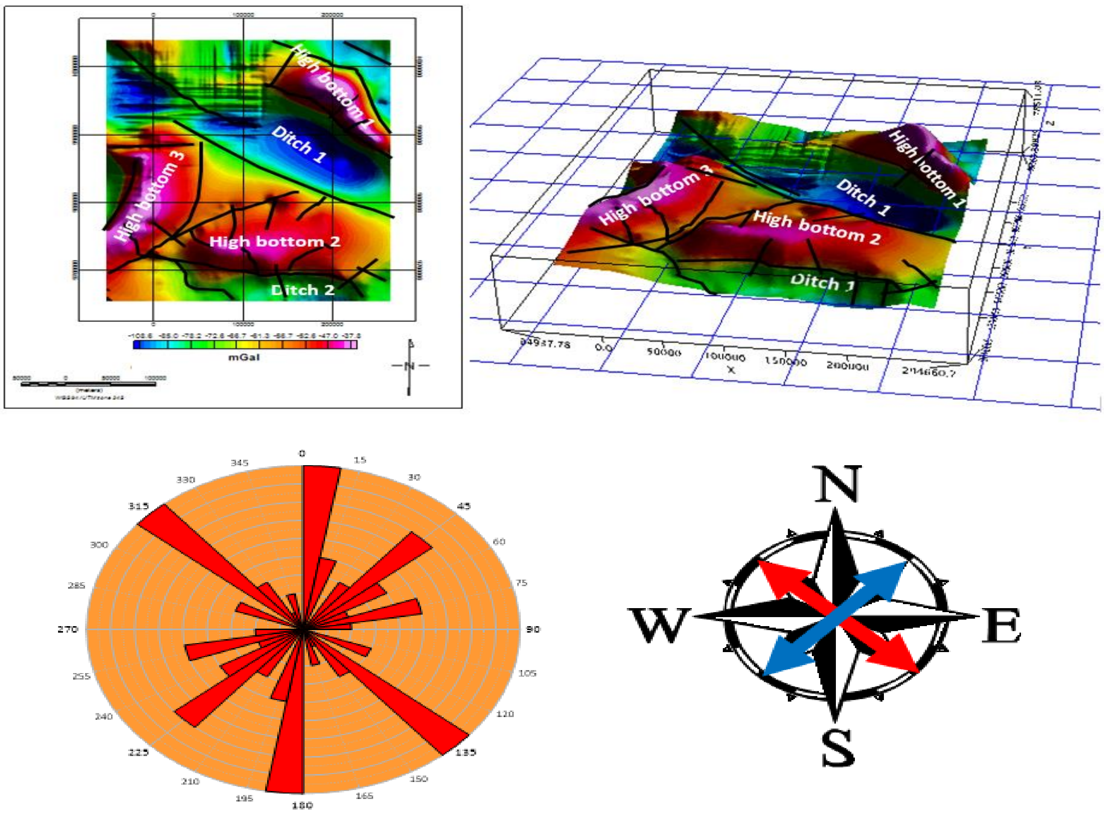

Figure 6. *Map of Bouguer anomalies and location of faults*

CONCLUSIONS

The main aim of this work is to highlight the geological structures of petroleum interest in Block 24 and Block 1 in the Democratic Republic of Congo. To do this, we were able to use magnetic and gravimetric data retrieved by Sonahydroc, the geophysical data used in this work come from the geophysical campaign carried out by CGG in 1987 and have been pre-processed for external effects such as Luni-solar correction, altitude, topography.

This study focuses on characterizing the elements of the petroleum system in Blocks 24 and 1 of the Congo Basin, Democratic Republic of Congo (DRC), using field data (gravity and magnetic). Processed datasets from 1987 Sonahydroc and CGG surveys (corrected for luni-solar tides, topography and elevation effects) reveal key structural features:

- NW-SE oriented fault systems, probably acting as conduits for hydrocarbon migration and compartmentalizing the reservoirs.
- Uplift of the basement beneath the Inongo high plateau, creating structural traps by draping folds in the overlying sediments.
- Syn-sedimentary collapse grabens to the northeast of the uplift, indicating rift-related subsidence during basin evolution.
- A plunging anticlinal structure (4-way closure) formed by compressive deformation, a prime target for the accumulation of clastic or carbonate reservoirs.

These results are in line with proven oil plays in the Congo Basin, where similar structures control the distribution of hydrocarbons in the Mesozoic and Cenozoic. The integration of magnetometry (mapping of basement architecture) and gravimetry (density contrasts in sedimentary layers) provides strong evidence for prospective areas, and has also enabled this work to highlight geological structures that may favor hydrocarbon production, migration and accumulation. Further seismic calibration is recommended to assess reservoir quality and seal integrity in this relatively unexplored region.

Thanks to this study, Blocks 1 and 24 of the Cuvette Centrale now have a sufficiently detailed geophysical record to enable an in-depth analysis of their structure and potential. This analytical framework provides a robust basis for strategically directing exploration efforts towards the most promising zones. It paves the way for a more targeted, rigorous and efficient assessment of the region's petroleum potential.

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