

## STRUCTURAL STUDY OF OIL TRAPS USING GRAVIMETRIC AND MAGNETOMETRIC METHODS IN BLOCK 9 BETWEEN THE BUSIRA, LOKORO AND LOMAMI SUB-BASINS (CENTRAL BASIN – DRC)

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### ABSTRACT

Block 9 is one of thirty-one blocks of the Central Basin cut out during oil prospecting from 1952 to 1988 using geological studies, geochemical and geophysical carried out in this largest basin among the three in the DRC. Certainly, the analysis and interpretation of gravimetric and magnetic anomaly data for the quest for oil potential in this block of the Central Basin of the DRC remains a major challenge. The current article highlights the possible oil traps from the processing of gravity and magnetic anomaly maps, also the extension of these structures through analyzes based on oil geology generally. Considering the oil blocks of the Central Cuvette of the DRC, the gravimetric and magnetometric studies for Block 9 remain an important element for the knowledge of the areas of petroleum interest on the structural level and the geological formations, between the Busira, Lokoro and Lomami sub-basins. The results of the investigations confirm that Block 9 presents a complex structural architecture dominated by zones of deep subsidence and local basement uplifts, offering conditions favorable to the accumulation and preservation of hydrocarbons.

**Keywords:** fault, anticline, unconformity, lineament, gravimetric anomalies, magnetic anomalies.

### INTRODUCTION

The Central Basin of the DRC, a vast intra-cratonic sedimentary basin, remains one of the most promising but still under-explored regions in Central Africa for hydrocarbons search. Among the 31 blocks defined between 1952 and 1988, Block 9 is one of them, located between the Busira, Lokoro and Lomami sub-basins, is of major structural interest, due to its tilted block architecture, its density contrasts, and the possible presence of structures likely to trap hydrocarbons [1].

For some time in the Central Basin of the DRC, the search for oil potential has given rise to much debate on the characteristics of the possible traps which may exist in the different oil blocks cut out through studies carried out between 1952 and 1988 in this large sedimentary basin likely to produce hydrocarbons and which are positioned between the sub-basins. Oil,

through the sedimentary mechanisms which demonstrate its genesis, remains hidden in very high depths compared to the earth's surface or buried in the emerged terrain, requiring specific techniques to exploit it where it is trapped in recognized geological structures capable of retaining it in a high concentration [2]. The techniques used during oil prospecting after geological analyzes are geophysical methods based on the understanding of structural geology in general. These methods are less numerous because of their very high investigative powers than in mining prospecting, they are: gravimetric, magnetometric, seismic and logging.

Modern oil exploration relies on geophysical methods capable of indirectly imaging the deep subsurface and identifying structural discontinuities favorable to the accumulation of oil and gas. In this context, gravimetry makes it possible to detect variations in density linked to structures such as horsts, grabens, ditches and anticlines, while magnetometry, particularly after reduction at the pole, helps to follow the lineaments, contacts and extensions of faults at the basement level. The integration of these two approaches constitutes a powerful tool for characterizing structural traps and guiding future exploration investigations in Block 9.

Regarding the objective this paper experimented in Block 9, located between the Busira, Lokoro and Lomami sub-basins of the Central Cuvette of the DRC: is to apply petroleum geophysical methods, such as: gravimetry to highlight possible hydrocarbon traps, identify areas of petroleum interest and magnetometry for the extension of the direction of these possible fractures or traps at the base level of the block (deep or endogenous rocks), also interpret the horizontal and vertical gradients to characterize the structural discontinuities, identify areas likely to host hydrocarbon traps.

## MATERIALS AND METHODS

This section will be devoted to the methods adopted and the different equipment used in this paper. The method adopted for this study is summarized in the following steps:

- We started with data acquisition, a crucial step because the gravimetric data used in this paper come from the Ministry of Hydrocarbons and the magnetic data from the National Hydrocarbons Company of Congo (Sonahydroc);
- And after we have carried out the data processing, this step makes it possible to filter the data resulting from the acquisition and cartographic representation of the gravimetric and magnetic anomaly data in Block 9 located between the three aforementioned sedimentary basins;
- In order, we carried out the interpretation of the data, which consists of highlighting the different results through the maps resulting from data processing.

To get there, we need the computer to incorporate certain processing software such as:

- Microsoft Office, useful for data entry and processing;
- Géosoft, to process and map spatial data of a very large volume;
- Surfer, focused on data processing and modeling, also spatial data mapping;
- ArcGIS is based in the processing and development of maps of different given surfaces.

## RESULTS AND DISCUSSIONS

In this point we will consider two major subpoints, these are the geographical knowledge of the region and its geology in all these contexts (environmental geology, tectonics and stratigraphy).

### Location and history of the study area

Our study area is Block 9 of the Central Basin of the DRC, it is located between the Busira, Lokoro and Lomami sub-basins. In relation to its geographical position (Figure 1), it is among the thirty-one (31) blocks cut out in the Congolese Basin, limited to the North by blocks 7 and 10B, to the South by block 18, to the East by Block 10 and to the West by Block 8 [3].

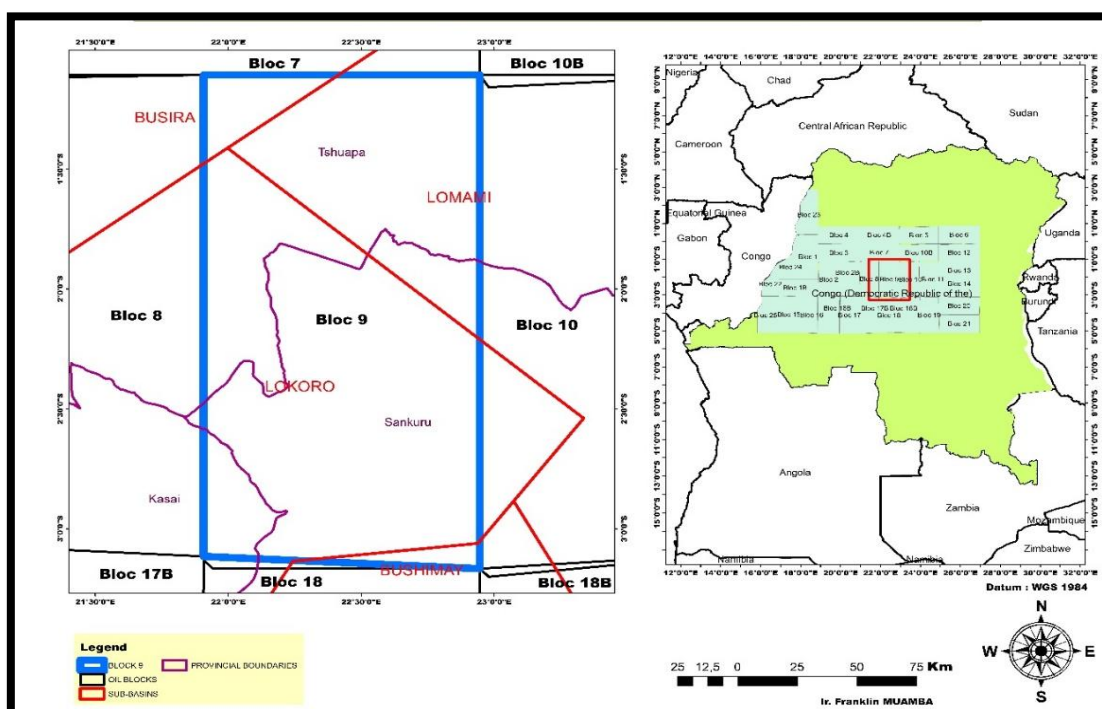


Figure 1. Location map of the study area.

The study area, of which block 9 is located, is characterized by a vast depression of sedimentary layers almost 12,000 m thick with an equatorial climate because of its distance very close to the Equator line in the forest where bears the same name, marked by abundant and regular rains all year round. That is to say, the flora is constituted by the large equatorial forest and the fauna by frugivores, carnivores and herbivores, which are or surrounded by the complex hydrography of the Congo basin, the majority of the rivers of which flow into the Congo river at the origin of the Salonga and Lomela rivers crossing Block 9 through the Kasai plateau [4].

Technically, the representation of oil blocks in the Central Basin was made possible thanks to previous studies, such as: surface geological, geochemical, geophysics (gravimetric, magnetometric and seismic reflection/refraction); interpretation of LandSat and Drilling images (exploration and stratigraphic) carried out between 1952 and 1988 by various foreign firms supported by the Congolese government through its Ministry of Hydrocarbons and the company Sonahydroc [5].

## Geological setting

The sedimentary filling of this basin can reach 12,000 meters thick compared to studies carried out in this large basin of the DRC. These sediments range from the Neo-Proterozoic to the Cenozoic and differ from the geology of the Amazon basin whose predominant age is the Paleozoic, but which constitutes the same base. The Cenozoic is made up of polymictic sandstones at its base and other sands of fluvial and aeolian origin at the top [6]. So, the Upper Paleozoic includes the Carboniferous and Permian formations. Concerning the Late Proterozoic to the Paleozoic (Devonian), three groups have been identified, among others:

- The Proterozoic age group, made up of marginal marine lagoon sediments;
- The Cambrian age group, presenting deposits of alluvial origin (Bobwamboli arkoses), Mamungi and Kole shales of deltaic facies;
- The Ordovician, Silurian and Devonian age group containing Galamboge quartzites (marine dunes), Alolo shales (fluvial) and Banalia arkoses (deltaic).

The geology of Block 9 is part of that of the Central Basin of the DRC, starting from Precambrian base of crystalline nature favoring the sedimentation of Mesozoic and Tertiary formations in this part of the basin (Figure 2). Logically, the sedimentation which dominates in Block 9 is that of post Cretaceous or Cenozoic, of which we have the Paleogene formations which adds to the unconformity of the Cretaceous Albian and Aptian of carbonate nature of a depression of fossiliferous formation of polymictic sandstones, dated from the Paleogene [7].

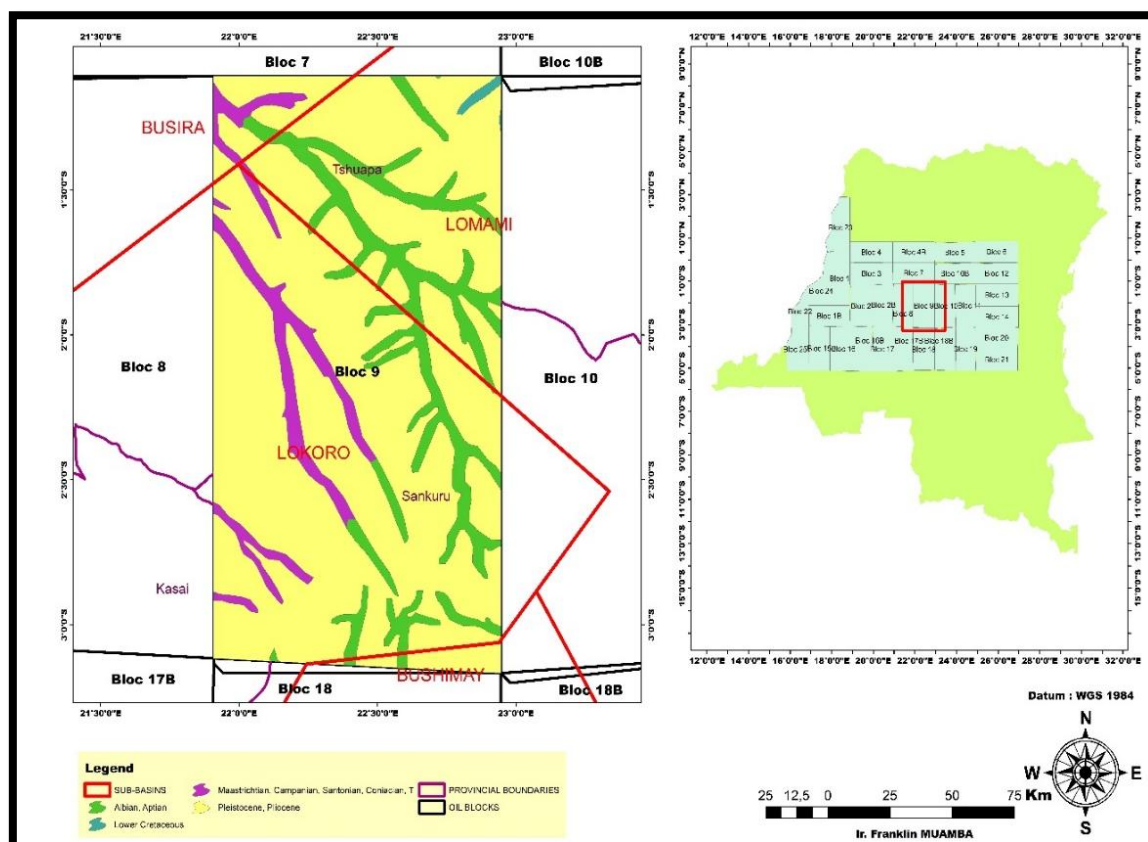


Figure 2. Geological map of Block 9 of the Cuvette Centrale DRC.

Regarding the regional tectonics, Block 9 is set in the tectonic evolution of the Central Cuvette in relation to its geographical position, the Central Cuvette which is an intracratonic depression, was formed during the last era of the Proterozoic as a flexural basin, resulting from the thermal weakening of the mobile basement following the Kibaraïne Orogeny [8].

The evolution of the basin can be associated with four main periods of tectonic activity:

- The post-collisional phase of the Pan African Orogeny (Cambro-Ordovician);
- The post-collisional phase of the Hercynian Orogeny (Permian);
- The opening of the South Atlantic (last phase of the Jurassic - Cretaceous);
- The opening of the East African Trench System (last phase of Cenozoic to the present).

In general, each of these episodes of renewed tectonic activity resulted in the reactivation of pre-existing fault sets in a transpressional and transtensional manner, producing half-graben basins and inverting previously formed sub-basins. Four successive generations of extensional half graben basins are recognized, each corresponding to a period of renewed tectonic activity, covered by sediments related to thermal subsidence. This produced a succession of stacked pre-rift, syn-rift and post-rift tecto-stratigraphic units.

In relation to the stretching dynamics, developing at the level of the accident craton, the geological structures which characterize Block 9 are the tilted block faults with the presence of several horsts and ditches linked to its location between the Lokoro, Lomami and Busira sub-basins of a subsidence going more towards the Lomami side, which we will seek to determine when processing the gravity and magnetic anomaly maps [9]. Starting from the litho-stratigraphy of the Central Cuvette/Basin (Figure 3), the two deep soundings carried out one in the north of the basin at Samba (depth 2,038.5 m), the other in the south at Dekese (depth 1,856.39 m) [10] and the seismic prospections [11] showed that the bedrock of the Phanerozoic terrains is made up of fine-grained red arkoses, in horizontal or slightly undulated layers, forming a continuous carpet whose thickness exceeds 1,000 m. These formations, buried under more than 1,000 m of Phanerozoic cover in the deepest parts of the basin, come out in outcrops on the eastern and northern edges of it and are found in Lower Zaire or present-day Kongo.

The problem of the existence of a northern limit of the interior basin during the sedimentation of the Mesozoic series arises from the fact that erosion made possible witnesses of this limit disappear. In two epochs, the Kimmeridgian and the Cenomanian, an opening of the basin towards the north or the northeast is probable and it is possible that this is also the case in the Albian time [12].

The scale of the litho-stratigraphy which characterizes Block 9 in relation to its geographical position, is a Precambrian base of crystalline nature. We have the Mesozoic formations, composed by the Sankuru supergroup, between: Lower Cretaceous, followed by Wealdian (Loia K1 series, which has a thickness which varies between 250 to 300 m; it seems to grow up to 350 to 400 m in the lower and middle Lomami region) and the Albian-Aptian formations (series of Bokungu K2). And we add the presence of the Lukula supergroup through the Maestrichtian formations, Campanian, Santonian, Coniacian and Turonian-K3 [13].

Still in Block 9, the sedimentation is closing with Cenozoic formations, including the Kalahari supergroup which comprises: Paleogene formations made up of the lower Kalahari polymictic sandstones which are essentially sands with millstones beds locally fossiliferous. We also note the Central Basin supergroup interacting with the African rift or tectonic trough, consisting of Pleistocene and Pliocene formations indicated by alluvial, eluvial and colluvial sediments [14].

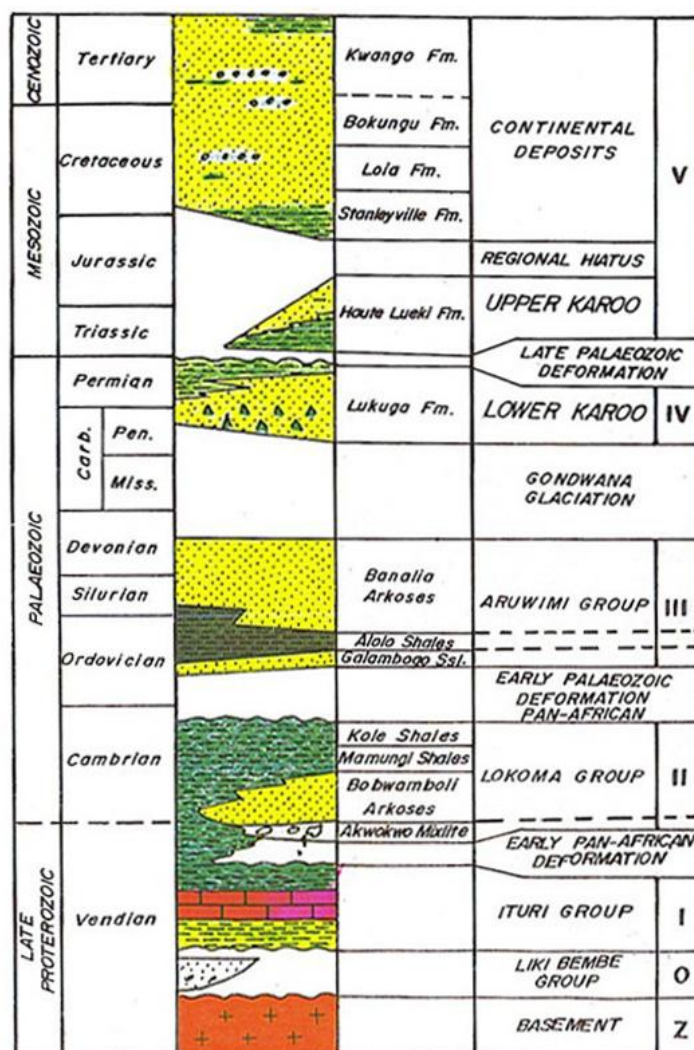


Figure 3. Lithostratigraphic column of the Central Basin [15].

## PETROLEUM POTENTIAL OF BLOCK 9

Everything became known after exploration of the Central Basin, which began in the fifties and continued into the eighties, carried out by several local and foreign companies. These studies focused on geology, geochemistry and geophysics (gravimetry, magnetometry and 2D seismic). Their respective interpretations and drilling were beneficial in understanding the realities of the Central Basin [16]. In the general context of the studies carried out, the construction of a 2D geological model consistent with empirical data derived from the Central Basin area of the Congo (lithology, temperature, maturity and oil composition) through the exploration campaign conducted in this sedimentary basin, calibrated and validated according to available results, made it possible to determine the following petroleum potential.

### Source rocks

In the Central Basin, five source rocks (Figure 4) have been interpreted and included in the model, with thicknesses ranging from 100 to 800 m. We add the Kisangani clays whose formation dates from the Jurassic-Cretaceous and contains a lacustrine kerogen type I. In

In addition, the Alolo, Mamungi and Kole argillites have been identified as potential source rocks with TOC varying from 1.69 to 3%. The Kisangani bituminous shales and the Loia argillites were also recognized as potential hydrocarbon source rocks in the Central Basin [17]. In the area of Block 9 and given the stratigraphy dominated by Mesozoic and Cenozoic formations deposited on a Precambrian basement, one can note the presence of the Liki Bembe Precambrian group, the Kisangani clays and the Loia formations of the Jurassic-Cretaceous as source rocks that cross Block 9 of the Central Basin.

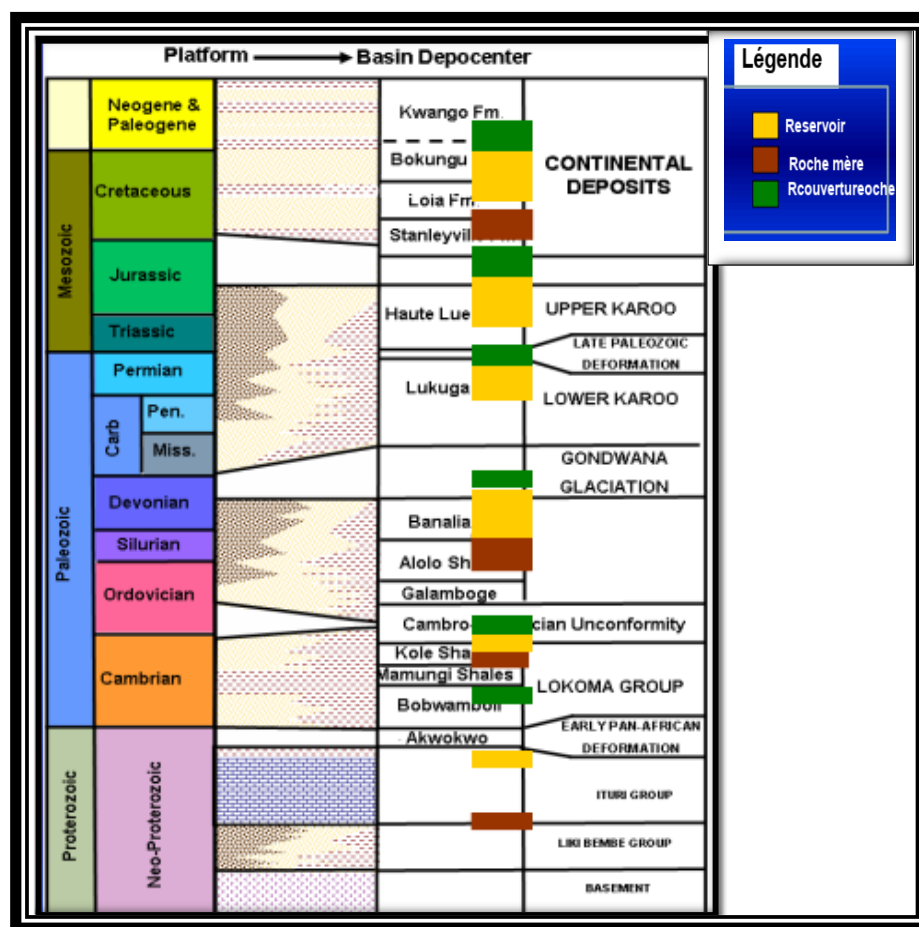


Figure 4. The Central Basin oil trilogy [18].

### Reservoir rocks

Little information is available on reservoir rock properties in the Central Basin. JNOC (1986) analyzed various stratigraphic units that outcrop around Kisangani. Good porosity has been measured in Jurassic, Cretaceous and Permo-Carboniferous sandstones. Jurassic, Cretaceous and Permo-Carboniferous sandstones have been identified in the Central Basin and are considered potential reservoirs with good porosity of about 30.5%. The Galamboge sandstones with porosity between 8.1 and 19% and the Bobwamboli arkoses (porosity of 13%) are reservoirs in Aruwimi and Lokoma. In Block 9, the Bokungu series of continental Cretaceous origin and the Upper Lueki Jurassic formations with porosity of 21% are retained as potential reservoirs in this area.

## Traps and prospects

In general, in the Central Basin, tilted-block structures and faults, anticlinoria and lateral facies variations identified in the basin represent excellent potential oil traps [19],[20]. Regarding the strategic position of Block 9, interesting prospects and leads have been identified in several of its sub-basins where actual exploration work is underway, we cited: Prospect A located in the Lomami – Busira sub-basins, which is in the same setting as Block 9 located between the depressions of the Lomami, Busira and Lokoro sub-basins [9].

## ANALYZES AND INTERPRETATIONS OF BLOCK 9 DATA

This point is devoted to the processing and interpretation of gravity and magnetic anomaly maps, to highlight possible hydrocarbon traps. Also, we will identify other oil potentials through the various analyzes which will be established as part of this part of the paper.

### Data presentation

The data that we will use in this paper are the geophysical data of block 9 of the Central Basin (Busira, Lokoro and Lomami), which come from the Ministry of Hydrocarbons. They were acquired by land and airborne routes during a long geophysical survey exploration campaign carried out in the Central Basin between 1952 and 1986 by the Belgian firm REMINA and the Compagnie Générale de la Géophysique (CGG). According to the Secretariat of the Ministry of Hydrocarbons, there were at least 6,000 stations carried out for each geophysical method, of which we present the following samples [21].

Geophysical methods are essential in oil exploration for imaging the deep subsurface (1,000 to 4,500 m) without drilling, thereby reducing economic and technical risks. They enable the identification of structural traps (oil and gas reservoirs), the estimation of reservoir volumes, and the targeting of costly drilling operations. Reflection seismic is the primary technique used.

### Gravimetric Data

Gravimetric data are acquired by land, some samples of which are presented in Table 1.

*Table 1. Gravimetric data from Block 9 of the Central Basin of the DRC.*

Objective	Longitude	Latitude	Bouguer anomalies (mGal)
1	22,65	-3,15	-104,6146
2	22,70	-3,15	-105,675
3	22,75	-3,15	-106,848
4	22,80	-3,15	-107,359
5	22,85	-3,15	-106,876
6	22,90	-3,15	-105,709
7	21,95	-3,10	-101,1685
8	22,0	-3,10	-99,6364
9	22,05	-3,10	-97,1444
10	22,10	-3,10	-94,1193
11	22,15	-3,10	-92,1662
12	22,20	-3,10	-91,6555
13	22,25	-3,10	-91,9249
14	22,30	-3,10	-92,3458

15	22,35	-3,10	-95,6571
16	22,40	-3,10	-97,5766
17	22,45	-3,10	-99,0751
18	22,50	-3,10	-100,4445
19	22,55	-3,10	-101,8084
20	22,60	-3,10	-103,2059

## Magnetic Data

These are magnetometric data acquired by airborne means, and Table 2 represents some samples from the stations.

*Table 2. Magnetometric data from Block 9 of the Central Basin of the DRC.*

Objective	Longitude	Latitude	Magnetic anomalies (nT)
1	21,94451	-3,116712	-107,4000015
2	21,94453	-3,115988	-107,0400009
3	21,94455	-3,115246	-106,6699982
4	21,94457	-3,114522	-106,2900009
5	21,9446	-3,113798	-105,9000015
6	21,94462	-3,113075	-105,5199966
7	21,94466	-3,112352	-105,1299973
8	21,94469	-3,111627	-104,7399979
9	21,94471	-3,110904	-104,3300018
10	21,94474	-3,11018	-103,9700012
11	21,94476	-3,109474	-103,5400009
12	21,94481	-3,10875	-103,1800003
13	21,94485	-3,108009	-102,7699966
14	21,94486	-3,107267	-102,3799973
15	21,9449	-3,106525	-101,9499969
16	21,94492	-3,105801	-101,5500031
17	21,94497	-3,105059	-101,1399994
18	21,94503	-3,104317	-100,7600021
19	21,94504	-3,103575	-100,3600006
20	21,9451	-3,102816	-99,93000031

## Gravimetric Processing and Interpretations

Gravimetry is a fundamental discipline of geophysics which consists of measuring and studying spatial and temporal variations of the Earth's gravity field. In addition, it is interested in the gravity field, and which consists of making measurements of the vertical component of the gravity vector using a gravimeter where she measures the acceleration of gravity to deduce the density of the formations as a parameter [22]. Gravimetry is a geophysical method which seeks to determine, based on disturbances in the gravity field at different points on the ground surface, the probable distribution, in the subsoil, of the various types of rocks characterized by their density [23].

As part of the processing of spatial and mapping information for exploration geophysics and geological modeling applied to the exploration of petroleum resources in interaction with gravimetry anomaly data from Block 9 of the Central Cuvette, we will carry out the following processing maps:

- ✓ Gravimetric Anomaly Map Block 9 or (AB);
- ✓ Separation of Gravimetric Anomalies Block 9 (residual and regional);
- ✓ Horizontal and Vertical Derivative Map.

### **Bouguer Anomalies of Block 9**

By definition, the Bouguer anomaly is the measure of gravity corrected for: Latitude, Altitude and plateau [24]. After the various processing of the anomaly data sampled in the field through the corrections which make it possible to bring all the measurements back to a theoretical value at the surface of the geoid, we can now establish the variation map of Bouguer anomalies or gravimetry of the Block 9 of the Central Cuvette of the DRC, between the Busira, Lokoro and Lomami sub-basins.

The gravimetric anomaly variation map presented in Figure 5, highlights at least three trends in the amplitude of the anomaly variations, of which we see for the strong anomalies the density of the formations varies between -57 and -95 mGal, medium anomalies we have -95.5 to -99.5 mGal and for low anomalies we have a density which varies between -99.9 and -107 mGal.

The strong anomalies give us information on the shoal position and the average also the weak anomalies consider the central deposits in Block 9. As a reminder this block is located in the middle of the Busira, Lokoro and Lomami sub-basins. By this light, we notice that the large part of our block is dominated by the shoal, which occupies the central part and extends towards the North, East, West and an appearance on the South side, which also embodies the uplift of the base or a small thickness of the sediment in a few places of this Block 9. Regarding the central deposition or the sedimentary power, we see it in the central part and is oriented in the East and West directions with a predominance of weak anomalies between 102 and 107 mGal, this indicates a high power of the sedimentary layers that we can speak of a presence of Graben in contact with the surrounding areas, indicated by elevated anomalies. We can also add for the central deposits, the ditches at the different limits of the block or the North-East, North-west, South-East and South-West parts. These amplitude variations for the anomalies affect the structural model of Block 9 through the different changes in anomalies and this pushes us to mention the derivation in gravimetry [25].

### **Derivative (Instruments, or methods)**

The horizontal gradient allows:

- Delineation of local anomalies,
- The delimitation of rises, plateaus, plains and layers by the analysis of horizontal amplitude variations.

Horizontal gradients can also be calculated. Indeed, the maximum of the horizontal gradients will be located directly above contacts or faults such that there is a density contrast on either side [26].

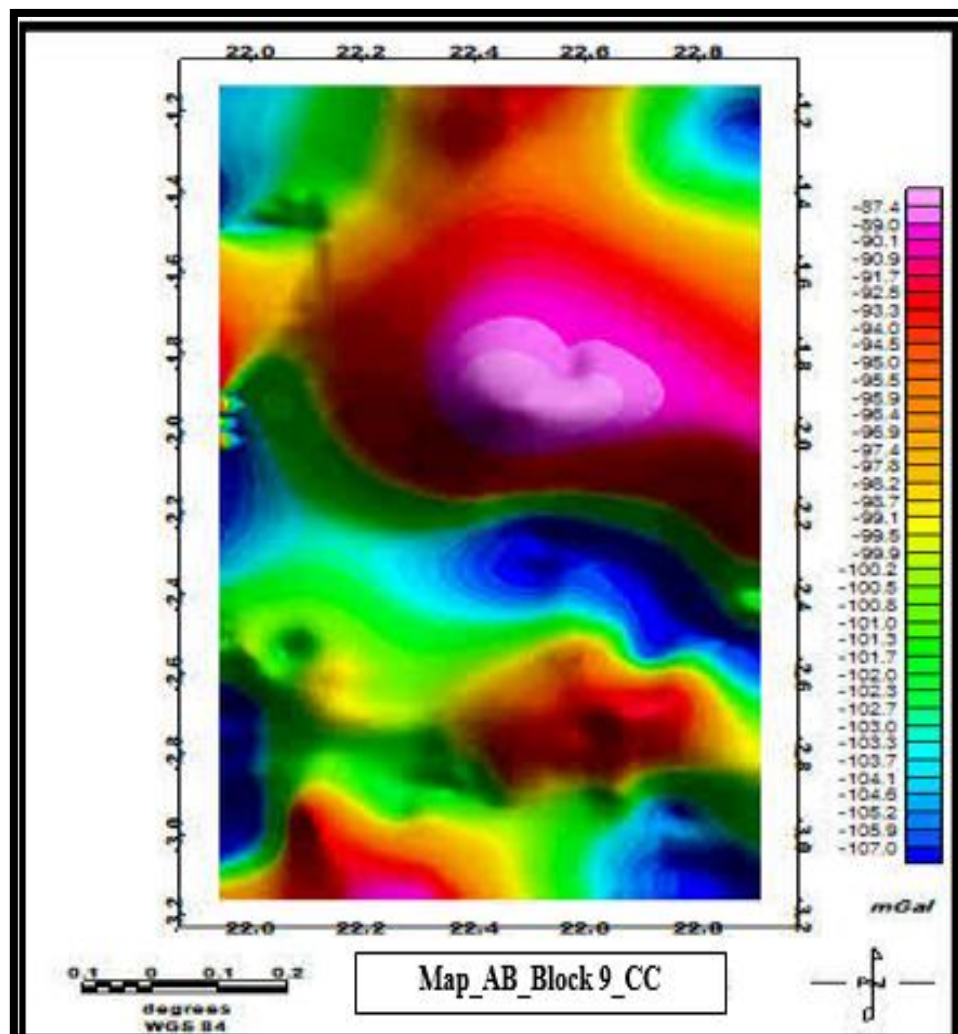


Figure 5. Gravimetry Anomaly Map of Block 9 of the Central Basin.

### Derivative with respect to the North-West direction

The map of the derivative with respect to the N-W direction highlights the gradient maxima oriented from North-East to South-West because it makes it possible to visualize and analyze the gradient variations in the study area. It highlights the areas where the gradients are most pronounced and the predominant directions of these gradients.

We observe from Figure 6, on the directional derivative that these maximum gradients are oriented much more towards the center of the region, a large part directed from the South-East and another part towards the North-East.

The directions of the gradients observed in the map directly oppose the orientation directions of the faults in Block 9. Also, we noticed the presence of anticlinorium structures towards the Northeast sides, Southeast, South-West and in the center of the block, following the change in amplitude (anomaly variation).

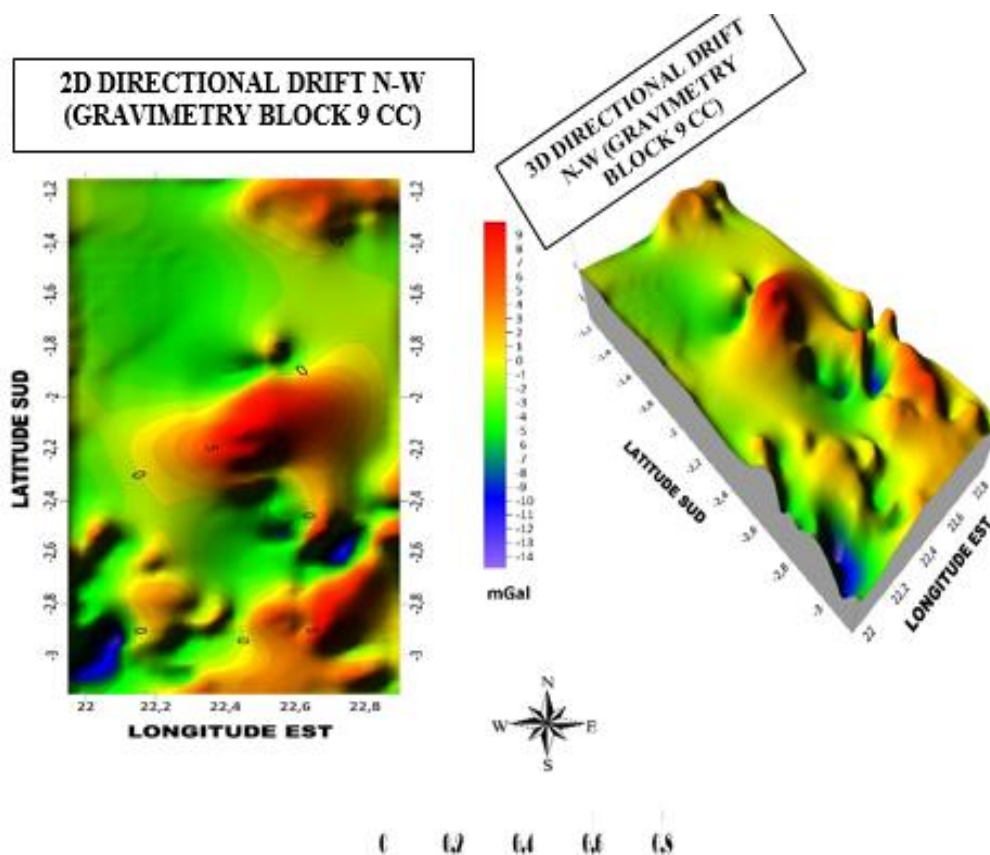


Figure 6. Directional drift map, North-west direction.

### Derivative with respect to the North-East direction

The map of the derivative with respect to the N-E direction (Figure 7) highlights the gradient maxima oriented from North-West to South-East because it makes it possible to visualize and analyze the gradient variations in the study area. It highlights the areas where the gradients are most pronounced and the predominant directions of these gradients.

This map allows us to observe that in our study area of Block 9 the maximum gradients are oriented from a large part to the center of the region following an East-West direction, another part is directed from the South-West. Variation in the geoid can be explained by the structure of the Earth's crust or by the topography that follows the change in rock density, which highlights faulted areas [27].

Thus, the choice of suitable directions for the derivatives reveals many structures and contacts clearly superimpose the tectonics in the North-East direction and the central part of which is dominated by an anticlinal structure followed by two collapse ditches in the East and South parts in the map, highlighted by the variation of anomalies.

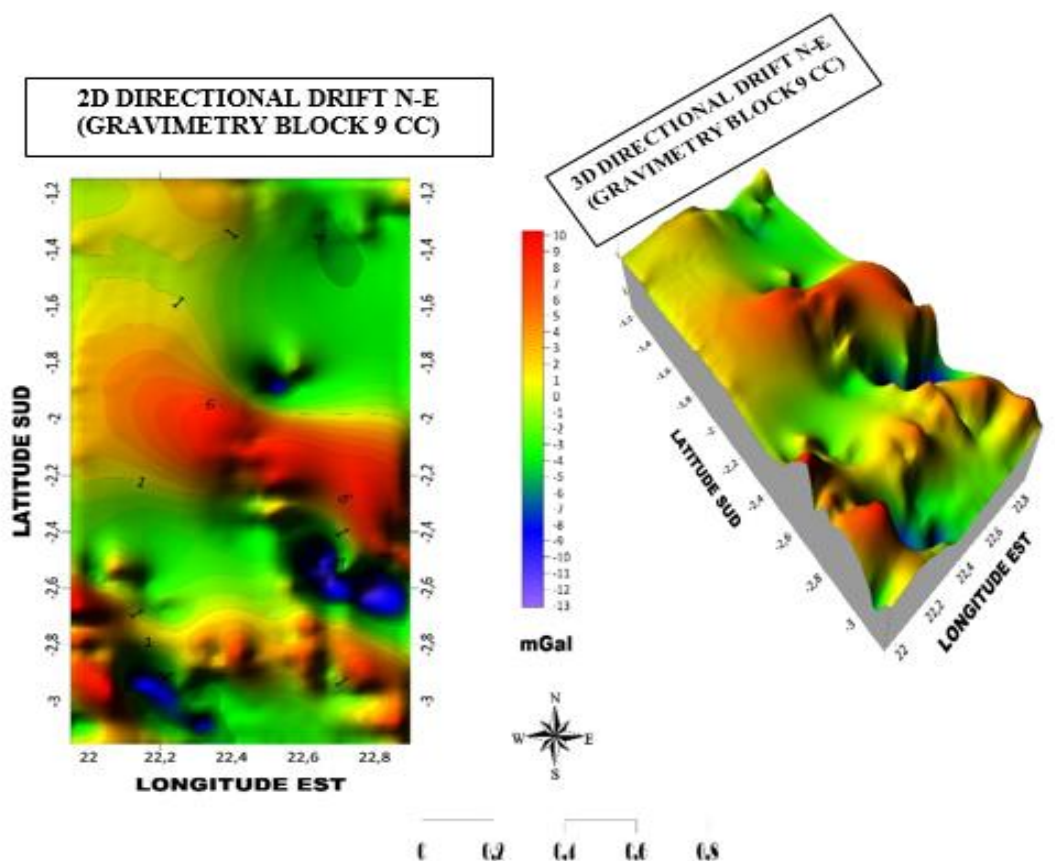


Figure 7. Directional drift map, North-east direction.

## Extension in gravity data

Gravimetry refers to a technique used to estimate density below the earth's surface. The upward extension in gravimetry consists of extrapolating the density data measured at the surface to greater depths. This makes it possible to map the distribution of materials on the surface and provide information on the geological structure and composition of underground layers [28].

## Extension upwards to 1000 m

Extending an anomaly observed on a given surface consists of calculating the shape and amplitude of this anomaly on a surface located at a different altitude. Extension upwards makes it possible to compare data acquired at different altitudes, for example on the topographical surface and in an airplane. It can also be shown that a downward extension is equivalent to a filtering of long wavelengths (high-pass filter) while an upward extension is a filtering of short wavelengths (low-pass filter). Extension upwards to 1000 m, see Figure 8.

The upward extension map to a depth of 1000 m using Bouguer anomaly data reveals that the Bouguer anomalies which are heavier are oriented from the North towards the centers, a part located North – West while the western part and a part to the East show signatures of weak Bouguer anomaly. While knowing that areas with weak signatures represent areas with more oil interest because they represent ditch or depression areas and areas with heavy anomalies show shoals or elevated areas. This map highlighted the different anticlinal structures almost in the corners of Block 9 and which can constitute hydrocarbon traps.

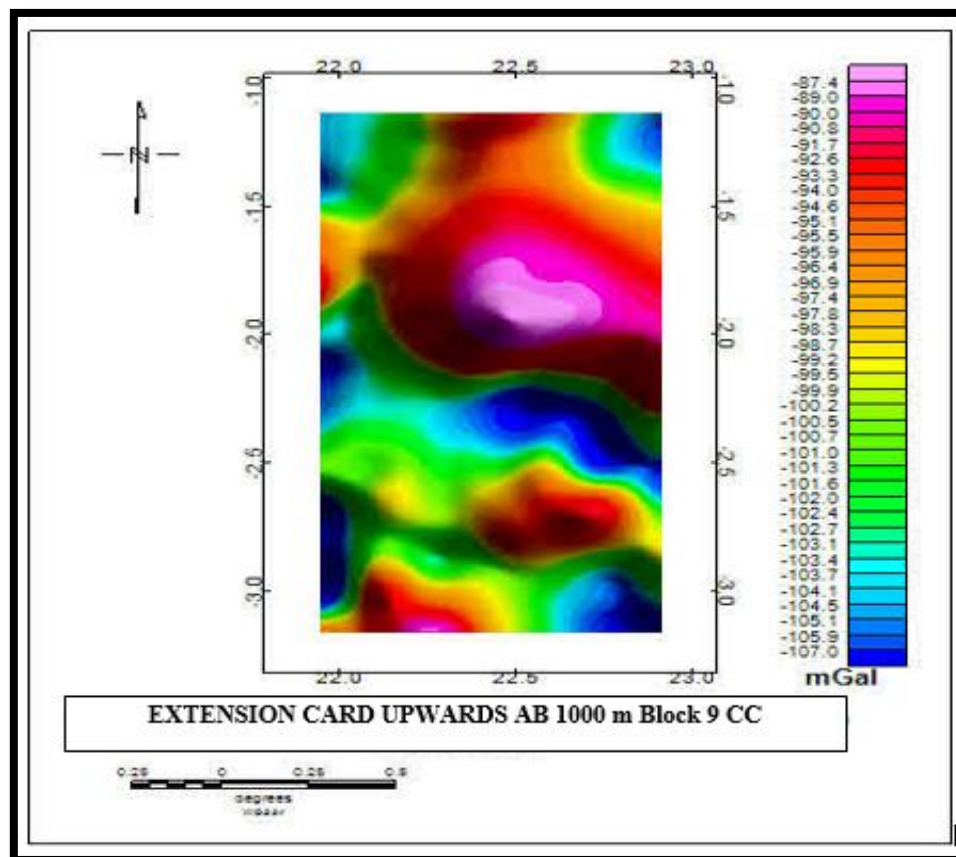


Figure 8. Map of extension upwards to 1000 m.

### Extension upwards to 4500 m

The upward extension map to a depth of 4500 m using Bouguer anomaly data reveals that the Bouguer anomalies which are heavier are oriented from the North towards the centers, a part located in the South and another in the West while the West, North-West, South-East, East and North-East parts show signatures of a weak Bouguer anomaly (Figure 9). While knowing that areas with weak signatures represent areas with more oil interest because they represent ditch or depression areas and areas with heavy anomalies show shoals or elevated areas.

All these two maps (extension upwards 1000 m and 4500 m), show all the anomalies which were observed on the map of the Bouguer anomaly and highlight the anticlinorium structures which dominate Block 9, which can be possible hydrocarbon traps.

### Magnetic Treatment and Interpretations

An iso-anomalous map gives a first idea of the position and shape of the magnetic structures. Iso-anomals almost parallel in one direction can be associated with the tectonic directions of the most magnetic strata or contacts and structures such as: faults, horsts, anticlines, synclines, veins etc. [29]. The analysis of the map of the magnetic anomaly field reduced to the pole (Figure 10) presents two magnetic anomalies of high amplitude in the shape of belts. The latter contains several anomalies of a circular shape.

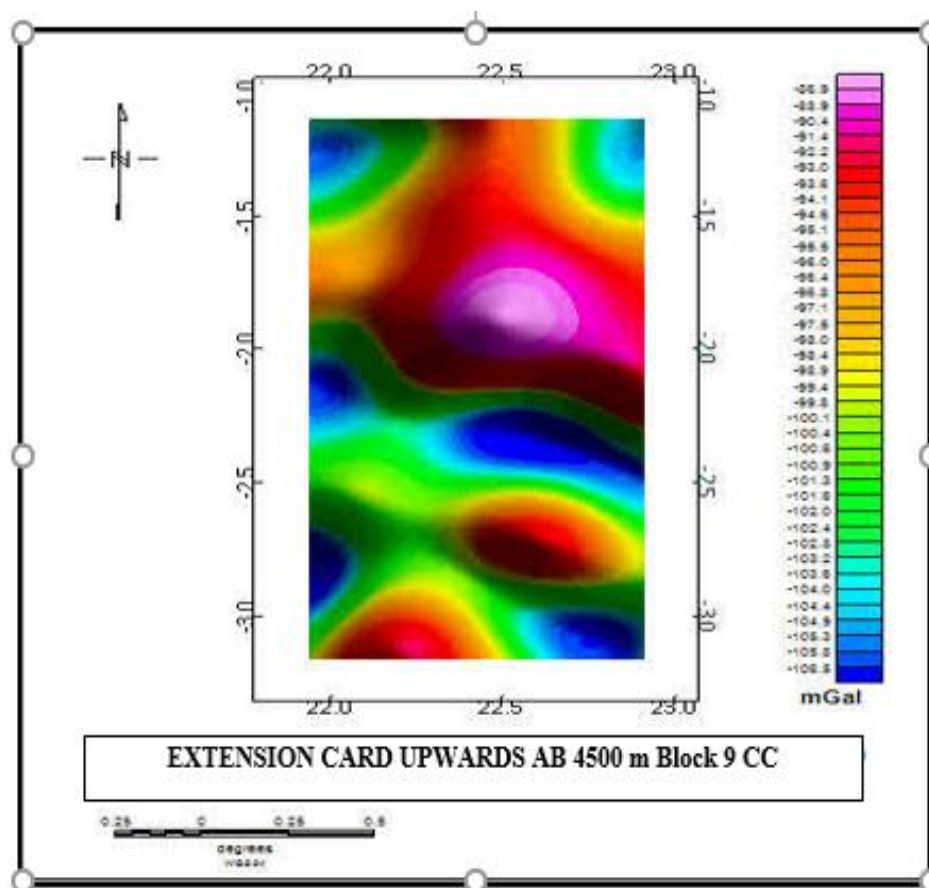


Figure 9. Map of extension upwards to 4500 m.

For understanding, pole reduction is a correction applied to data to bring it back to a gravity value measured at the geographic pole of the earth, due to the flattening shape of the earth at the poles, the value of gravity is slightly higher there than at the equator. Reduction at the pole is therefore necessary to compensate for this difference and obtain comparable and consistent data [30]. In addition, reduction at the pole consists of transforming at a given location all the anomalies observed into anomalies reduced at the pole.

The magnetic anomalies reflect the variation in the distribution and type of magnetic iron oxide minerals mainly magnetite in the earth's crust, in oil prospecting we see the appearance of the basement in relation to Block 9 which represents a sedimentary basin.

Furthermore, low coloration or weak anomalies indicate the opposite, i.e., sedimentary rocks poor in magnetite or sedimentary rocks with sedimentary protoliths. It also accentuates the extensions of the basin's faults known as Block 9, which lies between the Busira, Lokoro, and Lomami basins, down to the basement. In areas where the sedimentary basin is very deep (thick cover), the magnetic field is often weak and relatively stable (low background noise). Because the basement is far below the surface, the anomalies are broad and of low amplitude. Positive anomalies (magnetic highs), on the other hand, generally indicate a shallower basement, magmatic intrusions (diorites, gabbros) within the crust, or ancient volcanic rocks. They appear on maps as elongated or concentric zones of high intensity (Figure 10).

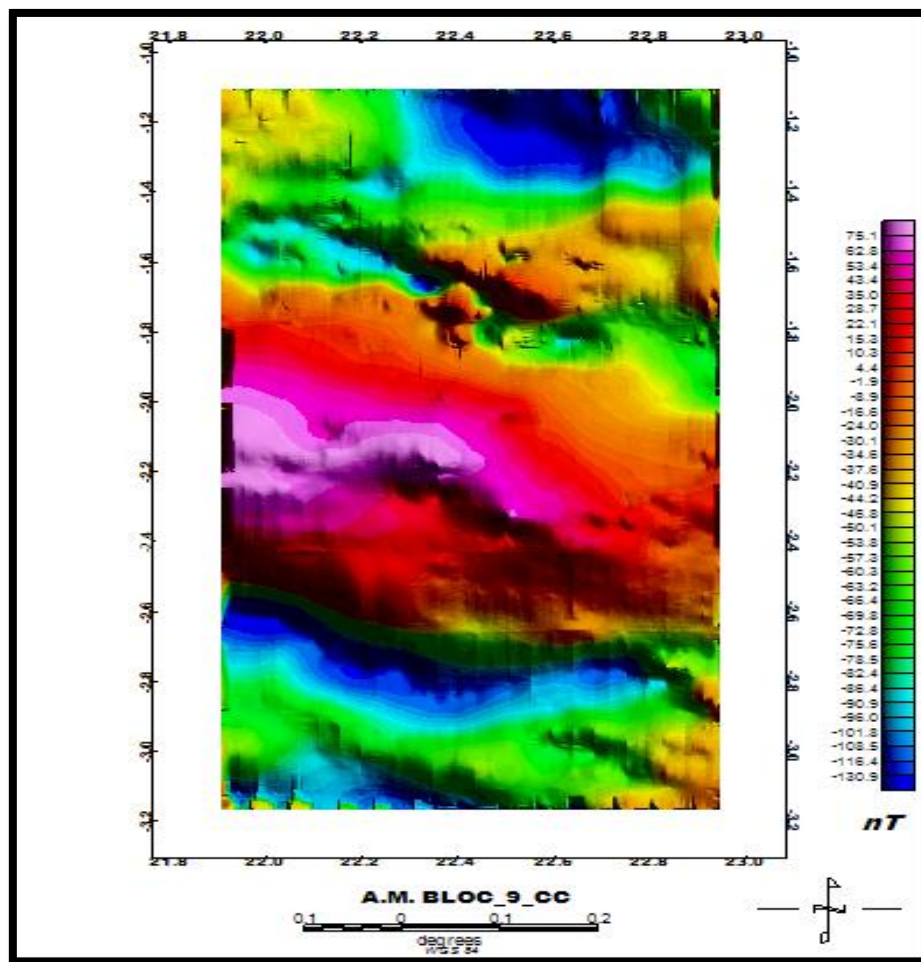


Figure 10. Block 9 magnetic anomaly map in 2D.

### Vertical gradient map

Generally, gradients, like derivatives, help to clearly highlight lineaments and anticlines, revealing extensions of faults on a magnetic anomaly map [31]. It is with this definition that we present the vertical gradient map in Figure 11 of this paper.

Figure 11 shows that when coloration is high (purple, red), i.e., the anomaly is strong, magnetization is strong which indicates a strong presence of metallic elements or rocks with high magnetic susceptibility or that the basement is uplifted, presence of rocks rich in magnetite or mafic igneous metamorphic rocks. Low coloration (blue, green) or weak anomalies show the opposite, i.e., sedimentary rocks poor in magnetite or sedimentary rocks with sedimentary protoliths. It also highlights the extensions of faults from the basin called Block 9, which is between the Busira, Lokoro and Lomami sub-basins, up to the basement.

We note a strong presence of rock with a strong anomaly in the central part, a part in the North and another in the South. This indicates the presence of magnetic rock rich in iron. Also, the extension of faults in the basement of Block 9 is oriented towards North-South and Northeast directions. We observe lineaments that trend East-West, which constitute directional faults through which fluid migration can take advantage.

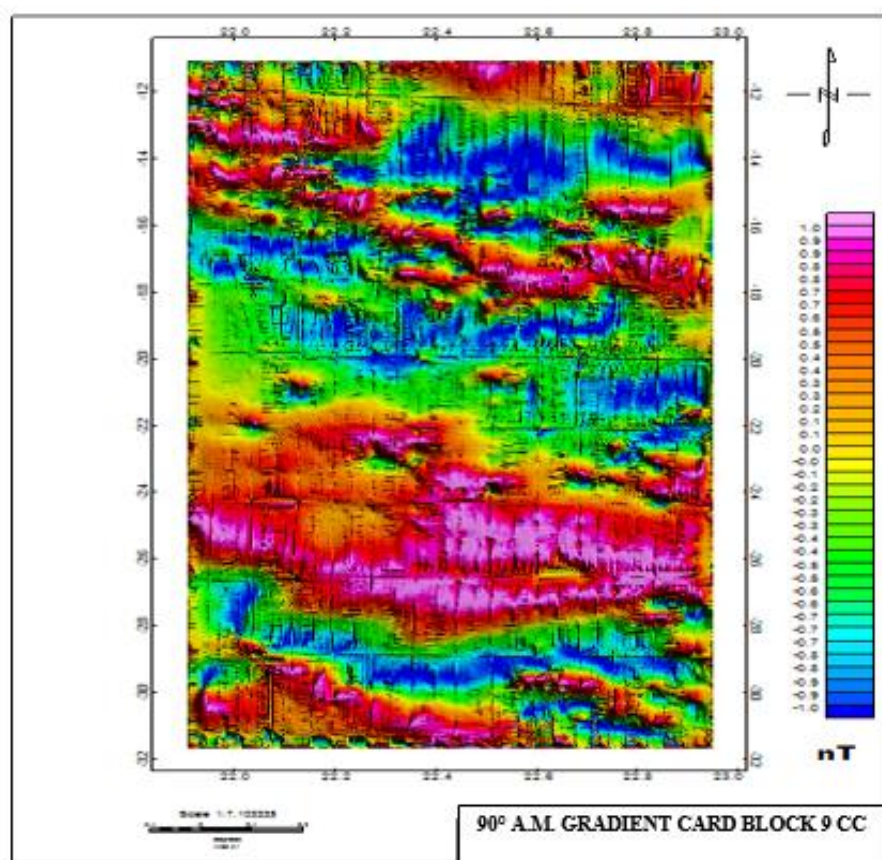


Figure 11. Vertical gradient map of Block 9.

## Horizontal gradient map

In Figure 12, we note a strong presence of rock with a strong anomaly in the central part, a part in the North and another part in the South. This explains the presence of magnetic rock rich in iron. It confirms the presence of horizontal lineaments trending East-West, North-South and the central part of Block 9 relative to the geographic North of the horizontal gradient map. These lineaments in the basement of the petroleum block can provide migration pathways by opening fault extensions.

## CONCLUSIONS

The objective of this article was to apply petroleum geophysical methods, such as gravimetry to highlight possible hydrocarbon traps, to identify petroleum-interest areas and magnetometry to extend the direction of these possible traps at the basement level (deep rocks).

Integration of gravimetric and magnetometric analyses applied to Block 9 highlighted several geological structures favorable to potential hydrocarbon traps, notably: anticlinorium located mainly in the central part and at the block's ends, collapse troughs and grabens, characterized by low-amplitude Bouguer anomalies suggesting large sedimentary thickness, major magnetic lineaments oriented East-West, North-South and Northeast, associated with fault extensions in the basement and potentially serving as fluid migration pathways, significant density contrasts between horsts and grabens, confirmed by horizontal and vertical gradient maps.

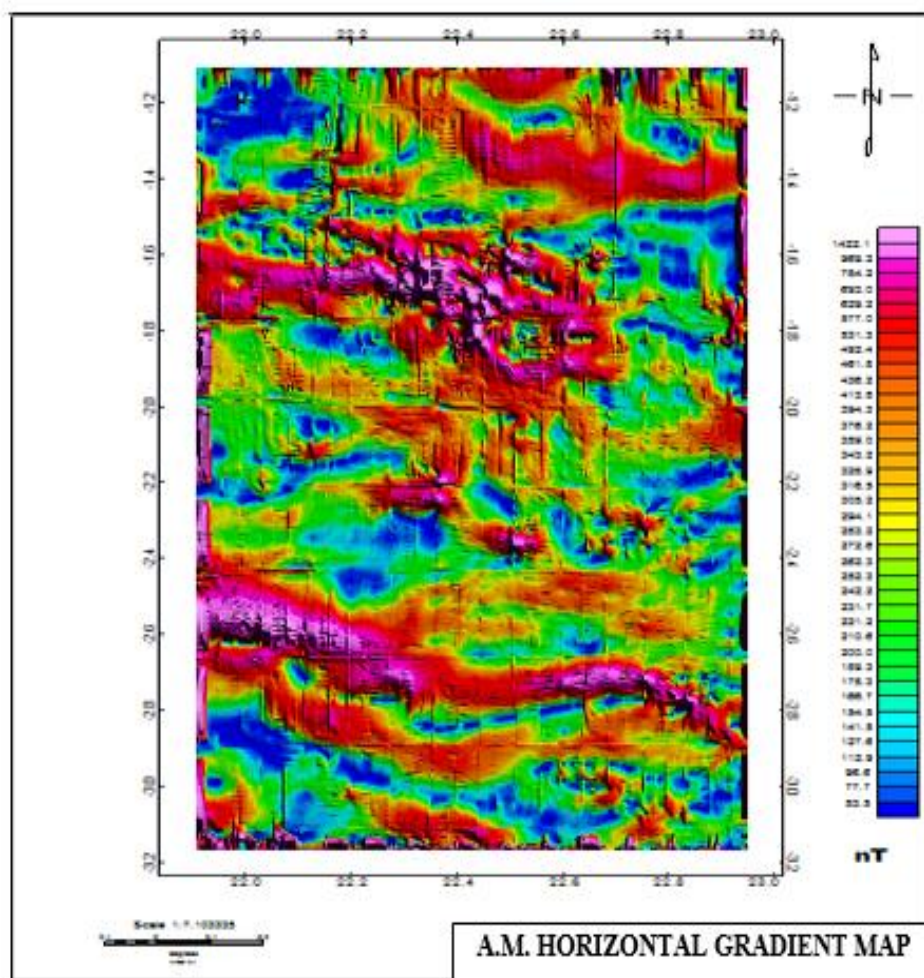


Figure 12. Horizontal gradient map of Block 9.

These results confirm that Block 9 presents a complex structural architecture dominated by zones of deep subsidence and local basement uplifts, offering conditions favorable to the accumulation and preservation of hydrocarbons. However, this study, based on sampled data and cartographic interpretation, constitutes a preliminary indirect structural approach. It should be completed by denser, higher-resolution geophysical surveys, 2D/3D seismic profiles to confirm trap geometry, detailed petrophysical and stratigraphic studies, and, ideally, targeted exploration drilling.

Looking ahead, multi-method integration remains essential to reduce uncertainties, validate structural models, and prioritize the most promising prospects, notably in deep depressions in contact with surrounding horsts.

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