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RESEARCH ARTICLE

Correlation between the 3D magnetic model and the geological section of Samapleu's Deposit (Western Ivory Coast)

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Abstract

Previous studies carried out on the copper-nickel deposit of Samapleu made it possible to carry out a 2D geological model suggested by Camil in 1984. Recent geophysics campaign, by magnetometric surveys made it possible to develop a 3D magnetic model of this deposit. The object of this study is to establish a correlation between this 3D model and the geological sections carried out on this deposit. It comes out from this study that the 3D magnetic model and the geological sections translate the same characteristics with knowing the direction, the dip and the form of Samapleu's copper-nickel deposit.

The three-dimensional magnetic model and the geological sections present a best correlation with the geometry of the deposit

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Introduction

Magnetometry is a geophysical method of prospection which makes it possible to chart the rocks starting from their magnetic susceptibilities, translated by the presence of ferromagnetic minerals such as magnetite and/or ilmenite. The magnetic data processing provides an outline charts and 3D models of the geological structures for a better characterization. The aim of this study is to correlate the characteristics of the tridimensional magnetic model of the copper-nickel deposit of Samapleu with the geological sections resulting from the cored surveys.

2. Presentation of the site

The Samapleu's copper-nickel deposit is localized in the department of Biankouma in the northern part of Man (western of Ivory Coast) in the UTM 29N zone of the WG84 system; in between latitudes 862000 and 856000 north then longitudes 614500 and 635000 east (Fig 1). It is a mountainous area drained by the catchment area of Mene and its principal affluent, Gouan (Angoran, 1978; Taha et Sahy, 1985).

This locality belongs to the intracratonic edge of the anorthoso-charnockite province of the Liberian age of Man (Touré, 1983). These rocks are felsic complexes, basic to ultra-basic (Fig 1). The sulphurated ores associated with the gabbro-pyroxenite complex are arranged in such a way that one passes from a gabbroic peripheral cortex to a heart pyroxeno-peridotitic (Ouattara 1998).

2. Methodology

2.1 Magnetic method

2.1.1 Principle and objective

Magnetometry has an aim the measurement of contrast of the magnetic susceptibility of the rocks. The magnetic susceptibility being the capacity of a material to get magnetized when placed in a magnetic field. The measurement

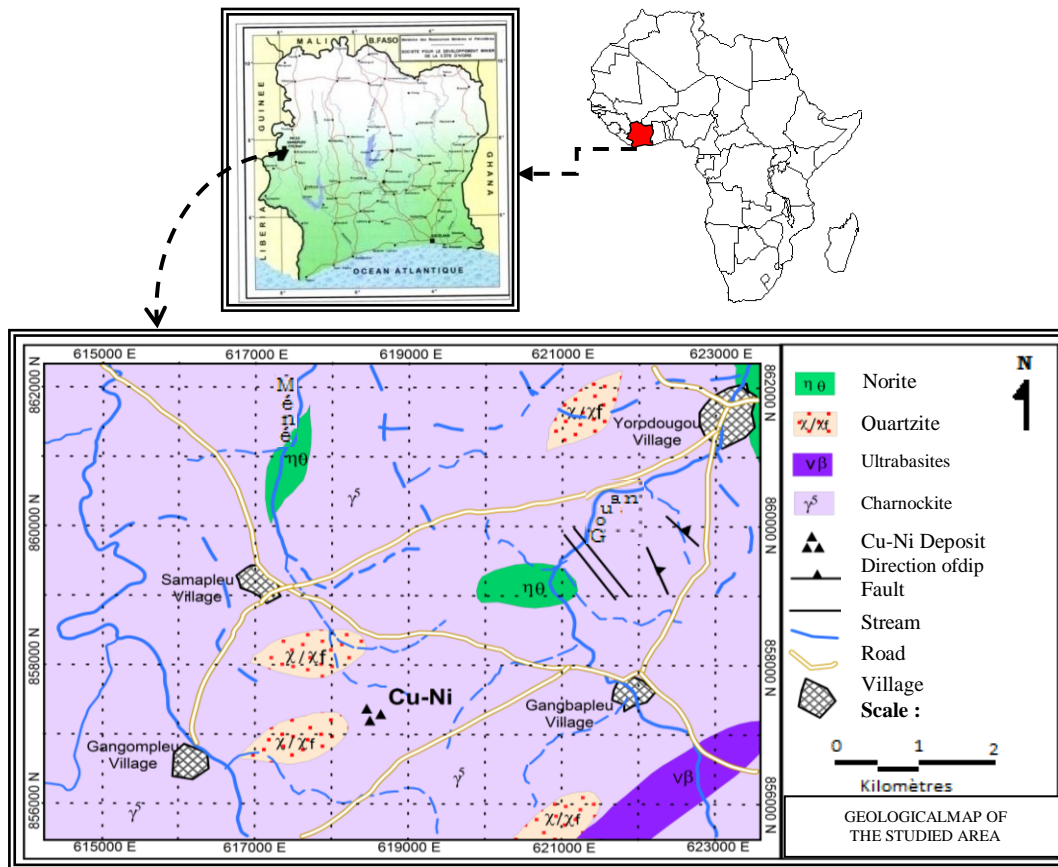


Figure 1: Localization and geological map of the study area, according to the Management of Geology, Abidjan Ivory Coast, July. (1998).

of the terrestrial field with a magnetometer makes it possible to discriminate the basement according to the acidity of the rocks. It is the basic principle of the magnetic prospection. This method when it comes to mining search allows:

- To carry out the geological cartography of the felsic and basic-ultra basic intrusions,
- To locate the structures (faults and contacts) having controlled the deposit and/or the ore re-mobilization through discontinuities in the magnetic signatures.

2.1.2 Data Acquisition

Data were gathered with two proton-magnetometers, one of which is fixed at the base station to record the diurnal variations of the field while the other magnetometer operates on the path. The console must always be directed towards the magnetic north to obtain a perfect coupling spins of the protons with the geomagnetic spectrum. Indeed, the protons being in the console must be directed in the direction of the geomagnetic field to avoid erroneous readings.

2.1.3 Data processing

2.1.3.1 Diurnal correction

After transferring data to the computer via the software Magmap 2000, we represented the curve of the diurnal variations of the field starting from the magnetometer data from the base station to correct the readings of the stations. This correction obeys to the following formula: $T_{i\text{cor}} = T_i - \Delta T_i$

Where T: represent the corrected value of the field recorded time t,

T_i : represent the value of the field recorded time t_i ,

ΔT_i : represent the diurnal variation of the field recorded time t_i at the base station.

2.1.3.2 Modeling of the magnetic data.

2.1.3.2.1 2D Modeling.

The reduction at the equator makes it possible to cancel asymmetrical magnetic sources at low latitudes. This asymmetry thus makes more difficult the interpretation of the magnetic charts obtained in the areas close to the magnetic equator. While applying this filter, the magnetic abnormalities are placed at the exact position of their source.

The mathematical expression of this transform is given by the following relation:

$$L(\theta) = \frac{[\sin(I) - i \cdot \cos(I) \cdot \cos(D - \theta)]^2 \cdot [-\cos^2(D - \theta)]}{[\sin^2(I_a) + \cos^2(I_a) \cdot \cos^2 D - \theta] \cdot [\sin^2(I) + \cos^2(I) \cdot \cos^2(D + \theta)]}$$

Where D : is the variation of the geomagnetic field, θ : is the angle between the direction, I : represents the slope of the geomagnetic field, I_a : is the corrected slope, $i^2 = -1$.

The purpose of the analytical continuation to the top is to bring back the data measured to a certain distance h_0 of the ground surface to a heighten relative in the observation plan by supposing that there is no magnetic source between the two plans. This way of proceeding decreases the high frequency space noise while emphasizing the abnormality of the major sources. Its mathematical expression is: $L(r) = e^{-hr}$

Where h is the distance sensor-surface of the ground relative in the plan of observation and r is the wavenumber of magnetic per ground unit.

2.1.3.2.2 3D Modeling

It was carried out with Euler 3D module of the Geosoft software. It is a mathematical application use to estimate the depth of the magnetic sources on the basis of partial derivation according to the three directions x , y and z . Its literal expression is given by:

$$N(B - T) = (x - x_0) \frac{\partial T}{\partial x} + (y - y_0) \frac{\partial T}{\partial y} + (z - z_0) \frac{\partial T}{\partial z}$$

Where $(x_0; y_0; z_0)$ is the position of the magnetic source of which the total value T is detected with the position $(x; y; z)$; B is the regional field and N represents the value of magnetic susceptibility measured to the point $(x_0; y_0; z_0)$ in SI.

2.2 Logs of checking

The drillings sections are carried out with the Target module of Oasis Montage made by GEOSOFT. To check and control the rooting of the magnetic abnormalities highlighted, twelve surveys were carried out on the principal Samapleu's deposit. The cored drillings data made it possible to carry out correlations with the depth of the magnetic sources and to know the lithological nature of the bodies. The results of the surveys are presented in the form of section each one including at least three logs of drillings.

3. Results and interpretation

3.1 Magnetic method

3.1.1 Charts of the field reduced to the equator

The qualitative interpretation of the magnetic data is made on the basis of the distortions observed on the level of the magnetic signatures. This step makes it possible to highlight information on the required magnetic structures. For our study, we are looking for the basic and ultra-basic complexes likely to contain mineralization in copper, nickel and platinoïd.

Figures 2 and 3 Show two magnetic bodies represented by the "magenta" color. The first is lengthened according to directions NE-SW and crosses the whole of the profiles. The second is located more at the South and appears in the form of circular area. Analysis of the figure 3 gives an idea of the rooting of the magnetic bodies observed. The main abnormal magnetic (of lengthened form) is more extended in-depth and always preserves its form. The figure 3 also shows a fall of the intensity of the magnetic signature on circular magnetic bodies.

This translated that the magnetic source tends to grow blurred in-depth for the benefit of one receiver which would be probably charnockite or gneiss. This magnetic source has thus its base more thinned much than its less deep part. Compilation of the magnetic data with the geological cartography of Samanickel Corporation shows a clear correlation between the magnetic signatures and the nature of the under unclaimed rocks. The red indents on figures 3 and 4 locate the geographical correspondences (geo-reference) between the magnetic charts and outcrop. Basic

and ultra-basic rocks such as the pyroxenite-peridotite and the gabbros are the magnetic sources highlighted in this study (Fig 4).

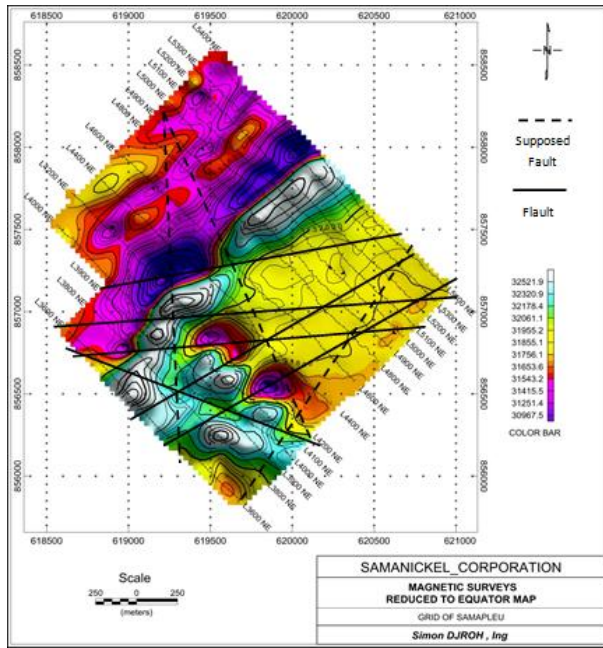


Figure 2: Charts of the reduced to the equator field.

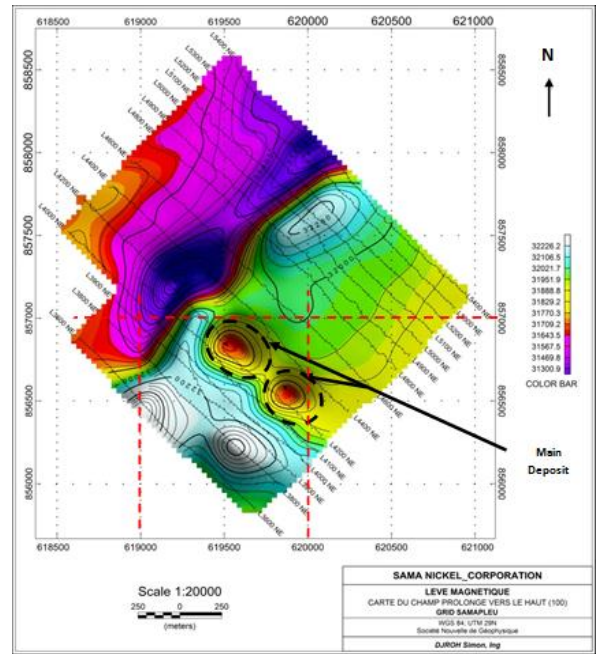


Fig 3: Chart of the upwards continuation field

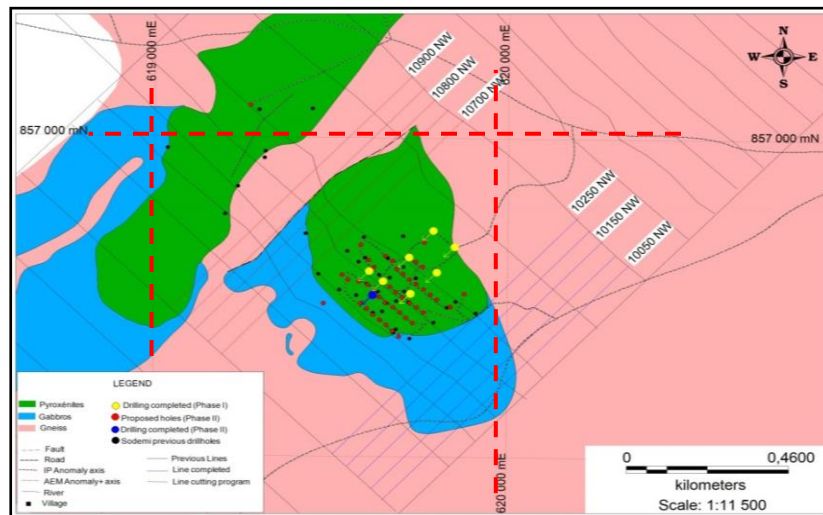


Figure 4: Outcrop Map of the area of study, according to Audet M A. (2010).

The figure5 gives a structural draft of the geological formations presented in the study area. Indeed, we subdivided the sector in three fields namely the magnetic fields, non-magnetic and of magnetic aureole (intermediate zone). The field magnetic, of brown color; corresponds to the corridors of the magnetic intrusions (dykes). This field presents two main directions namely NE-SW and NW-SE and it's the expression of the basic-ultrabasic rocks.

The non-magnetic field, of gray color, is also oriented NE-SW. This field corresponds to the magnetic signature of the gneisses and/or charnockites. The circular magnetic enclave (main deposit of fig 3) gives an idea on the chronology of the intrusions. Indeed, the metamorphosed siliceous rocks (gneiss and charnockites) constitute the preexistent base before the basic intrusion. Many distortions of the magnetic axes show that there exist tectonic undulations. Those undulations moved the various magnetic compartments. We defined four (4) major beams of faults whose directions are N-S, E-W, NE-SW and NW-SE. These tectonic undulations are also markers of the

liberian and eburnean megacycles which affected the geological formations of the study area. These obtained results are in conformity with those of Tagini (1971).

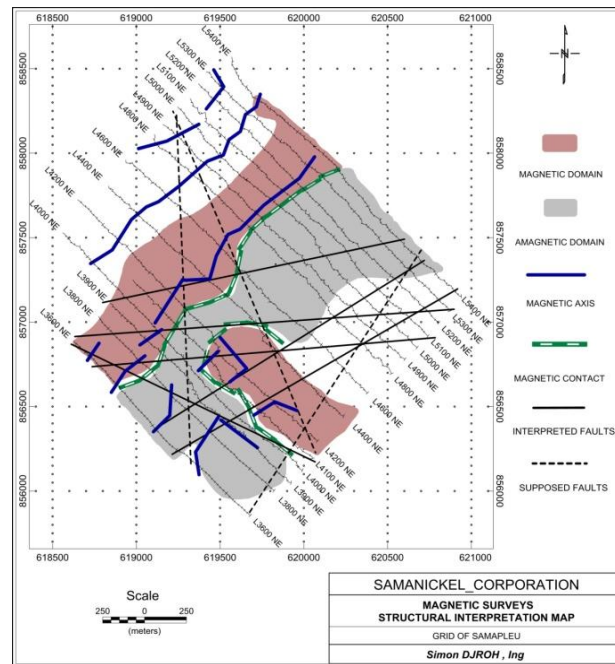


Fig 5: Structural map

Euler's deconvolution on total field makes it possible to estimate the depth of the magnetic sources. On the level of the main deposit (circular magnetic abnormalities) the magnetic sources have a depth moving of thirty meters to a hundred and twenty meters. With information's on the depth of these sources, associated with their geographical coordinates, made it possible to work out the tridimensional model of the main deposit of Samapleu (fig6). This model presents a magnetic anomaly oriented in direction N45°W (fig 6-a), as observed on the figure 2. Observation of the model under various angles provides very useful information's about the Samapleu's copper-nickel deposit. In fact, the magnetic source plunges towards north-east with a dip which borders 45° (fig 6-a and 6-b). Upstream dip, the depth of the magnetic sources can reach ten meters whereas downstream dip could clearly exceed two hundred meters. It is likely that the deposit is of intrusive type, whose ultra-basic magma would be extruded through notches of the Earth in the area located downstream dip according to open fractures within a granitic base metamorphosed (charnockite or gneiss)

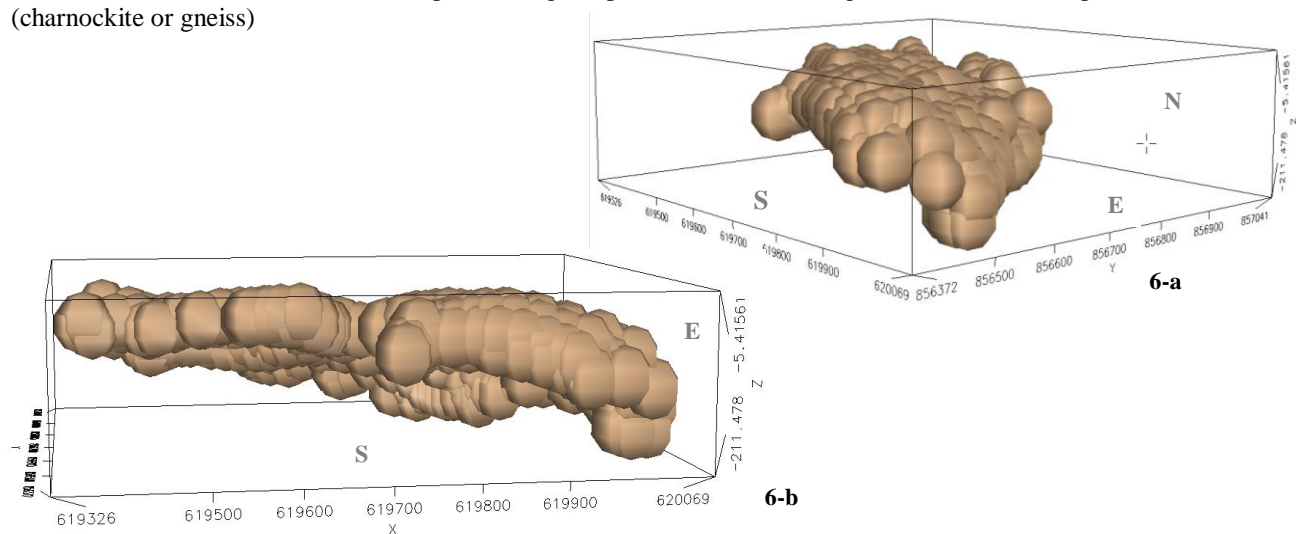


Fig 6: 3D Magnetic model of Samapleu's deposit.

3.2 Checking Survey

3.2.1 Chart of localization surveys

The positions of various surveys as well as the orientation of the sections are presented on the figure 7. The surveys all are oriented NE-SW in order to cross mineralization. It should be noted that the twelve surveys placed at our disposal do not cover the total surface area of the deposit. It also should be noticed that eight surveys are located in non-magnetic zones (clear color of fig 7). The analysis of the following sections, in particular section SF3 will make it possible to know the lithological nature of the crossed formations.

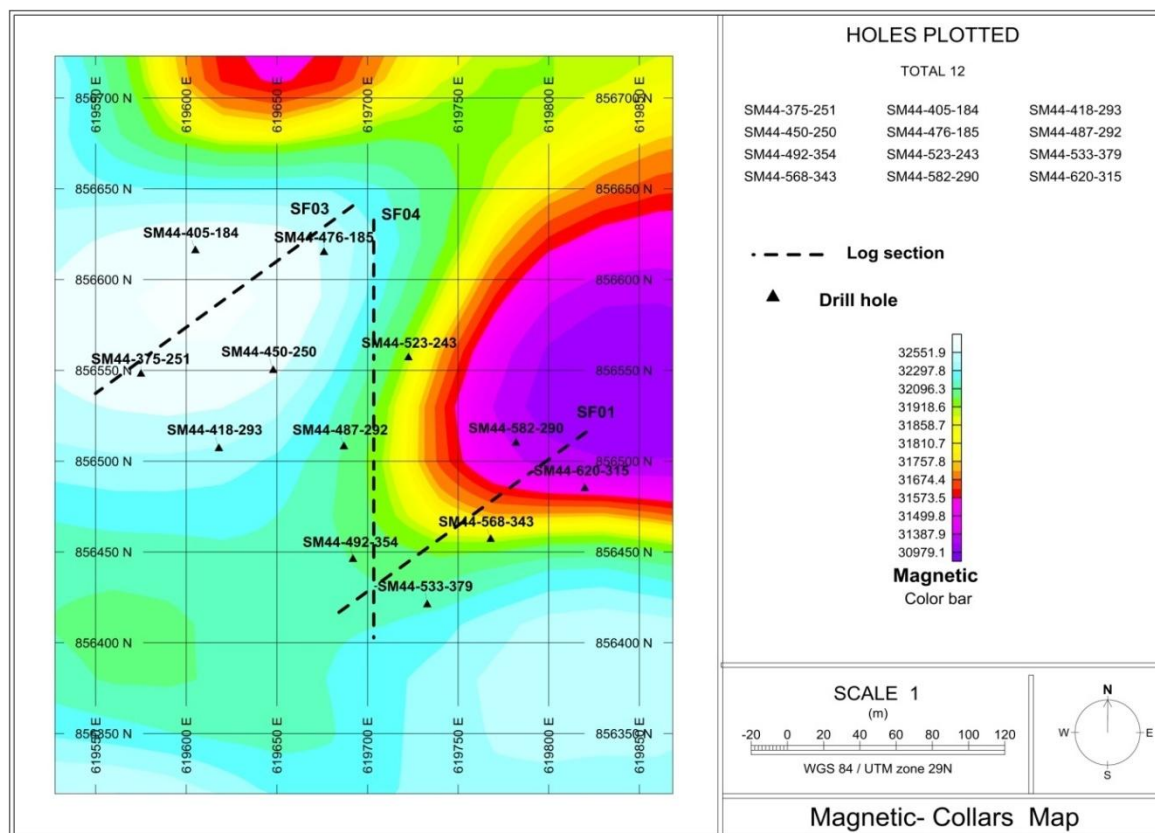


Fig 7: Surveys localization and drillings sections on the main deposit

3.2.2 Presentation of the drillings sections.

✓ DrillingsSectionSF01

Drillings section SF01 (Fig 8) is oriented N°60 E and made up of five wells of which SM44-620-315, SM44-582-290, SM44-568-343, SM44-533-379 and SM44-492-354. From the geological point of view, it shows a lithological succession made up of pyroxenite and gabbros in-depth. Pyroxenite presents an extension more developed much towards the south-west. This power reaches on average hundred meters compared to the northern area where it is sixty meters approximately.

Unlike pyroxenite, the gabbro presents an increase towards South-west and is quite plunged in the north-easting area. This unit is overcome by a deposit of laterite of which the thickness increases from the South-west to the north-east, reaching often twenty meters. The variation in the level of alteration (600 to 650 meters of altitude) from south-west to the north-east indicates that the magnetic source is a hill whose downstream dip presents a profile of alteration more developed.

On this section (fig 8), the top of the magnetic source, pyroxenites and gabbros range between eight upstream and twenty meters downstream.

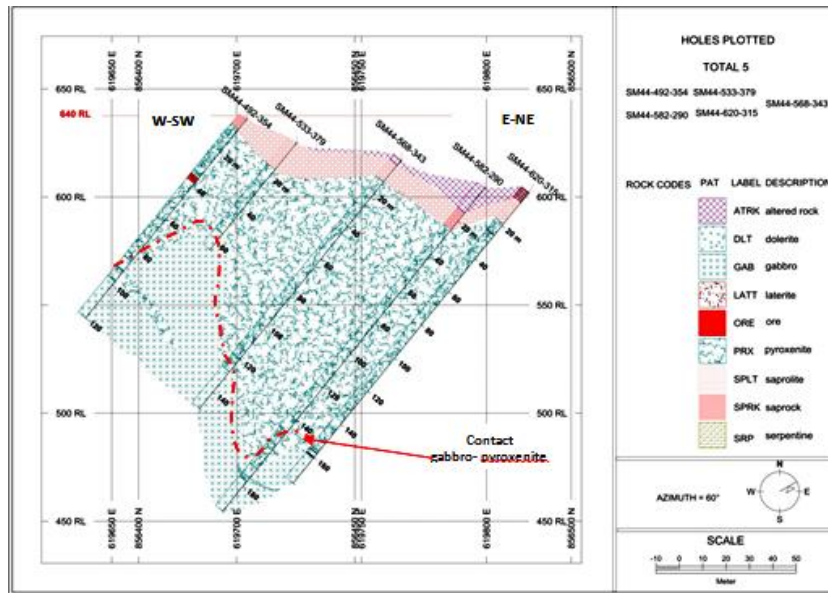


Fig 8: Drillings Section SF01.

✓ **Drillings Section SF03**

Drilling section SF03 (Fig 9) is oriented N°60 E and made up of three wells namely SM44-476-185, SM44-405-184 and SM44-375-251. The geology of this section is similar to that section SF01. Here, pyroxenites are developed also towards east-north-east to the profile. The gabbros plunge from towards east-north-east the area.

However, on section SF03, one observes in-depth a zone metamorphosed by hydration of pyroxenites into serpentine. The latter plunge in the same direction of as the gabbro and constitutes by place the zone of transition between pyroxenites and the gabbros.

This section (fig 9) also shows some dolerite intercalations, then lenticular injections of pyroxenites in the gabbros. Drillings of this section are located on a non-magnetic zone (cf figure7) whereas described lithology shows basic-ultrabasic rocks; this translated the probable existence of the basic rocks low in magnetite and/or ilmenite.

Just like section SF01, this unit is overcome by a layer of alteration of which the thickness increases from the west-south-west to east -north-east, reaching more than twenty meters in swallows dip. The growing alteration also indicates that the magnetic source is a hill whose base has a profile of alteration more developed. On the section SF03, the top of the magnetic source, pyroxenite and gabbro, is located between eight meters upstream and twenty six meters approximately downstream.

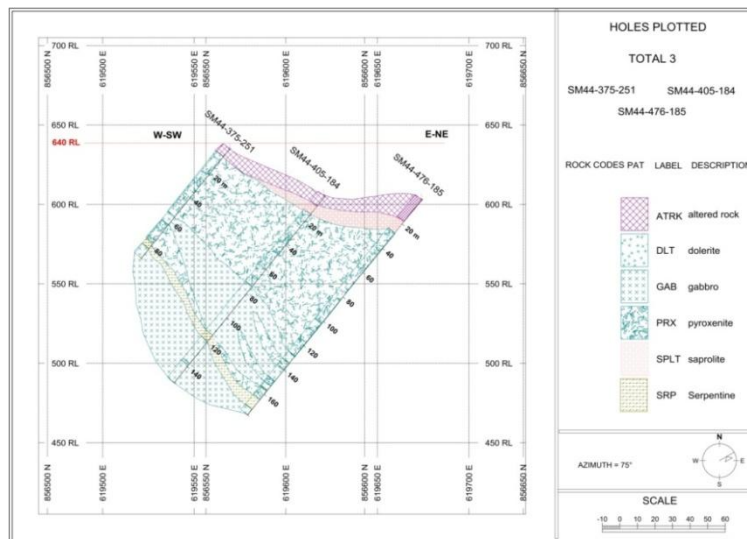


fig 9: Drillings Section SF03.

✓ **Drillings Section SF04**

Figure 10 presents the drilling section SF04. It is oriented north-south and made up of four wells namely SM44-523-243, SM44-476-165, SM44-467-292 and SM44-492-354. The geology of this section is similar with that of section SF03. It is made up of gabbros and pyroxenes in-depth with some peridotitic and doleritic intercalations. Beyond hundred meters of depth, one also observes a level of serpentine less thick with lenticular injections of pyroxenite in the gabbros. This unit is overcome by a layer of laterite of which the thickness varies also from eight meters in the south with twenty six meters approximately downstream towards the north.

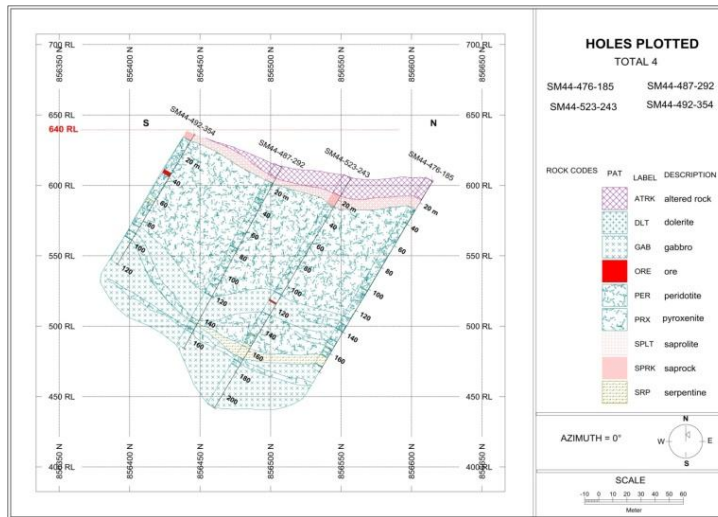


Fig 10: Drilling Section SF04.

3.3- 2D Geological model of Camil (1984)

The compilation of the geological data made it possible Camil (1984) to propose a model in two dimensions (fig 11). This model presents a lithology made up of pyroxenite, peridotite, and gabbro. This unit is overcome by a layer of deterioration, the whole resting on a granitic base. An opened fracture occupied by dunite, would be with the origin of the injection of mineral-bearing ultrabasic rock. Mineralisation is mainly associated with pyroxenite and the peridotite. Camil (1984) also highlighted a directed major fracture east-south (fig 11). According to this model, mineralisation plunges towards the north with a dip of surroundings 45°.

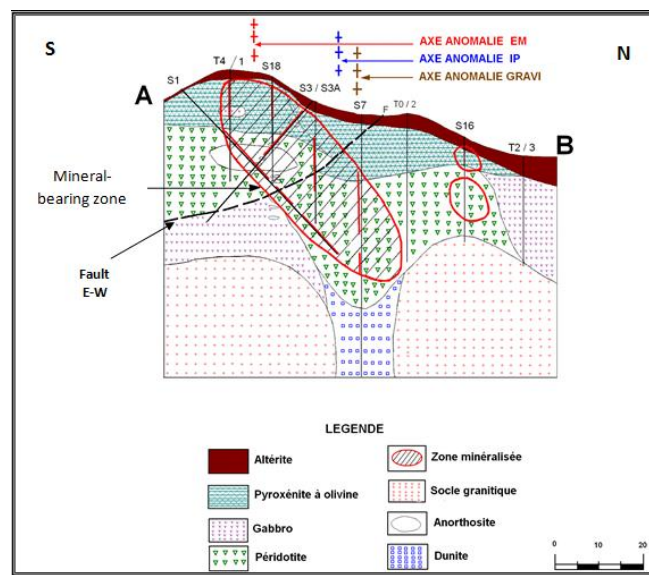


Fig 11: 2D Model of Samapleu's deposit, According to Camil (1984).

4- Discussion

The tridimensional magnetic model (fig 6) and the drillings sections of Samapleu's deposit present interesting similarities, they show that the deposit is oriented to the NW-SE direction and plunges towards the north-east. The cartography of surface and the drillings sections allot the magnetic signatures to pyroxenites and the gabbros as a whole.

The superposition of the cartography with the geological sections shows that the magnetic signatures correspond as a whole to the complexes pyroxenite-gabbros.

However, this study reveals the presence of non-magnetic pyroxenites of reduced extension in Samapleu's deposit. This translated a very small quantity of magnetite and/or ilmenite in their mineralogical composition. Such pyroxenites/gabbros could be born from an aluminous basic magma by substitution of the ferric ion (F^{3+}) by aluminum ion (Al^{3+}) during crystallization. Then, it would be formed alumina oxides instead of ferric oxides during the plagioclases crystallization.

The results of this work confirm the 2D model of Camil (1984) as for the orientation, the dip as well as the lithology of the samapleu's deposit as a whole.

They also give supplementary information which specifies that the deposit plunges towards north-east with a significant thickness to the north-east. They also reveal lenticular injections of peridotite and serpentine in-depth but don't mention the presence of dunite. In addition, this work restores the current 3D model in georeferenced coordinates compared to the 2D model of Camil (1984) which is in local coordinates.

5- Conclusion

The magnetic method provides necessary information's about the geological model of the samapleu's copper- nickel deposit it shows an excellent tridimensional presentation of the whole of the layer. This model indicates clearly that the layer is lengthened in the NW-SE direction with a neighboring dip north-eastern 45° . Upstream dip, the depth of the roof of the magnetic rock would be with approximately ten meters. However downstream dip, this roof would meet beyond two hundred meters. Concerning the geological sections, it is probable that the deposit is of intrusive type, whose basic magma would come from the notches of the earth due to the open fractures within a granite-gneissic base. The surveys of checking carried out in this project confirm the three-dimensional magnetic model in comparison with the depth of the roof of solid rocks met in cored drillings. This 3D model contributes to the improvement of knowledge of the samapleu's deposit.

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