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Study of the Gouméré Gold Mineralization (Northeast Of Côte d'Ivoire) From Induced Polarization And Drilling Sections

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Abstract: *Induced polarization works carried out in the Gouméré locality (north-eastern Côte d'Ivoire) has revealed significant IP anomalies (M> 8 mV/V) associated with a variable environment composed of conductive fields (ρ <700 Ωm) and resistant (ρ> 1500 Ωm). The control of these anomalies by drilling revealed that the sulphide gold mineralization studied is related to silicified levels and oxidized clays and / or sand, quartz granodiorites and veins and veins. The factors governing this mineralization are characterized by structural and hydrothermal.*

Keywords: *Induced polarization, IP anomaly, gold mineralization, Gouméré, Côte d'Ivoire.*

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I. Introduction

In the locality of Gouméré, induced polarization studies in profiling mode revealed the presence of important gold showings sometimes spreading over a few kilometers [1]. Since in the West African Craton mineralization is generally related to magmatism and structure [2] [3] [4] [5] [6], the origin auriferous occurrences in this locality remain unclear. The aim of this work is to provide details on the origin of the gold mineralization of the locality of Gouméré.

II. Framework Of The Study Area

2.1- Location

The study area is a prospect (covering an area of 60.08 km²) located in the Bondoukou region of north-eastern Côte d'Ivoire. It is delimited to the South by the localities of Gouméré and Lomo, to the North and Northwest by the localities of Iguéla and Tabagne, to the East and West respectively by the localities of Koboko and Hérébo (Fig.1). The relief is sometimes rugged, as it is found in its northern part hills and valleys, and in its southern part, alluvial plains. The soils are of lateritic and ferralitic type, not very thick, and moderately desaturated. The gravelly horizon is more important with frequent concretions. In places, soil surfaces are dominated by cuirasses [1][7].

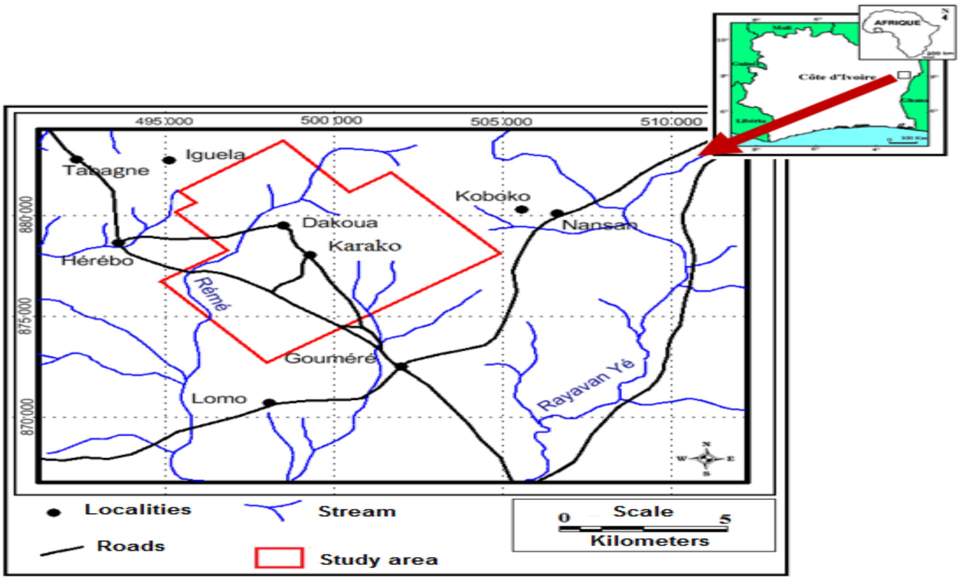


Fig. 1: Location of the study area [1]

2.2- Geological setting

Belonging to the Paleoproterozoic domain, the geology of the Gouméré region is home to a group of formations in which detritic rocks (quartzites, arkoses, sandstones), pluto-volcanics (andesites, gabbros, amphibolites) and syntectonic formations of metatonalites, microdiorites and metagranodorites (Fig.2). Tectonic is characterized by four phases of undifferentiated deformation [1] [8] [9] [10] [11]. The phase D1 corresponding to periplutonic deformations is synchronous with intrusions, with a schistosity S1 and epizonal metamorphism. The phase D2 is manifested by a very penetrating schistosity S2 with a rather strong dip; it is associated with major folds and N-S strike-slip corridors, and is also accompanied by a N-S shear (S / C) channel with a backlash. The phase D3 is defined by dextral setbacks N60° and shifts the S2 schistosity by generating a foliation S3 carrying a local elongation lineation L3, oriented E-W. The phase D4, described as an ultimate clamping phase of regional magnitude, is marked by an crenulation schistosity N120° that obliterates all previous penetratory microstructures [11].

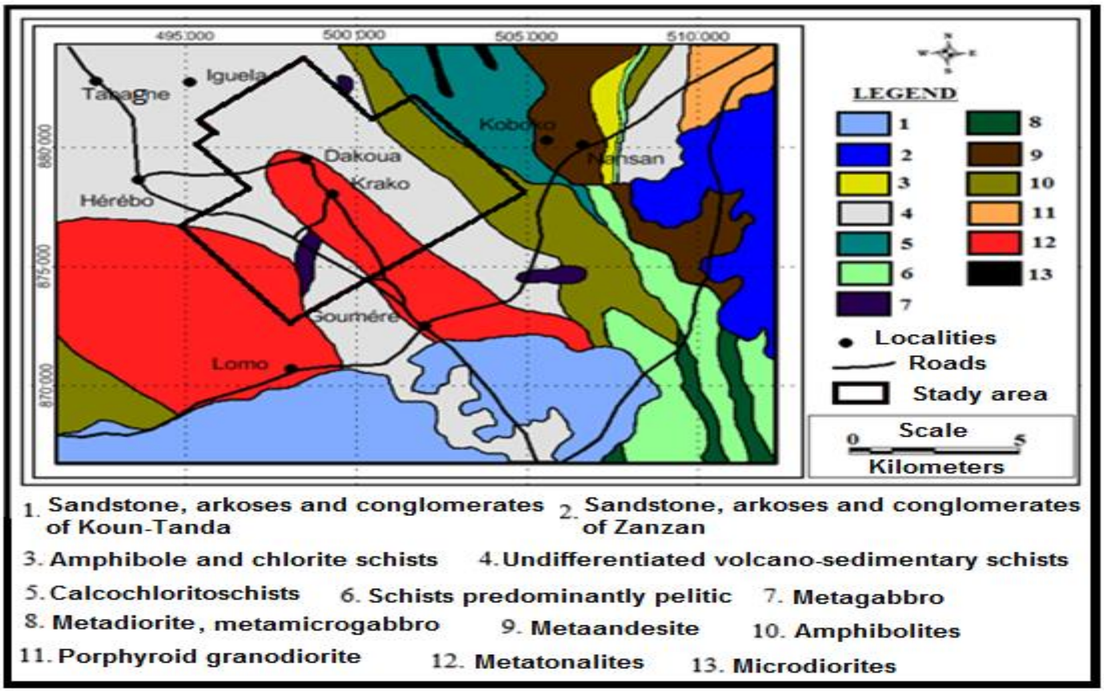


Fig.2: Geological map of the locality [1]

III. Methodology

3.1- Induced polarization

3.1.1- Principle

The studied prospect was subjected to a induced polarization survey in profiling mode with the rectangular gradient configuration for a study grid 200m x 25m. The apparent chargeability map obtained revealed four major IP anomalies oriented mainly NW-SE on which sections are made using the dipole-dipole configuration multi-separations (Fig.3). Induced polarization is particularly effective in the detection of sulphide deposits, especially disseminated ones [12] and allows 2D continuous imaging of subsurface resistivity and chargeability variations [13]. Its principle is to polarize the subsoil by injecting an electric current with a pair of electrodes and to measure the residual potential difference from several potential electrode pairs after power failure [14][15]. The highlighted IP effect is a function of the number of pores filled by the metals.

For this study, the measurements are made in the time domain, because it has the advantage of identifying in situ the presence of parasitic sources (telluric noise, electromagnetic coupling, bad contacts) thanks to the normalization of the form of the discharge curve [16].

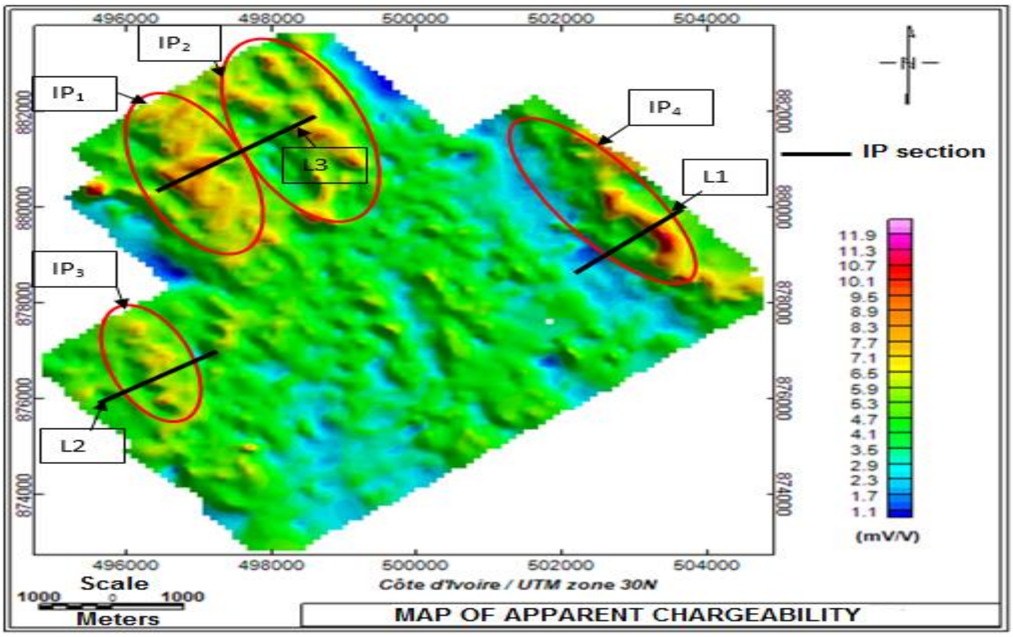


Fig.3: Apparent chargeability Card [1]

3.1.2- Inversion method

The induced polarization data collected during the surveys are arranged according to the different acquisition levels (n1 .... n6) corresponding to the investigation depth. At first, they are processed and presented in the form of pseudo-sections of apparent resistivity and chargeability using the software Oasis Montaj (Geosoft) and after, inverted from the software RES2DINV to obtain true-depth inverse sections. This inversion method used by the RES2DINV software is based on the softened least squares method developed by DEGroot-Hedlin and Constable in [17]. It is a stable optimization method that is used to determine cell resistivity (or chargeability) while minimizing the difference between measured and calculated apparent resistivity (or chargeability) values.
The function to be minimized, called the bijective function **Ψ**, is defined by:
Ψ (**ri**) = **giτgi** + λ**iriτCτCri** (1), where **i** corresponds to the number of the iteration, **λ** is the damping factor, **g** is the anomaly vector (difference between the apparent electrical resistivity and that calculated for all the cells of the model corresponds to the RMS value) and **C**, the damping matrix.

3.2- Sampling

The acquisition of the geological data consisted of a petrographic study, as well as the collection of samples in order to know the identity of the geophysical (electrical) signatures. The study area has a humid tropical climate, the phenomena of alteration are very advanced. Outcrops are usually rare. However, rock samples (58 in total) were collected and a selection of 22 samples was used to identify the nature of the geophysical (electrical) anomalies. Data of soil geochemistry, trenching, RC (Reverse Circulation) and DD (Diamond Drilling) core drilling were also collected for the development of this study. They come mainly from the activities reports of COMINOR mining company. Drilling data (RC, DD) are used for the control of mineralized geological units resulting from the interpretation of the resistivity and chargeability sections.

IV. Results And Discussion

4.1-IP pseudo-sections and sections

4.1.1-L1 profile

The L1 profile, 1600 m long and oriented NE-SW, is delimited by the 2425 and 4025 m stations (Fig.4). It is designed to study the IP4 anomaly identified in the East of the study area. The pseudo-sections show that the apparent resistivities (ρa) oscillate vertically between 211 and 1478 Ωm, whereas the apparent chargeabilities (Ma) vary sectorially from 3 to more than 6 mV/V. Levels 1 to 2 (n = 1 to n = 2) of the resistivity pseudo-section correspond to a environment of low resistivity (211 Ωm <ρa < 366 Ωm) (Figures 4a and 4b). On this profile, the observable conducting levels between the 2425 and 3225 m stations would be mineralized because they show polarized pockets. Resistant environments lining the bottom of the resistivity pseudo-section correspond rather to the substratum which is surmounted by a transient medium (between levels n = 2 and n = 4) which is less polarizable (4 <Ma <5) having a resistivity between 366 and 867 Ωm. At the 3625 m station, there is an anomaly that indicates the presence of a resistant intrusive that is certainly mineralized (Ma> 6). This structure shows that the basement (ρa> 1478 Ωm) is sub-flush and is also affected by a fault whose dip is greater than 45°. The inverted sections (Fig. 4c and 4d) reveal that the true resistivities (ρ) of the medium are between 30 Ω.m and 4100 Ωm, while the true chargeabilities range from 0.4 to 6 mV/V. On this L1 profile, the polarized (mineralized) levels are associated with both the conductive (stations: 2825 m and 3725 m - 4025 m) and resistant (station 3625 m) environments. The character of the conductive terrain militates in favor of sulphide gold mineralization of secondary origin. Moreover, the polarization of the resistant substratum supposes the existence of a mineralization of primary origin (station 3625 m) and of disseminated type, because the polarization of such a resistant formation (ρ> 4000 Ωm) is possible only through the spread of sulphide minerals. The mineralization is probably also controlled by the structural, because the fault zone between the 3225 and 3625 m stations presents likewise an interesting chargeability (M> 5 mV/V).

4.1.2- L2 profile

Like the previous one, L2 profile, made on the IP3 anomaly (cf Fig.3), is also 1600 m long and oriented NE-SW. According to Fig.5a, the apparent resistivity pseudo-section has results that are almost similar to L1 profile because the values vary from 209 to 1227 Ωm. On the other hand, the apparent chargeabilities (Ma) are higher than the previous ones. Conductive environments, more superficial, have a resistivity which oscillates between 209 and 277 Ωm. They introduced oneself in the form of pockets, the most remarkable of which is observed between the -3125 and -2875 m stations. The latter shows an ingrained or deep character, and looks like a well open fault zone. With the exception of this conductive pocket, the apparent chargeability pseudo-section (Fig.5b)

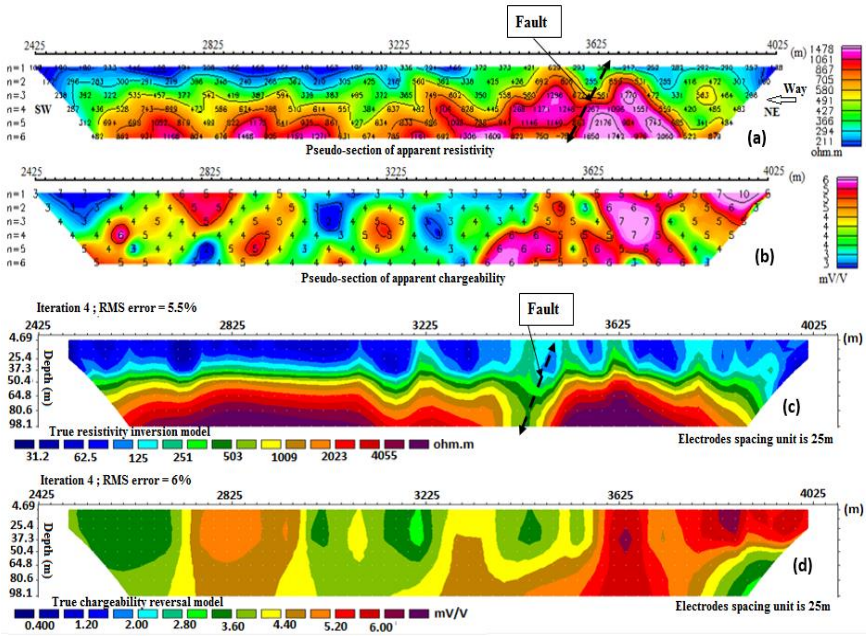


Fig.4:**Pseudo-sections and inversed sections of L1 profile**

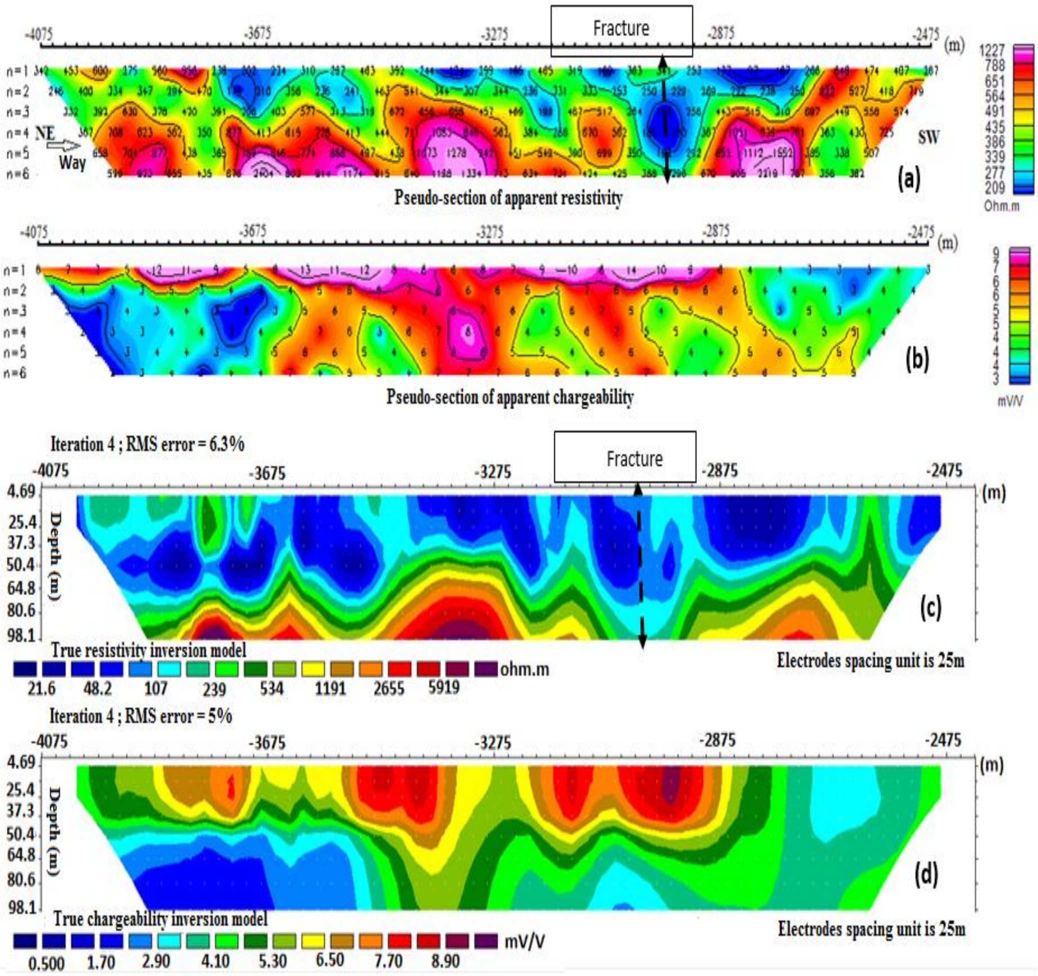


Fig.5: Pseudo-sections and inversed sections of L2 profile

indicates that all other conductive levels are highly polarized (Ma> 9 mV/V). As for the resistant environments (ρa> 788 Ωm), materializing the substratum, they appear on the whole, little polarized (Ma < 7 mV/V) with theexception of the levels located between the stations -3675 and -3275 m . This suggests mineralization hosted ina crystalline substratum. However, the inversed sections (Fig. 5c and 5d) reveal that the mineralization is rather superficial than deep since it is conductive, superficial environments which are polarized (M> 7 mV/V). This indicates that the IP3 anomaly (cfFig.3) corresponds to secondary sulphide mineralization.

4.1.3-L3 Profile

This profile, which is 2000 m long (Fig.6), is designed to characterize the IP anomalies located North of the study area (cfFig.3). He studies both IP1 and IP2 anomalies because of their proximity. Pseudo-sections obtained show that in this zone, the medium is, as a whole, conductive (23 Ωm <ρ_a 811 Ωm) and has high apparent chargeabilities (1 mV/V <Ma <18 mV/V) unlike previous environments (cfFig.4 and 5). In Fig.6a, a big conductive structure watched at station 1225 m, appears well rooted, but show a very complex IP response highlighting both polarized and unpolarized bodies. This indicates the presence of either mineralized vein bodies in a conductive domain, or a vertical dyke. On the other hand, relatively resistant environments (ρa > 324 Ωm) are quite mineralized since they have good IP signatures (Ma> 11 mV/V). This is also observed on the inversed sections (Fig.6c and 6d), because between the 1225 m and 2425 m stations, two major IP anomalies of chargeability higher at 17 mV/V are distinguished. This mineralization is related to felsic plutonic formations (granitoids). Faults affecting the felsic substratum probably favored the formation of identified mineralized quartz veins on the field. This indicates that, given their relationship to the polarized (mineralized) levels, they served as a drain for the circulation of the hydrothermal fluid causing the emplacement of mineralized quartz veins.

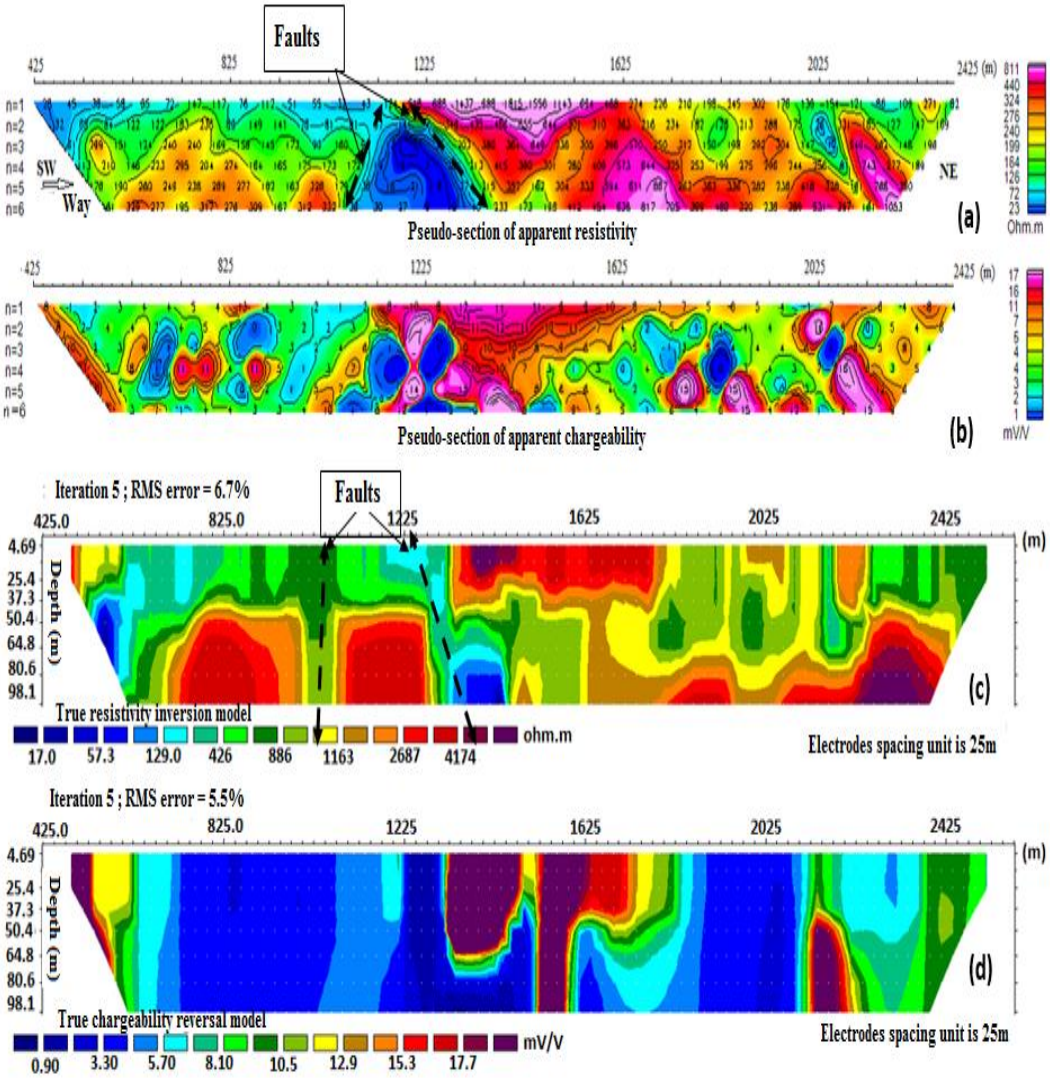


Fig.6:Pseudo-sections and inversed sections of L3 profile

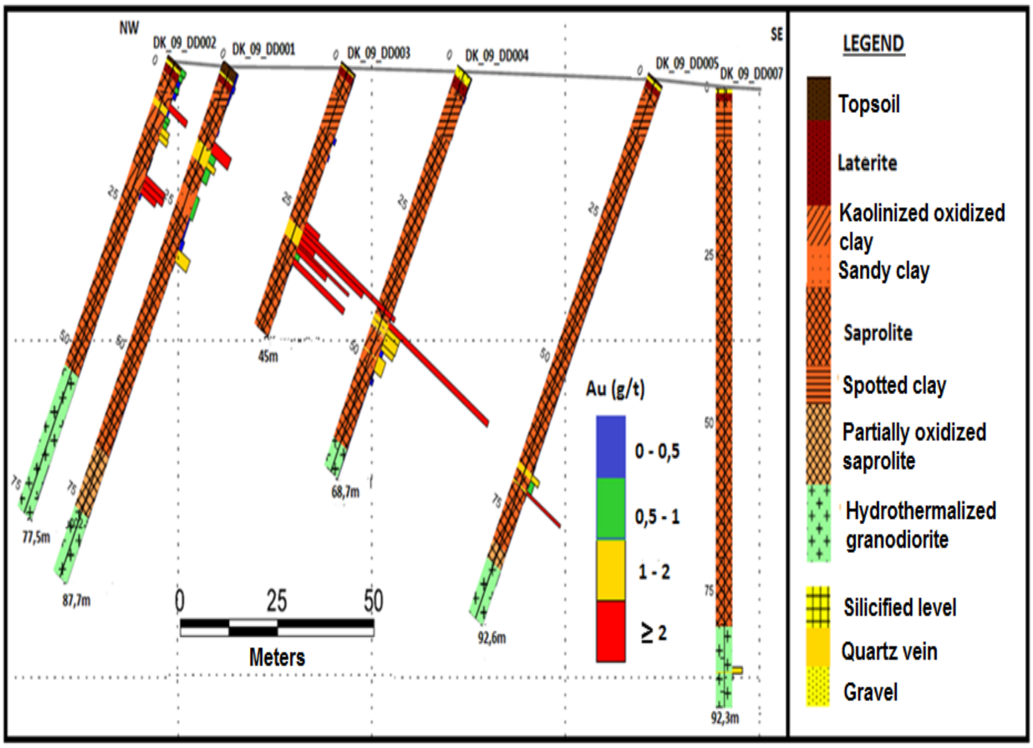
4.2- Geological Verification Sections and IP Synthesis

4.2.1- Description of the drill sections

Since the IP_1 and IP_2 anomalies are the most polarized (M> 10 mV / V) in the study area, they were selected to produce two drill profiles (Fig. 7 and 8) in order to identify the nature of the mineralized geological units.

4.2.1.1- DD profile

Performed to check IP_1 anomaly (cffig. 3), DD profile is oriented NW-SE according to the lengthening of the anomaly and is composed of six drillings having on average each a depth of 80 m (Fig.7). The results recorded by all the drillings are almost identical. In fact, the lithologies observed are composed of: lateritic terrains (maximum thickness of 3 m) surmountedby thin layers of topsoil (less than 1 m thick), followed by saprolite (more than 70 m thick) with intercalations of oxidized and sandy clays and generally cut by quartz veins and veins. The whole rests on a felsic substratum (granodiorite) sometimes hydrothermalised.Hydrothermalism is very active because several silicified levels are observed. At the metallogenic setting, analyzes indicated that the mineralization is generally related to the superficial and deep levels. Thus, high gold contents (≥ 2 g / t) are associated with oxidized and sandy clay levels, quartz veins and saprolite. The granodiorite is also mineralized, but with a gold content between 1 and 2 g / t (DK_09_DD007).



Fig;7:DD Drilling Section (COMINOR, Oral Communication)

4.2.1.2- RC profile

RC profile, having the same orientation as the previous one, is executed for the verification of the IP2 anomaly (cf Fig.3). It is also composed of six boreholes with an average depth of 90 m each (Fig.8). The lithology identified by these holes is similar to that of the previous profile (Fig.7) but with some variations. It is composed from the top to the bottom: lateritic soils (5 m thick) characterized by cuirasses and lateritic clays, saprolite (more than 60 m thick) with intercalations of oxidized clay levels and quartz veins, and a granitic substratum interspersed with gabbroic mafic dykes (borehole DK_14_RC112). The presence of silicified levels demonstrates that the area is affected by hydrothermal, which has therefore contributed significantly to the establishment of gold mineralization. Indeed, the high gold contents (≥ 2 g/t) are mostly associated with silicified zones and quartz veins. As for the granodioritic formations, analyzes show that the good contents (in gold) are only recorded at the environment of the hydrothermalized parts (Fig.8).

4.3- Correlation between IP anomalies and geological sections of boreholes

IP sections realized in the anomalous zones (cf Fig.3) showed that in the southern half (Fig.4 and 5), the true chargeabilities are between 6 and 9 mV/V and are generally associated with the conducting grounds and sometimes with the resistant formations. In the conductive environments, the mineralized horizons are associated to the hydrothermal promoting start-up quartz veins. On the other hand, in resistant soils, the sulphide mineralization is in disseminated form in granodiorites, but in basic volcanic formations, the observations of the ground made it possible to identify sulphide minerals disseminated in basalts. In the northern half, geological sections (Fig.7 and 8) have shown that the resistant structures shown on L3 profile (Fig.6) correspond on the one hand to felsic facies (granodiorite and / or granite) and mafic (gabbro) on the one hand, and quartz veins, on the other hand.

As for conductive environments ($\rho < 70\ \Omega m$), they are largely associated with the levels of oxidized and sometimes sandy clays. The saprolite ($400\ \Omega m < \rho < 3000\ \Omega m$) is very pronounced (more than 50 m thick) and is generally covered on the surface by lateritic soils (cuirass and lateritic clay). The presence of mineralized quartz veins (Fig.8) suggests that sulphide mineralization is also associated with faults. This implies that the control of the mineralization is not only related to the hydrothermal, but also to the structural.

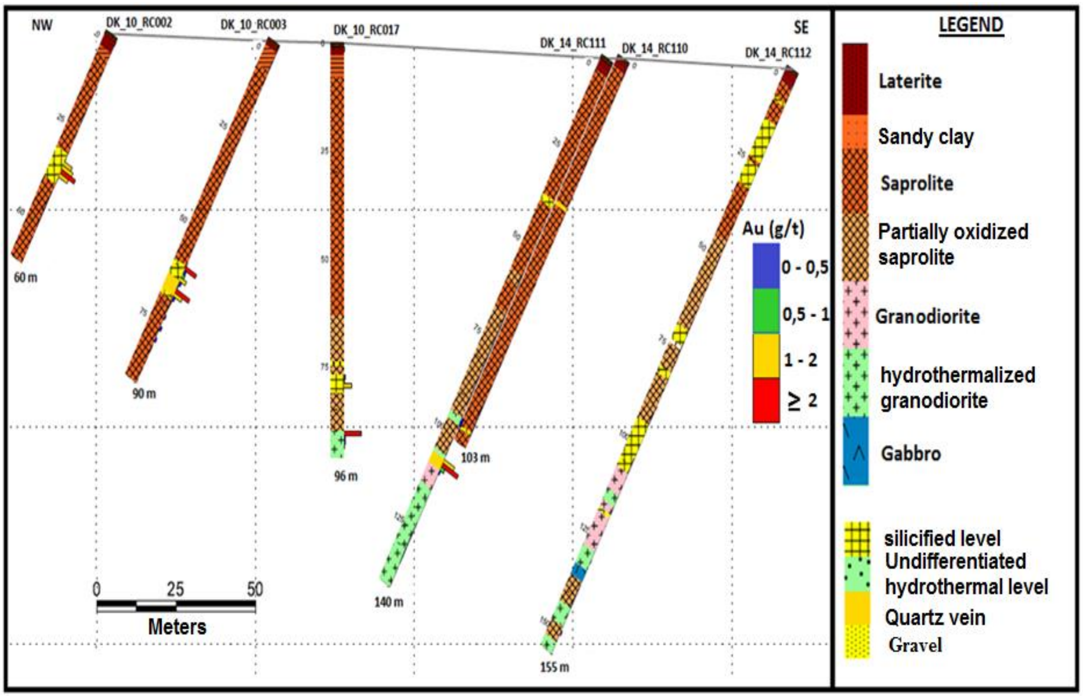


Fig.8: RC Drilling Section (COMINOR, Oral Communication)

V. Discussion

The geophysical survey by the induced polarization made it possible to highlight important gold showings in the locality of Gouméré. These indices are expressed on pseudo-sections and inversed sections by IP anomalies that are associated with conductive and resistant environments. This reveals that the sulphide gold mineralization studied is found in a variety of enclosures. The polarization of resistant rocks assumes that the sulphide mineralization is of disseminated type [18], because the electrode polarization phenomenon is greater when the total surface of the interfaces between the conductive grains and the electrolyte is large [15] [16]. Conversely, in conductive environments, although it may contain disseminated sulphides, the characteristic mineralization is massive [19]. In North of the prospect, the sulphide auriferous occurrences are largely related to the granodiorites because, in most of the holes, the good gold contents (≥ 2 g/t) were recorded in hydrothermal felsic formations (granodiorites and / or granites) and in silicified levels and oxidized sandy clays (cf Fig.7 and 8). Other studies conducted in the same region by some authors [1] [7] [20] on sulphide granodiorites have shown that the origin of the mineralizing fluids is similar to the case of the Bonikro gold deposit. [21].This type of gold mineralization is remarkably expressed in most Birimian gold deposits [4] [22]. In addition, the results of this study indicated that gold mineralization is also associated with quartz veins generally oriented NW-SE. This, thanks to the NW-SE shears that trace the major structural direction in the region. Other authors [23] argue that filler fluids are orthomagmatic in nature and / or remobilized from host formations due to the thermal anomaly of the granitoid pluton. This type of mineralization was observed by [24] in the Djibo furrow [25] of the Bouboulou-Bouda corridor in Burkina Faso. According to these authors, the polarization of quartz veins corresponds to a filling of NW-SE fractures by solutions in equilibrium.These solutions, loaded with gold and sulphides (pyrite and / or chalcopyrite), have their origin in the metamorphic and tectonic manifestations. In fact, by metamorphism and deformation, solutions are mobilized, drained and then deposited towards the relatively "low" pressure zones (fractures, diaclases, ...)[26]. This shows that gold and sulphides are mobilized from the plutonic host (granodiorite), and transported by the fluid solutions in the trap zones where they crystallize in a disseminated manner. Thus, gold and sulphides (pyrite and / or chalcopyrite) were introduced into the host (granodiorite) at the same time as vein quartz. As for the polarization of conductive lands, Aka's work [7] carried out in the same study area revealed that this phenomenon is generally related to the mineralization of sedimentary and volcano-sedimentary terrains. In this regard, two types of mineralization mix: mineralization related to the Tarkwaian (sedimentary) and Birimian (volcano-sedimentary) formations [8]. For this purpose, tarkwaian formations of the Bondoukou region (North-East of Côte d'Ivoire) would be well mineralized and present a style of gold mineralization approaching that of Ghana [27], but different that of Burkina Faso [28]. With the exception of mineralized felsic intrusives, the mineralized birimian volcanic formations present in Gouméré locality are dominated by basalts that are generally metamorphosed and altered. This is consistent with observations made by [20] and [30] highlighting metabasalts containing sulphides. These sulphide metabasalts are often enclave and deformed in the granodiorite, but also in the form of pebbles in the polygenic metaconglomerate [20].

VI. Conclusion

The geophysical survey by the induced polarization made it possible to highlight IP anomalies revealing the presence of important occurrences sulphured auriferous. Most of polarized environments (M> 8 mV/V) are linked on the one hand, to the conductive formations (ρ <700 Ωm) corresponding to silicified levels and clays and/or oxidized sandblasts and on the other hand, to the ground resistant (ρ> 1500 Ωm) characterized by granodiorites and quartz veins. In the region, the mineralization is controlled by the structural and especially hydrothermal. For further studies, multi-elements geochemical analyzes are needed to clarify the nature of the different mineralizations associated with geological formations.

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