The importance of hydrothermal alteration in Agbaou gold mineralization (Southern of West African Craton)

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ABSTRACT

Located in the southern part of the Fettêkro furrow, the Agbahou gold deposit is formed by a large band of NE-SW-oriented green rocks and framed by recent granitoids. The region of Agbahou (northern part of Divo) shows Birimiennes formations globally metamorphosed in the green shale facies. Metabasalts, Amphibolite, Métadolérites and Metagabbros (not far from the village of Iroporia), Épidiorites (around the town of Hiré), Métarhyolites and Metadacites, tuffs, breccia, shale and sediment are distinguished Related. Mineralization is collected in mafic metavolcanic (metabasalts), pyroclastic and in metasediments. Petrographic and chemical studies have shown that this mineralization is affected by hydrothermal alteration phenomena such as Silicification, Carbonation, Chloritization, Sericitisation, Sulfudation and Albitization. However, the most important are silicification, carbonation and Sulfudation, and to a lesser extent, chloritization, sericitization, and Albitization. In Agbahou, the mineralization is carried by a quartz vein and folia system which is of the vein type. But next to this type, there is another type of mineralization that is disseminated type mineralization. However, vein-type mineralization is the most dominant. The minerals of alteration quartz, carbonates (calcite, ankerite ± dolomite), Sericite, chlorite, albite and sulphides are frequently encountered in the walls of veins or associated with the corridors of mineralization constitute the minerals Accompanying the mineralization and whose presence is very marked as a guide for prospecting. Metal paragenesis contains pyrite, pyrrhotite, Arsenopyrite, chalcopyrite, sphalerite, and gold. The identification and the characterization of the hydrothermal alteration were carried out through the following diagrams.

Keywords: Southern part, Fettêkro furrow, gold deposit, mineralization, hydrothermal alteration, Birimian formation, Agbaou (Côte d'Ivoire)

1 INTRODUCTION

In Côte d'Ivoire, the Birimian geological terrains, structured during the Eburnean orogeny, are full of numerous deposits and metalliferous indices. They are dominated by greenstone belts which are the object of exploration or mining, presenting a great interest for gold. This is the case of the regions of Hiré-Oumé, Ity, Yaouré, Tongon, Afema and Agbaou where deposits have been discovered. The West African Birimian green rocks indeed contain plutonovolcanic, volcaniclastic and sedimentary rocks, metamorphosed under greenschist facies conditions and intruded by granitoid massifs (2.2-2.0 Ga), [1-5]. West African gold is mesothermal mineralization related to disseminated gold-rich quartz-Au-arsenopyrite lenses or quartz veins with free gold and Cu-Pb-Zn-Ag-Bi paragenesis (Ashanti, Prestea and Konongo, in Ghana; Aniuri, Asupiri and Aféma, in Côte d'Ivoire). These are late-orogenic mineralizations [6]. For these deposits, the mineralization is linked to a hydrothermal origin whose source seems to be attached to a pluton. Alteration is an important parameter present in most gold deposits, whether of the orogenic type [7-9] or associated with intrusions [10]; However, when discovering mineralized rocks in the field, understanding the alterations and overall [9]. hydrothermal system is important for exploration. Several studies have shown that there are close links between the emplacement of gold mineralization and hydrothermal alterations [11-14]. The objective of this work is to highlight the importance of hydrothermal alteration in the gold mineralization of Agbaou.

2 GEOLOGICAL CONTEXT

The Oumé-Fettêkro furrow, to which the Agbahou gold deposit belongs, is located in the southern part of the West African Craton (figure 1). The Agbahou region (northern part of Divo) shows globally metamorphosed Birimian formations in the greenschist facies. There are metabasalts, amphibolites, metadolerites and metagabbros, epidiorites, metarhyolites and metadacites, tuffs, breccias, shales and associated sediments. These formations can be grouped into four major lithological sequences [15] (figure 2): a mafic and sedimentary volcanic sequence, a mafic and

ISSN 2229-5518

sedimentary volcanic sequence, an essentially sedimentary sequence, a mafic volcanic sequence and finally, a sequence felsic volcanic and sedimentary. These Birimian formations are intruded by oriented or equant granitoids of regional extension. The Birimian formations in this region are intensely folded and have probably undergone polyphase deformation. Strike-slip faults affect the metabasite-granitoid contact and E-W fractures strike the granodiorite [16]. These fractures form subvertically dipping mineralized quartz veins. We also note the presence of NW-SE fractures, submeridian faults and finally, sinistral strike-slip structures.

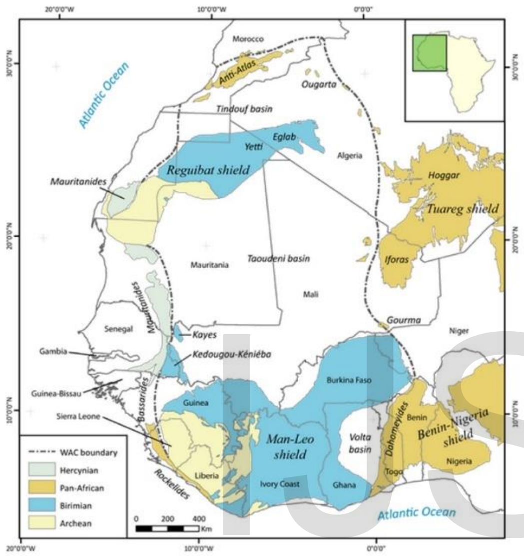

Fig.1: Simplified tectonic map of West African Craton [17].

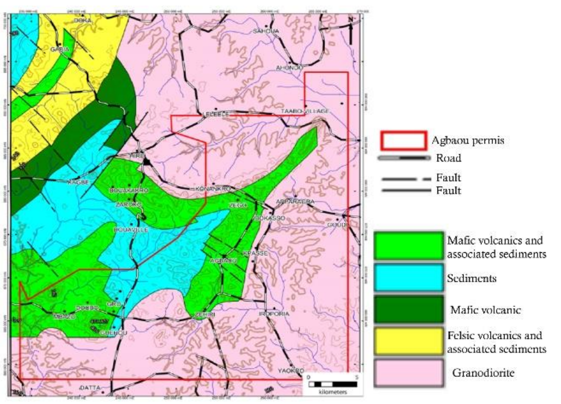

Fig.2: Geological map of the study area (BHP Minerals, 1992, [18])

At the scale of the Agbahou gold deposit, the geology has been better known thanks to core drilling and mapping of the mine pit during operation. It appears from this work that the deposit is in fact dominated by volcanic formations (of basaltic to andesitic composition), volcanosedimentary (tuffs, volcaniclastites) and associated sediments (sandstone, silt and argillite) (figure 3); these formations being intruded by veins of gabbro and diorite on the one hand, and veins of rhyolite and rhyodacite on the other. The gold mineralization of Agbahou is controlled by two major shear zones called ZTA (Agbaou Tectonic Zone) and ZTO (Western Tectonic Zone). They generally oriented NE to NNE along the volcano-sedimentary complex. Shear zones control the emplacement of mineralized quartz lenses and veins. These first-order shear zones contain second-order ductile-brittle shear zones, trending NE to NNE and dipping 50-80ºSE. These second-order shear zones host multiple mineralized quartz veins.

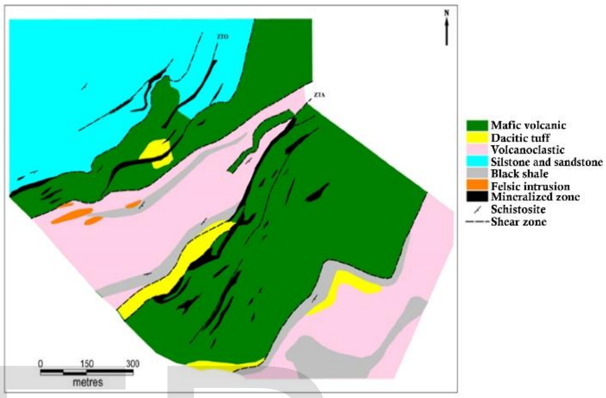

Fig.3: Lithostructural map of Agbaou mine

3 ANALYTICAL METHODS

3.1 Petrography

The macroscopic petrography was done on printouts of description sheets illustrating in detail our observations. They contain the following headings: drilling data (drilling name, location, azimuth, inclination), lithologic facies or mineralized pass intervals, lithology, color and color intensity of the lithology, the levels of silicification and carbonation, the alteration minerals, the sulphides and their proportions, the deformation gradient, the presence of quartz veins and the angle of the structures with respect to the core axis. At the microscopic level, the study of thin sections took place using polarizing microscopes at the Laboratory of Basement Geology and Metallogeny (LGSM) of the Félix Houphouët-Boigny University and at the Laboratory of the Direction de la Cartographie and Geological Prospecting (DCPG). Microscopic petrography made it possible to determine the mineralogical assemblages of the host rocks (original and altered minerals), quartz veins and their wall rocks.

3.2 Geochemistry

The major elements (SiO_2, Al_2O_3, total Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, TiO_2 and P_2O_5) are determined by plasma emission spectrometry (ICP).

The loss on ignition which corresponds to the loss of mass of the sample (water and volatile escape) is determined after heating to 1000°C and makes it possible to know the samples which are affected by the alteration. The processing of chemical analysis data, as well as the construction of diagrams was possible thanks to Excel. The objective is to study the minerals characteristic of hydrothermal alteration and the most altered rocks.

3.3 Metallogeny

To carry out this study, we analyzed all the mineralized zones so as to know the elements carrying the mineralization. Several longitudinal sections were produced using MapInfo-Discover software. It takes into account lithologies, mineralized lenses, sulphide zones, deformation and alteration zones. These elements favored the correlation from one section to another and to follow the distribution of the ore bodies. Ore samples were selected for further investigation by metallographic microscope and scanning electron microscope (SEM).

4 RESULTS

4.1 Petrographic study of hydrothermal alteration

At Agbahou, gold mineralization occurs in metavolcanites, pyroclastites and metasediments. The events that affected these formations and those at the origin of the establishment of gold mineralization by the formation of a system of quartz veins, are accompanied by pervasive and hydrothermal alterations. On drill cores, these different alterations are visible to the naked eye and observable under a microscope. They are important in the economy of a deposit. Carbonation, silicification and sulphidation are the most important alteration phenomena of the Agbahou deposit and to a lesser degree, chloritization, sericitization and albitization.

4.1.1 Carbonatation

Carbonation can be defined as the process by which host rocks are impregnated with carbonates. The carbonates encountered at Agbahou are calcite and, to a lesser degree, dolomites and ankerites. They are in very fine grains invading the surrounding formations on the one hand, and on the other hand in medium or coarse grains in the veins and veinlets. Irregular injections of carbonates are also observed in certain formations (figure 4A). The carbonate veinlets are generally parallel to the schistosity (figure 4B). However, there are calcite veinlets which rarely intersect it. Carbonation affected all types of country rocks; however, it appears more important in mafic lava where all calcic plagioclase and other minerals are destroyed and replaced by calcite, dolomite or ankerite. The carbonates are syn to post-tectonic (figure 4C and D). The recent carbonation at the origin of calcite porphyroblasts shows the existence of a spatio-temporal relationship with gold mineralization. At Agbaou, the ore zones are associated with intense carbonation, which is generally accompanied by the formation of ferrotitanium oxides. Carbonation probably appears as the precursor event of gold mineralization

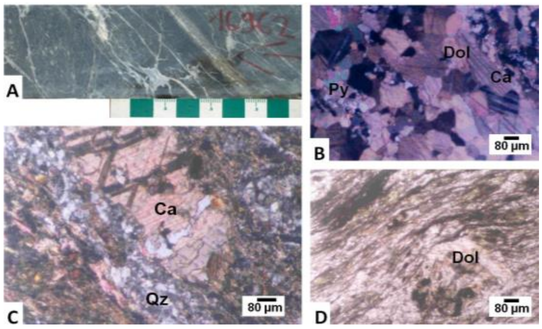

Fig. 4: Microscopic and macroscopic aspect of the carbonation phenomenon. (A) Injections of carbonates in mafic volcanics. (B) Vein formed of calcite-dolomite-pyrite. (VS). Fine syntectonic quartz-carbonate minerals bordering a post-tectonic carbonate porphyroblast. (D) Dolomite eye in a sericite-chloritic schist. Qz= Quartz, Chl= Chlorite, Ca = Calcite, Dol= Dolomite, Py = Pyrite.

4.1.2 Silicification

Silicification indeed appears as the process of impregnation of the surrounding rocks by silica (quartz, chalcedony, opal); it can be linked to magmatic and hydrothermal phenomena, to migrations of silica in certain metamorphic rocks and to precipitations of silica in sedimentary rocks (Foucault and Raoult, 2005[19]). At Agbahou, silicification includes at least two phases: one being a quartz-feldspar vein and the other being related to sulphides and carbonates. The first phase would correspond to vein alteration; these are phenomena of clogging of fractures by hydrothermal fluids highly enriched in gold and other metals (figure 5A). The second phase is manifested by the abundance of fine quartz minerals in basaltic rocks originally saturated with silica (figure 5B). This silicification seems contemporaneous with carbonation and fine pyritization, since most of the silicified domains contain veinlets of pyrite and calcite.

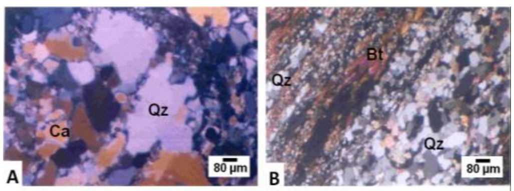

Fig. 5: Microscopic aspect of the silicification phenomenon. (A) Quartz in large crystals in a quartz-carbonate vein. (B) Quartz in fine crystals in a basalt rock. Qz= Quartz, Ca = Calcite, Bt = Biotite.

4.1.3 Chloritization

Chloritization as the formation of chlorite by transformation of certain clays during diagenesis and then epizonal metamorphism, by weathering or by retrograde metamorphism of ferromagnesian minerals (biotite, amphibole and pyroxene) [19]. The volcanic rocks with basaltic and andesitic composition of Agbaou, like the mafic metatufs, are generally formed of plagioclases, pyroxenes or amphiboles and/or clay minerals. These metamorphosed rocks in the form of shales are dominated by chlorite minerals. To the naked eye, just like in thin sections, the strong presence of chlorite gives the rock a predominantly greenish color (figure 6A and C). Chlorite minerals occur as patches, sometimes elongated along schistosities. These chlorite minerals generally come from the pseudomorphosis of amphiboles, biotite and pyroxene. The intensity of chloritization decreases as one approaches the zone of intense deformation. At the heart of the deformation zone, in the proximal zone of the quartz veins and in the roof or the wall of the mineralizations, we note a disappearance or a leaching of the chlorites in favor of the carbonates (figure 6B and D). This disappearance of chlorites is responsible for the discolored appearance of the alteration zone developed around the mineralized quartz veins. However, chlorite rims are sometimes observed, probably of hydrothermal origin.

4.1.4 Sericitization

Sericite minerals are generally common in volcanosedimentary and feldspar-rich sedimentary rocks. They are either alteration minerals or recrystallization minerals in metamorphic rocks [19]. Indeed, the highly sericite zone developed around the auriferous quartz veins or in the mineralized zones is of hydrothermal origin. Sericization accompanies the emplacement of gold mineralization. In most cases, sericitization is linked to a transformation by metamorphism or pseudomorphosis of the feldspars contained in the rocks. It is important in sediments and tuffs, and to a lesser degree in rhyolites. The metamorphosed feldspathic sandstones show quartz grains encased in a strongly sericite matrix (figure 10E).

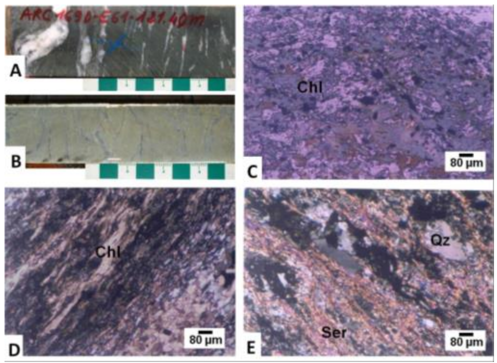

Fig.6: macroscopic and microscopic aspect of the phenomenon of chloritization and sericitization. (HAS). Greenish calc-chlorite schist. (B) Metabasalt strongly deformed, altered and discolored by the disappearance of chlorite. (C) Chlorite patches in a metabasalt. (D) Fibrous chlorite and carbonates in a strongly deformed and weathered metabasalt. (E) Sericitous shale of sedimentary origin. Sericite (Ser); Quartz (Qz); Chlorite (Chl).

4.1.5 Albitization

Albitization is an alteration that consists of the replacement of primary feldspars by secondary feldspars (albite). The albitization of potassium feldspars is done by simple replacement between potassium (K) and sodium (Na). In any case, the contribution of Na seems essential whether for the albitization of plagioclases or potassium feldspars. At Agbaou, albitization is very clear in the quartz veins. In mottled quartz veins or extension veins (called mottled quartz veins), the presence of feldspars associated with white quartz minerals is hardly perceptible to the naked eye (figure 7A). However, in shear veins which are generally formed of gray-colored quartz minerals (called smoky quartz veins), the existence of feldspars makes them gray-white (figure 7B). They appear as pegmatites formed of large crystals of quartz and feldspar. Under the microscope, coarse-grained quartz and plagioclase minerals are observed. In the extension veins, these phenocrysts are associated with a matrix of clay minerals, chlorite, carbonates and sulphides (figure 7C). Albitization has also been observed in mylonites, intensely deformed, silicified and carbonated rocks with recrystallization of plagioclase (albite) phenocrysts (figure 11D).

4.1.6 Metalliferous sulfidation and paragenesis

Sulphidation is the process of formation of sulphides. Sulphidation indeed began at Agbaou with early pyritization at the origin of fine pyrite minerals arranged along schistosity planes or quartz-calcite veinlets. At the Agbahou deposit, sulphidation is greater in intensely deformed zones. Sulphides are generally concentrated in mineralized zones characterized by the presence of numerous quartz-carbonate veins and/or veinlets. Quartz veins and their hosts with an abundance of sulphides hold the highest gold concentrations. However, areas devoid of quartz veins sometimes carry significant sulphide levels with probable gold grades. The sulphides occur either in the form of veinlets parallel to the schistosity, or in the form of automorphic phenocrysts with multiple inclusions of the gangue. Gold mineralization seems to be closely related to recent sulphides. Metalliferous paragenesis at Agbahou is mainly formed of pyrite, followed far behind by pyrrhotite, arsenopyrite, chalcopyrite, sphalerite and gold. Pyrite minerals occur in two aspects: early pyrite as fine grains aligned along the schistosity and late pyrite occurring as cubic aggregates or porphyroblasts (figure 8 A, B, C and D). Arsenopyrite also occurs as fine xenomorphic crystals, elongated rods following the schistosity and finally, diamond-shaped porphyroblasts (figure 8E). However, arsenopyrite crystals contain gangue and often sphalerite inclusions. Pyrrhotites are xenomorphic and stretched-grained sulphides, the most abundant after pyrites. They are however distinguished from pyrites by their magnetic property. The presence of pyrrhotites most often coincides with high gold grades. Chalcopyrite and sphalerite occur as isolated and rare very fine xenomorphic grains. They are inclusions in arsenopyrite and pyrite (figure 8 E). Gold is in fine or coarse grains in the form of nuggets. Gold anomalies appear in intensely altered sulphide rocks or fissures in silicates and carbonates. The phenomena of sulphidation are generally post to late metamorphic and at the origin of the remobilization of old pyrites, the setting up of porphyroblasts of pyrite, pyrrhotite and arsenopyrite which seem to be in close relation with the gold mineralization.

5 CHEMICAL CHARACTERIZATION OF HYDROTHERMAL ALTERATION

5.1 Hugues diagram

The Hugh diagram (figure 9 A) presents three (3) fields which are: Na-metasomatism, less altered rocks and K-metasomatism. The Agbaou samples fall into the field of Na-metasomatism and into the field of less altered rocks. This clearly expresses the fact that these are altered or certainly have a source related to hydrothermalism. Indeed, the samples of altered rocks (basalts and sediments mineralized or not) for the most part and certain metagabbros and metadiorites fall into the field of Na-metasomatism. The same is true of rhyolites (veins) which come from syntectonic cracks clogged during the rise of hydrothermal fluids. All the samples that fall into the Na-metasomatism field are mostly very rich in sodium elements (Na) with high ignition losses except for rhyolites which have a low ignition loss (<2). On the other hand, the samples that fall into the field of igneous rocks are divided into two groups. The samples located at the bottom, that is to say the basalts and mineralized basalts, are neither sodium nor potassium. This explains why there was a leaching phenomenon in these samples. While up-lying samples such as mineralized basalts and basalts, mineralized tuffs, gabbros and dacites might contain a fair proportion of sodium and potassium. It is strong to note that the alteration decreases as the samples evolve upwards. Finally, some rock samples (tuffs and sediments) taken from the non-mineralized zone fall into the K-metasomatism field; this implies that these rock samples are very rich in potassium element or are affected by potassium weathering. However, we note in Agbahou a predominance of Na-metasomatic alteration.

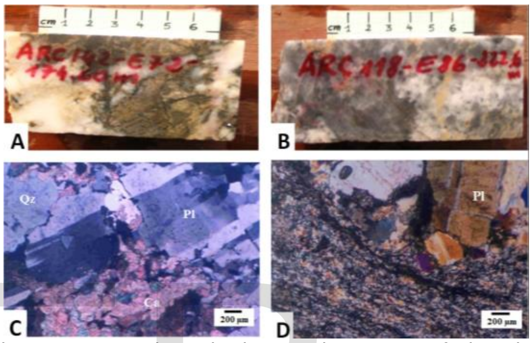

Fig.7: Macroscopic and microscopic aspects of alteration minerals. (A) Quartz vein mottled by the presence of tectonoclasts. (B) Greyish quartz vein mottled by the presence of plagioclase. (C) Phenocrysts of quartz and plagioclase associated with silicified, chloritized and carbonated tectonoclasts. (D) Plagioclase phenocrysts in a strongly deformed, silicified and carbonated matrix.

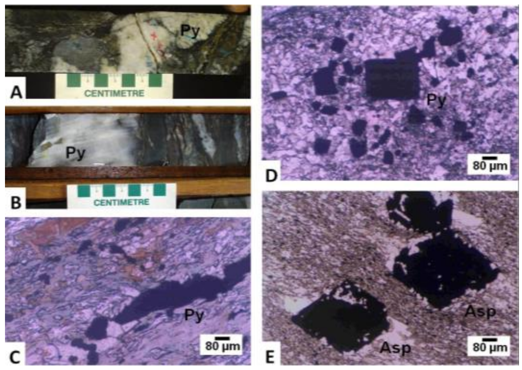

Fig. 8: Microscopic aspect of the sulfidation phenomenon. (A) Mass of sulphides in a quartz vein. (B) Pyrite aggregates in a quartz-carbonate vein. (VS). Elongated pyrite minerals in schistosity planes. (D) Fine xenomorphic crystals and automorphic phenocryst of pyrite. (E) Automorphic arsenopyrite phenocrysts with gangue inclusions. Py: Pyrite; Asp: Arsenopyrite; Qz: Quartz; Ca: Calcite

5.2 Diagram of the alteration of Hashimoto and Large et al (2021)

(figure 9 B) indicates that the rock samples all underwent hydrothermal alteration except for a few samples of basalt, sediment, metadacite and metarhyolite which are diagenetic. Altered rocks (mineralized or non-mineralized basalts, sediments, mineralized tuffs, metadiorite, as well as metagabbro) mainly fall into the domain of hydrothermal alteration. However, among these samples affected by hydrothermal alteration, four (4) of the basalt type, mineralized or not, are strongly altered. These samples generally show chlorite-carbonate, carbonate-muscovite (sericite), chlorite-pyrite-muscovite alteration; which means that the Agbahou gold deposit is affected by hydrothermal alteration phenomene such as carbonation, chloritization, sericitization and pyritization. However, for rocks that fall exactly within the diagenetic-trend field are on or near the hydrothermal-diagenetic boundary; which explains why these are moderately altered. We also note the presence of mineralized sediments that have undergone more or less slight alteration. The metarhyolites and metadacites, which on the other hand are not altered, evolve towards the albite pole; which implies that these rocks are rich in albite. The diagram shows a low intensity of the alteration indices (IA = 20-50) and a high intensity of the chlorite-carbonate-pyrite indices (ICCP = 55-95) of the samples located towards the Dolomite-Ankerite pole; which means that chloritization, sericitization and albitization are to a lesser degree, on the other hand carbonation and pyritization are the most important phenomene.

5.3 Diagram expressing phenomene of alteration

The rock samples analyzed from Agbaou include substantial variations in the concentrations of Na, Ca, Mg and Fe. As the intensity increases, the weathering is coupled with a gradual increase in (Na_2O + CaO) and (MgO + Fe_2O_3) (Fig. 9 D) resulting in intensely weathered and chemically modified rocks. The metasediments having values by weight (%) of (Na_2O + CaO) = 7 and of (MgO + Fe_2O_3) = 7.5, these values respectively increase to 13.5 and 11.5 in the ore sediments. Since the metabasalts have values by weight (%) of (Na_2O + CaO) = 9 and of (MgO + Fe_2O_3) = 11.5, these values respectively increase to plus 13 and 16.5 in the ore basalts. However, it appears that altered but non-mineralized basalts show high values of (Na_2O + CaO) > 15, indicating alteration phenomena by albitization and carbonation. Pyrite and chlorite are formed by ferromagnesian elements (MgO and Fe2O3) and albite and carbonates by alkaline elements (Na2O and CaO). Given the fact that we note a gradual increase in these parameters and that most of the samples are more concentrated in the center with a positive correlation, we can say that these different minerals (chlorite, albite, carbonates and pyrite) are present in the rocks of Agbahou. The intensity of these parameters being low in sediments, dacites and rhyolites, the samples corresponding to these rocks fall within the field of sericitization with destruction of plagioclase. The complete examination of this diagram therefore suggests that pyritization, chloritization, carbonation, albitization and sericitization are the hydrothermal alteration phenomena encountered at Agbaou.

5.4 Diagram of variation of Na%-K%

The Na-K variation diagram (figure 9 C) shows five trends: Na-metasomatism, K-metasomatism, silicification, desilicification and argilization. The rock samples from the Agbahou gold deposit analyzed fall into the silicification field with Na-metasomatism tendency, except the sediments which fall into the argillation field. The Na values of these rocks are generally between 1.5 and 7.5% and the K values are less than 2% except for the sediment which contains 0.8 and 2.5% respectively. The very low contents by weight (%) of Na in certain rocks (mineralized basalts or not) reflect an enrichment in silica (SiO_2) in these rocks. Since silicification is characterized by the presence of quartz, this means that silicification is an important phenomenon in Agbahou. On the other hand, in certain rocks (basalts mineralized or not, tuffs mineralized or not, mineralized sediments, metadacites, metadiorites and rhyolites), the values of Na increase which corresponds to a depletion of silica, hence the phenomenon of desilicification of the rocks.

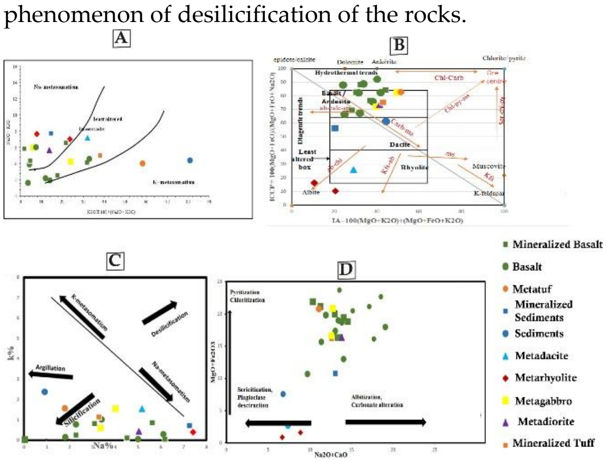

Fig.9: (A) **:** The diagram of Hugues (1972) for the identification of metasomatic hydrothermal alteration processes of Agbahou rocks; (B): Alteration plots showing all analyzed rock samples from Agbaou. IA/ICCP mailbox (A) from Large et al. (2001). Abbreviations: ab = albite; calc = calcite; carb = carbonate; ch1 = chlorite; ep = epidote; Kfs = potassium feldspar; ms=muscovite; py = pyrite; (C): Na%-K% variation diagram of Agbahou rocks showing types of Hydrothermal alterations from

Cuney et al. (1989); (D): Binary diagram from Maitre et al. (1989) showing the weathering phenomena of the Agbaou rocks.

6 DISCUSSION

6.1 Petrographic characterization of alteration

The lithologies of the Agbahou gold deposit are affected by regional greenschist facies metamorphism. The rocks of this region are affected by greenschist metamorphism [20]. These metamorphic conditions are also identical to those of several West African gold deposits [4]; [21-23]; except for the Konongo gold deposit (in Ghana) which shows a higher metamorphic grade (biotite and garnet [24]. However, highlighted in addition to the green shale facies, an amphibolite facies in the Tiébélé sulphide deposit [25]; which would make it similar to the Agbahou deposit. The Agbaou formations are affected by intense pervasive and vein alteration, thus testifying to the intensity of hydrothermal alteration in the area. Indeed, sericite, calcite, quartz, chlorite and sulphide alterations are observed. These weathering phenomena are similar to those described in the Bonikro gold deposit [22], in the Bobosso prospect [21].

6.2 Chemical characterization of alteration

According to the diagram of Hughes, the samples altered and rich in Sodium (Na) shows that most of the samples taken in the mineralized zones are very rich in sodium element. However, the samples that fall into the field of igneous rocks, which lie downwards, are neither sodium nor potassium; This explains why there was leaching in these samples. On the other hand, the samples that fall into the field of K-metasomatism are very rich in potassium element or are affected by potassium alteration. The geochemical data showed that the samples taken in the study area are affected by hydrothermal alteration which is manifested by the phenomene of silicification, pyritization, chloritization, sericitization and carbonation. This is analogous to the petrographic data as well as to the Bobosso prospect [21], to the Dougbafla deposit [22] except for the sulfidation and albitization found at Agbaou. According to the diagram of variation of Na%-K%, the samples which fall in the silicification field whose content in weight (%) of Na is weak indicates an enrichment in silica (SiO_2) in these rocks. Since silicification is characterized by quartz, this would mean that silicification is an important phenomenon encountered in Agbaou; This is therefore consistent with the petrographic study. However, the samples whose content by weight (%) of Na increases correspond to a depletion of the silica. On the Hacker diagram, the increase in Fe_2O_3 expresses the strong presence of chlorite in these samples. Therefore, it corresponds to the phenomenon of chloritisattion. Given the increase in CaO content in some samples; this explains why these samples contain more carbonates. Hence the presence of carbonation in these samples. It is important to note that the samples rich in K_2O reflect the presence of sericite in samples and the samples rich in Na_2O show the presence of albite. Consequently, these elements testify respectively to the phenomena of sericitization and albitization. This is consistent with the Agarf, Irbiben and Ifarar deposit [26 - 27]. The geochemical data also showed that certain mineralized samples (metabasalts and metatufs) are affected by hydrothermal alteration and are concentrated towards the capital minerals of the alteration, which are carbonates (Fe-Mg) (dolomite, ankerites), on the other hand others are found in the weak hydrothermal alteration field; This is similar to mineralized samples from the Bobosso prospect [21].

6.3 Characterization of gold mineralization

During this study, it appears that in Agbaou, the processes that affected the formations and the events at the origin of the establishment of the mineralization are accompanied by pervasive and hydrothermal alterations. The gold mineralization is partly grouped around fissural fillings made up of quartz veins. Significant gold grades are observed in pervasive alteration zones (sericitization, carbonation, sulfidation, chloritization, silicification and albitization) of the host rock as defined in the Bobosso gold deposit [21], Bonikro [22], gold deposits of Angarf, Irbiben and Ifarar (tagragra buttonhole from Akka, Anti-Atlas, Morocco) [27]. Carbonation, silicification and sulfidation are the most important alteration phenomene of the Agbahou deposit and to a lesser degree, chloritization, sericitization and albitization. On the other hand, in the deposit of Agarf, Irbiben and Ifarar, silicification and calcitization are the most important phenomene in the walls.

7 CONCLUSION

The Agbahou deposit located north of the city of Divo belongs to the Proterozoic domain, more precisely to the Oumé-Fettêkro furrow. The work, centered on a petrographic and geochemical study, made it possible to indicate that the Agbahou deposit has gold mineralization hosted in Birimian formations globally metamorphosed in the green schist facies such as mafic volcanics (metabasalts), pyroclastites and the sediments. Metabasalts are the dominant lithology of the Agbahou deposit. They are the carriers par excellence of gold mineralization. The processes that affected these formations and the events at the origin of the establishment of the mineralization by the formation of a system of quartz veins, are accompanied by pervasive and hydrothermal alterations which are silicification, carbonation, chloritization, sericitization, sulfidation and albitization. Silicification is characterized by the process of impregnation of the surrounding rocks by silica, carbonation is due to the process of impregnation of the surrounding rocks by carbonates (calcite, dolomite and ankerite), chloritization comes from the alteration of ferromagnesian minerals (biotite, pyroxene, amphibole), sericitization which comes from the alteration of biotite and plagioclases, sulfidation is formed by sulphides (pyrite, arsenopyrite, chalcopyrite, etc.) and albitization which comes from the alteration of feldspars. At Agbahou, two phases of silicification can be distinguished: one being a quartz-feldspar vein and the other being related to sulphides and carbonates. When moving away from the mineralized zones, an increase in chlorite and feldspar levels is observed, associated with a decrease in the proportions of quartz-carbonates-sericite-sulphides. Carbonation, silicification and sulfidation are the most important alteration phenomena of the Agbahou deposit and to a lesser degree, chloritization, sericitization and albitization. It is important to note that the chemical characterization of the hydrothermal alteration was done through the following diagrams: the diagram of Hugues, the diagram of Hashimoto and large et al (2001), the binary diagram of Maitre et al (1989), the diagram of the variation of Na%-K% of cuney et al (1989). There are two types of mineralization namely: a vein type mineralization but also a disseminated type mineralization; However the mineralization is carried by a quartz vein and veinlet system.

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