Lithostratigraphy of the Bonikro gold deposit; contribution to the setting of the Birimian units in the Fettèkro greenstone belt, Côte d'Ivoire.

Zié Ouattara[1, 2*], Yacouba Coulibaly[2], Marie-Christine Boiron[3]

[1]*Département de Géologie et matériaux, UFR des Sciences Géologiques et Minières, Université de Man, BP V20 Man, Côte d'Ivoire.*

[2]*Laboratoire de Géologie du Socle et de Métallogénie, UFR STRM, Université Félix HOUPHOUËT-BOIGNY, 22 BP 582 Abidjan 22, Côte d'Ivoire.*

[3]*Laboratoire de Géoressources, Université de Lorraine, CNRS, BP236, 54506 Vandœuvre-lès-Nancy, France.*

** Corresponding author: ziegbana@hotmail.fr*

Abstract

The main objective of this paper is to set the lithostratigraphy column of the southern Fettèkro greenstone belt in Côte d'Ivoire based on the Bonikro gold deposit investigations in order to put in light Birimian units chronology and understand the relation between the lithostratigraphy and the gold mineralization.

Three types of rocks groups are recognized. They are mafic, felsic and sediments. Each of these groups is made of different lithological units. The felsic group in the central part, is ore-bearing through the granodiorite and aplo-pegmatite dykes. The mafic has the basalt as the main lithology when the sediments are composed of siltstone, black shale and pyroclastite (volcano-sedimentary).

Among these lithological units, two are abundant: first, the basaltic complex occupying the east of the deposit and second the volcano-sedimentary rocks associated with sediments in the western side. These two units present an interface which is occupied in the south by the north-south to north-east trending Bonikro shear zone (BSZ) whereas in the centre and the NE, the interface is occupied by the BSZ and the granodiorite.

In consequence, the lithostratigraphic column realized in the south reveals that the basaltic unit and the pyroclastic unit were in contact before the setting of the BSZ. The Bonikro western side is where the petrographic diversity is well expressed. This side is likely where the lithological correlation is consistent and worthy. It appears that there is a contemporaneousness between the basaltic and the pyroclastic and sedimentary units.

Keywords: Lithostratigraphy, Gold, Birimian, Fettèkro, Bonikro, Côte d'Ivoire, West Africa.

Résumé

L'objectif principal de ce travail est d'établir la colonne lithostratigraphique du sud de la ceinture des roches vertes de Fettèkro en Côte d'Ivoire en se basant sur les investigations du gisement d'or de Bonikro. Cela permet ainsi de mettre en exergue la chronologie des unités birimiennes et d'expliciter la relation entre la lithostratigraphie et la minéralisation aurifère.

Trois groupes de roches composent ce gisement : mafique, felsique et sédimentaire. Chacun des groupes comprend différentes unités lithologiques. Le groupe de roches felsiques, occupant la partie centrale du gisement, encaisse la minéralisation à travers la granodiorite et les dykes aplo-pegmatitiques. Le groupe mafique a le basalte comme la principale lithologie tandis que les sédiments se composent de pélite, d'argilite et de pyroclastites (dépôts volcano-sédimentaires).

Parmi ces lithologies du gisement, deux sont abondantes: en premier, le complexe de volcanite mafique (basalte) occupant l'Est et en second, les roches volcano-sédimentaires et sédimentaires occupant l'Ouest du gisement.

Ces deux unités présentent une interface qui est occupée dans le Sud par le couloir de cisaillement de Bonikro (BSZ) d'allure nord-sud à nord-est alors que dans le centre et le nord, cette interface est occupée par la BSZ et la granodiorite.

En conséquence, la colonne lithostratigraphique réalisée dans le Sud révèle que les unités basaltiques et volcano-sédimentaires étaient en contact avant la mise en place du BSZ. Dans la zone Ouest de Bonikro où la diversité pétrographique est mieux exprimée, la corrélation lithostratigraphique a mis en évidence une contemporanéité entre les unités basaltiques et volcano-sédimentaire.

Mots clés : Lithostratigraphie, or, Birimien, Fettèkro, Bonikro, Côte d'Ivoire, Afrique de l'Ouest.

Introduction

The Fettèkro greenstone belt is one of the most productive gold belt in Côte d'Ivoire. Numerous gold occurences have been recorded before and in its southern part, since 2008, some of the gold projects have given right to at least three gold deposits: Bonikro (15.9 kt at 1.8g/t), Agbahou and Hiré (Fig. 1; Olson, 1989; Gnanzou, 2006; Houssou *et al*., 2011, 2017; Houssou, 2013; Ouattara, 2015; Ouattara *et al*., 2015).

The interests in the Fettèkro greenstone belt started some decades ago with the rocks exposed in the Toumodi volcanic area (Yacé, 1976, 1982, 1984; Mortimer, 1990) and in the northern part (Lemoine, 1983). The studies from the south to the north of the belt were able to define an individual Eburnean volcanism which has its own characters (Yacé, 1982) and to set its lithostratigraphy (Yacé, 1976, 1982; Lemoine, 1983; Mortimer, 1990, 1992).

In term of correlation of these geological understandings, the southern Fettèkro was for sometimes automatically linked to the Toumodi area (central part of the belt). That was a consequence of the scarcity of the outcrops in the southern Fettèkro belt. This part is truly affected by a strong lateritisation which intensity cannot be seen elsewhere in this belt (Yacé, 1982, Ouattara *et al*., 2015), therefore the correlation and the geological studies were limited.

In this context, the discovery and then, the exploitation of gold in this southern part gave the opportunity to be more focused on the area (Chermette, 1935; Archambault, 1935; Gnanzou, 2006). That is the case of the Bonikro gold deposit which become as a unique opportunity to define the southern Fettèkro lithologies and to better constraint the Birimian units.

Therefore, this work main objective is the setting of the lithostratigraphy in the southern Fettèkro belt. The specific objectives are about to (i) identify the Birimian units, (ii) correlate these units, and (iii) make the relation between the lithostratigraphy and the gold mineralization.

1. Regional geological overview

The Fettèkro greenstone belt is part of the Proterozoic basement in the Baoulé-Mossi domain of the West African Craton (WAC) formed between 2.2 and 1.9 Ga (Feybesse *et al*., 2006). This domain covers almost all the Côte d'Ivoire and is limited towards the West by the north-south trending Sassandra-Cavally fault.

The western Côte d'Ivoire belonging to the Archaen domain or Kenema-Man is structured by two orogenies: the Leonian (3500 – 2900 Ma) and the Liberian (2900 – 2500 Ma).

The Bonikro gold deposit, 231 km in NW Abidjan, belongs to the Hiré town and formed with the differents gold prospects and the Hiré gold deposit the Oumé – Hiré gold district. These two deposits are really closed to the Agbahou gold deposit (about 15 to 25 km).

The Fettèkro greenstone belt to which these deposits belong is one of the seventeen Birimian volcano-sedimentary belts in Côte d'Ivoire. These belts, mostly striking NE-SW to NNE-SSW, are made of birimian formations commonly associated with the granitoids.

The Fettèkro greenstone belt, a 300 km long and 40 to 5km width extends from south of Dabakala (north of the belt) to Divo (south of the belt). Around the parallel 7°, it is divided in two parts. The Toumodi area represents the central part of this belt (Yacé, 2002).

The geology of this greenstone belt is made of schist, sandstone, quartzite and conglomerates aligned NNE and affected by different injections of métabasites and métaacidites. (Yacé, 1982; Lemoine, 1988; Mortimer, 1990; Leake, 1992; Daouda, 1998; Houssou *et al*., 2011; Houssou, 2013, Ouattara, 2015; Ouattara *et al*., 2015; Houssou *et al*., 2017). The discordant granodiorite of Toumodi outcrops as one of the most extended granitoïd in Côte d'Ivoire: 60 km long and 10 to 20 km width. The area of Toumodi shows the most atypical and spectacular Birimian rocks in Côte d'Ivoire with the presence of the ingimbrites, the lapillis and pillow lavas (Yacé, 2002, Coulibaly *et al*., 2017).

Because of the scarcity of the outcrops in the south Fettèkro (Divo area) most of the informations generated came from the characterization of the auriferous gold veins of Hiré and later by the mineral exploration and exploitation. According to Sonnendrucker (1967) the Birimian of Hiré is composed of sedimentary and volcano-sedimentary formations (silicic, intermediate and mafic metavolcanites, arkose, arkosic schist, conglomerates and associated sediments. These formations are metamorphosed in the greenschist metamorphic facies and intruded by massive granodiorites. On their way to constraint the auriferous quartz of Hiré, Archambault (1935) and Chermette (1935) noted that the Birimian formations are intensively folded and locally, the metamorphism around the massifs reaches almost the amphibolite facies.

Gnanzou (2006) made the same observation in Hiré and presented the characters of these auriferous quartz veins. Houssou (2011) investigated the Agbahou gold deposit and put in light that it is made of two major lithological units i.e an easterly mafic to intermediate unit and a westerly volcano-sedimentary and associated sediments unit. These units are intercalated by the mafic sills and cut by the silicic dykes.

The Bonikro deposit presents a similar geology as to what has been settled in the Agbahou deposit. Two main units: a mafic volcanite unit in the eastern Bonikro and a volcano-sediments and associated sediments units in the western part of Bonikro. These units are metamorphosed into the greenschist facies and are intruded by the granodiorite and cut by the aplo-pegmatite dykes. These units are separated by the Bonikro shear zone (BSZ) (Ouattara *et al*., 2015).

The felsic group, striking NE, is dominated by the K-feldspar porphyritic granodiorite but locally we also have the dacite, rhyodacite and the aplo-pegmatite dykes. The silicic dykes namely dacite and rhyolite cut the Birimian formations. The mafic rocks are made of porphyritic basalt and the Basalt sensus stricto which show sometimes the amygdular textures. The Bonikro sediments are represented by the siltstone, black shales (argilites) and pyroclastites.

The greenstone belts are made of Birimian volcanic and of sedimentary rocks which are commonly associated with granitoïds.

The Baoulé-Mossi domain has been in the centre of scientific debates which helped to its better understanding even if some of the debates are still on. Firstly, in term of orogeny, some authors (Tagini, 1971; Yacé, 1993) evoke the Eburnean megacycle (2250 – 1800 Ma) when others (Lemoine, 1988; Boher, 1991) recognized the influence of two orogenies i.e the Burkinian (2500-2150 Ma) and the Eburnean s.s (2250 – 1800 Ma). Secondly, the Birimian itself is still a subject of debate as evoked above.

After its introduction by Kitson (1928) when he was describing rocks from the valley of the river Birim in Ghana, the term "Birimian" and especially the relation between its stratigraphy and units have been discussed for decade (Mineral Commission, 2002). For some authors, the volcanic formations are younger than the sedimentary sequences (Junner, 1935, 1940; Milési *et al*., 1989, 1991). Historically, this stratigraphy is admitted by the geologists in Ghana where in the birim valley these volcanic rocks were firstly described. An inverse stratigraphy has been proposed by Arnould (1961) and Tagini (1971). From others, there is a contemporaneaousness between these two units (Leube *et al*., (1990); Hirdes *et al*., (1996). This is mostly the case of this belt.

The northern Fettèkro was described through the Tinbéguélé series by Lemoine (1988) and consisting on a sequence of basaltic lavas, acidic lavas and pyroclastics, basaltic breccias, and acid epiclastic sediments. By the central Fettèkro belt, Mortimer (1990) argued that in the Toumodi volcanic group rocks were volcanogenic and mostly volcaniclastic rather than a simple division between lower and upper Birimian.

2. Materials and methods

Our investigations are based on fieldwork and laboratories analysis. The fieldwork consisted to cores analysis from the deposits' coresheds, also the description of the lithologies within the Bonikro open pit benches during the mapping. The laboratories analysis helped to the data interpretation.

In the objectives to take into account all of the lithologies, the older cores, particularly those drilled during the exploration campaigns were logged at the Yamoussoukro's coreshed (Fig. 1). The ressources cores were logged at the Bonikro and Oumé coresheds.

These loggings aim to describe the lithologies, to select appropriate samples for both lithologies and mineralizations finally to prepare the thin sections and to observe them at the microscopic scales.

Then the deposit benches have been mapped. That have helped to determine more relations between the lithologies and to compare with the observations through the bore holes.

These two levels of observations become essential to define benches, lines and to select the key holes that can be of interest for the synthetisation of the lithology evolutions.

At the digitalization step, all of the data were put on map and also through Micromine software. The lithological correlations and interpretation were redrawn in the northern, central, eastern and western part of the pit.

Almost 55 thin sections have been made and observed firstly on a polarizing microscope at the Laboratoire de Géologie du Socle et de Métallogénie (LGSM), University Félix HOUPHOUËT-BOIGNY, Côte d'Ivoire and also observed at its Laboratory of Georessources in University of Lorraine, Nancy, France under a polarizing microscope associated with an axiovision 4.7 for picture capture.

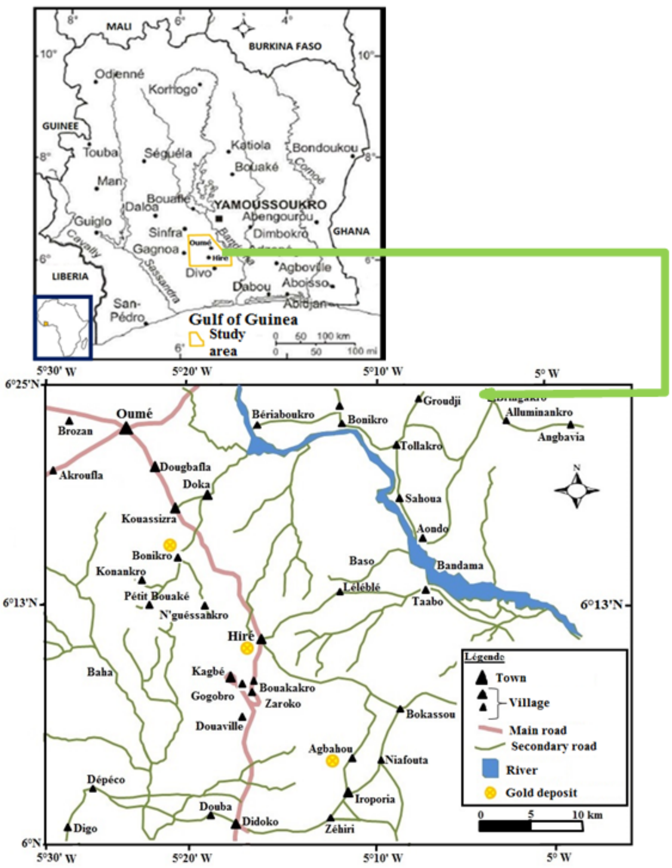

Figure 1: Location of the Bonikro gold deposit and neighbors deposits on the Oumé –Hiré disctrict. (Ouattara, 2015)

3. Results

3.1. Lithological description

The Bonikro gold deposit is mainly hosted by granitoids in the southern Fettèkro greenstone belt in the Oumé-Hiré gold district (Fig. 1&2). The petrography of the deposit has been evoked by Ouattara *et al*. (2015). The principal granitoid, a granodiorite, has intruded two main lithologies: (i) the mafic volcanic unit and (ii) the volcano-sedimentary unit.

All of these lithologies have undergone a regional greenschist facies metamorphism and are used to set the deposit lithostratigraphic columns

3.1.1. The mafic volcanic unit:

This unit is located in the western side of the deposit (Fig.3). From the centre of the deposit to the west, the lithologies present different facies i.e sheared basalt, porphyritic basalt and amygdular basalt. In the centre, the basalt is sheared due to the setting of the granodiorite and also the BSZ. This is explaining why a sequence of the sheared basalt is found in the west in the interface of the granodiorite and the volcano-sediments unit. In this proximal zone, the basalt appears light green and affected by veins of calcite, ankerite and sulphides. The intermediate zone, when getting out of the intrusion, the basalt become more and more greenish porphyritic but the effects of the alteration remain important. The basaltic lava and breccia are in the distal to unaltered rock zones and are found deeper by core drilling and also under the limit of the pit.

In these areas, the basalt becomes more amygdular with the calcite occupying the cavities and also present the hyaloclastites.

3.1.2. The volcano-sedimentary unit

The lithologies of this unit are consisting of sediments and volcano-sediments and all are found in the western Bonikro part (Fig. 3). In the proximal zone, the siltstone made of fine grained, grey light to grey dark, are composed of quartz, muscovite, chlorite and pyrite. The siltstone are associated at some extend with the conglomerate.

The black shales are in the intermediate zone and show the graphite in its fine folded bedding. The pyroclastites are found in the deposit distal zone. The felsic rocks groups are also present.

3.2. Lithostratigraphy

The lithology distribution is progressive from the surface to the depth of the Bonikro gold deposit: the beddings show a weak to moderate dip towards the north-east, the east and the south-east of the pit. The granodiorite, the host of the gold mineralization, appears as sub-vertical on the surface and dips moderately towards the north-west under the surface. Therefore, at a same ground level, the granodiorite appears and extends globally from the south-west to the north –east while the east is occupied by the volcanic mafic sequences (Fig. 3). In the aims of understanding the Bonikro lithological successions, this work will be focused on the description of the north, the west and the south of the Bonikro pit where the relation between the lithologies is well defined.

The east of the Bonikro pit is completely dominated by the basalts (Fig. 3A and 3D). Because of this monolithology, this work did not find suitable to consider the zone as a focused area for the purpose of the lithostratigraphy.

Figure 2: Geological overview of the Oumé-Hiré gold district. (Modified after Olson, 1989).

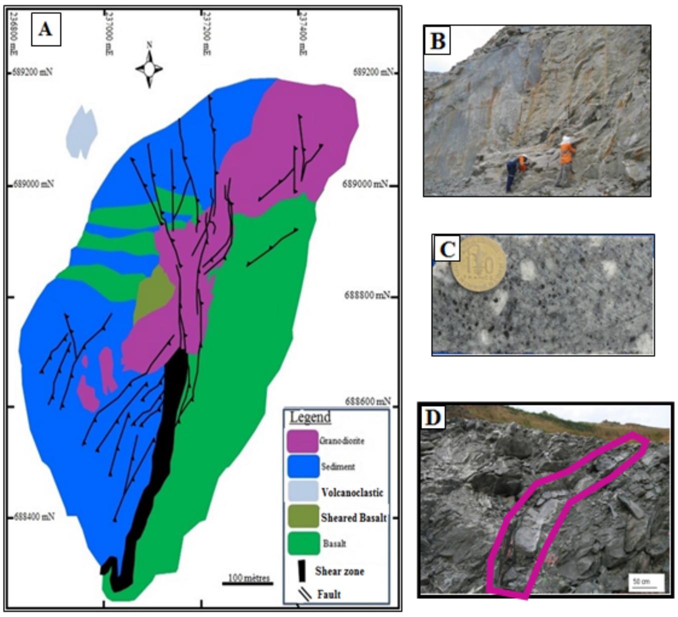

Figure 3: Geological map of the Bonikro gold deposit pit (A) and views of its northern granodiorite (A and B) and its eastern basalt (C).
B: Northern Bonikro wall showing the granodiorite.
C: Macroscopic view of a granodiorite core sample.
D: Eastern Bonikro showing the abundance of the sheared basalt around the granodiorite (outlined).

3.2.1. Northern Bonikro pit

The observation of the pit benches in the north of the Bonikro gold deposit puts in light the granodiorite intercalated between the volcano-sedimentary and the basaltic formations (Fig. 3). When looking in the north of the deposit, the volcano-sediments appear in the west when the basalts are occupying the east. The granodiorite appears crosscutting both volcano-sediments and basalts and also the faults even if some faults on the granodiorite borders seem to control it (Fig. 3&4).

In the north-east, the granodiorite is associated with the basalts which are autobrechifiated and presents some hyaloclastites aspects.

The north-west presents the granodiorite with the siltstone and volcano-sediments.

The northern Bonikro is deeply dominated by the basalt. The granodiorite appears from the depths 100 to 300 meters.

The stratigraphic column in the north shows that the granodiorite has intruded the metamorphic volcano-sediments and basalts (Fig. 4). The shape of the granodiorite shows that the lithology comes from the East (beneath the basaltic unit) then has been re-oriented probably by the shear zone contact between basaltic and sedimentary units. This column was not able to definitely set which one of the intruded formations is the oldest.

3.2.2. Western Bonikro pit

It is the zone where the Bonikro lithological diversity is well appreciated. This western part is dominated by the sedimentary formations with their different components and the volcanoclastites. This part also contains the felsic and volcanic rocks. The north-west presents the sediments and felsic rocks on surface and are not containing economic gold. In contrast, the south-west present the aplo-pegmatite dykes appearing in the top of the granodiorite. This south-west shows also that the pluton is affected by the pink alteration zones. The black shales and pyroclastites observed in the west and the north-west give right to the events that occur in these parts: an oxydo-reduction in the west and the explosive volcanism in the zone.

In the west, we notice on surface a sequence of sedimentary rocks with intervals of metabasalts. Diamond drilling was able to touch the granodiorite from 350m to 650m depth, the basalt is dominating beneath the granodiorite.

The lithological diversity in the west help to synthetize the lithostratigraphy. Two couples of drilling holes have been selected for this purpose. These two couples have been drilled "in scissor" so their strikes are opposites. The first couple (BD230 and BD232) drilled towards west intercepted the felsic when 100 m from there, the second couple (D236B and D237B) was drilled towards the east and did not intercept the felsic (Fig. 5 & 6).

The correlations between the drilling holes BD230 and BD232 put in light three horizons from the surface to the depth (Fig. 5):

- the first horizon (I) is formed by the sequences of sedimentary rocks and volcano-sediments with intervals of moderate schistose basalts. This horizon goes from the depth 41 to 65m in the hole BD230 where the basalt is affected by a moderate foliation. In the hole BD232, this horizon starts from 41 to end at 98m depth.

We observe siltstone sequences with some beddings of conglomeratic volcano-sediments and basalts. The way these three lithologies are tangled is a proof that they are contemporaneous. Also, it is evident that these three lithologies have been settled before the late phase of thrusting that has affected them;

- the second horizon (II) is marked by the porphyritic basalts. In the hole BD230 this horizon goes from 65 to 239,85m depth. This zone contains some intervals of siltstone, volcano-sediments but is still dominated by the basalts with amphibole phenocryst. This amphibole phenocryst are disappearing and as a result, the basalt is more and more schistose. This is observed in the contacts zones with sediments or with the dykes (at -193.49 m, between -200 and -200.32m and between -200.68 and -201 m). When approaching the felsic, we notice the pile of sulphides and a brittle shear zone. In the BD232, this zone of porphyritic basalt is deeper and goes from 98 to 299.33 m.
- the third horizon (III) is almost composed of the granodiorite even if the basalt appears at his beneath. The hole BD230 presents this horizon in the intervals from 239m to the end of the hole (-612.90m) with the contact between the felsic and mafic at -582.9 m. The granodiorite is straightaway affected by the sericitic and albitic alterations until the first mylonitic zone at -300m. The foliation is remarkable in this mylonitic zone as well as the presence of molybdenite. The sheeted veins zone succeeds to the mylonitic zone and ends at -381m marked by another mylonitic zone. Thus, the sericitization is strong and is associated with the silicification. The third mylonitic zone appears at -467m and shows firstly the sheeted veins then succeeded by the pink alteration.

In the hole BD232, this third horizon covers the intervals going from -300m to the end of the hole at (-620.55 m). The contact between the felsic and the mafic is discordant at -602.8 m. Here also, the pluton is affected by the alternations of sericitized zones, sheeted veins, silicification and the pink alteration. Nevertheless, these contacts are not sheared (brittle, mylonite) as was the case in the hole BD230. Finally, the thickness of the intrusion become higher when we move towards BD230 so towards the east. In consequence, the extension of the intrusion may be limited in the west of the Bonikro pit.

The lithological correlation between the drilling D236B and D237B discriminated two horizons as described below (Fig. 6):

- The first horizon has volcano-sediments and dacite in alternation with the basalt. It goes from the depth of 200m in both drilling holes D236B and D237B.
- The second horizon is marked by the alternations of volcano-sediments and basalt. In comparison with the first horizon, the dacite disappears almost totally while the volcano-sediments become more abundant or their thickness become higher. In the hole D236B, this alternation ends rapidly because from -394m, the basalt remains the unique lithology though at some parts, it is cut by the dykes. Concerning the D237B, the alternation between the basalt and the volcano-sediments is noted. At the depth 282m, the basalt is affected by the autobrechification and the contact with the sediments is at -313.43m. This is worthy and shows that when we move to the north (towards D237B), the basalt become deeper while the thickness of sediments remains important.

Definitely, the lithological correlation indicates that in the west of the Bonikro gold deposit, the lithostratigraphy is made as: basalt / volcano-sediments / granodiorite. Thus, it is likely the chronological setting of these three main lithologies. The basalt and volcano-sediments are alternating on subsurface and have undergone a greenschist facies metamorphism before the intrusion of the granodiorite. The hole BD232 presented the volcano-sediments that probably may be contemporaneous with the weakly schistose basalts and those volcano-sediments that are discordant on the porphyritic basalt.

3.2.3. Southern Bonikro pit

The south of the Bonikro gold deposit helps to understand the relation between the sediments and the basalts before the intrusion of the granodiorite. The south indeed is marked on the surface by the distinct contact between the easterly volcanic units and the westerly sediments. The Bonikro shear zone (BSZ) is the contact between these two lithologies but that does not set which one is supposed to be the oldest.

This south is deeply dominated by the basalts even if at 400 m (or 100 to 300m) the felsic appears and once again, the basalts continues.

In the heart of the Bonikro pit, the interface between the sediments and the basalts is occupied by the granodiorite and the BSZ. A part of the sheared basalt is in the west due to the brittle component of the BSZ that has affected the rocks.

3.3. The Bonikro gold mineralization

The gold mineralization in the Bonikro deposit is primarily hosted within the granodiorite intrusion (Bout, 2009). Gold is therefore in the interface between the two birimian units consistent with the lithostratigraphy and specially the appearance of the granodiorite. It is why, in the south, the east and the west, the ore is rare or shows an extension as low grade. In the north and the central part, where the granodiorite is larger and associated with the BSZ, the highest grade is recovered (Bout, 2009).

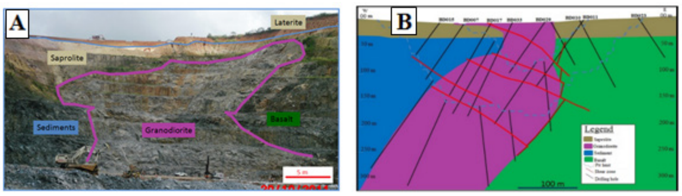

Figure 4: Lithostratigraphy columns of the northern Bonikro gold deposit pit (A -B).

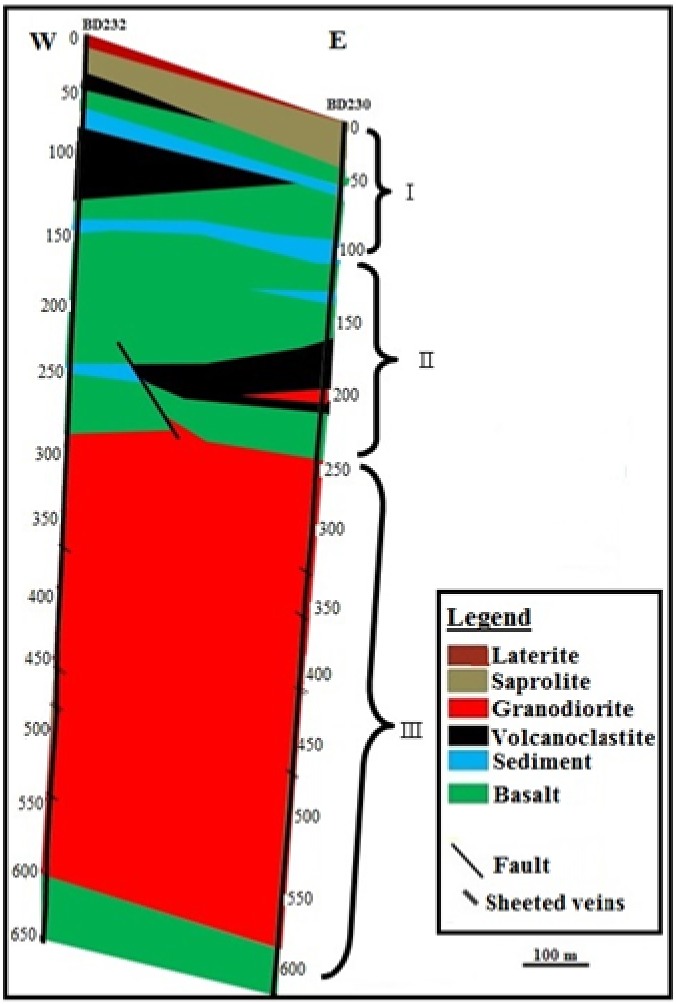

Figure 5: Lithostratigraphy column of the western Bonikro pit through the drill holes BD230 and BD232.

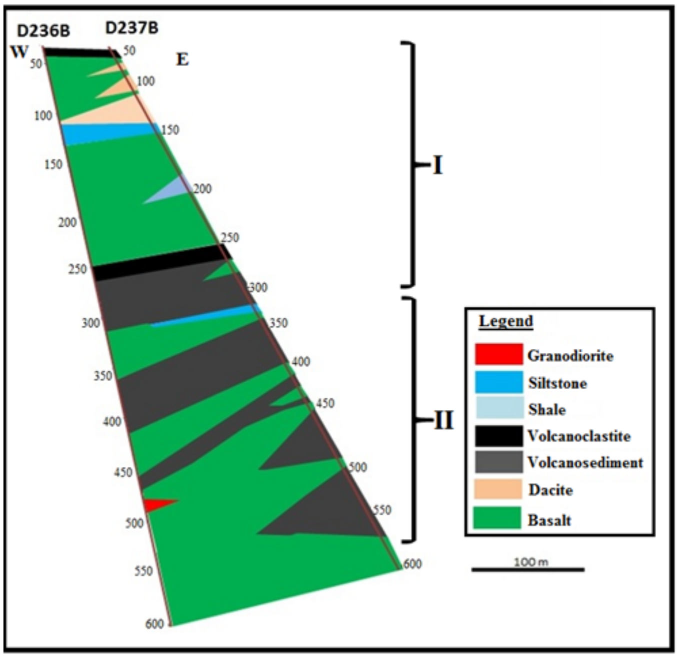

Figure 6: Lithostratigraphy column of the western Bonikro pit through the drill holes D236B and D237B.

Discussion

A contemporaneaousness between the Birimian units

The Birimian units observed in the southern Fettèkro greenstone belt are the mafic volcanics in the eastern side and the volcanoclastics associated with the sediments in the western side.

The stratigraphic correlations suggest that the basaltic rocks and those volcanoclastics and sediments are the primary rocks of this belt. Their setting chronology help to put in light some points of interests (Fig. 7).

The volcanic lithologies have been settled in relation with the birimian volcanism which also had an explosive character. This is shown by the westerly pyroclastites (Ouattara *et al*., 2015). Elsewhere in the Fettèkro especially in the Toumodi area, different authors (Yacé, 1982; Mortimer, 1991; Coulibaly *et al*., 2017) concluded to such type of explosive volcanism. Moreover the pillow lavas also found in Toumodi suggest to them that it was a subaqueous explosive volcanism.

Particularly in the Bonikro western side where these two Birimian units are abundant, the volcanoclastics and sediments are alternating with the basalts in sub-surface. In the depth, when the volcanoclastites become rare, we observe a progressive abundance of basaltic and sedimentary rocks. These alternations, common in the West African birimian belts, are the signs (proofs) that these units have been concomitantly settled. Similar observations have been made in Ghana and allowed Leube *et al*. (1990) to admit a contemporaneousness between the volcanites and the sedimentary rocks. The geochronological datation undertaken on these formations (Hirdes *et al*., 1992; Hirdes et Davis, 1998) has also confirmed that contemporaneousness.

The sedimentary rocks in the western Bonikro are also composed of black shales. This presence is evoking a setting environment of an anaerobic conditions probably in a stagnant water in the depth or protected from the sunlight. The graphite also observed within these black shales can be related to such type of environment where reductions reactions were important. In the Aboisso greenstone belt, Assié (2008) concluded that the graphite in the Aféma gold deposit came from such environment type. Moreover, these black shales imply that the Fettèkro may have a subaqueous component or the volcanic materials were eroded and accumulated in an aqueous area.

The regional but also contact metamorphisms of greenschist facies have affected almost the lithologies of Bonikro. In the neighbor deposit of Agbahou, Houssou (2013) admitted that this metamorphism locally attend the amphibolite facies in the shear zones. It is likely what is observed in the West Africa birimian furrows (Hirst, 1942; Leube *et al*., 1990; Hirdes *et al*., 1992; Taylor *et al*., 1992; Sylla et Ngom, 1997; Bourges *et al*., 1998).

A zone of magmatism

The geology of the Bonikro gold deposit has revealed that the felsic group rocks is composed of silicic lava, porphyritic dacite, aplo-pegmatite dykes and granodiorite. Also, the mafic group rock contains different lithological units: basalt, porphyritic basalt and sheared basalt (Ouattara *et al*., 2015).

The lithological correlation showed that the granodiorite and the aplo-pegmatite dyke cut the basalt in the eastern and the western part of the deposit. Likely, the magmatism that was able to settle the mafic rocks groups was different to the magmatism from which the felsic rocks group derived.

In the western part of Bonikro, the observation of the pyroclastites in relation with the siltstone was of interest. The pyroclastites are made of two types of clasts (Ouattara et al., 2015 and Ouattara, 2015): the sub-rounded mafic clasts and the rounded dacitic clasts. These clasts have undergone a weak transport and provide an evidence that some mafic rocks may derive from the same magma with some intermediate rocks.

A gold-rich interface

The main lithologies of the Bonikro gold deposit are the mafic volcanic in the east and volcano-sedimentary and sediments in the west. These two main lithologies are separated on the one hand by the Bonikro shear zone (BSZ) and on the other hand by the felsic group composed of granodiorite, aplo-pegmatite dyke and the felsic volcanites. From the south to the north of the Bonikro pit, the interface between these two lithologies strikes from N000° to N025° that is from the meridian to the birimian direction. This lithological distribution suggests that the felsic group which is central and controlled by the interface appeared lately (Fig. 7). This distribution of basaltic rocks in the east and volcano-sedimentary formations in the west as observed at Bonikro (Ouattara *et al*., 2015) is similar to the observations made by Houssou (2013) in the Agbahou gold deposit even if in this neighbor deposit situated at 25 km in the south-east of Bonikro, the intrusives are mafic (diorite and gabbro).

The interface between the mafic volcanic and volcano-sedimentary rocks in the Birimian is known to contain gold mineralisation (Olson, 1989; Assié, 2008; Kadio *et al*., 2010).

The lithostratigraphy described in the Bonikro deposit is similar to the almost prospects and gold deposits in the birimian formations. Thus, these deposits has a common setting environment: the interface between the volcanic and volcano-sedimentary rocks of birimian age. As a matter of fact, (i) the Agbahou gold deposit near Bonikro is characterized by a mineralization that is on horseback on mafic volcanites and volcano-sediments (Houssou, 2013), (ii) in Aféma, south-west Côte d'Ivoire, the gold ores are situated at the contact of volcanic and volcano-sedimentary formations (Assié, 2008 ; Kadio *et al*., 2010), (iii) the Tongon gold deposit in northern Côte d'Ivoire, the mineralization is hosted in a sequence of volcanoclasts and metasediments (Olson, 1989), (iv) in the Angovia gold deposit, central Côte d'Ivoire, the ore is localized in a contact between a unit of mafic volcanites and sediments and are intruded by the plutons (Milési *et al*., 1989); (v) in Ghana, the gold deposits of Ashanti, Abawso, Prestea, Bogosu and Konongo are linked to the Kumasi basin sediments closely with the contacts of birimian volcanites in the belts of Akropong, Sefwi and Ashanti (Oberthür et *al*., 1997 ; Wille et Klemd, 2004) ; (vi) In Burkina Faso, the Diabatou gold deposit in the Basiéri belt is located in the interface of basaltic and andesitic volcanics and metasediments (Bos, 1967 ; Lenz *et al*., 1991), (vii) In Sénégal, the Sabodala gold deposit is at the contact between the metabasalts and the volcanoclastites. Such type of interface gold rich is implying that the volcanic materials when eroded and accumulated in the stagnant environment have been reduced and they are preserved their gold.

These zones of contacts between mafic volcanic and volcano-sediments are characterized by their closeness with the magmatic intrusions. Mostly these plutons were un-mineralized. It appears now that some of these plutons are mineralized as in (i) Bonikro (Ouattara et al., 2015, Ouattara, 2015); (ii) Hiré gold deposit situated between the Bonikro and Agbahou deposits; (iii) the Bobosso prospect near Dabakala in Côte d'Ivoire, the mineralization is mainly hosted by quartzic diorite (Gnanzou, 2014); (iv) in Ghana, the mineralizations of Ayanfuri are developed in granitoidic plutons (Yao *et al*., 2001); (v) In Mali, the Morila gold deposit is hosted by the quartzic diorite, granodiorites and leucogranites (McFarlane *et al*., 2011). That allowed these authors (McFarlane et al., 2011) to link the Morila with the model of an intrusion-related gold deposit.

This closeness with the plutons has been used as a clue to discriminate two types of granitoids first in Ghana, then that has been extended to the Côte d'Ivoire. On a one hand, the larger granitoids of batholitic tendancy and characterized by their abundance in biotite. They have been settled between 2116 and 2088 million years and are known as cape coast type in Ghana or Baoulé type in Cote d'Ivoire. On the other hand, we have the small size granitoids marked by their abundance in hornblende, they are called dixcove type in Ghana when in Côte D'Ivoire, they are known as the Bondoukou type. Their ages vary from 2180 to 2170 Ma (Bodin, 1951).

The setting of the granodiorite in the Bonikro gold deposit was controlled by the Bonikro Shear Zone (BSZ). All of the lithologies in closeness with the granodiorite are sheared (Fig. 7). The BSZ strikes from NS to NE. This shear zone is also observed in the nearer Agbahou deposit and known as the Agbahou Tectonic Zone or ATZ (Houssou et al., 2017). It is almost a 30 km length of shearing between the deposits of Agbahou and Bonikro showing clearly that the gold mineralization is also structurally controlled (Ouattara, 2015; Houssou et al., 2017).

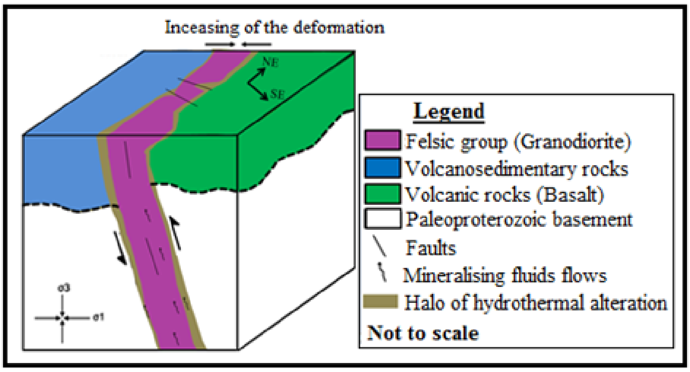

Figure 7: Model of the lithostratigraphy setting of the Bonikro gold deposit.

Conclusion

This study about the Bonikro gold deposit allowed us to precise in one hand the lithostratigraphy of the southern Fettèkro greenstone belt and in other hand, the magmatic origin of the rocks bearing gold ore and their post deposition evolution. Results indicated that the primary rocks recorded in the Bonikro gold deposit are likely the mafic sequences and the sediments. The mafic rocks include the basalt and the mafic volcanoclastics. Then, these have been eroded and formed the sedimentary rocks. Some of the volcano-sedimentary and sediments show some contemporaneousness with the mafic volcanic rocks. The presence of the volcanoclastic in the area is consistent with the fact that the eruptive volcanism occurred in the Fettèkro greenstone belt. These aforementioned rocks have undergone the greenschist facies metamorphism and more over have been by the granodiorite, and as a result, we have an exceptional deposit where gold is primarily associated with an intrusive (granodiorite).

The lithostratigraphical description of the deposit is summarised in the western Bonikro, from the oldest to the youngest lithology: Basalt / volcano-sediments / granodiorite.

Three mains horizons are noticeable. From the surface to an average of 150 m, both volcanic mafic and volcano-sediments associated with sediments are alternating. The second horizon from 150 to 300 m is made of the volcano-sediments. The third horizon starts around 300 m and continues deeply. This later horizon is made of the granodiorite and then the mafic volcanic.

The basalt is likely the Birimian basement in Bonikro but in the first horizon, the abundance of

volcano-sedimentary rocks associated with the mafic volcanic shows a contemporaneous

between these units. These lithological settings were important in the sense that they controlled the setting of the intrusion moreover they helped to the preservation of the gold ore, giving to Bonikro an example of an intrusive controlled gold in the Birimian units. These data confirm results obtained in the birimian formations in other West Africa countries.

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