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Litho-geochemical Characterizations of the Kourouba Gold Mineralization in the North East of the Republic of Guinea

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Abstract
The essentially gold resources of the countries of the West African sub-region are associated with the formations of the Proterozoic Birimian greenstone. In Guinea, these formations are located in the Siguiri basin which covers the prefectures of Siguiri, Mandiana, Dinguiraye, Kankan and Kouroussa. In the region, significant gold deposits related to these formations are being mined and others are depleted. Despite the existence of a similar regional geological context, each of the deposits found in the West African craton has particular litho-geochemical, structural, textural or mineralogical characteristics. Which attests that in the sub-region, for the search for gold, litho-geochemical, structural and mineralogical studies are crucial. Thus, this study aims to identify the lithologies and alterations that control the Kourouba gold mineralization. To achieve this goal, we modeled the survey data and performed geochemical analyses with different diagrams. At the end of this study, we obtained that the Kourouba area has a lithology that presents itself from the surface to the depth as follows: Laterite, Baryonic clay, Saprolite clay and Mafic with an alternation of Cherts in certain areas. The geotectonic context that controls mineralization is of the active continental margin types with the presence of iron-rich schistose meta-sediments. Two (2) degrees of alteration have been identified, the mineralizations are filonial and disseminated in the mafic rocks.

Keywords: lithology, geochemistry, mineralization, Kourouba, correlation, alteration

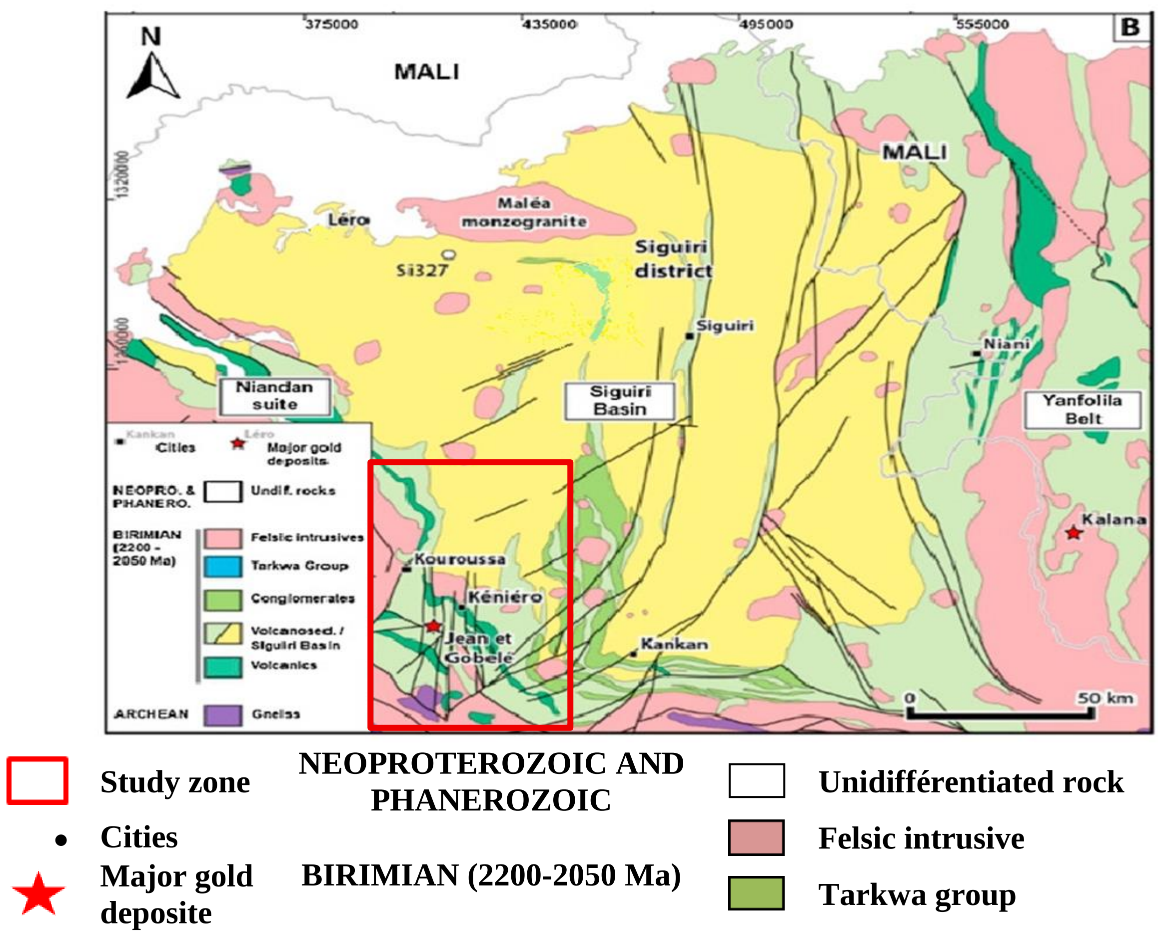
I-Introduction:

The Republic of Guinea, an integral part of the West African craton, is full of immense potential in terms of subsoil resources, among which bauxite, iron and precious metals feature prominently, including gold (with a reserve estimated at 700 tonnes) (Kouamelan, 1996). For the case of gold, the essentially resources of the countries of the West African sub-region are associated with the formations of Proterozoic Birimian greenstone (basalts, andesite, amphibolites, chloritoschists, gabbro, volcano-sediments, rhyolite, rhyodacite and sediments represented by shales and greywacke) (Salvi et al., 2016). In Guinea, these formations are located in the Siguiri basin or Upper Niger basin which covers the prefectures of Siguiri, Mandiana, Dinguiraye, Kankan and Kouroussa (Mamedov et al., 2010). In the region, significant gold deposits related to these formations are being mined and others are depleted.

Despite the existence of a similar regional geological context, each of the deposits found in the West African craton has particular litho-geochemical, structural, textural or mineralogical characteristics. Indeed, in the Ashanti gold deposit in Obuasi (Ghana), two main types of ore are extracted, the auriferous quartz veins and the gold sulfide releases in metasediments and metavolcanoes (Osae et al., 1999), in Côte d'Ivoire, the Agbahou gold deposit contains three (3) lithological units, a volcano-plutonic unit, a volcano-sedimentary unit and the

late felsic veins (Houssou, 2013). The author specifies that the deposit is related to a shear zone-oriented northeast. According to Sangaré et al. (2014) the deposit of Kalana, Republic of Mali is formed by metavolcano-sedimentary rocks and crossed by magmatic rocks with alkaline affinity. The mineralizations are controlled by two families of quartz veins intersecting with regional schistosity. The first family is oriented N-S, NE-SW or E-W and the second is oriented N-E. Lebrun et al. (2017) assert that the orogenic Siguiri gold-bearing district, Republic of Guinea is located in the weakly metamorphosed sedimentary rocks of the Upper Birimian Group at Lower Tarkwa of the Siguiri Basin. They add that the district is characterized by a long history of deformation associated with four main events, the first two of which are compressions (N-S and E-W), the third is the gradual evolution from the second to early transpression and then to a late NNW-SSE transtension and the fourth is also a NE-SW compression. Finally, they note that a composite geochemical section through the fracture zones of the deposit indicates that gold mineralization in the Siguiri district is associated with enrichments in Ag, Au, As, Bi, Co, Mo, (Sb), S, Te and W relative to the bed. From the above, it appears that the West African craton presents a diversity of structural, textural, lithological and mineralogical characteristics. What attests that in the sub-region, for the search for gold, litho-geochemical, structural and mineralogical studies are crucial, hence the choice to make a litho-geochemical characterization of Kourouba Gold Mineralization, Kouroussa Prefecture, Republic of Guinea. Thus, this study aims to identify the lithologies and alterations that control the Kourouba gold mineralization.
To achieve these objectives, the methodological approach will consist of conducting studies on the survey data carried out and carrying out geochemical analyses.

II-Geological framework of the study region
Geologically, the Kouroussa region belongs to the Siguiri basin (**fig. 1**).



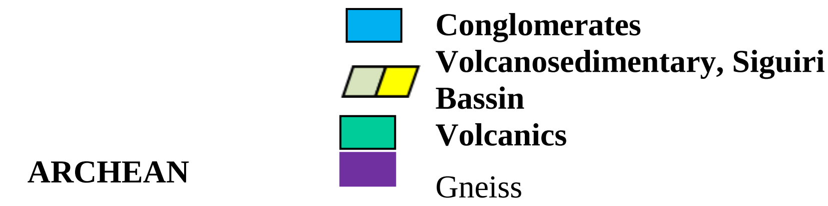
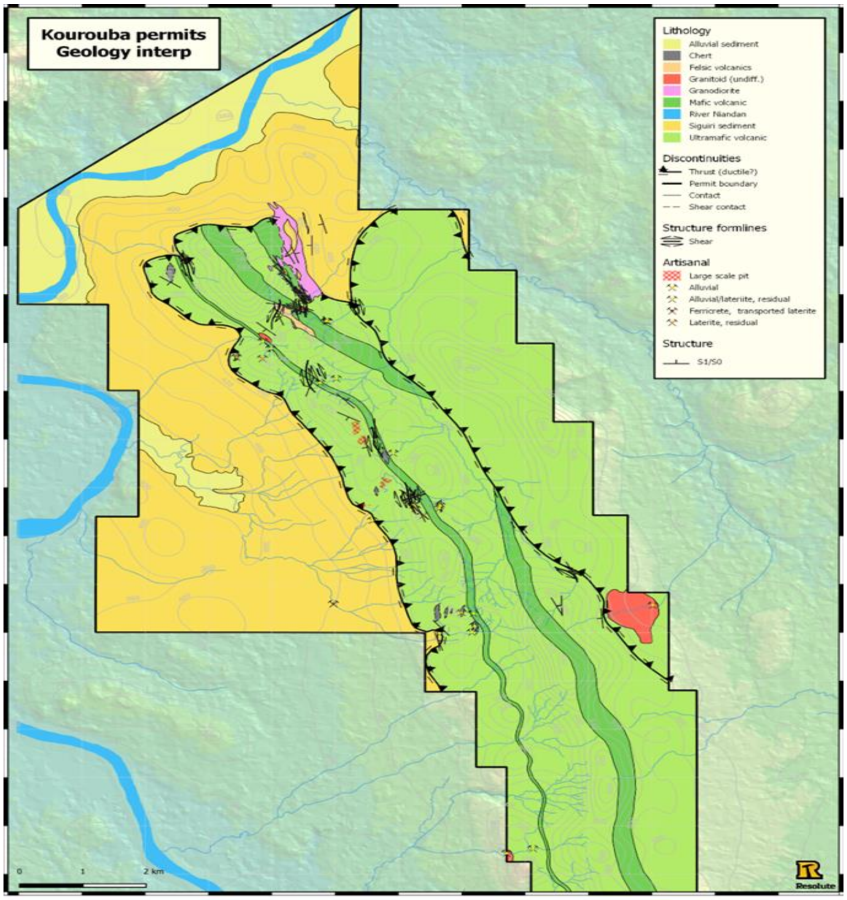


Fig. 1 : Geolocal map of the Siguiri basin (**Bessoles, 1997**)

The studies of Mamedov et al. (2010) have proven that Upper Guinea is located in the contact area between the Archean terrains of the Man craton outcropping in the southern half of the sector and the Paleoproterozoic Birimian terrains. To the north, the Neoproterozoic sandstones of the Taoudéni basin rest in discordance on the Birimian grounds. The elements of relative chronology and radiometric datings allow integrating sedimentary, magmatic, tectonic and metamorphic events, recognized on this map into a coherent geological history at the scale of northeastern Guinea. The geological ages are represented by the Achaean which corresponds to the emplacement of granitic plutons around 2780 Ma, from the Paleoproterozoic whose earliest recognized magmatic event corresponds to the emplacement of the Niani volcanic complex which dates back to 2210 Ma, the rocks of the Niani magmatic complex exhibit the geochemical characteristics of a calc-alkaline magmatism generated above a subduction zone. The Neoproterozoic is represented by fluvial and coastal conglomerates and sandstones that are deposited in discordance on the northernmost Birimian lands (Mamedov et al., 2010). In the region, the Mesozoic is represented by alterites (saprolites, mottled clays and lateritic cuirasses) of which the oldest recognized were formed from the Jurassic at the expense of doleritic sills. As for the Quaternary, it is essentially represented by fluvial sediments (vases, silt, sand, gravels).

Geology framework of the study area

Locally, the geology of Kourouba relates to that of Niandan-Kiniéro. The study permit from the company ToroGold Succ (our study area) contains the geological formations of two (2) large families of rocks: sedimentary and magmatic (**fig. 2**).



Legend

Lithology	Discontinuities	Artisanal
Alluvial	Thrust (Ductile ?)	
Chert	Permit boundary	
Felsic volcanic	Contact	Large scale pit
Granitoid (Unidifférentiated)	Shear contact	Alluvial
Granodiorite		Alluvial/Laterite, residual
Mafic volcanic		Ferricrete, transported
Riva Niandan		Laterite, residual

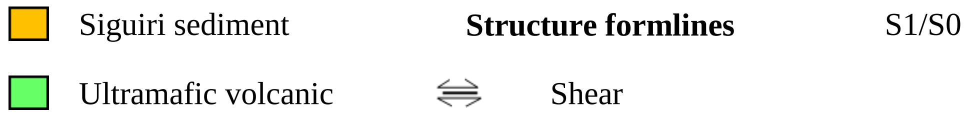


Fig. 2 : geolocal map of the Kourouba permit

Sedimentary rocks are represented by alluvial sediments, laterites, ferricrètes and cherts, and igneous rocks are represented by felsic (Granitoids, granodiorite and volcanic) as well as volcanic mafic and ultramafic.
According to Mamedov et al. (2010), in the chain of Niandian and the Kiniéro series, the first hydrothermal manifestations are early and contemporary with the establishment of the volcanic series. They are characteristic of sulphide cherts, possible responsible for the first mineral concentrations. The gold mineralization is related to the veins, stringers and stockworks of sulphide quartz. These quartz structures, linked to a strike-slip system have a predominant direction (N-S, NNE and SSW).
The small intrusive bodies frequent in the North of the Niandian Range, such as those of Morignoumala, could develop on their surface gold mineralization **(**Mamedov et al., 2010).

III-Methodology

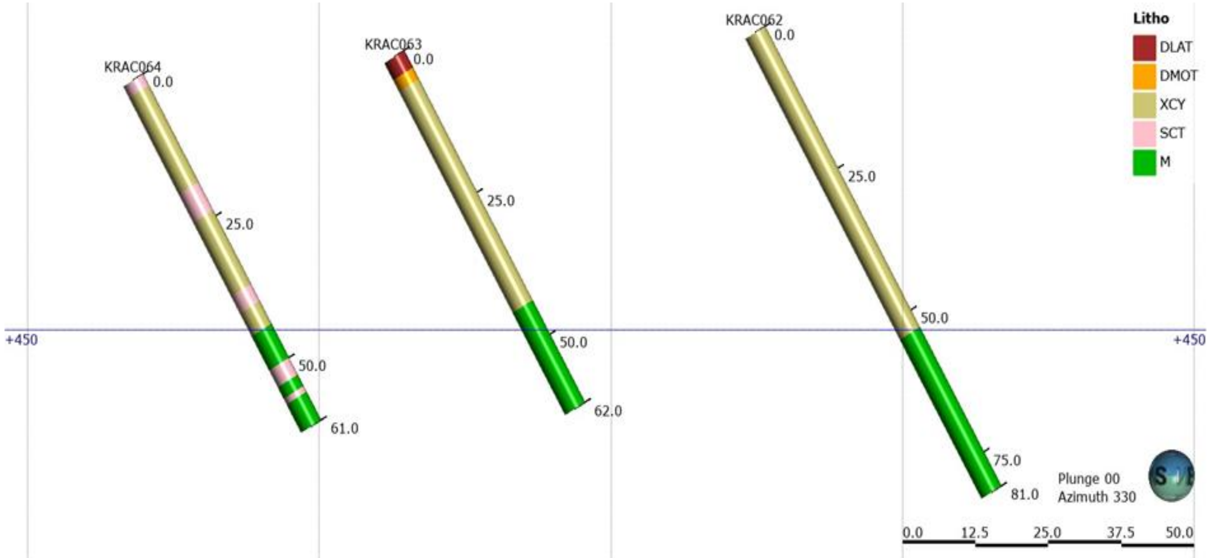
The methodological approach is subdivided into two stages, a field research campaign in the Kourouba area and office work. During fieldwork, for the analysis of rock chemical composition, nine (9) samples were taken and analyzed using the Vel XRF handheld EXW. Cores collected in three holes drilled using a X300 Air Core Drill Rig were macroscopically described. During the office work, the results of geochemical analyses were projected into the triangular diagram using the Triplot v4.1.2 software, Adobe Illustrator CS 11.0.0 Fr was used for the digitization of binary diagrams and Leapfrog Geo 5.1 software served as a tool not only to digitize the three (3) drill holes (KARC062, KARC063 and KARC064) but also to make correlations between the lithology observed in macroscopy with the mineralization data, the different levels of alteration and the quartz veins.

IV Results

The results mainly concern the lithology of the study area (**1**), the geochemical analysis of the samples (**2**), the correlation between mineralization and lithological formations on one hand and the correlation between mineralization and different alterations on the other hand (**3**).

IV-1 Lithological result

The lithology is based on the analysis of the results of three (3) drill holes made in the Kourouba area (**fig. 3**).



DLAT : Laterite ; **DMOT :** Layered Clay ; **XCY :** Saprolite ; **SCT :** Chert ; **M** : Meta-Sedimentary

Fig. 3 :lithological sections of the KOUROUBA area

This study shows that it is mainly formed from top to bottom by the following geological formations: Laterite, Baryolated clay, Saprolite clay and Mafic with an alternation of Cherts in certain areas **(fig. 4a, 4b, 4c, 4d, 4e and 4f).**

Fig. 4a : Laterite

Fig. 4b : Saprolite

Fig. 4c : Chert

Fig. 4d : meta-sediment

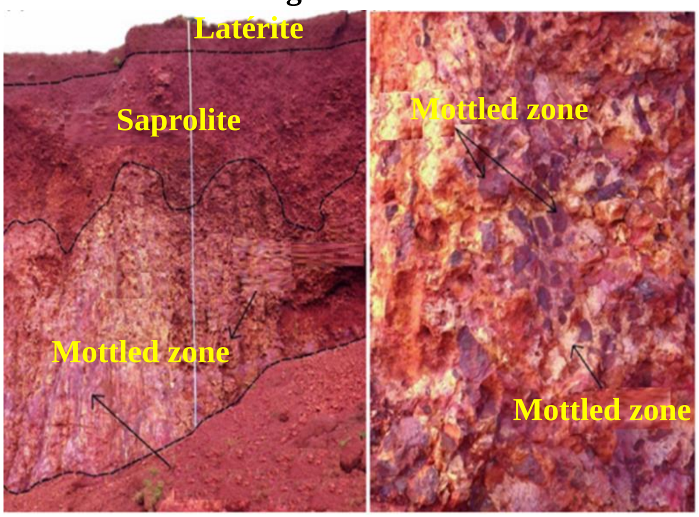


Fig. 4e : Profile presenting the laterite, the saprolite and the mottled zone (multicolored clay)

Fig. 4f : stockwerk outcrop

The first drill hole KRAC062 with a depth of 81 m is divided into two (2) lithological groups linked to four (4) alteration zones (fig.3). From 0 to 53 m it is the completely rotten coarse saprolite because it does not retain any aspect of the altered bedrock that corresponds to the lithology of clay saprolite; from 53 to 81 m corresponds to the mafic facies (M) distributed as follows: from 53 to 77 m it is the fine saprolite from which certain aspects of the bedrock are preserved; from 77 to 80 m it is the saprolite-fresh transition zone, hence its name saprock; from 80 to 81 m: it is the fresh rock (F) whose alteration has led to the facies mentioned above.

The second drill hole KRAC063, 62m deep, has a complete alteration profile (fig.3). At the surface, we find deposited laterite (0 to 3 m), then bariolated clay or mottle zone (3 to 5 m), clayey saprolite (5 to 44 m) and finally from 44 to 62 m are mafic rocks (M) divided into three (3) subgroups: the lower saprolite (XL) keeping certain aspects of the fresh rock (44 to 58 m), the saprock which corresponds to the saprolite-fresh rock transition zone (58 to 61 m) and from 61 to 62 m the fresh rock (F).

Finally, the last drilling KRAC064 with a depth of 61m, is mainly characterized by two (2) lithological groups with a particular alternation of geological formations (fig.3). From 0 to 44 m the lithology is represented by an alternation of cherts (SCT) (0 to 2 m, 19 to 24 m, 37 to 40 m) and saprolitic clay facies (XCY) (2 to 19 m, 24 to 37 m and 40 to 44 m). From 44 to 61m by an alternation of saprock (XP) related to mafic (M) (44 to 50 m, 53 to 55 m and 56 to 61 m) and cherts (50 to 53 m, 55 to 56 m).

IV-2 Geochemical result using lithological data

The result of the geochemical analysis of the Kourouba permit samples is shown in **Table 1**.

Table 1 : Geochemical analysis of Kourouba samples (in %).

Locality	Kourouba	Kourouba	Kourouba	Kourouba	Kourouba	Kourouba	Kourouba	Kourouba	Kourouba
Samples	CR50315	CR50316	CR50317	CR50349	CR50351	CR50352	CR50384	CR50385	CR50386
SiO_2	54,34	51,40	52,11	54,16	55,14	54,30	60,30	62,15	53,83
Al_2O_3	20,73	23,05	27,43	21,64	21,87	23,70	21,07	24,61	38,34
Fe_2O_3	12,47	10,90	9,02	13,36	12,08	11,03	9,50	7,29	3,25
FeO	11,20	9,81	8,12	12,02	10,87	9,92	8,55	6,56	2,93
TiO_2	0,86	0,94	0,95	0,85	0,91	0,88	0,86	0,90	0,92
CaO	0,14	0,81	0,61	0,19	0,22	0,29	0,24	0,30	0,03
MgO	2,82	2,84	1,42	1,64	1,57	1,57	1,37	0,25	0,25
Na_2O	5,78	6,94	5,66	5,90	5,30	6,11	4,22	2,70	1,31
K_2O	0,34	0,63	0,61	0,17	0,19	0,13	0,43	0,26	0,31
MnO	0,10	0,08	0,07	0,06	0,07	0,05	0,04	0,04	0,04
P_2O_5	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
LOI	3,00	2,60	2,43	2,10	2,73	2,00	2,01	2,03	2,70
Total	100,55	100,21	100,32	100,06	100,08	100,05	100,04	100,54	100,96
$CaO+Na_2O$	5,90	7,70	6,30	6,10	5,50	6,40	4,50	3,00	1,30
$Log(Fe_2O_3/K_2O)$	1,56	1,24	1,17	1,90	1,81	1,92	1,35	1,45	1,02
$Log(SiO_2/Al_2O_3)$	0,42	0,35	0,28	0,40	0,40	0,36	0,46	0,40	0,15
CIA	76,82	73,33	79,94	77,57	79,31	78,39	81,18	88,28	95,89
DF1	-12,36	-10,45	-10,12	-15,49	-13,32	-12,07	-10,58	-9,16	-4,40
DF2	5,38	6,31	5,42	5,37	4,98	5,75	4,76	3,76	2,78

The above geochemical data have been projected in the diagrams below:

a- Diagram of TiO2 versus SiO2 of (Tarney et al., 1977)

The geochemical data of the study area were projected in the Tarney (1977) TiO2 versus SiO2 diagram. It reveals the presence of sedimentary rocks in the analyzed samples from the Kourouba permit **(fig. 5).**

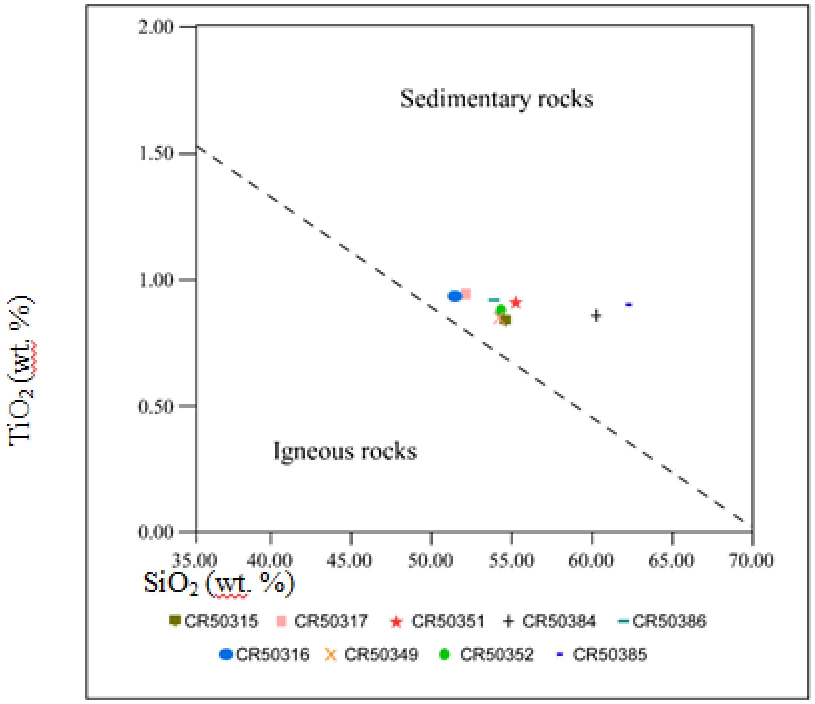


Fig. 5 : Positioning of metasediment samples from the Kourouba areas in the TiO2 versus SiO2 diagram of (Tarney, 1977).

b- **Log Diagram (Na2O/K2O) versus Log (SiO2/Al2O3) of (Herron, 1988)**

The geochemical data of the kourouba samples projected in the Log (Na2O/K2O) versus Log (SiO2/Al2O3) diagram by Herron (1988) fall into the iron-rich clay domain, which also confirms that its sedimentary rocks are iron-rich schistose meta-sediments (**fig. 6**).

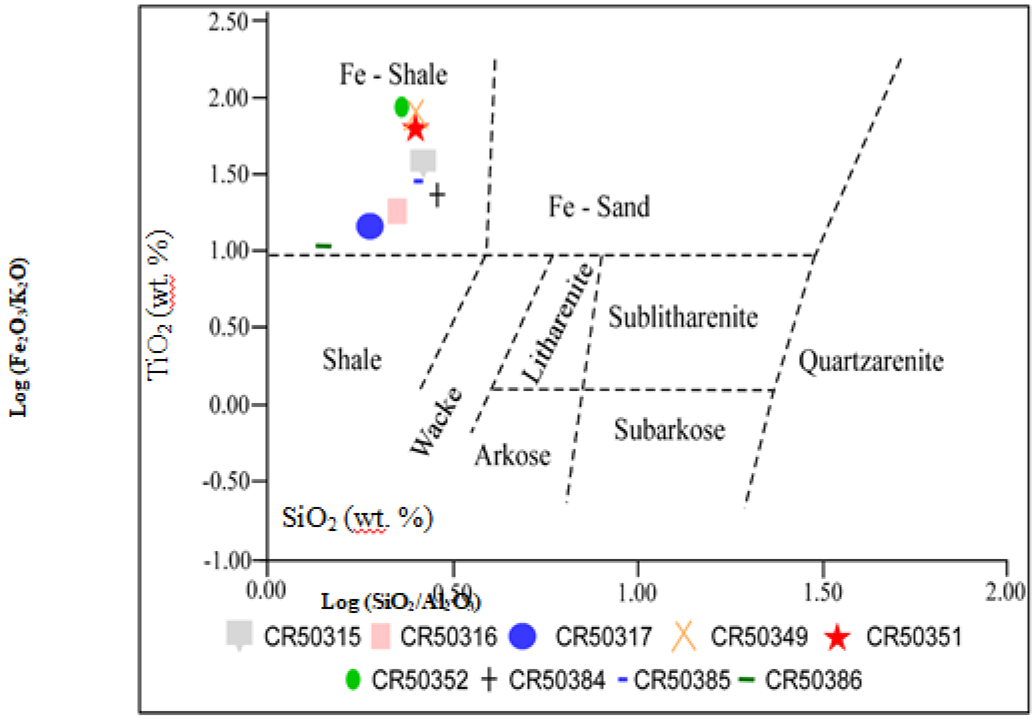


Fig. 6: Positioning of metasediment samples from the Kourouba sectors in the Log (Na2O/K2O) versus Log (SiO2/Al2O3) diagram of (Herron, 1988).

c- Triangular diagram of (Fedo et al., 1995)

The projection of geochemical data from Kourouba in the triangular diagram by Fedo et al. (1995) shows that all the rocks are derived from the alteration of basalts with varying degrees of alteration: intermediate (Smectites) and strong (rocks rich in aluminous minerals) **(fig. 7)**.

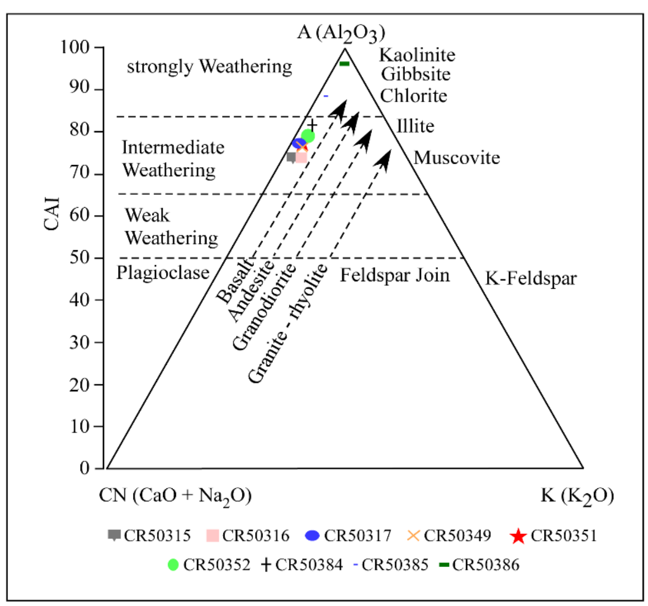


Fig. 7: Positioning of metasediment samples from the Kourouba areas in the A-CN-K and CIA diagram of (Fedo et al., 1995).

d- Discrimination diagrams of (Bhatia, 1983) and (Roser et al., 1986)

The discrimination diagrams of Bhatia (1983) and Roser et al. (1986) show us the domains of deposition of meta-sediments. The analyzed samples are presented in two (2) domains: ocean island arc margin domain and active continental margin domain. However, the discriminant diagram of **Bhatia (1983)** shows a membership of meta-sediments in the domain of active continental margins **(fig. 8A and 8B).**

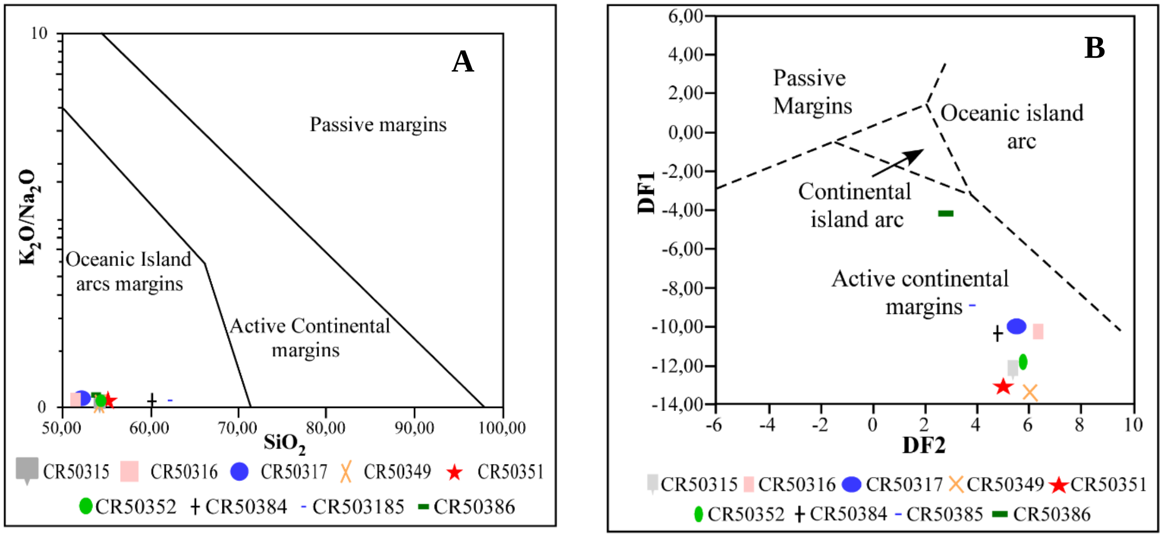


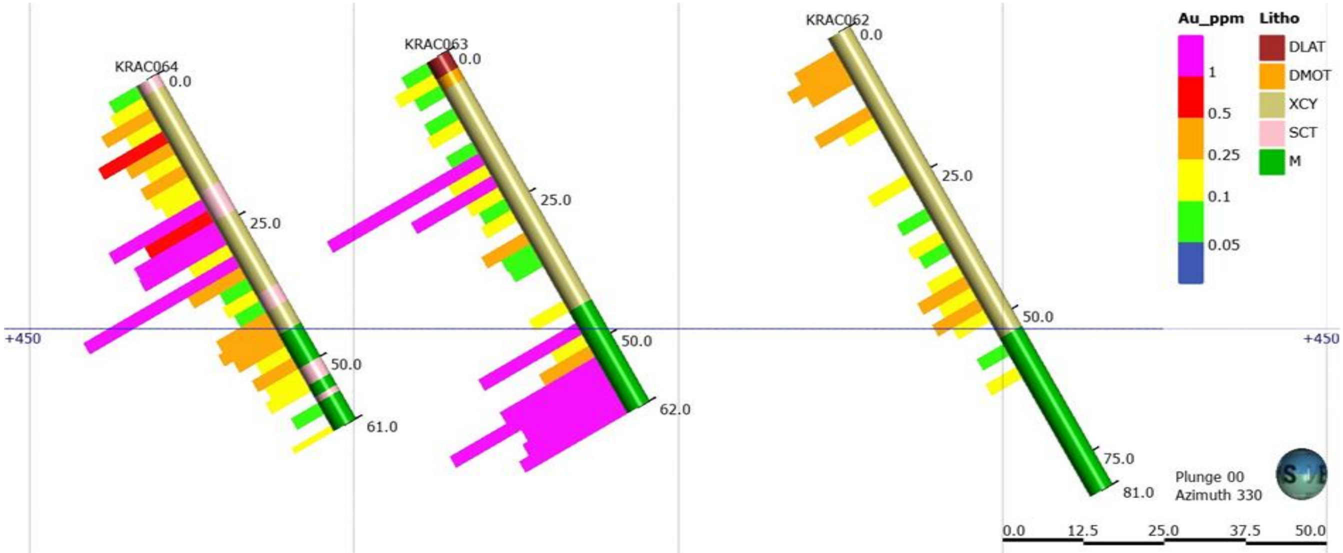
Fig. 8: : (**A**) Samples of metasediments from the Kourouba sectors in the K2O/Na2O versus SiO2 diagram of (Roser et al., 1986). (**B**) Samples of metasediments from the Kourouba sectors in the diagram DF1 versus DF2 of (Bhatia, 1983).

In sum, the geochemical analysis of the samples from the Kourouba zone shows that the rocks are deposits of metasediments (iron-rich shale) from the domain of active continental margins and resulting from the alteration of basalts with various degrees of alteration: intermediate (Smectites) and strong (rocks rich in aluminous minerals).

IV-3 Result of correlations

IV-3-1 Correlation between lithology observed with mineralization data

Analysis of lithological correlation results with mineralization data obtained from the three (3) drill holes **(KRAC062, KRAC063 and KRAC064)** reveal that there are two types of mineralization in the kourouba zone **(fig. 9).**



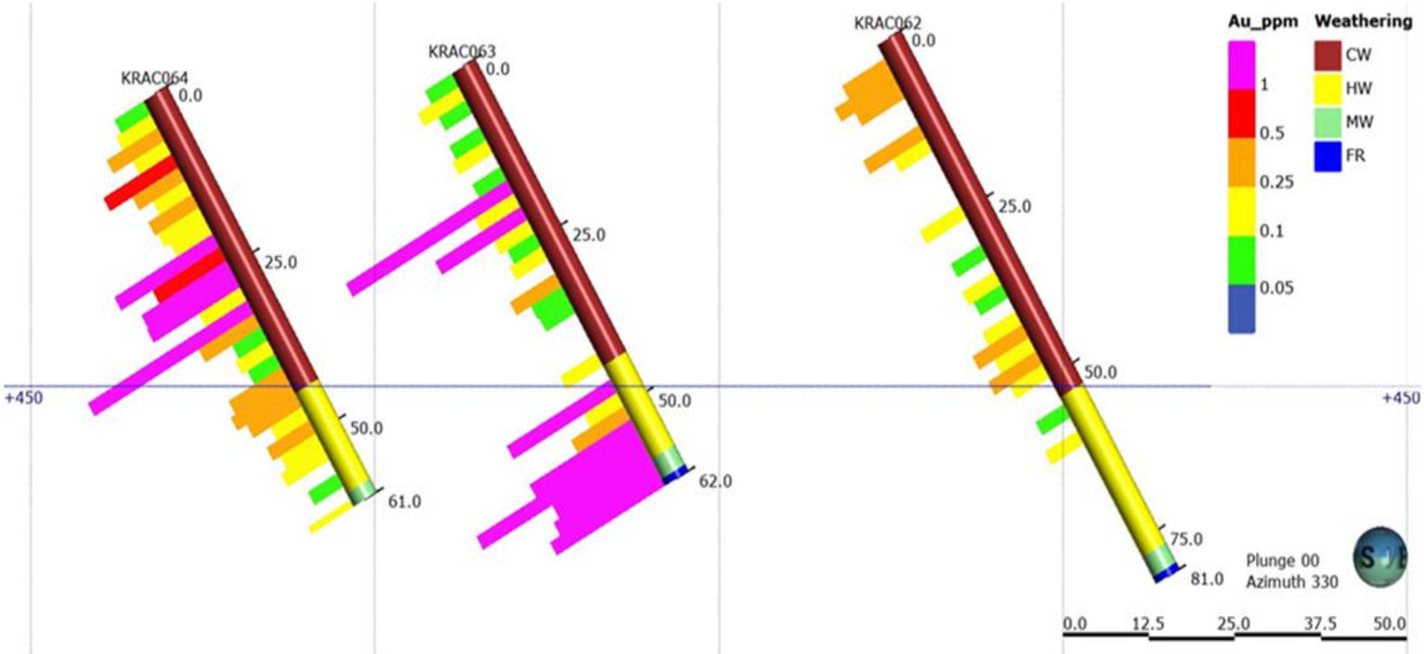
DLAT: Laterite; **DMOT:** Layered Clay; **XCY:** Saprolite; **SCT:** Chert; **M:** Meta-Sedimentary

Fig. 9: correlation of lithology with the data on the mineralization of the Kourouba zone.

Hole **KRAC062** shows low mineralization in the mafic and is just at the Saprolite-Mafique boundary with a high mineral concentration in almost all of the saprolitic profile. Saprolite being a soft and completely rotten rock, underwent microtectonics that favored the presence of fine cracks which were subsequently invaded by mineralizing solutions to form the gold veins. Thus this hole KRAC062 is characterized by a mineralization linked to the quartz veins. While the two (2) other drill holes KRAC063 and KRAC064 are almost mineralized from start to finish with a very high concentration of gold in the mafic. Knowing the characteristics of basic magma whose crystallization led to the mafic (unsaturated magma), it would have been confirmed that these mafic are syngenetic to mineralization and this latter lying in disseminated form in the mafic if the holes were deeper.

IV-3-2 Result of the correlation between mineralization data and different levels of alteration

The analysis of the correlation results between the mineralization data and the degree of alteration obtained using drilling in the kourouba zone reveals that **(fig. 10):**



CW: fine saprolite completely altered; **HW:** highly altered coarse saprolite; **MW:** moderately altered saprolite and **RF**: fresh rock

Fig. 10: the correlation between mineralization data and degree of alteration

Hole **KRAC062** has three levels of alteration. From 0 to 50 m deep corresponds to fine saprolites that are completely altered; from 50 to 80 m deep, the transition zone is formed at the base by moderately altered saproct followed by highly altered coarse saprolite; from 80 to 81 m deep, it is the fresh rock that constitutes the source rock of the Kourouba area. The fine and coarse saprolites have low gold contents ranging from 0.25 to 0.05 ppm. The rest of the formations in this hole do not show mineralization.

Then, the second hole **KRAC063** is characterized by three levels of alteration. From 0 to 45 m depth, corresponds to fine saprolites that are completely altered; from 45 to 61 m depth, the transition zone which is characterized by moderately altered saprocks topped with highly altered coarse saprolites; from a depth of 61 to 62 m it is the fresh rock that constitutes the bedrock.

In the end, the last hole **KRAC064** has two levels of alteration. From the surface to 45 m depth, the rocks are formed of fine saprolites completely altered; then of the transition zone from 45 to 61 m depth, characterized by highly altered coarse saprolites and moderately altered saprocks.

All the profiles of drill holes **KRAC063** and **KRAC064** are completely mineralized with gold grades up to 1 ppm in all formations.

IV-3-3 Correlation result between mineralization data and quartz veins

The result of the correlation between the data from the Kourouba gold mineralization and the quartz vein structures made it possible to distinguish two (2) types of mineralization **(fig. 11):** the filonial mineralization (1) in the saprolitic zone containing numerous quartz veins and disseminated mineralization (2) in meta-sediments characterized by weak quartz veins and high gold content.

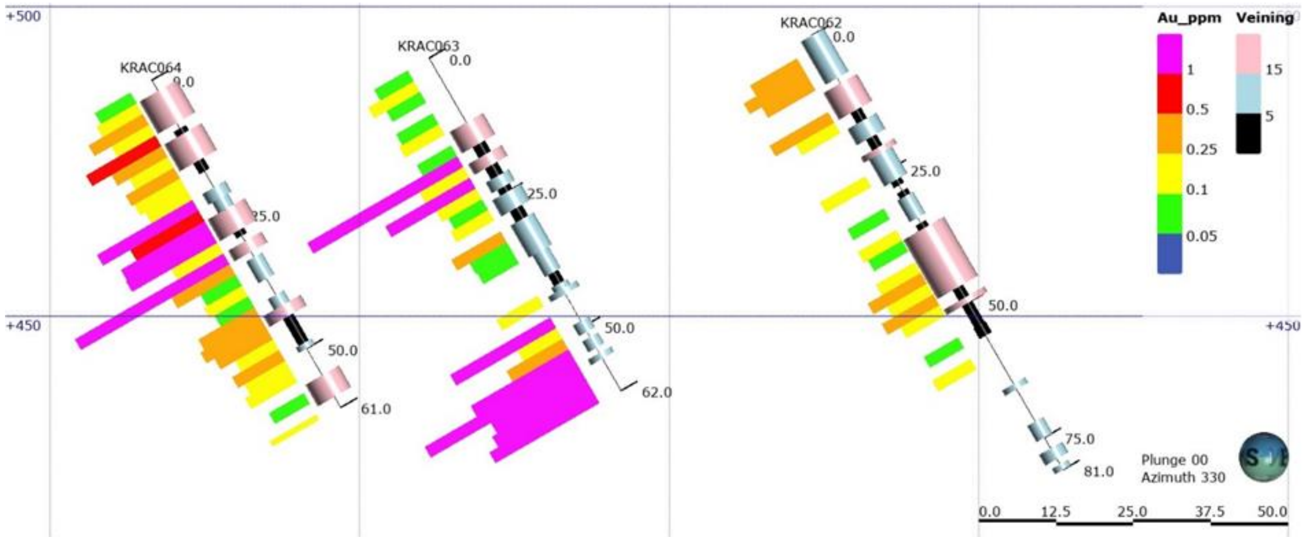


Fig. 11 : Section veining-assay

In summary, the different correlations demonstrate that the lithologies of the Kourouba zone are almost all mineralized, however, there are mainly two types of mineralization: the vein mineralization (1) in the saprolitic zone containing numerous quartz veins and disseminated mineralization (2) in meta-sediments characterized by weak quartz veins and high gold content.

V- Discussion

Compared to the results of other studies carried out in the sub-region or in the West African craton, our study area characterized by a dissemination of mineralization in the mafic and quartz veins in themeta-sediments present similarities with the Ashanti gold deposit in Obuasi, Ghana (Osae et al., 1999; Fougerouse et al., 1997; Assié, 2008; Fougerouse et al., 2017; Ouattara, 2015). What is different from the late-Eburnean deposit of Kalana (Birimian, Southwest of Mali) where mineralizations are carried by two families of quartz veins intersecting on regional schistosity (Sangaré et al., 2014). Like our study area, high gold contents were found in the quartz veins and a dissemination of gold in a polymictic conglomerate in the Sanu Tinti deposit, Siguiri gold district (Lebrun et al., 2017). Finally, if the domain of active continental margins is the geotectonic context that favored the implementation of mineralization in our study area, that of the Agbahou deposit, Divo, Côte d'Ivoire is a zone where transcurrent faults of lithospheric extension by friction generate thermal corridors capable of generating by fusion the calc-alkaline andesitic magma (Houssou, 2013).

V- Conclusion

From the analysis of the aforementioned results, the lithological section of Kourouba is presented from top to bottom as follows: Laterite, Baryonic clay, Saprolite clay and Mafic with an alternation of Cherts in certain areas. The insertion of geochemical data into the diagram models revealed in the samples the presence of sedimentary rocks, particularly iron-rich schistose meta-sediments belonging to the domain of active continental margins. The rock samples taken in the area revealed that these rocks are derived from the alteration of basalts with various degrees of alteration: intermediate (Smectites) and strong (rocks rich in aluminous minerals). The studies in the Kourouba zone highlighted two types of mineralization: (1) vein-bearing and (2) disseminated. All sections of the holes are almost mineralized but the largest quantities of gold are disseminated in the mafic.

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