American Journal of Life Sciences
2025, Vol. 13, No. 6, pp. 170-179
https://doi.org/10.11648/j.ajls.20251306.11

Research Article

Lithology, Sulfide Mineralization, and Hydrothermal Alteration in an Emerging Birimian Gold District: Yas Permit, Boundiali Area, Bagoue Basin, West African Craton

Ronald Sosthene DesireYapi Atto[1, *], Yaya Ouattara[2], Chiaye Larissa Koffi epse Coulibaly[1], Sylvain Monde[2]

[1]Mines and Reservoirs Department, University of Man, Man, Côte d'Ivoire

[2]Laboratory of Geology, Mineral and Energy Resources, Felix Houphouët-Boigny University, Abidjan, Côte d'Ivoire

Abstract

The Birimian greenstone belts of West Africa are globally recognized for hosting some of the most prolific orogenic gold deposits. In Côte d'Ivoire, the Bagoue Basin forms a major segment of the Boundiali Belt and represents one of the most promising yet underexplored gold provinces. This study focuses on the lithological, petrographic, and mineralogical characterization of the volcano-sedimentary formations within the YAS exploration permit, located in the Boundiali area. The research is based on a detailed analysis of diamond drill cores obtained from three mineralized targets (Targets 2, 3, and 10). The intercepted sequences are dominated by sedimentary units including sandstones, shales, and polymictic conglomerates, locally intruded by fine-grained mafic dykes. These rocks display intense and multiphase hydrothermal alteration, mainly silicification, chloritization, carbonation, and potassic alteration, which are closely associated with polymetallic sulfide mineralization composed of pyrite, pyrrhotite, arsenopyrite, and chalcopyrite. The occurrence of visible gold within Target 3 confirms the presence of a structurally controlled orogenic gold system, spatially related to NE-SW-trending shear zones. Collectively, these results demonstrate the strong influence of structural and hydrothermal processes in the metallogeny of the Bagoue Basin and emphasize the significant exploration potential of the YAS permit for future large-scale gold discoveries in northern Côte d'Ivoire.

Keywords

Birimian, Boundiali Belt, Bagoue Basin, Lithology, Sulfide Mineralization, Hydrothermal Alteration, Côte d'Ivoire

1. Introduction

West Africa hosts one of the richest and most complex Proterozoic crusts, where the Birimian formations exhibit exceptional mineralization potential, particularly for gold and polymetallic metals. Côte d'Ivoire, with its extensive Birimian basement, provides a privileged setting for mineral exploration and for investigating the geodynamic processes that shaped the West African Craton [1]. In the northwestern part of the country, the Bagoue Basin is characterized by Birimian volca-

*Corresponding author: sosthene.atto@univ-man.edu.ci (Ronald Sosthene Desire Yapi Atto), adesirsosthene@gmail.com (Ronald Sosthene Desire Yapi Atto)

Received: 10 October 2025; **Accepted:** 21 October 2025; **Published:** 28 November 2025

no-sedimentary sequences that remain partially explored but are recognized for their high gold prospectivity. These formations record a complex interplay between volcanism, sedimentation, and hydrothermal alteration, generating environments favorable to the concentration of metal-bearing minerals [2, 3].

Despite the strategic importance of these terrains, litho-petrographic data remain fragmented and are rarely integrated into detailed geological maps. This gap limits the understanding of lithological and structural controls on mineralization and constrains the optimization of exploration strategies. This study aims to define the lithological, mineralogical, and hydrothermal controls on gold mineralization in an emerging district of the Ivorian Birimian through an integrated analysis of drill cores from the YAS permit (Boundiali, Bagoue Basin). The objectives are to refine the lithostratigraphic architecture, identify key alteration signatures, and evaluate their mineralization potential.

2. Geographic and Geological Context

Boundiali is a town located in northwestern Côte d'Ivoire, serving as the administrative center of the Bagoue region. It is situated approximately at 9°51′N latitude and 6°29′W longitude (Figure 1). This northern location places Boundiali in the transitional zone between the humid tropical forests of southern Côte d'Ivoire and the Sudanian savannas of the north. The town's significant distance from major southern urban centers highlights the importance of studying local resources, particularly mineral resources, for regional development.

Geologically, the Boundiali Belt belongs to the Baoule-Mossi domain of the West African Craton, characterized by Paleoproterozoic (2.2-2.1 Ga) volcano-sedimentary sequences intruded by granitoids [4, 5]. The Bagoue Basin forms a major structural depression composed of alternating volcanic rocks (basaltic to andesitic flows, tuffs) and sedimentary rocks (sandstones, shales, conglomerates) metamorphosed to greenschist facies. The regional structural framework is dominated by NE-SW-trending shear zones, characteristic of the Eburnean orogeny, which control hydrothermal fluid circulation and the emplacement of gold deposits [1, 6].

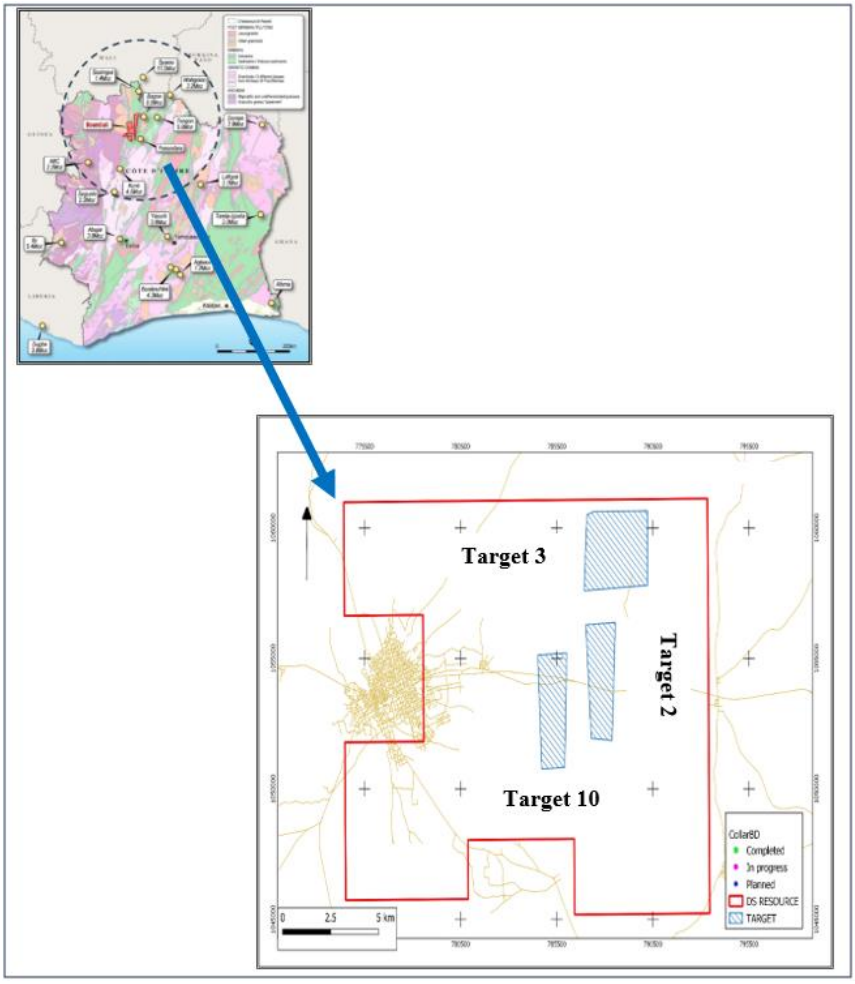

Figure 1. *Location of the Boundiali permit.*

3. Methodology

The main dataset for this study consists of drill cores obtained through diamond drilling (DD), which served as the reference material for all analyses and interpretations (Figure 2).

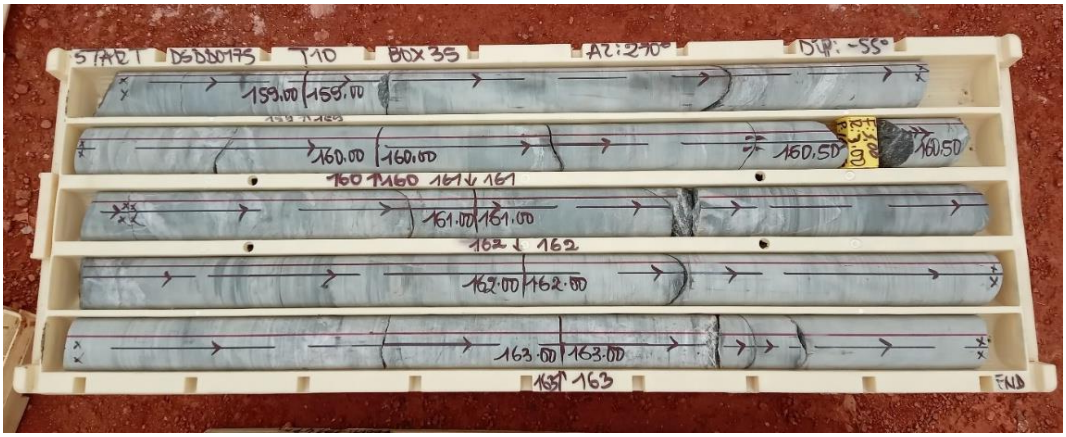

Figure 2. *Drill cores obtained from a DD hole.*

Three priority targets (Targets 2, 3, and 10) were selected within the YAS permit at Boundiali due to their gold potential and the presence of representative volcano-sedimentary outcrops. Outcrops and drill cores were systematically observed and logged, recording lithology, grain size, textures, structures, and visible signs of hydrothermal alteration. Representative samples were prepared as thin sections for petrographic analysis, allowing the identification of mineralogy, textures, and alteration phases (silicification, chloritization, carbonatation, and potassic alteration). Thin section preparation and analysis were carried out at the Laboratory of the Earth Sciences and Mineral Resources Training and Research Unit (UFR STRM) at Felix Houphouët Boigny University (U-FHB), Cocody.

Field and core data were integrated into a GIS to produce a detailed lithostratigraphic map highlighting altered zones as indicators of mineralization. Correlating lithofacies and alteration signatures with sulfide minerals (pyrite, pyrrhotite, arsenopyrite, chalcopyrite) allowed for the assessment of gold potential and prioritization of targets for future exploration.

4. Results

4.1. Lithology, Mineralogy, and Alteration of Targets 2, 3, and 10

Lithostratigraphic and petrographic analyses of the drill holes targeting Targets 2, 3, and 10 allowed for a detailed characterization of lithological facies, sulfide assemblages, and hydrothermal alterations. Detailed observations for each target are presented below.

4.1.1 Target 2

(i). Lithology

The drill hole at Target 2 is dominated by a heterogeneous sedimentary sequence, primarily composed of siltstones and sandstones, interbedded with shales, including characteristic black and graphitic facies (Figure 3). Quartzite layers and graphitic schists indicate variable depositional environments and evidence of hydrothermal/metamorphic influence. Minor lithologies include sericitic schists and a mafic volcanic breccia. Granodiorite intrusions and brecciated zones suggest significant local tectonic activity.

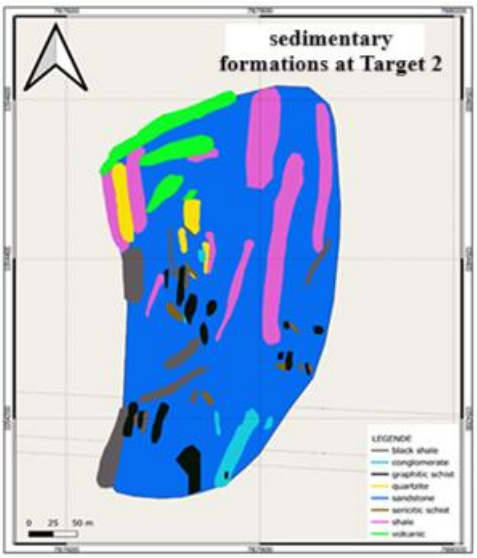

Figure 3. *Lithological map of the sedimentary formations at Target 2.*

(ii). Sulfide Mineralization and Hydrothermal Alteration

Sulfide mineralization is ubiquitous and structurally significant within Target 2. Pyrite (FeS_2) dominates, occurring mainly as disseminated grains but locally as massive and cubic crystals. Arsenopyrite (FeAsS) and pyrrhotite ($Fe_{1-x}S$) are locally concentrated in massive aggregates, while chalcopyrite ($CuFeS_2$) is subordinate. In foliated units, pyrite aligns along foliation planes and displays deformation, suggesting a tectono-hydrothermal influence on the emplacement or remobilization of mineralization.

The host rocks exhibit a complex hydrothermal assemblage characterized by intense and pervasive silicification, moderate potassic alteration, variable chloritization, localized carbonatation, and strong graphitic alteration in black shales.

Overall, Target 2 represents a diverse sedimentary sequence impregnated with intense sulfide mineralization dominated by pyrite, with localized concentrations of arsenopyrite and pyrrhotite. The combination of major hydrothermal alterations and deformed structures indicates sustained hydrothermal activity and significant structural control on the localization of mineralization, preferentially concentrated in sandstones (Figure 4).

These characteristics confirm the high gold potential of this area and provide precise indicators for future exploration campaigns.

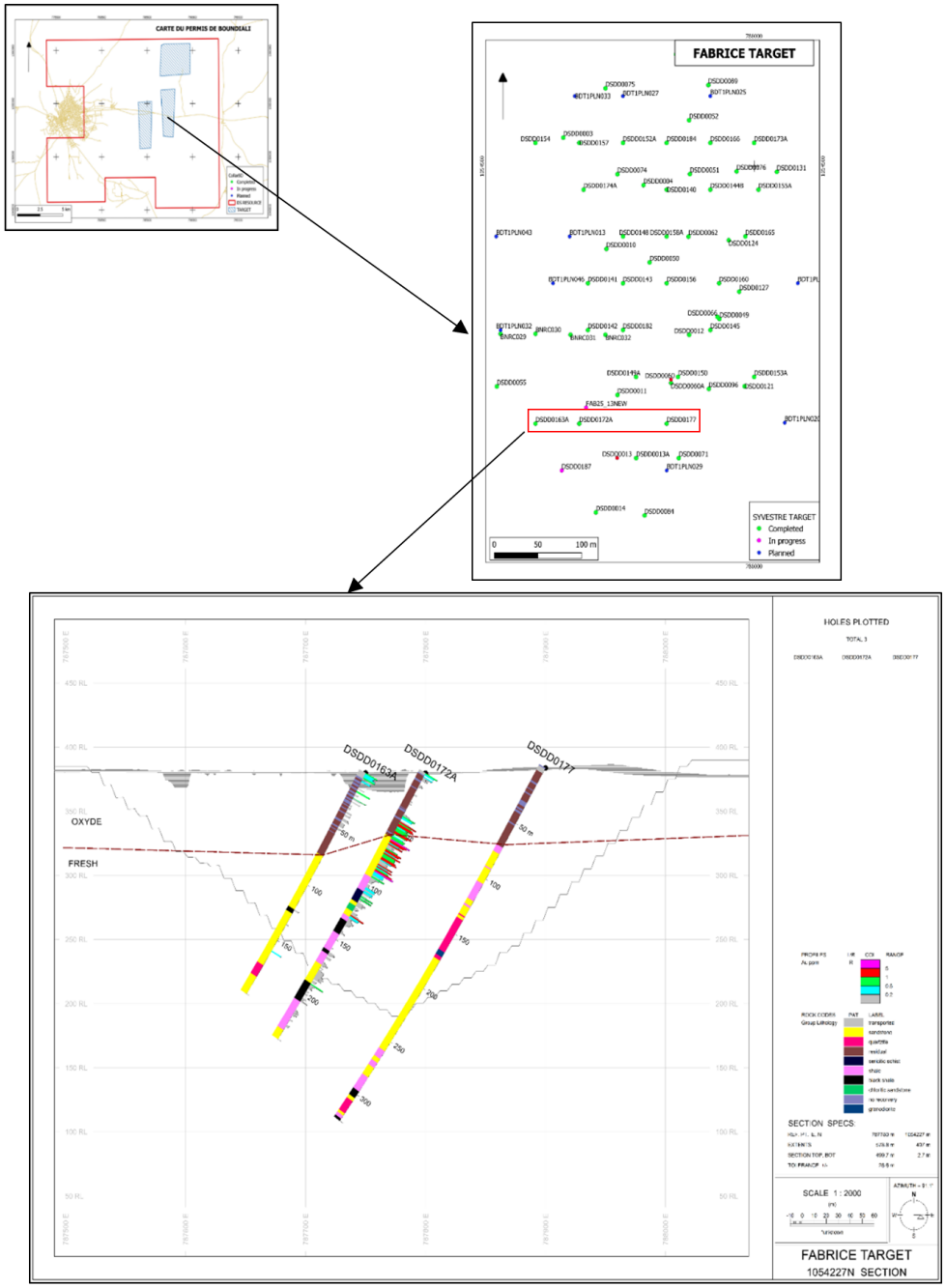

Figure 4. *Lithological section of the mineralized zone at Target 2.*

4.1.2. Target 3

(i). Lithology

Target 3 is dominated by fine- to medium-grained sandstones, interbedded with gray to black shales. Quartzite layers are less frequent but locally well-developed (Figure 5). Minor lithologies include sericitic schists and mafic volcanic intercalations. Tectonic structures such as foliation and zones of brittle deformation are widespread, indicating significant tectono-hydrothermal reorganization.

(ii). Sulfide Mineralization and Hydrothermal Alteration

Pyrite (FeS_2) dominates the sulfide assemblage, occurring mainly as disseminated grains and locally as massive accumulations. Arsenopyrite (FeAsS) and pyrrhotite ($Fe_{1-x}S$) are present in low to moderate amounts, occasionally forming veined concentrations. Chalcopyrite ($CuFeS_2$) is rare. Sulfides are concentrated along foliation planes and within shear zones, highlighting the structural control on mineralization. Additionally, visible gold ("VG") was specifically observed in drill hole DSDD0063 (Figure 6).

Dominant hydrothermal alterations at Target 3 include silicification, chloritization, and carbonatation, locally associated with potassic feldspathization and epidotization. These assemblages indicate a polyphase hydrothermal system under strong structural control.

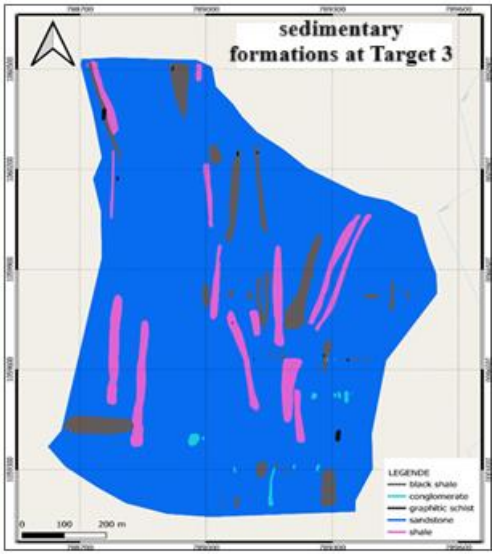

Figure 5. *Lithological map of the sedimentary formations at Target 3.*

Figure 6. *Visible Gold (VG) at Target 3.*

Furthermore, in this target, mineralization is hosted within the sandstones, as illustrated in Figure 7.

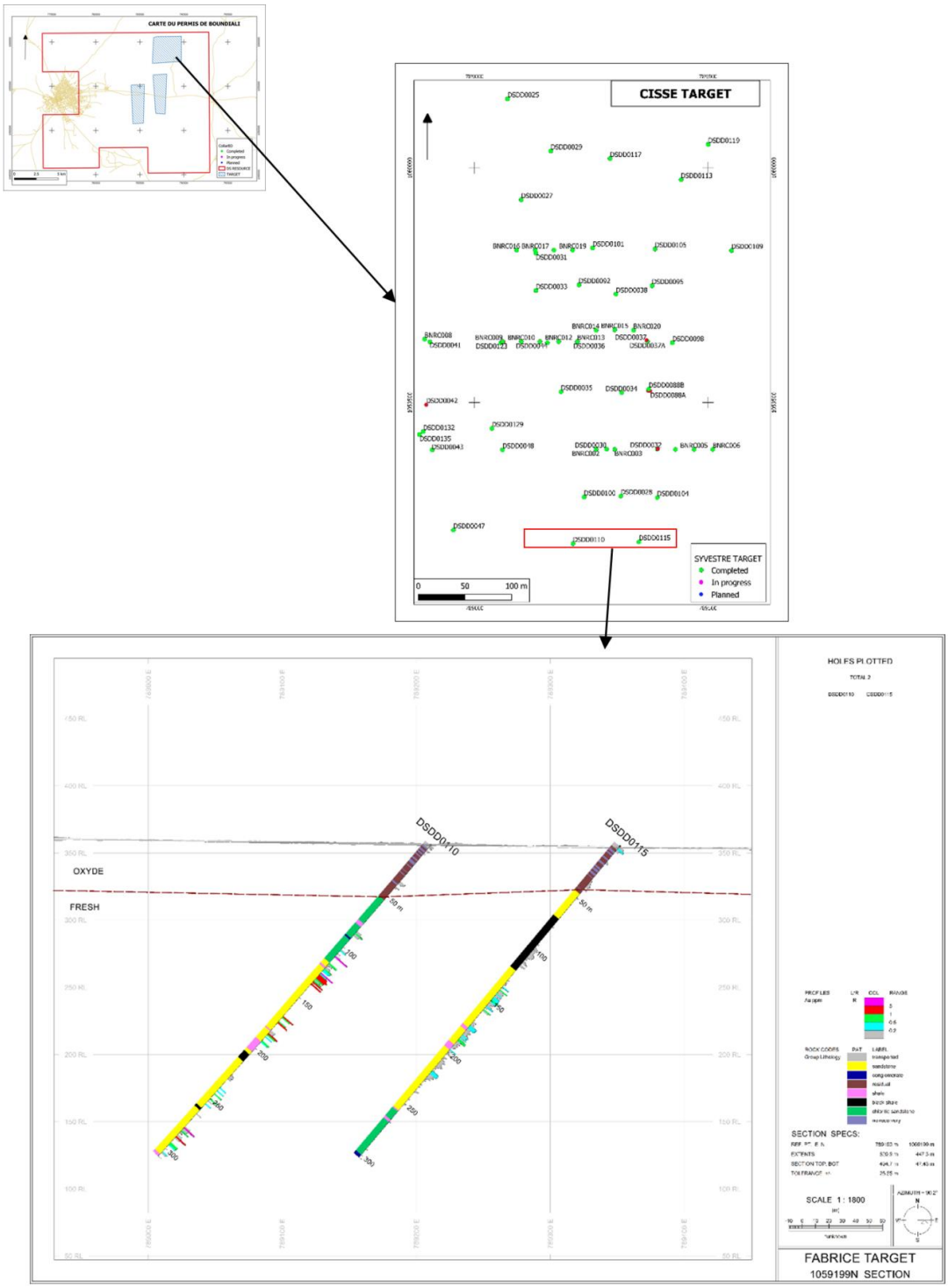

Figure 7. *Lithological section of the mineralized zone at Target 3.*

4.1.3. Target 10

(i). Lithology

Target 10 is composed of interbedded sandstones and shales, with occasional quartzite horizons. The black graphitic shales are predominant and often display fine laminated textures (Figure 8). Mafic volcanic intercalations are less frequent but indicate intermittent volcanic activity during sedimentation. Structural features such as foliation, fractures, and brecciated zones reflect post-depositional tectonic control.

Figure 8. *Lithology of the sedimentary formations at Target 10.*

(ii). Sulfide Mineralization and Hydrothermal Alteration

Pyrite (FeS_2) is the dominant sulphide, occurring both disseminated and locally massive. Arsenopyrite (FeAsS) is sporadic, while pyrrhotite ($Fe_{1-x}S$) forms localized concentrations. Chalcopyrite ($CuFeS_2$) is observed only in trace amounts. The distribution of sulphides is structurally controlled, with concentrations along foliation planes and fractures.

Hydrothermal alteration is characterized by pervasive silicification, weak to moderate potassic alteration, localized chloritization, moderate carbonation, and well-developed graphitic alteration within the black shales.

Drill core data from Target 10 indicate a predominantly arenaceous-pelitic sedimentary sequence (sandstones and shales). This sequence hosts sulphide mineralization dominated by the pyrite-pyrrhotite-arsenopyrite assemblage, which occurs mainly as disseminations but is locally concentrated. The mineralization is closely associated with hydrothermal alteration zones characterized chiefly by silicification, chloritization, and carbonation, whose intensity and extent vary spatially. Subtle alteration phases (hematite, epidote, albite, sericite) reflect the complexity of hydrothermal fluids that circulated through these formations.

At this target, mineralization occurs within the sandstone units, as illustrated in Figure 9.

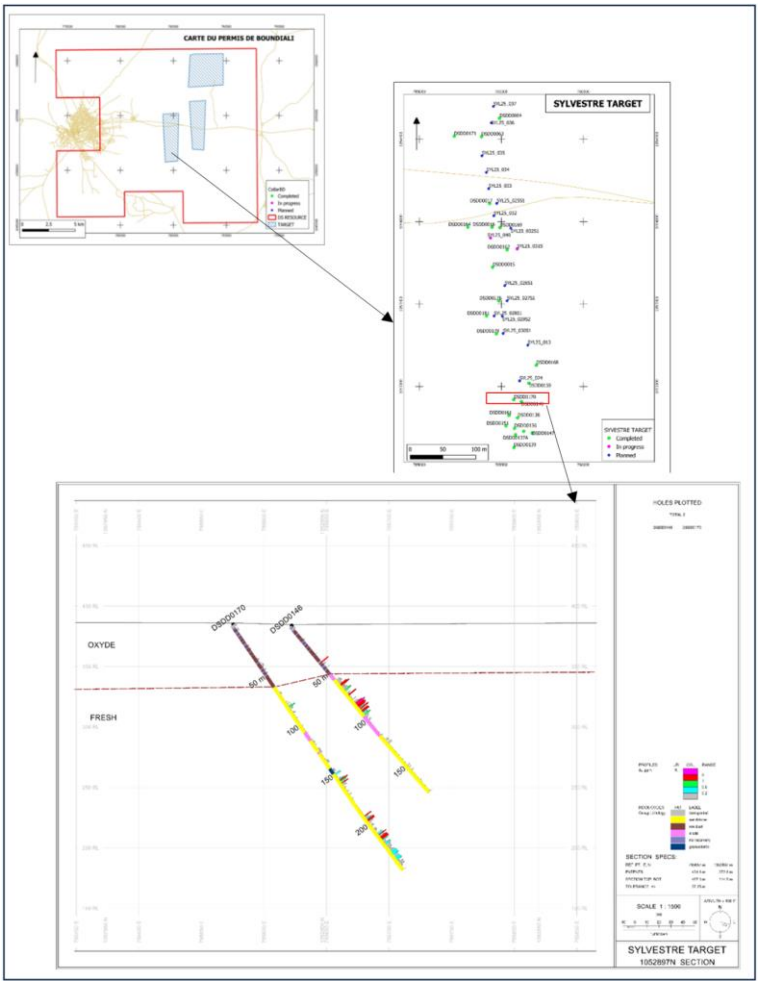

Figure 9. *Lithological section of the mineralized zone at Target 10.*

4.2. Synthesis of Results

This analysis reveals that drill cores from Targets 2, 3, and 10 within the YAS permit area intersect Birimian volcano-sedimentary sequences dominated by sandstones and shales, interbedded with conglomerate and quartzite horizons, and locally intruded by mafic, dioritic, or granodioritic bodies. These sequences exhibit significant grain-size and structural variability, including foliation, fracturing, and brecciated zones, indicative of marked tectono-hydrothermal reorganization.

Sulphide mineralization is ubiquitous and polymetallic across all targets. Pyrite (FeS_2) is the dominant sulphide, accompanied by pyrrhotite ($Fe_{1-x}S$), arsenopyrite (FeAsS), and chalcopyrite ($CuFeS_2$), with occasional occurrences of visible gold (VG). Sulphides occur as disseminations, massive aggregates, or locally concentrated zones, commonly associated with quartz veins, dykes, or stockworks-indicating both lithological and structural control on their distribution. Sulphide abundances vary, with pyrite reaching up to 35% and arsenopyrite up to 15% in some intervals. The sequences display a complex and often overprinted hydrothermal alteration assemblage, characterized by pervasive silicification, widespread chloritization, variable carbonation, and accessory alterations involving epidote, K-feldspar, sericite, albite, and hematite. The spatial variability in alteration intensity and penetration reflects the movement of mineralizing fluids within a structurally controlled network and post-depositional tectonic reactivation. Integration of lithological, mineralogical, and structural data highlights a clear structural control on the localization of mineralization, which is primarily concentrated within fractured or deformed sandstone and shale units. The identified hydrothermal corridors confirm the high gold potential of the YAS permit and provide robust exploration vectors for future targeted drilling.

This synthesis underscores the critical role of lithology-alteration-structure interactions in the formation of Birimian orogenic gold systems in northwestern Côte d'Ivoire.

5. Discussion

5.1. Synthesis and Interpretation of the Main Results

Analysis of drill cores from Targets 2, 3, and 10 reveals that the geological sequences are predominantly sedimentary in origin, mainly composed of sandstones, shales (black and green), and conglomerates. The local presence of quartzites, graphitic schists (Target 2), and sericitic schists (Target 10) reflects variations in depositional environments and subsequent hydrothermal and metamorphic overprints. This lithological composition closely resembles that of other Birimian belts, such as the Ashanti Belt in Ghana, where sedimentary formations also play a key role as hosts for gold mineralization [7].

The mineralized assemblage is typically polymetallic, dominated by pyrite, pyrrhotite, and arsenopyrite, with subordinate chalcopyrite. Pyrite generally occurs as disseminations, while arsenopyrite and pyrrhotite may form massive concentrations. The occurrence of visible gold (VG) in drill hole DSDD0063 at Target 3, associated with quartz veinlets within sandstone, provides direct evidence of local gold potential.

Hydrothermal alterations are both intense and multiphase, dominated by pervasive silicification, chloritization, carbonation, and potassic alteration (K-feldspar or sericitization), complemented by graphitic alteration in the black shales and graphitic schists of Target 2. Accessory minerals such as epidote, albite, and bornite (notably at Target 10) indicate the complexity of hydrothermal fluid evolution. The presence of faults, brecciated zones, and deformed sulphides further suggests a strong structural control on mineralization localization.

These observations collectively support the interpretation of a sedimentary basin affected by major hydrothermal events that facilitated metal mobilization and concentration, particularly gold. The combination of diagnostic sulphide assemblages (frequent arsenopyrite) and characteristic alteration types (silicification, potassic, and carbonate alteration) is consistent with classical orogenic gold systems described throughout the Birimian belts of West Africa.

5.2. Scientific Contribution and Regional Context

his study enhances the geological understanding of the Boundiali sector within the Bagoue Basin by providing a detailed local-scale description of the lithologies, mineralogy, and hydrothermal alterations. The identified sedimentary sequences fit within the broader framework of the Birimian formations [8, 9], where the alternation of volcanic and sedimentary deposits is well documented.

The emphasis on sedimentary units-particularly the black shales and graphitic schists observed in Target 2-is of special significance for gold exploration, as these facies can act as chemical traps that promote gold precipitation [10]. The occurrence of visible gold associated with a sulphide assemblage dominated by pyrite, pyrrhotite, and arsenopyrite (± chalcopyrite) is consistent with the characteristics of orogenic gold deposits within the West African Craton [11, 12].

The hydrothermal alteration patterns, especially pervasive silicification, sericitization, and potassic alteration, confirm the involvement of SiO_2 - and K-rich fluids similar to those documented in major Birimian gold systems [1, 11]. The presence of quartz stockworks and veinlets (Target 3) represents a key exploration guide for identifying structurally controlled auriferous zones.

5.3. Correlation with Previous Studies and Interpretation of Discrepancies

he results are generally consistent with established knowledge of Ivorian and West African Birimian geology, including NNE-SSW to NE-SW structural orientations, regional metamorphism (green schist facies), and structural control of gold mineralization [1, 5]. These structures are comparable to those observed in orogenic gold systems within the Birimian of Mali and Burkina Faso [6]. Our observations complement the foundational work of [13] on the Birimian troughs and [4] on volcanic and sedimentary units in the Bagoue Basin. Local descriptions, such as the mafic volcanic-sedimentary breccia (DSDD0141, Target 2) or the residual saprock sandstone (DSDD0065, Target 3), provide additional nuance, particularly regarding volcanic material resedimentation or specific tectono-sedimentary events.

A notable difference from some regional studies is the predominance of sedimentary rocks in the investigated targets, whereas the literature often emphasizes the volcanic component of the Birimian belts. This local lithological heterogeneity highlights the importance of sedimentary units as potential hosts for gold mineralization and underscores the need to consider their role in future exploration campaigns.

6. Conclusion

Integrated analysis of drill cores from the YAS permit area in Boundiali highlights a lithological assemblage dominated by sedimentary formations (sandstones, shales, conglomerates) enriched in graphitic and sericitic zones and affected by multiphase hydrothermal alteration (silicification, chloritization, carbonation, potassic alteration). The systematic association of pyrite, pyrrhotite, arsenopyrite, and chalcopyrite, combined with the occurrence of visible gold in Target 3, indicates a typical orogenic gold system controlled by structure and SiO_2-K-rich hydrothermal fluids, comparable to models described in the Birimian belts of Ghana and Mali.

These results emphasize the major role of Birimian sedimentary units as potential hosts for gold mineralization and reinforce the prospective potential of the Bagoue Basin, paving the way for targeted studies on the chronology, sulphide geochemistry, and three-dimensional structural modeling of the area.

Abbreviations

VG	Visible Gold
U-FHB	Felix Houphouët Boigny University
UFR STRM	Earth Sciences and Mineral Resources Training and Research Unit
DD	Diamond Drilling

Acknowledgments

The authors would like to thank the “DS Ressources” for authorizing access to the Boundiali site.

Author Contributions

Ronald Sosthene DesireYapi Atto: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing

Yaya Ouattara: Conceptualization, Data curation, Funding acquisition, Investigation, Project administration, Resources, Supervision

Chiaye Larissa Koffi epse Coulibaly: Formal Analysis, Methodology, Resources, Software, Visualization

Sylvain Monde: Data curation, Formal Analysis, Investigation, Methodology, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Feybesse, J. L., Beziat, D., Lahondere, D., Milesi, J. P., Vinchon, C., Castaing, J. Y., Tegyey, M., & Triboulet, C. (2006). Geology of West and Central Africa. Paris: French Geological Survey (BRGM).

[2] Kouakou, Y. K. N., Yao, G. F., Nangah, K. Y., Guety, T. P., & Yao-Kouame, A. (2022). Geochemical characteristics of volcanic host rocks of gold and sulphide mineralization at Mangodara in the Paleoproterozoic greenstone belts of Banfora, southern Burkina Faso (West African Craton). In JSDC-6 - Abstract book, PTR Mines, Petroleum, Water and Soil (p. 37). CAMES. Available online: jsdc. cames. online.

[3] Konan, R. A., Kouame, S., N'Guessan, Y. E., & Brantson, E. T. (2024). Mapping of deep geological formations within the Akakro locality, Toumodi region, Central Côte d'Ivoire - West Africa. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.4885210

[4] Pouclet, A., Kouamelan, A. N., Djemai, S., Doumbia, S., & Vidal, M. (2006). Review of the Palaeoproterozoic (Birimian) volcanism in central Ivory Coast (West Africa) and its geodynamic implications. Journal of African Earth Sciences, 44(3), 379-406.

[5] Egal, E., Coffi, K. E., Giresse, P., KOFFI, G. J., Osse, M. A., & Konan, G. (2002). The Paleoproterozoic (Birimian) of southwestern Côte d'Ivoire (western Africa): geology and U Pb geochronology from new mapped region. Journal of African Earth Sciences, 35(2), 167-180.

[6] Baratoux, L., Metelka, V., Naba, S., Jessell, M. W., Gregory, M., & Ganne, J. (2011). Juvenile Paleoproterozoic crust evolution in the southern West African Craton: The Boromo-Goren greenstone belt, Burkina Faso. Precambrian Research, 191(1-2), 18-45.

[7] Oberthür, T., et al. (1996). Gold mineralization in the Ashanti Belt (Ghana): genetic constraints from alteration assemblages and ore paragenesis. Economic Geology, 91, 289-312.

[8] Lüdtke, G., Accoley, O. Y., Ahile, K., & Houssou, S. A. (1998). *Explanatory notes of the geological map of Côte d'Ivoire at 1: 200,000, Bondoukou sheet (071).* Directorate of Geology, Abidjan.

[9] Lüdtke, G., Accoley, O. Y., Ahile, K., & Houssou, S. A. (1999). *Explanatory notes of the geological map of Côte d'Ivoire at 1: 200,000, Dabakala sheet (072).* Directorate of Geology, Abidjan.

[10] Phillips, G. N., & Powell, R. (2010). Gold-only deposits and myths: a discussion of LGM and LP orogenic systems. Geoscience Canada, 37(1).

[11] Milési, J. P., Ledru, P., Ankrah, P., Johan, V., Marcoux, E., & Vinchon, C. (1991). The metallogenic relationship between Birimian and Tarkwaian gold deposits in Ghana. *Mineralium Deposita*, *26*(3), 228-238.

[12] Milési, J. P., Feybesse, J. L., Ledru, P., Dommanget, A., Marques, J. C., Vinchon, C., Johan, V., Tegyey, M., Castaing, J. Y., Poujol, M., & Barbey, P. (1992). The Paleoproterozoic of the western margin of the West African craton: a segment of the Amazonian chain individualized by the Eburnean orogeny. *Chroniques de Recherche Minière, [Chronicles of Mining Research] 507*, 3-26.

[13] Tagini, B. (1971). *Structural outline of Côte d'Ivoire: an essay on regional geotectonics.* Doctoral dissertation, University of Lausanne. Rap. Sodemi, Abidjan, 266 pp.