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NEW PETROGRAPHIC DATA FROM THE EASTERN PART OF THE YAOURÉ VOLCANO-PLUTONO-SEDIMENTARY GREENSTONE BELT (CENTRAL CÔTE D'IVOIRE, WEST AFRICA)

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ABSTRACT

ABSTRACT: This petrographic study conducted in the eastern part of the Yaouré trough aims to characterize lithological diversity and to specify the mineralogical and textural features of the geological units. The methodology combines field observations (mapping and macroscopic description of outcrops) with petrographic analyses in thin sections, allowing the identification of mineralogical composition, textures, and alterations. The results reveal a wide variety of volcanic rocks (dacites, basaltic andesites, pillow lavas, pyroclastics), metasedimentary rocks (quartzites, cherts, sandstones, carbonate tuffs, tourmaline bearing chloritoschists, cataclasites), and intrusive rocks (microgranites, granites, gabbros, diorites, granodiorites). Microscopic observations highlight a notable abundance of carbonate phases, associated with chloritization, sericitization, and silicification. These hydrothermal alterations, often linked to episodes of fracturing and fluid circulation, indicate an environment favorable to gold mineralization. The observed lithological organization, marked by effusive and explosive volcanic sequences intruded by late plutonic bodies, fits within the Birimian geological framework. It confirms the inclusion of the studied area in this domain and emphasizes a context conducive to the circulation of mineralizing fluids and the formation of gold deposits.

Keywords: Yaouré Greenstone Belt, Microscopic, Petrographic, Mineralogical, Hydrothermal Alteration, Gold Mineralization.

1 INTRODUCTION

The Man Ridge, derived from the West African Craton, exhibits a geological architecture characterized by the alternation of greenstone belts and volcano sedimentary basins, metamorphosed under greenschist to amphibolite facies and

crosscut by several generations of granitoids [1], [2], [3]. The development of the West African Craton crust occurred in two major stages: the first, of Archean age (3.5 to 2.5 Ga), corresponds to the formation of the Man nucleus; the second, Paleoproterozoic or Birimian (2.2 to 1.6 Ga), resulted from the accretion of island arcs and oceanic plateaus (Hirdes et al., 1996). The organization of Birimian formations at the scale of the craton reflects a complex polycyclic structural evolution [4], [5], [6], closely associated with the Eburnean orogeny.

Within this geodynamic framework, the Yaouré volcano plutono sedimentary trough occupies a particular position in the Ivorian Birimian. Its eastern part is distinguished by a complex lithological architecture, rare outcrops due to vegetation cover and supergene alteration, as well as a high gold potential [7], [8]. Several major lithological units have been described in the western part; however, the eastern part remains poorly documented. The present study aims to fill this gap by providing new data derived from field observations and petrographic analyses under the microscope. It focuses on specifying the nature of the rocks, their mineralogical and textural characteristics, and discussing their implications for regional geological evolution.

2 GEOLOGICAL CONTEXT

Located in the southern part of the Man-Leo Ridge, within the West African Craton, Côte d'Ivoire comprises two major geological units (Fig. 1A). The first and most extensive is the Precambrian crystalline basement, which covers approximately 97.5% of the national territory. The second corresponds to the Meso-Cenozoic coastal sedimentary basin, occupying the remaining 2.5%, and resting unconformably on the Precambrian formations.

The crystalline basement is subdivided into two distinct geochronological domains, separated by the Sassandra Fault [9]: the Kenema-Man domain of Archean age, located in the west, and the Baoulé-Mossi domain of Paleoproterozoic age, located in the east [10], [11], [12]. Between these two domains lies a transitional zone, known as SASCA (Sassandra-Cavally), situated between the Sassandra Fault and longitude 6°W [13].

The Yaouré volcano-plutono-sedimentary trough, located in central Côte d'Ivoire northwest of Yamoussoukro, represents a strategic area of interest for gold exploration. This attractiveness is reinforced by the presence of the Yaouré mine, situated west of the study area. Volcanic, hypovolcanic, and coarse detrital units identified in Yaouré are dated between 2105 ± 4 Ma and 2108 ± 5 Ma, and fall within the Bandaman volcanic cycle, corresponding to the terminal phase of the Eburnean orogeny [14], (Fig. 1B).

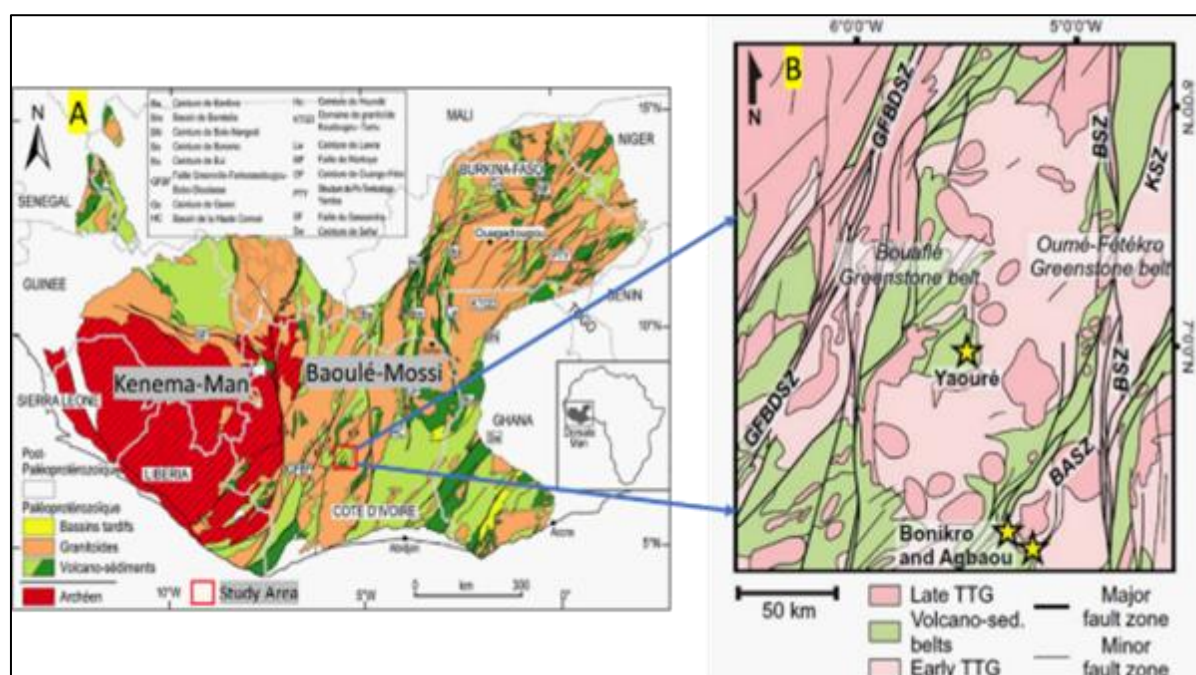


Figure 1: A: Simplified geological map of the Man Ridge (modified from the BRGM SIG Africa map [15], showing the study area (red square). B: Simplified geological map of the Bouaflé belt, highlighting the main fault zones of the region, including: the Grenville-Ferkessédougou-Bobo Dioulasso shear zone (GFBDSZ), the Brobo shear zone (BSZ), the Boni-Andokro shear zone (BASZ), and the Katédougou shear zone (KSZ) [14].

The Bandaman cycle is characterized by the development of bimodal rocks (volcanic and subvolcanic) of juvenile character, associated with coarse sedimentary series deposited in narrow basins controlled by fault structures. This relatively short-lived sequence was emplaced between 2117 and 2080 Ma, in stratigraphic discontinuity with the older Birimian formations [14].

3 MATERIALS AND METHODS

Data acquisition in the study area is primarily based on a petrographic approach combining field observations and laboratory analyses. The fieldwork phase allowed the macroscopic identification of rocks and the collection of key lithological parameters, including color, texture, mineralogical composition, alterations, deformation structures, and the possible presence of sulfides.

The laboratory phase was devoted to refining these observations through petrographic study. For this purpose, thirty-six thin sections were prepared and examined under a SCOPE polarizing microscope at the Laboratory of Geographic Sciences, Civil Engineering and Geosciences (LaSCIG3) of the Institut National Polytechnique HOUPHOUËT-BOIGNY in Yamoussoukro.

4 RESULTS

In the eastern part of the Yaouré trough, the identified units are grouped into two major categories. The first corresponds to magmatic rocks, while the second comprises metamorphic rocks.

4.1 Magmatic rocks

4.1.1 Dyke or Hypovolcanic Rocks

4.1.1.1 Aplite

Aplite is mainly composed of feldspars altered to sericite ($\approx 50\%$), quartz ($\approx 20\%$), muscovite ($\approx 20\%$), and opaque minerals, with disseminated pyrite. It exhibits dominant hydrothermal alteration in silica and sericite, associated with a homogeneous aphanitic texture (Fig. 2A). Microscopic examination reveals a preferential orientation of minerals, indicating moderate deformation. Muscovite occurs as interlaced sheets with quartz and sericite, while quartz, locally altered, forms zones of intense silicification. Finally, biotite, carbonates, and iron oxides complete the assemblage ($\approx 10\%$) (Fig. 2B).

4.1.1.2 Dolerite

Dolerite, of grayish hue, displays a fine-grained to subvolcanic texture typical of hypovolcanic rocks (Fig. 2C). It is mainly composed of pyroxenes and green hornblende ($\approx 50\%$), altered by hydrothermal processes into chlorite, epidote, and biotite ($\approx 25\%$). Secondary carbonates account for about 20%, while opaque minerals (oxides and sulfides, including pyrite) represent 5% (Fig. 2D). This composition reflects a mineralogical evolution strongly influenced by hydrothermal processes.

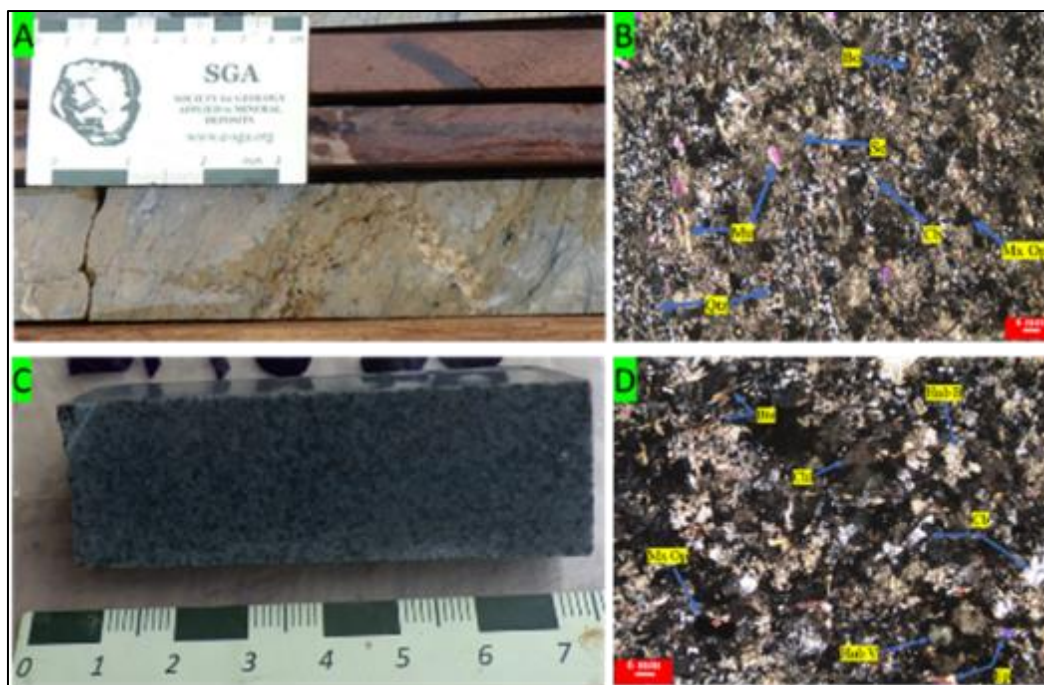


Figure 2: A: Macroscopic aspect of aplite ; B: Microscopic aspect of aplite; C: Macroscopic aspect of dolerite; D: Microscopic aspect of dolerite; Hb V : Green hornblende; Px : Pyroxene; Mu : Muscovite; Qtz: Quartz; Bo : Biotite; Mx Op : Opaque minerals; Chl : Chlorite; Ep : Epidote; Cb : Carbonate; Se : Sericite.

4.1.2 Volcanic rocks

They exhibit a predominantly microlitic texture and are subdivided into two groups: mafic volcanics and more localized felsic volcanics.

4.1.2.1 Felsic Volcanic Rocks

4.1.2.1.1 Dacite

At the macroscopic scale, the rock displays a light-colored matrix traversed by elongated ferromagnesian minerals, imparting a fluidal to sub-porphyritic texture (Fig. 3A). Microscopic analysis reveals a silicified matrix dominated by pyroxene ($\approx 40\%$), accompanied by quartz ($\approx 20\%$), green hornblende ($\approx 20\%$), and muscovite ($\approx 20\%$) (Fig. 3B). The mineralogical features, notably the preferential orientation of hornblende and the presence of recrystallized quartz, indicate advanced hydrothermal alteration.

4.1.2.1.2 Felsic pyroclastics

These leucocratic rocks with porphyritic texture are distinguished by the predominance of large feldspar clasts, associated with chlorite, silica, and minor opaque minerals (Fig. 3C). Their alteration is dominated by sericitization and silicification, with chlorite resulting from the transformation of biotite. Microscopic analysis reveals a composition dominated by plagioclase ($\approx 50\%$), accompanied by sericite ($\approx 20\%$), quartz ($\approx 10\%$), muscovite ($\approx 10\%$), orthoclase ($\approx 5\%$), and opaque minerals ($\approx 5\%$) (Fig. 3D). Altogether, they reflect intense sericitic alteration and localized silicification, characteristic of felsic pyroclastics.

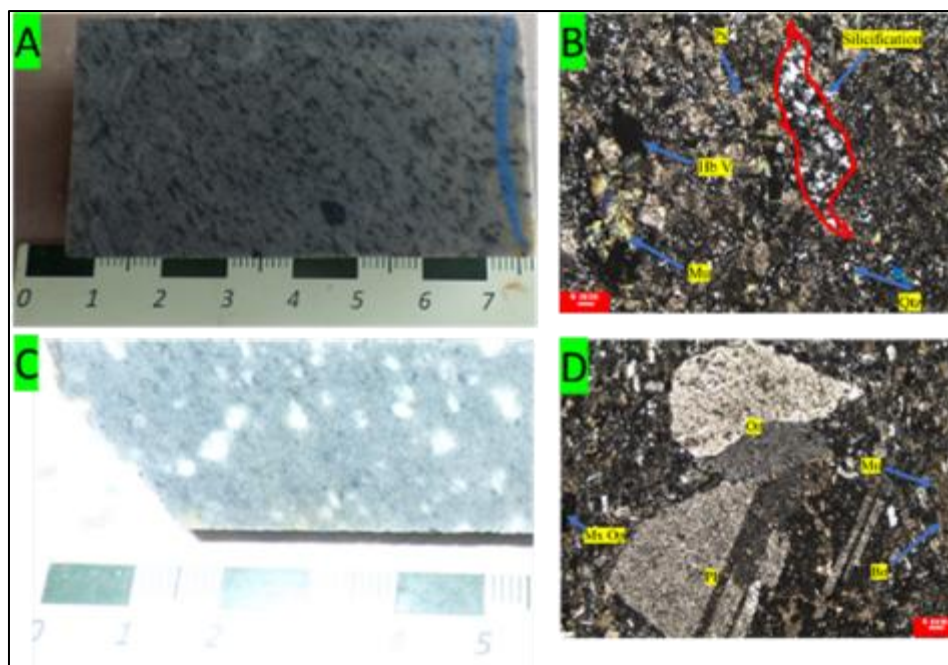


Figure 3: A-B: Macroscopic (A) and microscopic (B) aspects of dacite from eastern Yaouré ; C-D: Macroscopic (C) and microscopic (D) aspects of felsic pyroclastics; Hb V : Green hornblende; Px : Pyroxene; Mu : Muscovite; Qtz ; Quartz; Bo : Biotite ; Mx Op : Opaque minerals; Chl : Chlorite; Ep : Epidote; Cb : Carbonate; Or : Orthose; Pl : Plagioclase; Al : Albite.

4.1.2.1.3 Felsic pillow lavas

Felsic pillow lavas are of rhyolitic to dacitic origin, recognizable by their whitish to orange hue, modulated by alteration of alkali feldspar (Fig. 4). Their hyaloclastite is composed of kaolinite, sericite, carbonates, chlorite, and epidote.



Figure 4: Outcrop of felsic pillow lava of rhyolitic to dacitic origin.

4.1.2.2 Mafic volcanic rocks

4.1.2.2.1 Mafic Pillow Lavas

The observed formations display rounded to ellipsoidal morphologies, visible either as silicified outcrops or as altered rocks rich in clay minerals (Fig. 5A). In thin section, they show an exclusively ferromagnesian composition dominated by pyroxene (50%), followed by amphiboles (25%), carbonates and epidote (20% each), while opaque minerals represent about 5% (Fig. 5B).

4.1.2.2.2 Mafic Pyroclastics

The Yaouré pyroclastics exhibit a gray to green hue, with coarse mafic clasts dominated by hornblende (Fig. 5C). The matrix is rich in carbonates (25%), while green hornblende accounts for about 35% and pyroxenes for 20% of the modal composition. Chlorite (10%) and epidote (10%), derived from the alteration of hornblende and pyroxenes, are also

present (Fig. 5D). The overall mineralogical assemblage reveals strong carbonatization, indicating pronounced hydrothermal alteration in these pyroclastics.

4.1.2.2.3 Basaltic Andesite

The observed basalts predominantly exhibit an aphanitic to microlitic texture, with a few coarse millimetric crystals. The basaltic andesite of Kossou is characterized by a predominance of amphiboles, pyroxenes, and feldspars, accompanied by moderate proportions of carbonates, epidote, chlorite, and opaque minerals (Fig. 5E). Microscopic analysis confirms the dominance of amphiboles ($\approx 35\%$), followed by feldspars ($\approx 30\%$), pyroxenes ($\approx 10\%$), epidote ($\approx 15\%$), and chlorite ($\approx 10\%$) (Fig. 5F). Feldspars show marked alteration, while some older amphiboles, recognizable by their rounded and dark morphology, reflect a complex mineralogical evolution. Overall, the assemblage indicates significant hydrothermal alteration, with secondary formation of epidote and chlorite.

4.1.3 Plutonic Rocks

4.1.3.1 Microgranite

Microgranite displays a mesocratic hue and a porphyritic texture (Fig. 6A). Its composition is dominated by carbonates ($\approx 50\%$) and biotite ($\approx 40\%$), with minor proportions of amphibole and opaque minerals ($\approx 5\%$) (Fig. 6B). The matrix is strongly altered, with quartz crystals often cryptic or masked by carbonate alteration.

4.1.3.2 Granite

Granite occurs as localized intrusions, notably at Alley Yaokro. It is leucocratic with a granular texture, locally porphyritic, composed of quartz, potassium feldspar, plagioclase, and biotite, with traces of muscovite and opaque minerals (Fig. 6C). It is marked by intense potassic alteration, expressed by feldspar recrystallization and the formation of secondary biotite, accompanied by silicification and carbonatization in fractured zones.

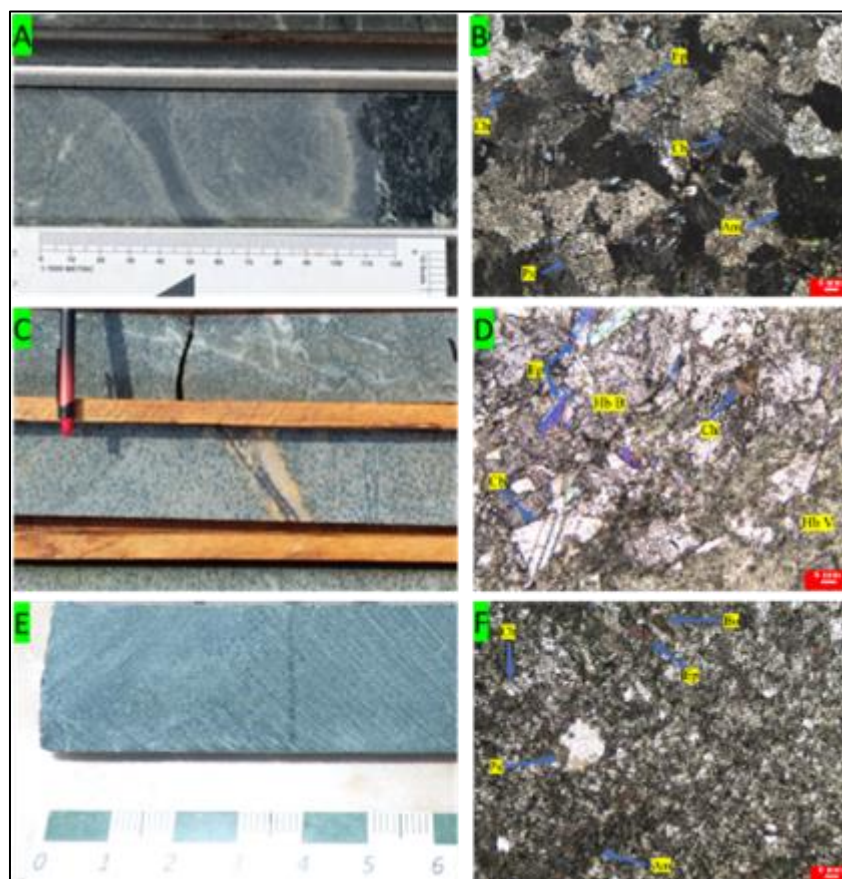


Figure 5: A-B: Pillow lava, macroscopic (A) and microscopic (B) aspects; C-D: Mafic pyroclastics, macroscopic (C) and microscopic (D) aspects; E-F: Basaltic andesite, macroscopic (E) and microscopic (F) aspects; Chl: Chlorite; Ep: Epidote; Px: Pyroxene; Cb: Carbonate; Am: Amphibole; Hb V : Green hornblende; Hb B : Brown Hornblende; Bo : Biotite; Cb : Carbonate.

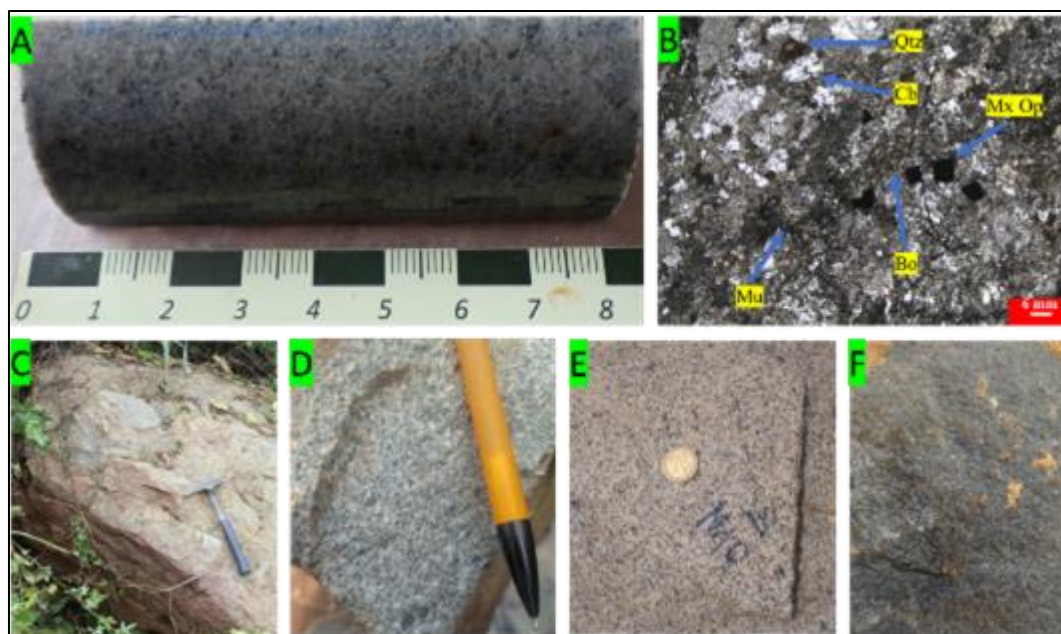


Figure 6: A-B: Macroscopic (A) and microscopic (B) aspects of microgranite; C: Granite; D: Gabbro; E: Granodiorite; F: Diorite; Qtz: Quartz; Cb : Carbonate; Mx Op: Opaque minerals; Mu: Muscovite; Chl: Chlorite; Bo: Biotite.

4.1.3.3 Gabbro

Gabbro, with its coarse-grained texture typical of mafic rocks, is composed of plagioclase, amphibole, and pyroxene. Its color ranges from black to dark green depending on the degree of alteration (Fig. 6D). It is strongly affected by hydrothermal alteration dominated by chloritization, reflecting post-magmatic fluid circulation.

4.1.3.4 Granodiorite

Granodiorite crops out at Toumbokro and south of the Jagger prospect. It is leucocratic with a granular texture, locally porphyritic, dominated by quartz, feldspars, and biotite, with secondary alteration to chlorite. It is crosscut by diorite intrusions and affected by mineral lineations oriented N10° (Fig. 6E).

4.1.3.5 Granodiorite

Diorite, mesocratic with a granular texture, is composed of plagioclase, amphibole, pyroxene, and opaque minerals. It crops out in the Toumbokro area, as enclaves within granodiorites, and is locally associated with sulfide concentrations (Fig. 6D). Its presence is well documented at the surface, although no drill cores have intercepted it.

4.2 Metasedimentary Rocks

4.2.1 Quartzites

Quartzites crop out mainly between Bocabo and Kossou, with a strong concentration at the Road Cut Zone (RCZ) prospect. They are characterized by intense silicification and an abundance of sulfides, dominated by pyrite and locally chalcopyrite. Their grayish to pearly hue is reminiscent of jasperoid quartz.

These formations are crosscut by microfractures partially filled with secondary minerals (biotite, chlorite, tourmaline), indicating post-deformation hydrothermal circulation (Fig. 7A). Microscopic analysis reveals a composition largely dominated by quartz ($\approx 95\%$), occurring as interlobate grains with undulatory extinction. Biotite and opaque minerals (oxides and sulfides) occupy the residual proportion, often associated with microfractures ($\approx 5\%$) (Fig. 7B).

4.2.2 Carbonate Tuffs

Drill cores obtained from the Road Cut Zone (RCZ) prospect intercepted two distinct facies of consolidated tuffs.

4.2.3 Light Orange Felsic Tuff

This tuff facies, with an orange to pinkish hue, exhibits a felsic matrix dominated by carbonates, associated with biotite, quartz, amphibole, and opaque minerals. Alteration is marked by moderate carbonatization and chloritization,

imparting a massive to bedded texture enriched in secondary minerals (Fig. 7C). Microscopic analysis shows a composition dominated by carbonates ($\approx 30\%$) and biotite ($\approx 30\%$), followed by quartz ($\approx 20\%$), amphibole ($\approx 10\%$), and chlorite ($\approx 5\%$), complemented by opaque minerals and muscovite ($\approx 5\%$) (Fig. 7D). Overall, this facies reflects moderate hydrothermal alteration strongly influenced by carbonates.

4.2.4 Brown Tuff with Strong Carbonatation

This tuff facies is characterized by a homogeneous brown hue, reflecting intense hydrothermal alteration dominated by carbonatation. Its mafic-derived matrix contains numerous fragments of opaque minerals, indicating a dark volcanic contribution and sustained post-depositional alteration. It is more uniform and less differentiated than the first facies (Fig. 7E). Microscopic analysis confirms the predominance of carbonates ($\approx 80\%$), associated with modest proportions of chlorite, biotite, and opaque minerals ($\approx 20\%$) (Fig. 7F). These secondary minerals, dispersed within the matrix and often bordering carbonate crystals, reflect complex hydrothermal alteration linked to the circulation of fluid systems enriched in carbonates.

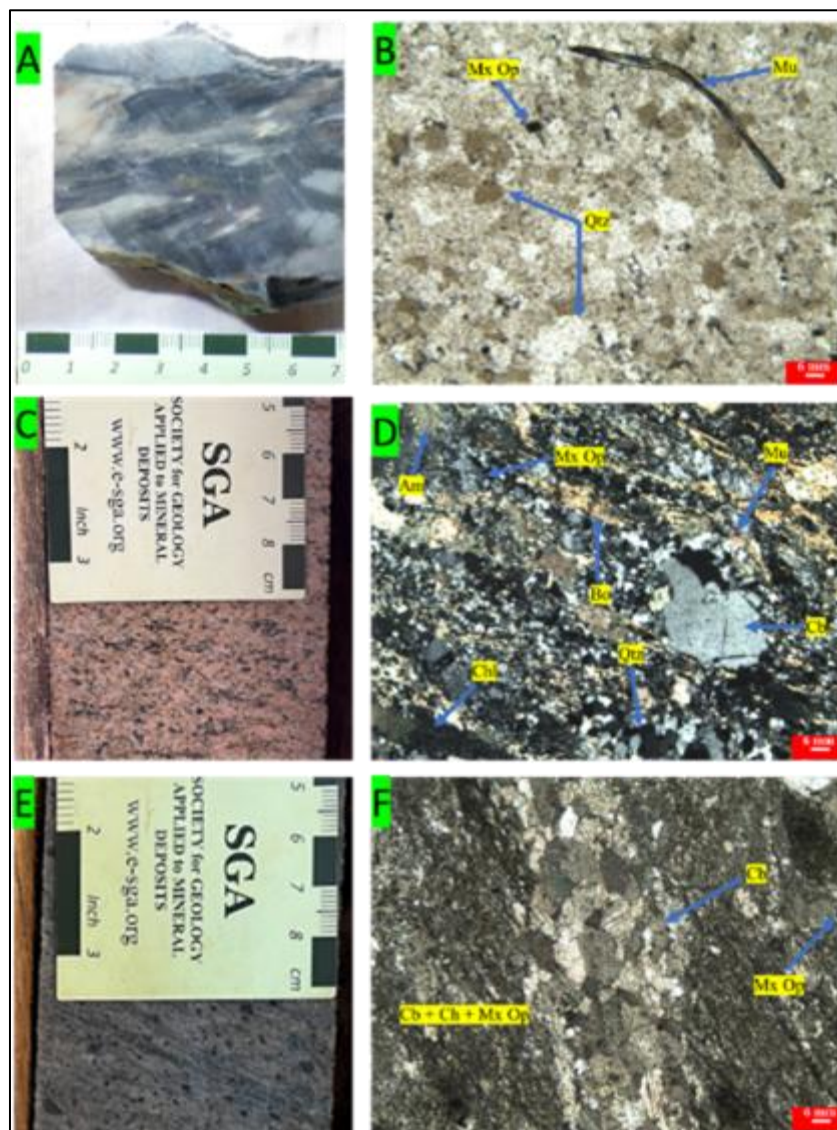


Figure 7: A-B: Macroscopic (A) and microscopic (B) aspects of quartzites; C-D: Macroscopic (C) and microscopic (D) aspects of light orange tuff with felsic matrix; E-F: Macroscopic (E) and microscopic (F) aspects of brown tuff with strong carbonatization; Mu: Muscovite; Qtz: Quartz; Bt: Biotite; Mx Op: Opaque minerals; Ch: Chlorite; Cb: Carbonate; Am: Amphibole.

4.2.5 Tourmaline-bearing chloritoschist

Metamorphosed mafic volcanics exhibit a well-developed foliation and hydrothermal alteration dominated by chlorite, epidote, silica, and locally sericite. The rock shows a banded organization alternating dark and leucocratic minerals, with diffuse carbonatization and the presence of opaque minerals (Fig. 8A). Microscopic analysis reveals a composition

dominated by carbonates ($\approx 40\%$), tourmaline ($\approx 30\%$), chlorite ($\approx 15\%$), quartz ($\approx 10\%$), and biotite ($\approx 5\%$) (Fig. 8B). Overall, this assemblage reflects complex hydrothermal alteration associated with foliated structuring

4.2.6 Cataclasite

Formed through intense fracturing in shear zones, cataclasite appears with an orange coloration, rich in feldspars, carbonates, and pyrite (Fig. 8C). Microscopically, it is composed mainly of feldspars and carbonates, associated with biotite, chlorite, tourmaline, epidote, and opaque minerals (Fig. 8D). The presence of fractures and carbonate alteration indicates intense brittle deformation and post-deformation hydrothermal circulation.

4.2.7 Sandstones

Sandstones located east of the study area result from the consolidation of quartz grains and sand bound by a clay-siliceous cement. Their color ranges from gray to orange depending on the degree of alteration. They contain pelitic and conglomeratic levels, with stretched and sigmoidal quartz pebbles (Fig. 8E). Microscopically, they are dominated by quartz ($\approx 60\%$), followed by sand ($\approx 25\%$), chlorite ($\approx 10\%$), and opaque minerals ($\approx 5\%$) (Fig. 8F).

4.2.8 Cherts

Cherts from the Kilo zone are characterized by a compact and homogeneous texture, composed of microcrystals of quartz and tourmaline with gray, brown, or black hues. Alteration is dominated by silica, tourmaline, and carbonates, with traces of hematite and limonite in the most altered sections (Fig. 8G).

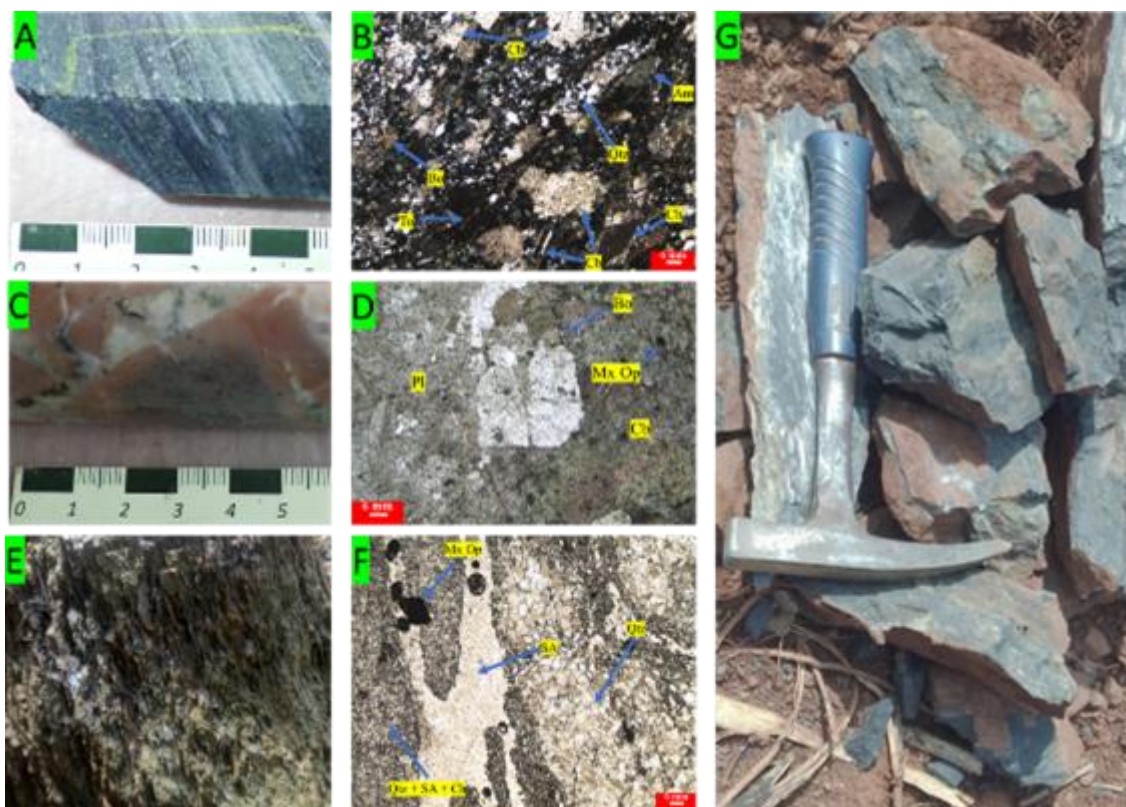


Figure 8: A-B: Macroscopic (A) and microscopic (B) aspects of chlorite schists; C-D: Macroscopic (C) and microscopic (D) aspects of cataclasite; E-F: Macroscopic (E) and microscopic (F) aspects of sandstone; G: Aspect of cherts observed at the Kilo prospect; Qtz: Quartz; Bo: Biotite; Ch: Chlorite; Am: Amphibole; To: Tourmaline; Mx Op: Opaque minerals; Cb: Carbonate; Pl : Plagioclase; SA : Sand

5 DISCUSSION OF RESULTS

Observations conducted in the eastern part of the Yaouré trough highlight a clear predominance of volcanic rocks (dacites, pillow lavas, pyroclastics, basaltic andesites), complemented by metasedimentary formations (quartzites, cherts, sandstones, carbonate tuffs, tourmaline-bearing chloritoschists, cataclasites). These units are intruded by a variety of hypovolcanic and plutonic bodies (aplites, dolerites, microgranites, granites, gabbros, diorites, granodiorites), reflecting a complex magmatic evolution.

This lithological organization is fully consistent with previous studies. According to [16], [17] Fabre (1984), the stratigraphy of the Yaouré complex is structured around migmatitic gneisses, sedimentary and volcanic sequences with basaltic pillow lavas, intruded by gabbros, ultramafics, diorites, rhyolites-dacites, and discordant granites, as well as polygenic conglomerates comparable to Tarkwaian formations in Ghana. Similarly, the authors [14] describe massive and pillow basalts at the Yaouré mine, associated with interstratified black schists, indicative of a deep subaqueous environment, followed by volcanic and sedimentary basins bounded by faults. Finally, the authors [8] identify three major lithological groups magmatic, metamorphic, and volcano-sedimentary also present in our study area.

Our results therefore confirm the presence of these same lithological groups and their regional organization. The abundance of carbonate phases in volcanics and altered units reflects active hydrothermal circulation subsequent to rock emplacement.

6 CONCLUSION

The petrographic study conducted in the eastern part of the Yaouré trough highlights a wide lithological diversity, including volcanic, metasedimentary, and intrusive rocks, reflecting a complex geological evolution. The presence of pyroclastics suggests that volcanism in this sector experienced explosive episodes in addition to effusive manifestations.

Microscopic observations reveal a notable abundance of carbonate phases, associated with chloritization, sericitization, and silicification. These hydrothermal alterations, often linked to episodes of fracturing and fluid circulation, constitute typical markers of environments favorable to gold mineralization.

Ultimately, the combination of mafic volcanics, metasediments, shear zones, and late intrusions creates a geological framework conducive to the circulation of mineralizing fluids and the formation of gold deposits, making the eastern Yaouré trough a zone of high metallogenic potential.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

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