

Typology and petrographic characteristics of Birimian granitoids at the chilled margins of doleritic dykes in the Téra-Ayorou pluton (Liptako, Western Niger)

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World Journal of Advanced Research and Reviews, 2026, 30(02), 957-967

Publication history: Received on 04 April 2026; revised on 10 May 2026; accepted on 13 May 2026

Article DOI: <https://doi.org/10.30574/wjarr.2026.30.2.1316>

Abstract

The doleritic dykes intersecting the granitoids of Ayorou and Kandadji sectors belong to the Birimian domain of the Léo-Man shield (West African Craton). These rocks have been the subject of several studies, but these works have not interested on their characteristics at the contact area with the doleritic dykes. The aim of this work is to determine the typology and petrographic characteristics of the Liptako granitoids at the chilled margins of the doleritic dykes in the Ayorou and Kandadji sectors. The methodology conducted consists of sampling and laboratory works. The typology of granitoids in both sectors consists of locally porphyritic or foliated granodiorites, locally migmatitic or two-mica biotite granite, microdiorite and porphyritic diorites. They have been intersected by quartzo-feldspathic, pegmatitic, aplitic, doleritic veins, and the development of leucosomes and melanosomes at the chilled margins of thick dykes (40-60 m). The foliated granodiorite and two-mica granite are characterized by hydrothermal alteration or low-grade post magmatic metamorphism process; corresponding to hornblende and biotite chloritization and plagioclase sericitization. The relationship between granitoids and the doleritic dykes at their chilled margins is traduced by slightly increase in metamorphic structures and alteration minerals and decrease of crystals size, linked to the emplacement of the doleritic dykes.

Keywords : Typology; Petrography; Doleritic dykes; Chilled margins; Granitoids; Liptako

1. Introduction

Petrographic studies can provide information on the texture, structure and mineralogical composition of rocks. Coupled with geochemical and geochronological studies, they can reveal genetic links between petrographic facies and the geological history of a rock complex. One of the first petrographic studies carried out by [1] provided an inventory of the granitoid generations of the Paleoproterozoic domains of the West African Craton. More specifically, lithological studies conducted on plutons intersecting the greenstone belts of the Niger Liptako have highlighted the close petrogenetic relationships between the TTG series (tonalites, trondhjemites, granodiorites) and the granites, diorites and syenites ([2]; [3]; [4]). Other works have attempted to understand their petrology, structural setting and genesis and magmatic evolution ([5]; [6]; [7]; [8]; [9]; [10]). These authors demonstrated that the Liptako granitoids are made up of a variety of granodiorites, quartzite diorites or tonalites, quartzite syenites, biotite or two-mica granites and pegmatites, variable in structural and geochemical characters and emplaced in arc and subduction zone settings. To follow in the footsteps of these authors, this study attempts to characterize the Liptako granitoids at the margins of doleritic dykes in the Ayorou and Kandadji sectors, using a petrographic approach.

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1.1. Geological setting

The Niger Liptako is located at the northeastern margin of the Léo-Man shield and belongs to the Baoulé-Mossi Paleoproterozoic domain (Figure 1a). The Niger Liptako basement is represented by alternating granitoid plutons and greenstone belts, emplaced during the Eburnean orogeny (2.1-2.0 Ga, [11]; [5]; [12]). The Liptako basement comprises four greenstone belts (Gorouol, Diagorou-Darbani, Sirba and Makalondi) and three granitoid plutons (Téra-Ayorou, Dargol-Gotheye and Torodi, Figure 1b). The basement consist of volcanic rocks (basalts, tuffs, cinerites), metamorphic rocks (amphibolites, pyroxenites, schists) and plutonic (TTGs : granites, syenites, diorites) ([2]; [4]; [13]; [14]; [15]; [16]; [17]; [18]; [19]; [20]; [21]; [7]; [22]; [8]; [9]; [10]; [22]; [23]). Quartz, quartz-feldspath, pegmatite and dolerite veins intersect the greenstone belts and granitoid plutons in various directions ([4]; [5]; [8]; [9]; [10]; [24]).

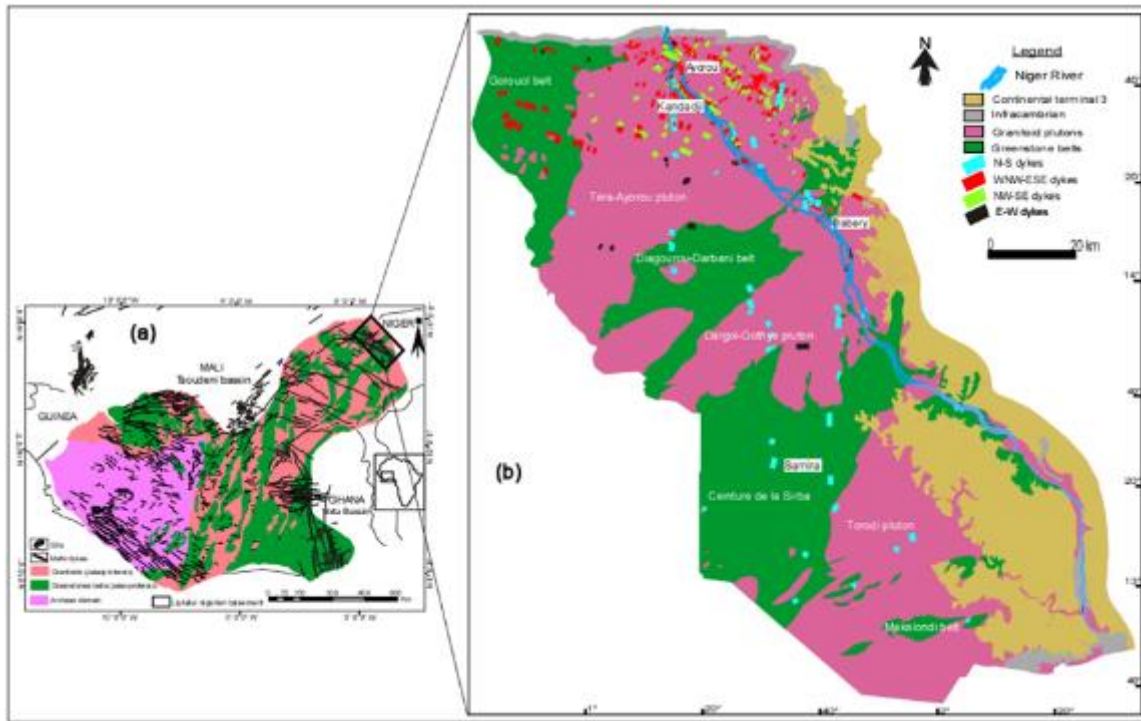


Figure 1 Geological maps of (a) the Léo-Man shield ([1] modified by [26]; [27]) and (b) the Niger Liptako ([2])

The sectors of Ayorou and Kandadji are located at the north of the Téra-Ayorou pluton (Figure 2). The geology of both sectors consists of granodiorites, diorites, syenites, granites, migmatites and quartz, quartz-feldspath, pegmatite ([2]; [4]; [28]; [10]). Granodiorites occupy around 70 % of the granitoid volume in this pluton ([4]). They are characterized by a metamorphic foliation with a circular trajectory at the center of the pluton and a generally NE-SW orientation at its extremities ([4]; [5]; [8]; [9]). Radiometric studies indicated that the granodiorites and diorites of the Téra-Ayorou pluton were emplaced around 2158-2000 Ma ([4]; [29]; [30]; [28]). Post-Eburnean doleritic dykes (1790 Ma, [27] and 1013-896 Ma, [31]) oriented essentially along two subparallel directions WNW-ESE and NW-SE intersect the granitoids of these sectors (Figure 2). WNW-ESE-trending dykes occupy around 80% of the outcropping dykes in both sectors, while NW-SE-trending dykes account for less than 20% ([32]). The dykes of both trends are medium to coarse-grained in the centers and fine-grained at the chilled margins. It indicated a partially preserved subophitic texture and constitute of plagioclase, augite, ferro-edenite, biotite, chlorite, apatite and Fe-Ti oxides ([32]). These dolerites are continental tholeiites and are characterized by a similar affinity to oceanic plateau basalts (OPB), which emplaced in an intraplate setting ([32]). The doleritic dykes of Téra-Ayorou pluton are characterized by brittle tectonic formulated in a phase of deformation and subdivided into two episodes D1 and D2. Episode D1, is compatible with N-S extension whereas episode D2, is associated with a WSW-ESE extension ([33]).

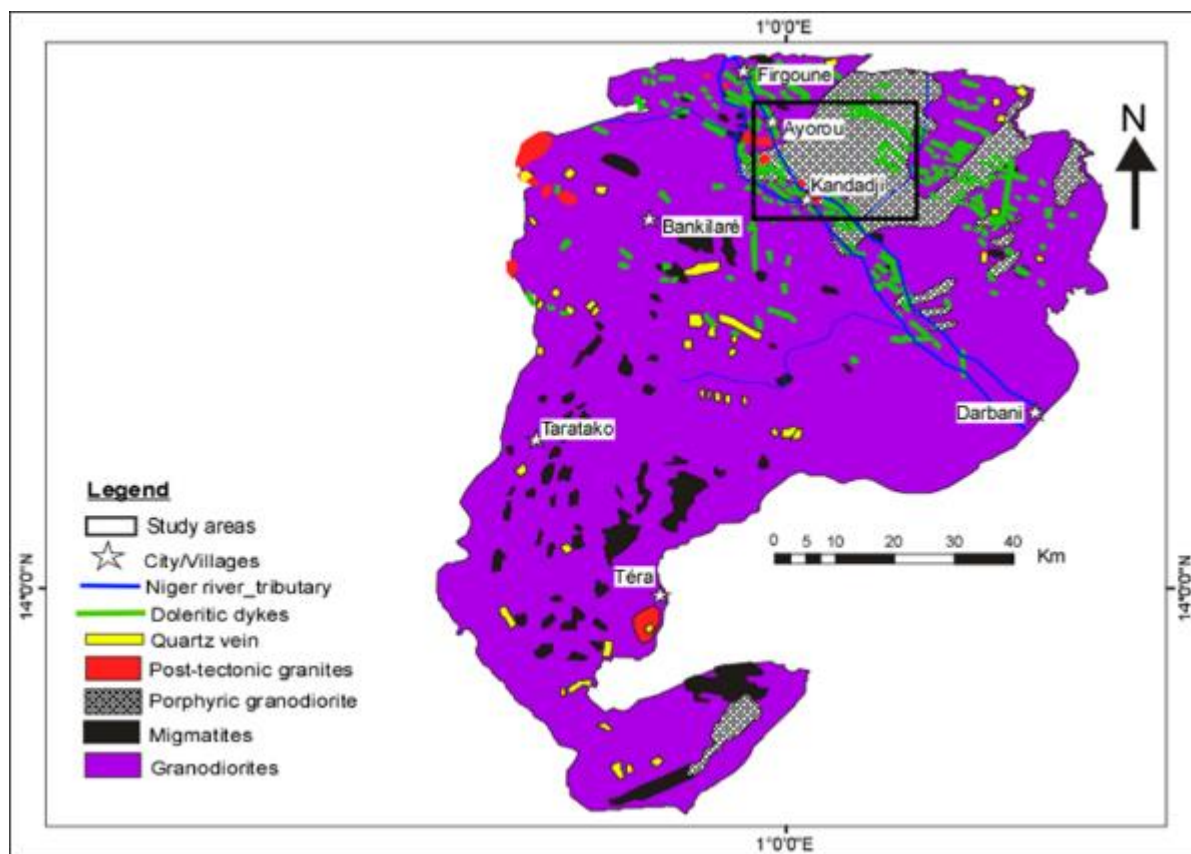


Figure 2 Geological map of the Téra-Ayorou pluton and location of the Ayorou and Kandadji sectors (extract from the geological map of Niger Liptako, [2])

2. Methodology

The methodological approach used in this study consists of sampling in the field and samples processing in the laboratory. Sample collection involved macroscopic description and sampling of granitoid outcrops at doleritic dyke chilled margins. Sampling took into account the thickness of the doleritic dykes and emphasized the fresh, weathered character of the outcrops. In both sectors, over twenty samples were collected. Laboratory processing consisted of twenty thin sections preparation at the *Centre de Recherche Géologique et Minière (CRGM)*, and microscopic observation and description of the thin sections using a LEICA transmitted light polarizing microscope at the *Laboratoire des Eaux Souterraines et Géoressources* of Abdou Moumouni University. Textural, mineralogical and crosscheck relationship analysis of the outcrops and thin sections enabled us to determine the typology and petrographic facies characteristics of the granitoids. We also determine a relative chronology between the types of rocks and the effect of the intrusion of doleritic dyke in the granitoid plutons.

3. Results

Field and laboratory data analysis revealed granitoids at the doleritic dyke margins in both sectors are represented essentially by several granodiorites, granites and diorites. The outcrops of doleritic dykes are observed at the chilled margins (Figure 3a, b, c) in the Kandadji and Ayorou sectors. They are characterized at these parts by a brownish or black tints (Figure 3a, b, c), corresponding to alteration patina of ferromagnesian minerals. Microphotographs of the chilled margins (Figure 3d) indicate doleritic typical textures (fine-grained) and mineralogical composition corresponding to clinopyroxene. The ophitic texture is partially preserved and the crystals are monthly altered. The fine-grained facies at the chilled margins of these doleritic dykes can be explained by the quick magma cooling at the contact of granodiorite.

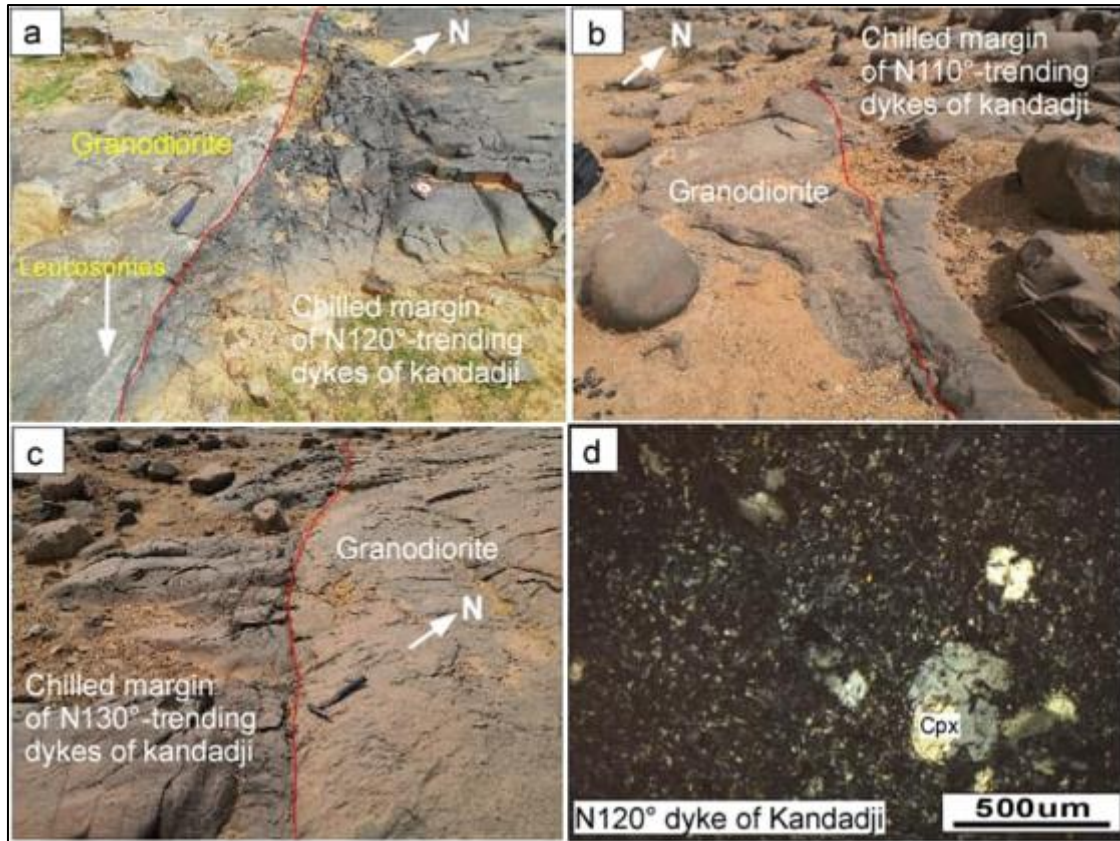


Figure 3 (a, b, c) photographs showing the outcrops of granodiorite at the chilled margins of doleritic dykes in both sectors and (d) microphotographs of chilled margins of N120°-trending dyke of Kandadji. Cpx: clinopyroxene

3.1. 1-Granodiorites

Granodiorites are the most dominant lithology in both sectors. It's observed at the chilled margins of all WNW-ESE and NW-SE-trending doleritic dykes. They have a greenish-grey tint, a medium grained or porphyritic texture and a massive or foliated structure. Medium grained granodiorite is sometime gneissic and frequently foliated, and represents the most common host rock at the chilled margins of the doleritic dykes (Figure 4a, c). The porphyritic granodiorite outcrops in the form of small rounded masses disaggregated. It is characterized by large plagioclase and K-feldspar crystals, and shows no tectonic characters (Figure 4b). Medium grained granodiorite is distinguished by the presence of metamorphic foliation, mineral lineation, fractures with quartzite, quartz-feldspar, pegmatitic and aplitic point-filling, and leucosomes and melanosomes (Figure 4a, d, e, f). Leucosomes and melanosomes are materialized respectively by whitish quartzo-feldspathic pockets and dark pockets of colored minerals (Figure 4a, e, f). The appearance of the porphyritic granodiorite in small outcrops and the presence of ductile structures on the foliated granodiorite indicate that the latter was emplaced before the porphyritic granodiorite.

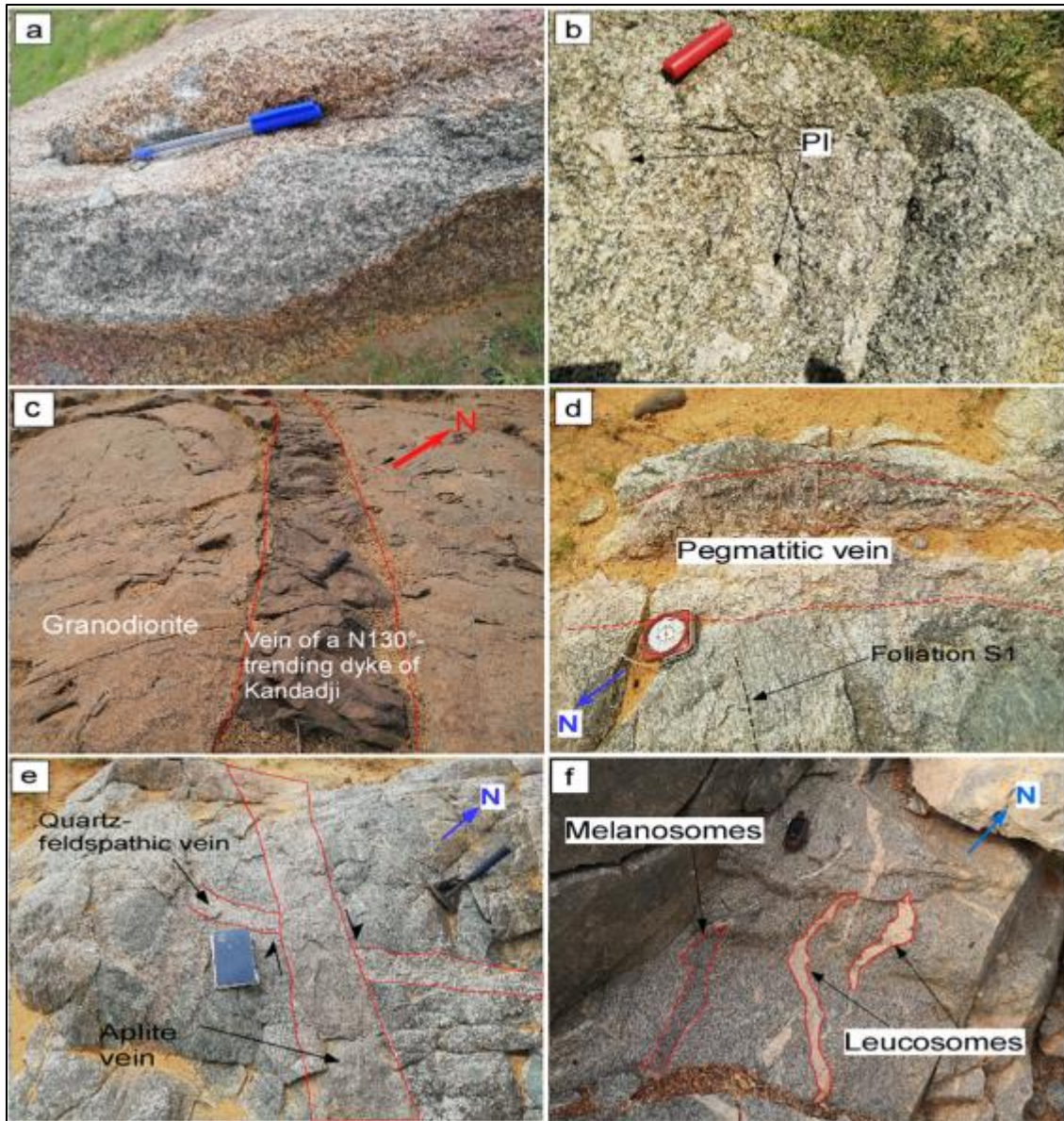


Figure 4 Photographs showing (a) the outcrop of foliated granodiorite at the chilled margin of N120°-trending Kandadji dyke and (b) the outcrop of porphyritic granodiorite at the chilled margin of N130°-trending Ayorou dyke, (c, d, e and f) veins of quartzo-feldspath, pegmatite, dolerite, leucosomes, melanosomes and aplite affecting the foliated granodiorite in both sectors

Microphotographs of both granodiorite types indicate the composition of plagioclase, K-feldspar, biotite, hornblende, quartz, chlorite, zircon, epidote and Fe-Ti oxides (Figure 5). Plagioclase appears as subautomorphic crystals, which are often mottled and most show sharp contours and flake-like spots of sericite within them. Biotite crystals appear as flakes in elongated (Figure 5a) and basal (Figure 5b) sections. Elongated sections transform into chlorite and Fe-Ti oxides. Basal sections show black-tinted globular spots corresponding to Fe-Ti oxides (Figure 5b). Hornblende occurs in elongated greenish sections and transforms into chlorite on the crystal margins (Figure 5a, b, c, d). Quartz indicate small globular crystals in the interstices of plagioclase and K-feldspar crystals (Figure 5a, b). K-feldspar is observed as subautomorphic crystals and locally alters in clay minerals (Figure 5a). The development of sericite on plagioclase laths and the transformation of biotite and hornblende into chlorite are typical of low-grade post magmatic metamorphism process or hydrothermal alteration.

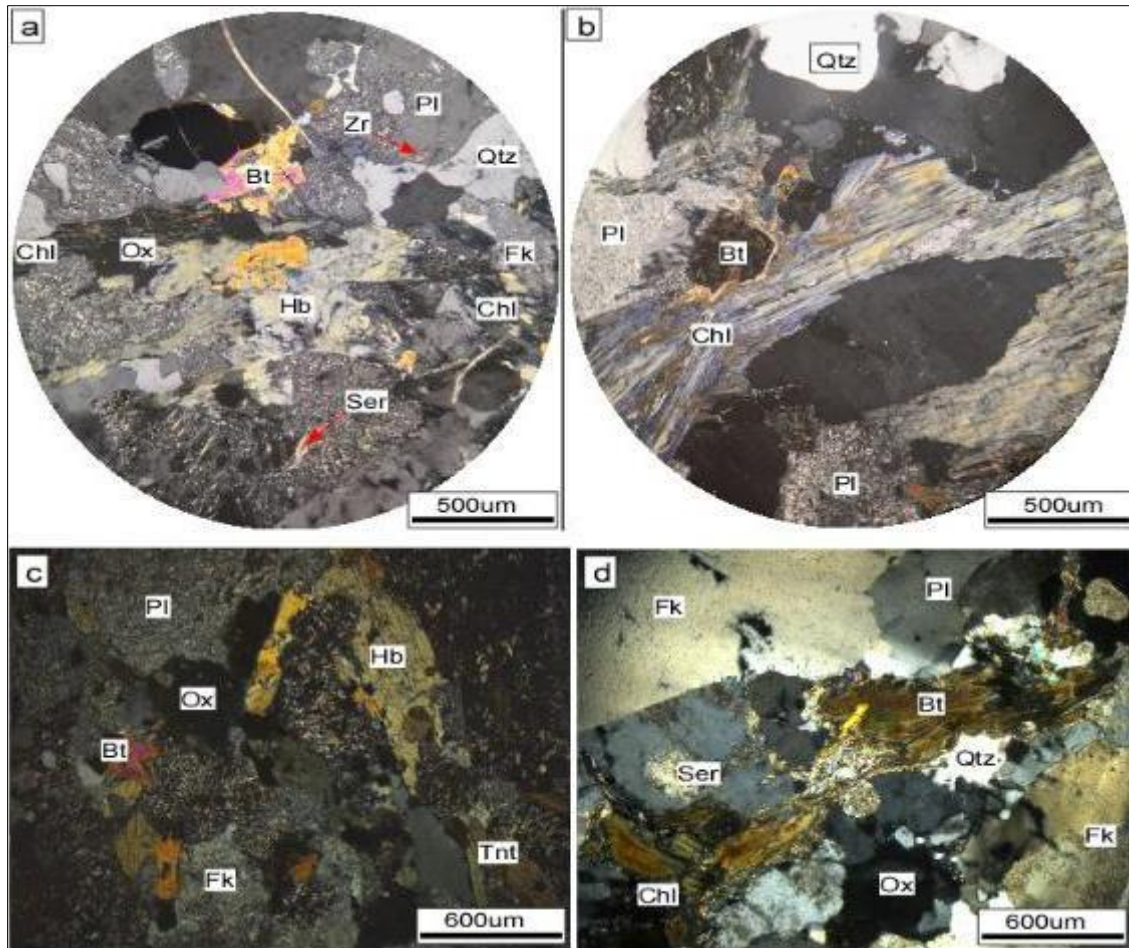


Figure 5 Microphotographs showing the mineralogical compositions of (a, c) foliated granodiorite and (b, d) porphyritic granodiorite. Pl: plagioclase, Hb: hornblende, Bt: biotite, Fk: K-feldspar, Qtz: quartz, Chl: chlorite, Ser: sericite, Zr: Zircon and Ox: Fe-Ti oxides.

3.2. 2-Granites

Granite outcrops were observed at the margin of the N110° and N120°-trending Kandadji dykes and N120° and N130°-trending Ayorou dykes. On the basis of color and mineralogical composition criteria, two types of granite have been identified, namely the grey-tinged, locally migmatitic biotite granite and the whitish-tinged two-mica granite (Figure 6a, b). The biotite granite is observed as massive outcrop or aplite vein in the foliated granodiorite. It is characterized by quartz, quartz-feldspar or pegmatitic veins, biotite enclaves and quartz-feldspar segregation pockets (Figure 6a, b). Two-mica granite has been observed as small size isolated outcrop or as digestion enclaves in Ayorou N110°-trending doleritic dyke (Figure 6b, d), with fractures locally filled by quartz veins.

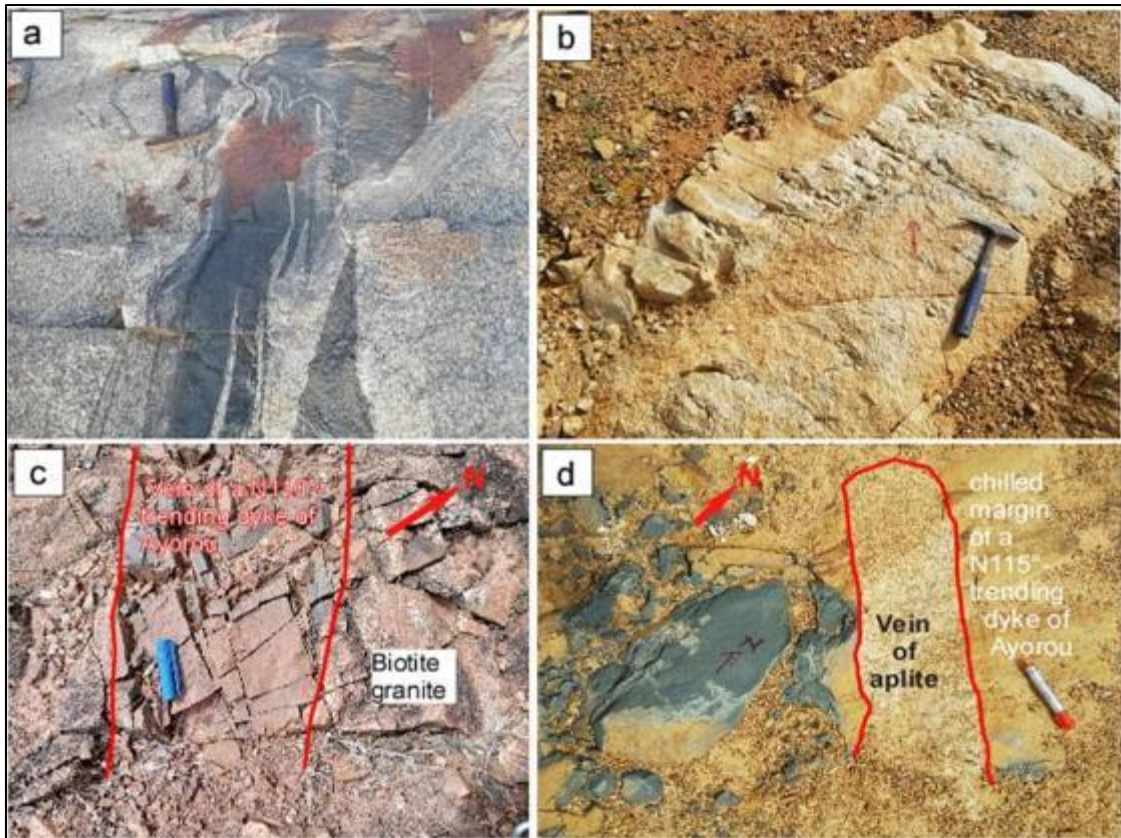


Figure 6 Photographs showing outcrops of (a) migmatitic biotite granite at the margin of a N100°-trending Ayorou dyke and (b) two-mica leucogranite outcrop. In (c) photograph showing the intrusion of a doleritic vein in a biotite granite and (d) leucogranite enclave hosted by the Ayorou N110°-trending doleritic dyke

Microphotographs of biotite and two-mica granite mineralogical composition consists of quartz, K-feldspar, plagioclase, microcline, muscovite, chlorite, biotite, Fe-Ti oxides. The microcline is observed as subautomorphic crystals with periclinic macules in two-mica granite (Figure 7d). K-feldspar and plagioclase occur as subautomorphic crystals with unclear contours. Plagioclase is locally characterized by the polysynthetic macle, but most crystals indicate a development of sericite (Figure 7a, b). Biotite and muscovite show respectively brownish and violet to blue flakes. Biotite flakes have been occupied by Fe-Ti oxide globular, and locally transform into chlorite (Figure 7c).

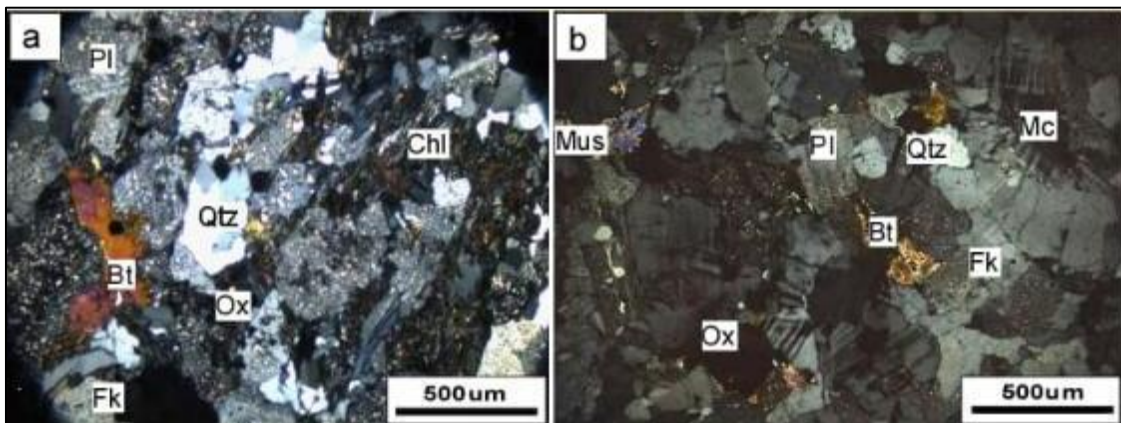


Figure 7 Microphotographs of (a) biotite granite and (b) two-mica granite. **Pl**: plagioclase, **Mc**: microcline, **Bt**: biotite, **Fk**: K-feldspars, **Qtz**: quartz, **Chl**: chlorite, **Mus**: muscovite and **Ox**: Fe-Ti oxides

3.3. 3-Diorites

Diorite outcrops were found in the form of small balls at the chilled margins of N110° and N120°-trending Ayorou doleritic dykes (Figure 8a, b). They were observed in two forms: grey porphyritic diorite with large plagioclase, amphibole and biotite crystals (Figure 8a) and greenish-grey microdiorite (Figure 8b). Microphotographs of the two diorite types reveal plagioclase, biotite, hornblende, K-feldspar, quartz, titanite (sphene) and Fe-Ti oxides (Figure 8a', b'). Plagioclase is characterized by prismatic crystals with polysynthetic macle and sericite development. K-feldspar is characterized by xenomorphic crystals with unclear contours. Titanite shows diamond-shaped, flattened, bright-brown crystals with sharp contours, strong relief and contain small brown rutile inclusions (Figure 8b'). Hornblende occurs as elongated brownish- to greenish-hued crystals, while biotite occurs as fibrous, purplish-hued relict crystals (Figure 8a').



Figure 8 (a and b) Photographs showing (a) porphyritic quartz diorite, (b) quartz microdiorite, and (c and d) Microphotographs showing the mineralogical composition of (c) porphyritic diorite and (d) microdiorite. Pl: plagioclase, Hb: hornblende; Bt: biotite, Qtz: quartz, Fk: K-feldspar, Tnt: titanite, Chl: chlorite and Ox: Fe-Ti oxides

4. Discussion

Petrographic characteristics of granitoids at doleritic dyke chilled margins in the study areas reveal various types of rocks. Several indicators, notably the intrusive nature, the abundance of foliated granodiorite in the study areas, the mineralogical composition and alteration characteristics of the various lithology and the overlapping relationships between the outcrops observed, effectively demonstrate the primitive nature of the foliated granodiorite, representing the host common rock for the other facies described. The typology and petrographic characters are typical of results obtained by many authors in Niger Liptako and the West African Craton.

The results of this study highlighted petrographic facies similar to the granitoid generations described by [1] in the Birimian domains of the West African Craton. They are also in agreement with hypothesis formulated by [4], according to whom intrusions of granite, porphyritic granodiorite and quartz-feldspars, aplite and pegmatite veins intersect the foliated granodiorite of the Niger Liptako. Furthermore, the genetic relationship evoked in [2]; [7]; [10] have demonstrated that the biotite granite of the Niger Liptako originates from the residual magma formed from the foliated granodiorite, corroborates with the hypothesis proposed in this study. Similarly, the nature of these granitoids and their

petrographic characters are similar to those of the Birimian granitoids from Côte d'Ivoire described by [34]; [35] and [36]. The petrographic characteristics of the granitoids of both sectors are also comparable to those of Burkina Faso ([12]; [37]) and Morocco ([38]).

Alteration minerals such as sericite, chlorite, epidote highlighted in granitoids in this work are common to hydrothermal alteration minerals described in the Niger Liptako by [15]; [6]; [10] and in the Baoulé-Mossi domain of the West African Craton ([39]). They are also typical of the low-grade post magmatic metamorphic minerals highlighted in Niger Liptako, by [2]; [3]; [4]; [15]; [19]; [6]; [7]; [10]. The formation of alteration and metamorphic minerals has been associated by these authors to the emplacement of granitoid plutons coupled with NW-SE tectonic compression. In fact that the Ayorou and Kandadji doleritic dykes have been emplaced in intraplate extension setting ([32]), the significant development of these minerals in granitoids at the chilled margins indicate the additive effects of contact metamorphism during the emplacement of doleritic dykes.

5. Conclusion

Petrographic study of the granitoids at the chilled margins of doleritic dykes in the Ayorou and Kandadji sectors show a foliated and porphyritic granodiorites, granites with local migmatitic biotite and two micas, quartz microdiorite and porphyritic diorite. The granitoids of both sectors have petrographic characteristics similar to those of Birimian domains of the West African Craton, but mineralogical composition and degree of alteration are slightly modified by contact metamorphism occurring by the emplacement of doleritic dykes. This is traduced by the increase of alteration minerals (chlorite, epidote, sericite) in the granitoids and decrease of crystals size in the doleritic dykes (fine grained at the chilled margins). This metamorphism effects are also traduced by the minor transformation of foliation into folds, leucosomes and melanosomes, which are common to the Eburnean orogenic event.

Compliance with ethical standards

Acknowledgments

We thank all co-authors and reviewers for their kind edits, which helped to improve the quality of this manuscript.

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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