http://journal.uir.ac.id/index.php/JGEET

E-ISSN : 2541-5794
P-ISSN : 2503-216X

Journal of Geoscience,
Engineering, Environment, and Technology
Vol 7 No 3 2022

RESEARCH ARTICLE

# Petrography and Geochemistry for Proposal of Geodynamic Model For The Irbiben Granite in Tagragra d'Akka inlier, (western Anti-Atlas, Morocco)

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Received: Aug 16, 2022; Accepted: Sep 23, 2022.
DOI: 10.25299/jgeet.2022.7.3.10275

**Abstract**

This study aims to contribute to improve the knowledge on the setting of the Irbiben granites, located south of the gold deposit of this locality (Tagragra d'Akka buttonhole, Anti-Atlas, Morocco). The petrographic characterization showed leucocratic porphyry rocks, with a mineralogy dominated by quartz and phenocrysts of plagioclase, alkali feldspars of sometimes centimetric size as well as very small sulphides of metallic luster. Two generations of quartz have been identified: a $Q_I$quartz with undulating extinction phenocrysts testifying to an episode of deformation orchestrated in this inlier, and a $Q_{II}$ quartz with more rounded and limpid minerals indicating an intense silicification. Plagioclase and alkali feldspars are deeply altered to sericite and epidote. Geochemical characterization classifies these rocks as calc-alkaline series granites, rich in potassium, with a peraluminous character indicating their crustal origin. Their arc geochemical signature, Ba enrichment, and negative Nb, Ti, and P anomalies are characteristic of a subduction zone. This subduction could be associated with an episode of convergence between an oceanic lithosphere located in the north and the West African craton in the south, as shown by the proposed geodynamic model.

**Keywords:** Petro-geochemistry, granite, geodynamic model, Irbiben, Anti-atlas, Morocco

## 1. Introduction

Located north of the West African craton, Morocco shows signs of activity from several geological periods (Mortaji, 1989, Lama et al., 1993, Walsh et al., 2002) manifested by abundant magmatism accompanied by topographic bulges.

The Anti-Atlas, a domain located north of the Reguibat ridge, has several inliers including the Tagragra d'Akka inlier, located in its western part. This Precambrian inlier with Paleoproterozoic basement and Adoudounian cover hosts gold mineralization distributed in several deposits including Irbiben (Zouhair, 1992, Benbrahim, 2005, Boya, 2014). Some granites in the area have been the subject of petrogeochemical studies (Mortaji, 1989) and several subsequent works (Zouhair, 1992, Benbrahim, 2005). However, some results are still debatable, especially the petrogenesis and the source of the magma.

It is with the aim of deepening the knowledge on the Irbiben granite that this study is registered. It consists of a petrographic characterization, to be compared with geochemical data, and then leads to a proposal for a model of setting of these rocks

## 2. Geological setting

Boya's work in 2014 revealed different rock origins in the Irbiben deposit, split into three groups: a magmatic origin, a sedimentary origin, and a metamorphic origin (Fig.1). The magmatic rocks consist of basic dykes, granites and aplites. The dykes are widespread in the deposit, close to the mineralized structures and further in the southern part of the deposit, where they present a contact with a granite. They are generally oriented N40 to N60.

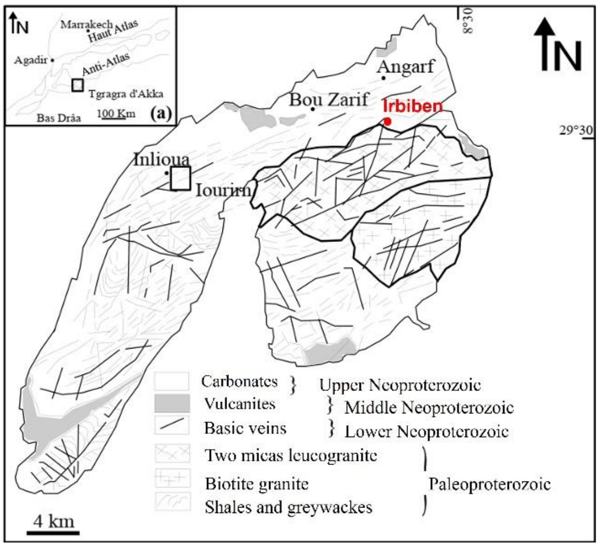


Fig. 1. Location and geological map of the Tagragra d'Akka inlier; (Mortaji 1989, Benbrahim, 2005, modified)

The sedimentary rocks are grauwackes while the metamorphic rocks, initially sedimentary, are composed of metagreywackes, metasandstone and sandstone schists alternating at metric scale with metapelites.

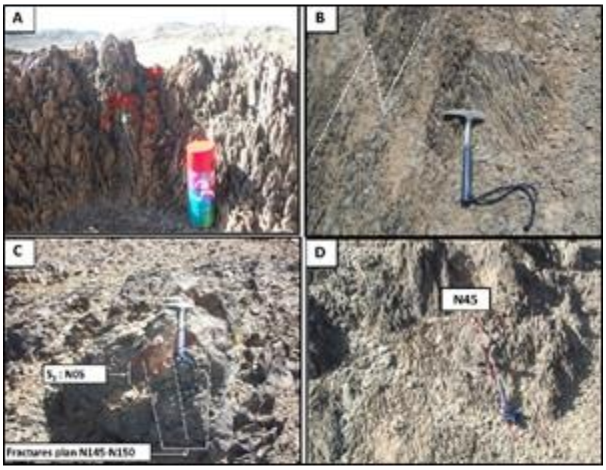


Fig. 2. Schistosities, fracturations and folding in Irbiben gold deposit (Boya, 2014)

The deformation in this area is materialized by several structural markers such as schistosities, folds and fractures, previously dated and attributed to the Eburnian and Pan-African orogenic cycles (Pothérat et al., 1991; Zouhair, 1992). Four families of schistosity have been described in the entire inlier (Hassenforder, 1987; Marignac, 1990; Pothérat et al., 1991; Zouhair, 1992), two of which have been identified at Irbiben, with a third, less likely, designated "F-fracture". The S1 schistosity is penetrative and parallel everywhere to the $S_0$ stratification that it follows, thus forming a $S_0S_1$ factory (Fig. 2A). This factory will be affected by folds giving a Z-shape observable in the area (Fig. 2B). Its direction, identical to that of the stratification, may change from N40 to N65, depending on the intensity of the folding. The $S_2$ schistosity is of fracture type, with average directions from N05 to N30, with a subvertical dip towards the west. It corresponds to the S2 schistosity recognized in the inlier (Zouhair, 1992). It intersects the $S_0S_1$ at a prominent angle (Fig. 2A) and combined with the $S_1$, it is responsible for the frit flow of the shales in the deposit (Boya, 2014). It is affected by some folding (Fig. 2B). It is associated with the major deformation episode D2 dating from the early Pan-African (Zouhair, 1992). F fracturation appears as a network of fractures, with directions between N140 and N170 as shown in figure 2C (Boya, 2014). Fracture schistosity is well developed in some basic dykes. Its direction corresponds to that of the faults recorded in the area, responsible for the dextral movements in the basic dyke. Host and quartz veins are regularly folded in the area, in the form of a Z (Fig. 2B), testifying to a predominantly dextral ductile deformation. The folds observed in the sandstone shales have axial planes with a direction close to N40 to N60 (NE-SW) and vertical axes (Fig. 2D) (Boya, 2014).

Numerous quartz veins, of variable size and type, have also been identified. These are four types of quartz: (i) $Q_1$ smoky quartz, set in the stratification, (ii) grey $Q_2$ quartz (Fig. 3C), which intersects the stratification and some diorite dykes, (iii) grey to smoky grey $Q_3$ quartz, which fills in late veinlets within $Q_2$ quartz or in the metasedimentary host rock, and finally (iv) the later $Q_4$ quartz. The emplacement of the $Q_2$ quartz follows a shearing event associated with a complex deformation event. It is associated with gold mineralization. $Q_3$ quartz also hosts gold mineralization. $Q_4$ quartz is different from the others in that it is lighter in colour and cross-cuts the other pre-existing structures. It is not related to the gold mineralization in the entire inlier.

## 3. Methodology

Thirteen (13) granite samples were collected from the study area, 7 of which were selected for the preparation of 7 thin sections and 6 geochemical analyses on total rock. The thin sections were made in the litholamellage unit of the Geology, Mineral and Energy Resources Laboratory (GRME) of the Félix HOUPHOUET-BOIGNY University. These slides were microscopically characterized using the Optika B-150 microscope, equipped with an image capture device linked to a computer. This characterization allowed the classification of these rocks based on their mineralogy and texture.

The geochemical analyses (major elements, loss on ignition and trace elements) were carried out by mass spectrometry coupled to an inductive plasma (ICP-MS) at the Reminex Research Center of Guemassa in Marrakech. This instrumental technique based on the separation, identification and quantification of the constituent elements of a sample according to their mass is based on the coupling of a plasma torch generating ions and a mass spectrometer that separates these ions in mass. The analytical data were processed using the GCDKit software for plotting and the results allowed the geochemical characterisation of these rocks through their classification, the mobility of their elements as well as their geodynamic context of setting.

Table 1. Proportions (% wt) of oxides in samples

| Samples | $SiO_2$ | $TiO_2$ | $Al_3O_2$ | $Fe_2O_3$ | FeO | MnO | MgO | CaO | $Na_2O$ | $K_2O$ | $P_2O_5$ | PF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GRAN 1 | 75,16 | 0,17 | 13,58 | 0,23 | 2,07 | 0,01 | 0,47 | 1,27 | 1,6 | 4,13 | 0,04 | 1,34 |
| GRAN 3 | 74,13 | 0,18 | 14,09 | 0,22 | 1,96 | 0,01 | 0,43 | 1,46 | 1,67 | 4,62 | 0,03 | 1,3 |
| GRAN 6 | 78,83 | 0,03 | 13,22 | 0,07 | 0,65 | 0,01 | 0,13 | 1,11 | 2,03 | 3,71 | 0,05 | 0,8 |
| GRAN 7 | 74,6 | 0,19 | 14,04 | 0,22 | 1,97 | 0,01 | 0,33 | 1,31 | 0,030 | 4,53 | 0,04 | 1,1 |
| GRAN 12 | 76,39 | 0,03 | 14,15 | 0,07 | 0,59 | 0,01 | 0,18 | 1,77 | 1,49 | 3,91 | 0,04 | 1,4 |
| GRAN 13 | 75,23 | 0,25 | 13,54 | 0,14 | 1,24 | 0,02 | 0,44 | 1,84 | 2,04 | 4,15 | 0,03 | 1,66 |

Table 2. Proportions (ppm) of trace elements in samples

| Samples | As | Pb | Sb | Se | Sn | Sr | W | Y | Zn | Rb | Zr | Ba | Be | Bi | Cd | Co | Cr | Cu | Ge | Li | Mo | Nb | Ni |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GRAN 1 | 44 | 87 | 32 | 40 | 39 | 3 | 23 | 3 | 18 | | | 426 | 0,2 | 20 | 5 | 7 | 56 | 189 | 10 | 15 | 8 | 8 | 17 |
| GRAN 3 | 8 | 66 | 32 | 40 | 45 | 43 | 23 | 4 | 12 | 218,79 | 76,94 | 464 | 0,2 | 20 | 4 | 22 | 43 | 80 | 10 | 15 | 8 | 8 | 17 |
| GRAN 6 | 17 | 74 | 32 | 40 | 20 | 26 | 23 | 3 | 11 | | | 125 | 0,2 | 20 | 4 | 14 | 50 | 66 | 10 | 15 | 8 | 8 | 17 |
| GRAN 7 | 21 | 64 | 32 | 40 | 20 | 59 | 23 | 3 | 4 | 119 | 88,49 | 563 | 0,2 | 20 | 4 | 7 | 56 | 87 | 10 | 15 | 8 | 8 | 17 |
| GRAN 12 | 18 | 64 | 32 | 40 | 37 | 78 | 23 | 3 | 22 | 147,63 | 18,13 | 252 | 0,2 | 20 | 4 | 22 | 49 | 87 | 10 | 15 | 8 | 8 | 17 |
| GRAN 13 | 8 | 53 | 32 | 40 | 35 | 86 | 23 | 4 | 13 | 165,77 | 166,41 | 817 | 0,2 | 20 | 4 | 9 | 55 | 79 | 10 | 15 | 8 | 9 | 17 |

## 4. Results

### 4.1. Petrographic data

In order to highlight the different minerals in samples, this section presents a synthesis of observations. It is composed of microscopic description of two representative samples and of a mineralogical synthesis from all samples observations.

#### 4.1.1 Sample GRAN 3

Massive leucocratic rock with a porphyroid grainy texture, this sample is composed of medium-sized quartz, plagioclase and centimetric automorphic alkali feldspar phenocrysts, metallic luster sulphides and millimetre-sized chlorites (Fig. 3A). Alteration of the alkali feldspars and plagioclases gives the rock a pinkish colour. The glittering of the small sulphide crystals disseminated between the quartz and feldspar grains gives it a more or less brilliant luster. Under the microscope, its mineralogy is dominated by clear minerals such as quartz, plagioclase and alkali feldspars, which make it colourless in natural light. It also contains alteration minerals (sericite, chlorite and epidote) and automorphic opaque minerals (sulphides and oxides).

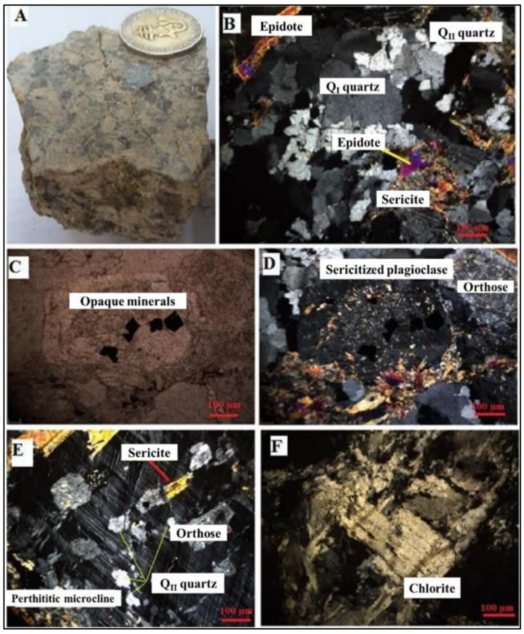


Fig. 3. Macroscopic and microscopic views of sample GRAN 3

Quartz is variable in size, xenomorphic with a light grey polarisation hue. They are the most abundant in the rock. Some are coarse and less clear. However, others often appear as small clear crystals in the other minerals and sometimes form clusters in the interstices. There are thus two generations of quartz (Fig. 3B): coarse $Q_I$ quartz and $Q_{II}$ quartz, generally resulting from recrystallisation, with smaller crystals. Plagioclases, in the form of phenocrysts or sometimes medium-sized crystals, are abundant and deeply altered into sericite and epidote, making their macles difficult to observe. Sericite, an alteration mineral progressively replacing plagioclase and alkali feldspar, is abundant. Colourless in natural light, it has an orange-yellow polarisation (Fig. 3D and 3E). It is generally associated with epidotes, which are bright blue to purplish blue polarization (Fig. 3B). This assemblage sometimes moulds the quartz crystals and occupies almost all the spaces left between the primary minerals. Some chlorites are observed in these rocks. They are subautomorphic, pleochroic with a greenish polarisation showing oxides in their cleavage plane. These come from the alteration of biotites. The rare microcline crystals occur as a coarse beach with numerous inclusions of quartz, plagioclase and orthoses giving it a perthitic appearance (Fig. 3E). Opaque minerals probably representing oxides or sulphides are automorphic (Fig. 3C) and often cluster in places.

#### 4.1.2 Sample Gran 13

If symbols are defined in a nomenclature section, symbols and units should be listed

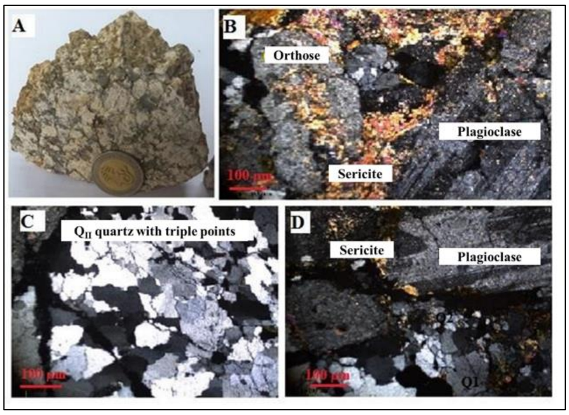


Fig. 4. Macroscopic and microscopic views of sample GRAN 13

Altered granitoid, leucocrate and porphyroid grainy texture, its mineralogy is dominated by coarse grains of quartz, plagioclase and orthose of variable sizes from millimeter to centimeter. Hydrothermalism is very advanced (Fig. 4A). Microscopically, the quartz is coarse and xenomorphic. A parcularity is observed in the arrangement of these quartz, it is the "triple point" (Fig. 4C). This arrangement testifies to the presence of stresses probably generated during the different orogenic cycles that affected the precambrian rocks of the Tagragra d'Akka inlier. Plagioclases are also abundant and occur as automorphic phenocrysts, often with a dirty appearance. This reflects a very advanced sericitisation, materialised by the formation of sericite and an obliteration of the polysynthetic macles of the altered plagioclases (Fig. 4B and 4D). The sericite often forms a brightly coloured assemblage with the epidotes. In addition to plagioclases, some sericites progressively replace the weathering alkali feldspars (Fig. 4B). Some subautomorphic, pleochroic, green to greenish-brown polarising minerals have oxides in their cleavage plane. These are chlorites resulting from the alteration of biotites. The opaque minerals are automorphic and can be assimilated to sulphides and oxides.

### 4.2 Mineralogical synthesis

Tables 3 and 4 below summarize the main microscopic observations. The Irbiben granite is porphyroid, generally with QI quartz, plagioclase and orthose phenocrysts, QII quartz of which constitute the primary minerals. Biotite and/or muscovite are sometimes added to these. Some perthites have been observed. The alteration minerals are generally composed of sericite, generally associated with epidote, and then chlorite. They are respectively derived from the alteration of plagioclase and alkali feldspars and biotite. Table 3 summarizes the petrographic description while Table 4 presents the mineralogical proportions per sample.

Table 3 : Summary description of Irbiben granite samples

| Samples | Aspect | Colour | Texture | Origin | Mineralogy | Metallography |
|---|---|---|---|---|---|---|
| **GRAN 3** | Massive | Leucocrate | Porphyroid grainy | Plutonic | QI and QII quartz, plagioclases, microcline, orthose, sericite, chlorite, epidote | Automorphic sulphides |
| **GRAN 5** | Massive | Leucocrate | Porphyroid grainy | Plutonic | QI and QII quartz, plagioclases and alkali feldspars, sericite, epidote, muscovite, biotite | Automorphic sulphides |
| **GRAN 7** | Massive, low altered | Leucocrate | Grenue porphyroïde | Plutonic | QI and QII quartz, plagioclases, microcline, sericite, epidote, orthose phenocrists, perthite | Automorphic sulphides |
| **GRAN 8** | Massive, low altered | Leucocrate | Grenue porphyroïde | Plutonic | Plagioclases, QI and QII quartz, sericite, epidote, biotite, chlorite, orthose phenocrists, perthite | Automorphic sulphides |
| **GRAN 9** | Massive | Leucocrate | Porphyroid grainy | Plutonic | QI and QII quartz, plagioclases, orthose, sericite, biotite, perthite | Automorphic sulphides |
| **GRAN 12** | Massive | Leucocrate | Porphyry micrograiny | Periplutonic | QI and QII quartz, orthose, plagioclases, sericite, epidote | No sulphide |
| **GRAN 13** | Massive, altered | Leucocrate | Grenue porphyroïde | Plutonic | QI and QII quartz, plagioclase, orthose, séricite, epidote | No sulphide |

Table 4 : Mineralogical proportions of Irbiben granite samples

| Minerals | GRAN 3 | GRAN 5 | GRAN 7 | GRAN 8 | GRAN 9 | GRAN 12 | GRAN 13 |
|---|---|---|---|---|---|---|---|
| QI quartz | + + + + | + + + | + + + | + + + | + + + + | + + | + + + |
| QII quartz | + + + | + + + + | + + + + | + + + | + + + + | + + + + | + + + + |
| Plagioclase | + + + + | + + + | + + + | + + + + | + + + | + + | + + + |
| Orthose | + + | + + | + | + | + + + | + + | + + |
| Microcline | + | | + | | | | |
| Séricite | + + + | + + + | + + + | + + + | + + | + + | + + + |
| Epidote | + + | + + + | + | + + + | | + | + + |
| Chlorite | + | | | + | | | |
| Muscovite | | + + | | | | | |
| Biotite | | + | | + | + + | | |
| Perthite | | | + | + | + | | |
| Sulphide/Oxide | + + | + + | + | + | + | | |

| | |
|---|---|
| + + + + | Very high |
| + + + | High |
| + + | Medium |
| + | Rare |

### 4.2. Geochemical data

#### 4.2.1 General features

The six granite samples studied show almost identical characteristics: high $SiO_2$ content between 74.13 and 78.83 %, high $Al_2O_3$ contents from 13.22 to 14.15 %, with an average content of 13.77 % and an $Al_2O_3/(CaO+Na_2O+K_2O)$ molecular ratio higher than 1.13. The sum of the alkalis $Na_2O+K_2O$ generally varies between 4.56 and 6.29% ; the ratio $(Na_2O+K_2O)/CaO$ can reach 4.51. $K_2O$ is the more important alkali. The sum of $TiO_2+FeOt+MnO+MgO$ is between 0.81 and 2.72. This indicates a very low proportion of coloured minerals, such as observed in thin sections.

#### 4.2.2 Nomenclature and classification

The Middlemost (1994) and QAPF Streickeisen (1974) diagrams reveal that the samples are granites (Fig. 5), with relative high silica contents, especially that of sample GRAN 7, falling in the lower part of high content quartz granitoids.

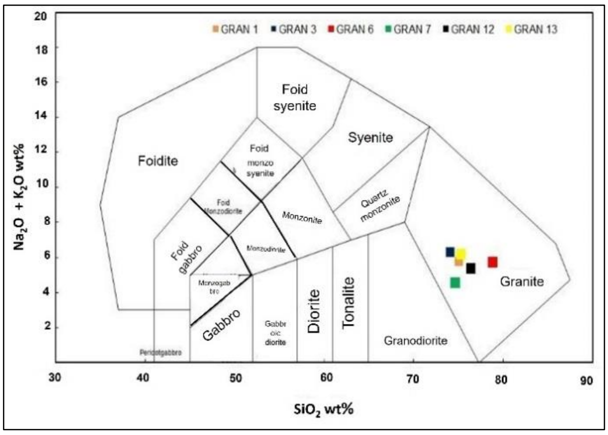


Fig. 5. Nomenclature of Irbiben granite using Middlemost diagram (1994)

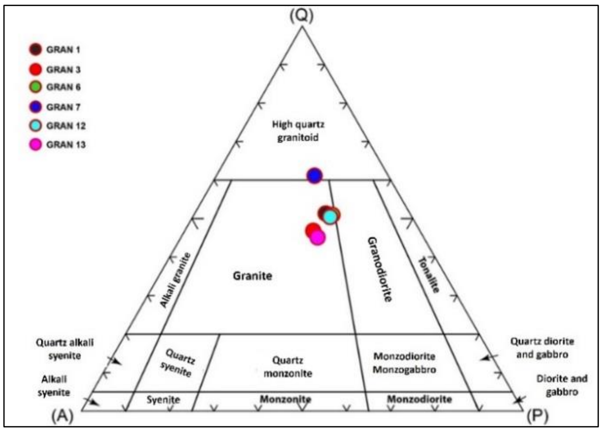


Fig.6. Nomenclature of Irbiben granite using Streickeisen diagram (1974)

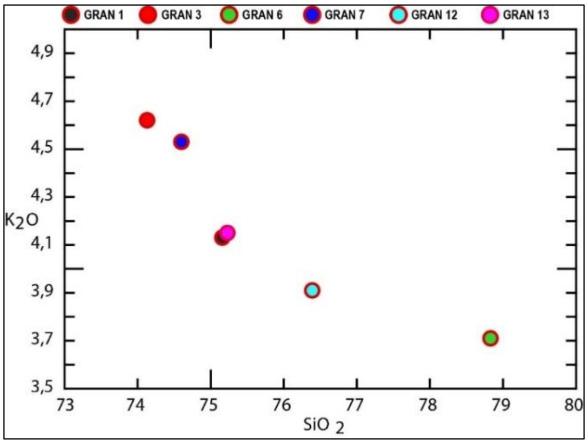


Fig. 7. Diagram of $K_2O$ vs $SiO_2$

## 4.2.3 Evolution of the chemical composition during differentiation

The oxide $K_2O$ shows a very clear negative correlation with $SiO_2$ (Fig.7), linked to some alkaline mobility during the alteration processes. Indeed, lithophilic elements with high atomic radius (L.I.L.E) such as Ba, Rb and K are very mobile elements during weathering (Ngom, 1995). The Ba-Sr diagram (Fig. 8) shows an increase in strontium (Sr) accompanied by an increase in barium (Ba). This positive correlation would be linked to the fixation of these elements in the structure of plagioclase and biotite (Hanson, 1978, N'Dri, 2014), minerals concentrated in the melt residue. According to Rickwood's $K_2O=f(SiO_2)$ diagram (1989), these rocks are derived from highly potassic calc-alkaline magmatic series (Fig.9).

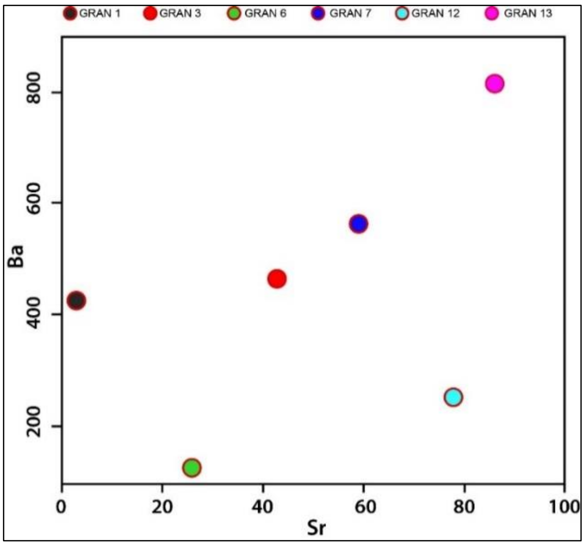


Fig. 8. Diagram of Ba vs Sr

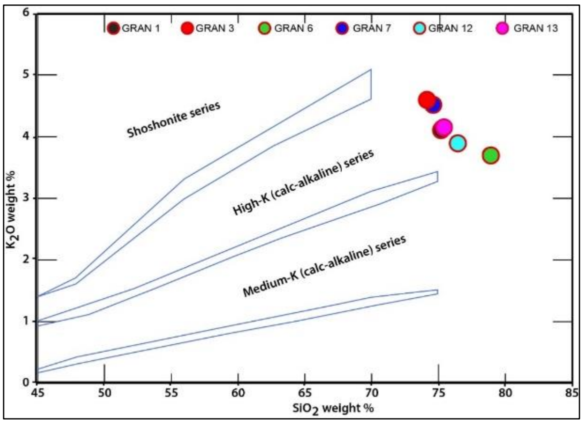


Fig. 9. Irbiben granite in Rickwood diagram (1989)

### 4.2.4 Spider diagrams

The trace element compositions of the different granite samples studied are plotted in the Thompson (1982) chondrite-normalized diagram (Fig.10). Positive anomalies in Ba and K indicate an enrichment in these elements while negative anomalies in P, Sr and Ti indicate a depletion in these elements.

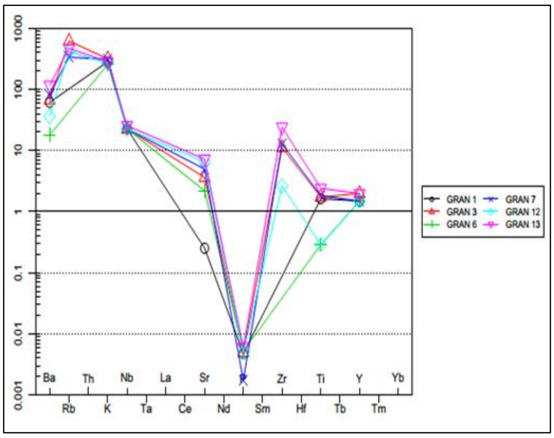


Fig. 10. Chondrite-normalized trace elements diagram (Thompson, 1982)

### 4.2.5 Geotectonic context

Plottind of the geochemical data into the granite discrimination diagram of Pearce et al. (1984) reveals that the Irbiben granites are volcanic arc granites (VAG) (Fig. 11). This indicates a subduction mode of emplacement for these granites. Plotting of the data of the studied rocks in the Maniar and Piccoli alumina saturation diagram (A/CNK-A/NK) for igneous rocks (1989) reveals that the Irbiben granitoids are peraluminous (Fig.12), with a ratio $Al_2O_3/CaO+Na_2O+K_2O$ higher than 1.1. This peraluminous character would thus prove a crustal origin of the granites.

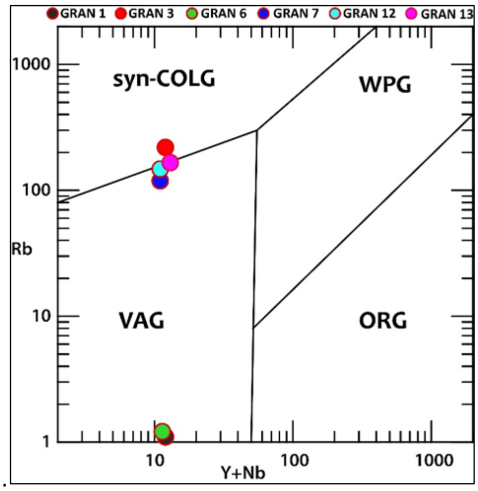


Fig. 11. Irbiben samples granite in discrimination diagram of Pearce et al. (1984)

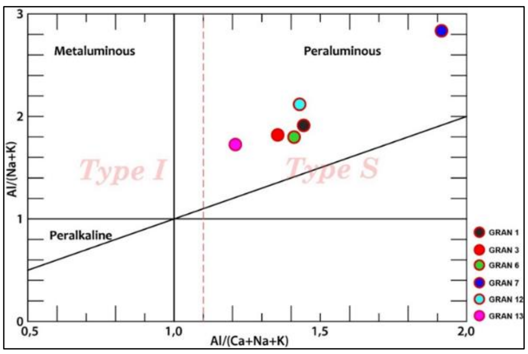


Fig. 12. Irbiben samples granite in Maniar and Piccoli (A/CNK-A/NK) diagram (1989)

## 5. Discussion

### 5.1. Petrography, geochemistry and nomenclature

Petrographic results show coarse-grained granites in south of the Irbiben god deposit. Their mineralogy consists of a large proportion of quartz of variable size, plagioclase and orthoses phenocrysts. These results corroborate those of Mortaji (1989) who identified in the northern part of the buttonhole leucogranites, either equigranular or porphyroid. Furthermore, the diagrams of Streickeisen (1974) and Middlemost (1994) confirmed the petrographic description : all the samples appear in the field of granites. The microscopic study revealed two generations of quartz, the first of which is composed of phenocrysts that are sometimes isolated and the second of small quartz (microcrystalline), very clear and grouped in clusters. These different generations of quartz had already been mentioned by Hassenforder (1987), Marignac (1990), Pothérat and Ait Kassi, (1991) in areas of the Western Anti-Atlas of Morocco. Zouhair (1992) agrees with them with his work revealing that three structural phases are recorded in the Akka inlier, with a quartzogenesis marked by four generations of quartz ($Q_{I}$, $Q_{II}$, $Q_{III}$ and $Q_{IV}$), of which two could be described at Irbiben. Benbrahim and Aissa (2005) and Boya (2014) have shown the link between gold mineralisation and 2 generations of quartz, $Q_{II}$ and $Q_{III}$, with QII quartz well expressed in the Irbiben deposit.

The plagioclases in high proportion as phenocrysts are partially altered to sericite. The Irbiben granite has thus been subject to hydrothermal alteration, even if moderate. This has also been described in the host rocks of the gold mineralisation in the ore deposit by Boya (2014). This hydrothermal activity led to the formation of secondary minerals such as epidote, sericite, chlorite or neoformed quartz. The poverty of ferromagnesian minerals ($Fe_2O_3+MgO < 1.5$) and the low Y contents (≤ 3ppm) mark the highly fractionated character of these rocks, indicating that it is a highly fractionated rock as underlined by Kouamelan (1996) on the Vavoua granites in Ivory Coast.

### 5.2. Petrogenesis and geotectonic

The granites studied are derived from potassium-rich calc-alkaline magmatism. The potassic character of these rocks proves that they are differentiated, as indicated by Tagini (1971) for whom an evolved rock is rich in potassium. Furthermore, Gamsonre (1975) studying the granitoids of Ouahigouya (Upper Volta), attributes this abundance of potassium to the destruction of ferromagnesian minerals, specifically biotite. For this author, the various granitisation processes lead to a progressive destruction of the biotite which then leads to a progressive release of potassium. This potassium accumulates in the rocks as they evolve or differentiate. This could explain the lack of biotite in these rocks.

The results of this work show that the Irbiben granites are peraluminous, and therefore of crustal affinity, as shown by Debon and Lefort (1983). Indeed, the positive Ba anomaly of these rocks cannot be justified only by magmatic differentiation; it would also prove a crustal origin. According to Yobou (1993), high contents of certain elements such as Rb, Ba and Sr rather suggest crustal contamination.

From a geotectonic point of view, these rocks mainly show an arc geochemical signature (VAG: volcanic arc granite), which implies their formation in a subduction context. However, many studies on arc magmatism (Marquer et al., 2000; Morris et al., 2000, N'Dri, 2014) show that these characters are not automatically linked to contemporary subduction but can be inherited. From this point of view, it is possible to suggest that the Irbiben granite was emplaced during the Eburnian cycle, but inherited arc features from earlier magmatism. The existence of a volcanic arc is still questionable due to the total absence of volcaniclastic formations in the Irbiben area, which would imply a back-arc context. However, felsic metatufs have been dated at 2072 ± 8Ma by Walsh et al. (2002) in the Tagragra of Tata inlier, an inlier close to the Tagragra d'Akka. This lack of volcanism may be explained by a weak low-temperature subduction event, resulting in the partial melting of silicate sediments, leading to the formation of granitic magma. This viscous magma, due to the great thickness of the continental crust, could not rise to the surface. Furthermore, the silico-clastic nature of the Paleoproterozoic sedimentary series in which these granites were emplaced confirms the presence of a continental domain of pre-Eburnean age.

### 5.3. Geodynamic model

The sedimentary products resulting from the disintegration of antebirimic micro-cratons produce sediments materialized by a succession of sandstones and pelites. The basement is then affected by the first phase of tectonic-metamorphic deformation D1 (Fig.13). The D1 deformation is marked in the basement by the S1 schistosity and the formation of the QI exudation quartz, followed by folds. The S1 schistosity is related to regional greenschist metamorphism. The folds are linked to a compressive episode which is the origin of the relief of the buttonhole but also of the modeling of the PI formations. The D1 deformation preceded magmatism, which saw the formation of the granites from which the enclosing basement formations were dated. An episode of convergence occurred between an oceanic lithosphere to the north and a continental lithosphere to the south, which would be the West African craton. The density of the ocean floor, combined with a large volume of sediment from the continents, caused subduction. More low-temperature silicates were therefore carried to depth during this subduction. The partial melting thus initiated affects the low-temperature minerals in the sediments by producing felsic magmas. According to Cocherie (1978), for high A/CNK ratios (1.21 to 1.91 in our case), the molten material would probably be of sedimentary origin. Thus, in the thick continental crust, large stocks of granites have accumulated which may correspond to low temperature melts and which, because of their low fluidity, could not reach the surface. The Irbiben granites in the Akka inlier are suspected to be derived from this felsic magma.

Figure 13 shows the proposed geodynamic model for the setting of the Irbiben granite.

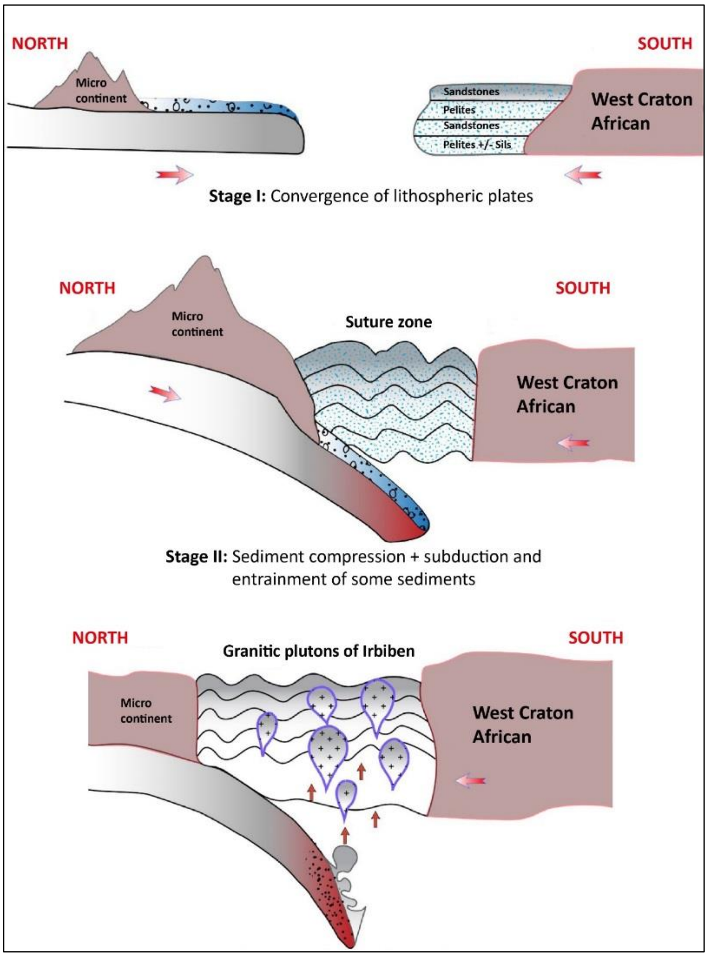


Fig. 13. Geodynamic model proposed for the setting of the Irbiben granite.

### 6. Conclusion

The petrogenetic study of the Irbiben granite has shown that it is porphyroid, with phenocrysts of primary felsic minerals, often with biotite and/or muscovite added. Subject to hydrothermal alteration, a secondary mineralogy has been highlighted and consists of sericite, the most pronounced alteration mineral, epidote often associated with sericite and then chlorite. The presence of two generations of quartz, in particular a recrystallisation quartz QII, is associated with the metamorphism affecting the zone. The processing of geochemical data shows that this granite, which comes from a calc-alkaline series rich in potassium, is an evolved rock. Its peraluminous character suggests a crustal origin. Combined with its volcanic arc signature, this rock is expected to have originated from a subduction zone or to have inherited arc characteristics from magmatism that preceded it.

In order to give our readers a sense of continuity, we encourage you to identify


### Acknowledgements

The samples were collected from the Irbiben deposit, previously exploited by Akka Gold Mining, a subsidiary of the Managem mining group, which also funded for the geochemical analyses. We would like to thank the managers of this company.

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