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Petrographic Characterization of the Badaraka Alkaline Ring Complex (Damagaram, South-East Niger)

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ABSTRACT

The anorogenic Badaraka ring complex is located about 6 km to the east of Zinder, in the Pan-African province of Damagaram-Mounio, and to the northeastern end part of the Pan-African Nigerian Shield. Elliptical in shape (long axis: 6 km; short axis: 4 km), this small complex is intrusive in a calc-alkaline granite of Pan-African age and a Neoproterozoic gneiss. The methodological approach used consisted of field and laboratory work. This work aims to determine the petrographic characteristics of the 'Younger Granites' of Badaraka through a new geological mapping of the study area. Results show that Badaraka is an alkaline complex saturated to supersaturate in silica with a sodium affinity. It composes of quartz alkaline trachytes, trachytic tuffs, and alkaline microsyenite crossed by quartz alkaline syenites. This petrographic sequence is made of three major successive magmatic phases, namely volcanic, hypovolcanic and plutonic, it is a typical model of anorogenic complexes emplacement by subsidence. This set of rocks ranging from trachytes to syenites through microsyenite presents frankly alkaline mineralogy with a predominance of potassium feldspar of perthitic orthosis type or sanidine, associated with quartz. Ferromagnesian minerals are sodium amphibole of arfvedsonite type, sodium pyroxene of acmite type, biotite, and opaque oxides.

I. INTRODUCTION

At the end of the Pan-African orogeny, geological evolution in West Africa is marked by the establishment of anorogenic (juvenile) ring complexes in late to post-Pan-African provinces ([1], [2]) Ranging in age from 586 to 141Ma ([3], [4]). The anorogenic Niger-Nigeria province is singular by the decrease in age of its complexes from 408 to 141Ma from north to south. This decrease has been interpreted as the consequence of the progressive displacement of the African plate on a fixed hot spot ([5], [6]). The Damagaram-Mounio province (South-East, Niger), NE end of the Benin-Nigeria Shield was the site of the development of anorogenic complexes from the Carboniferous onwards([1], [7], [8]). Apart from the reconnaissance work of [9] and [10], the Damagaram-Mounio province has been little studied compared to the equivalent areas of the Aïr (Niger) and Northern Nigeria. Many small anorogenic complexes are poorly known from petrographic, geochemical, structural, and geochronological points of view. This is the case of the Badaraka Complex, the object of the present study. This work aims to determine the petrographic characteristics of the 'Younger Granites' of Badaraka through a new geological mapping of the study area.

II. Regional geology of the Damagaram-Mounio

The Damagaram-Mounio is the northeastern end part of the Benin-Nigerian Shield and is located in the southern trans-Saharan segment of the Pan-African chain that extends from the Hoggar in the north to the Gulf of Benin in the south[11]. According to the work of [12], this Pan-African belt presents numerous elongated North-South blocks. These blocks are separated by strike-slip shear zones (Figure 1), resulting from the Pan-African collision of the West African Craton with the eastern mobile belt ([12], [13]).

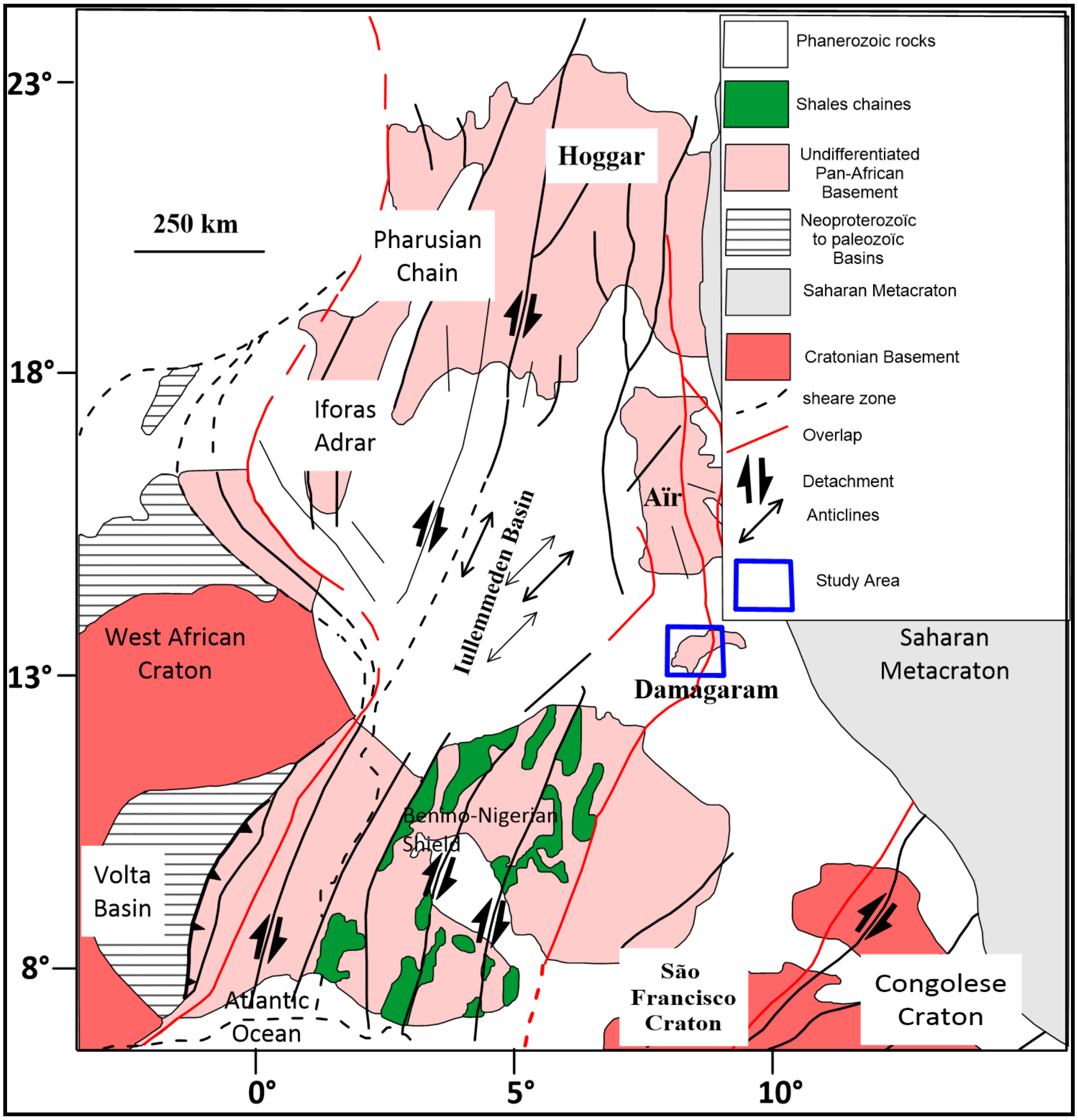

Figure 1:Location of Damagaram province in the Trans-Saharanchain([13], modified).

Geologically, the Damagaram-Mounio consists of metamorphic rocks of the Neoproterozoic age, including migmatites, gneisses, metamorphic conglomerates, schists, and quartzites ([9], [14], [15]) cut by ancient syn to late-tectonic calc-alkaline granites of Pan-African age. These formations are cut by young anorogenic alkaline to hyper alkaline granites, the oldest of which have a Carboniferous age (330 Ma). These "Younger Granites" are annular, sub-annular to elliptical complexes.

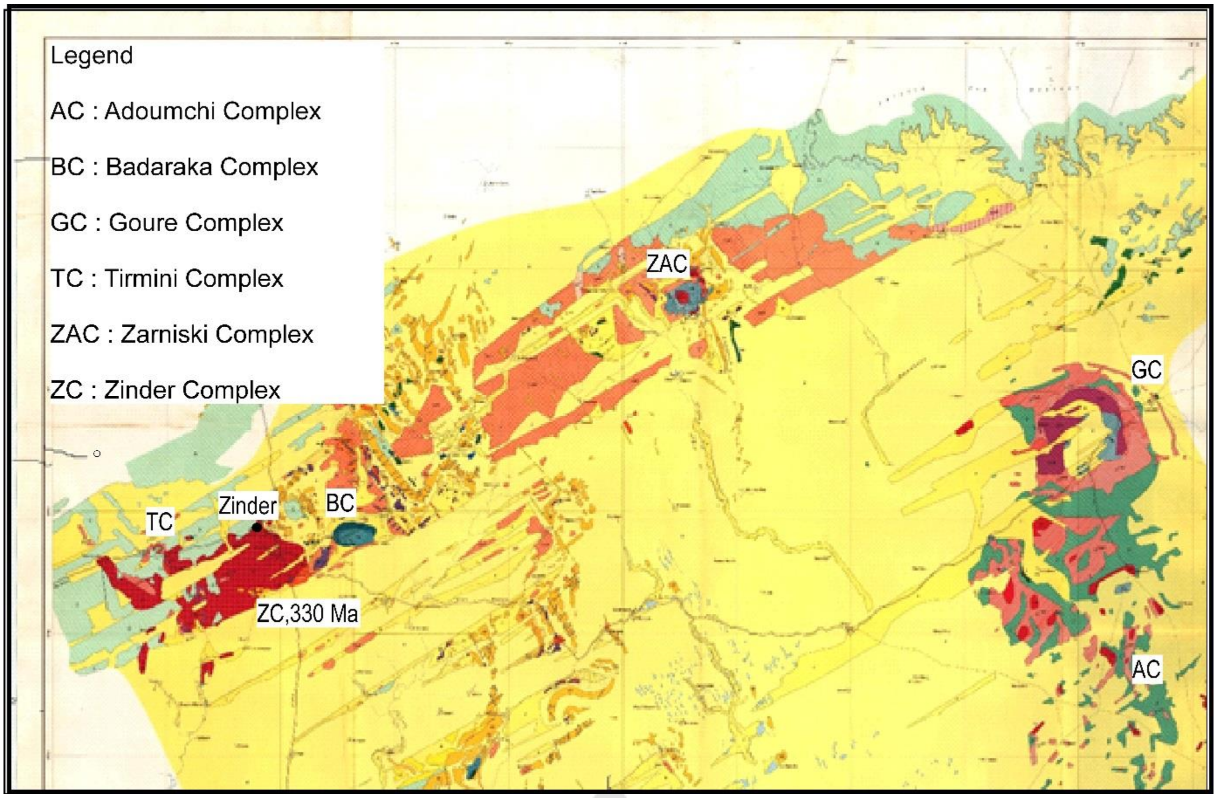

Figure 2: Location map of the Damagaram-Mounio Complex (from the map[9], modified).

III. MATERIAL AND METHODS

The methodology implemented consisted of field and laboratory work. Three sampling campaigns and structural measurements were carried out on the whole complex and its plutonic casing. Petrographic analyses Have been done with a binocular magnifying glass and then with a LEICA DM2700 polarizing microscope at the Groundwater and Geores sources Laboratory of the Abdou Moumouni University of Niamey (Geology Department). A thin section was made at the laboratory of the Geological and Mining Research Center (GMRC) of Niger.

IV. RESULTS AND DISCUSSION

IV.1 Mapping of the Badaraka Complex

The Badaraka alkaline complex, intrusive in a calc-alkaline granite of Pan-African age, is located about 6 km east of the town of Zinder (Figure 2). Its elliptical shape is typical of the shearing emplacement model ([16], [17]), which suggests that the elliptical shape of a complex may reflect a "compressional" emplacement with sufficiently low stresses that the deformation is not penetrative. According to the mapping of [9], the petrography of the Badaraka complex is characterized by a succession of quartz-hornblende syenite, trachyte, quartz-hornblende syenite, microsyenite and quartz-hornblende syenite. This succession occurs from west to east (Figure 3A1). The new mapping shows that quartz alkaline syenites constitute the central body of the complex intersecting trachytes, trachytic tuffs, and a microsyenite along the southern margin (Figure 3A2). Petrographic and mineralogical analyses highlight a magmatic lineage showing the three main magmatic phases typical of the anorogenic complex model ("Cauldron subsidence" of [18]): volcanic, hypovolcanic, and plutonic. According to the mineralogical composition and texture as well as the geometrical relationships, the three major phases are presented from the oldest to the most recent:

- The volcanic phase is represented by trachytes and trachytic tuffs;
- The hypovolcanic phase is represented by quartz alkaline microsyenite;
- The plutonic phase is represented by quartz alkaline syenites (Figure 4).

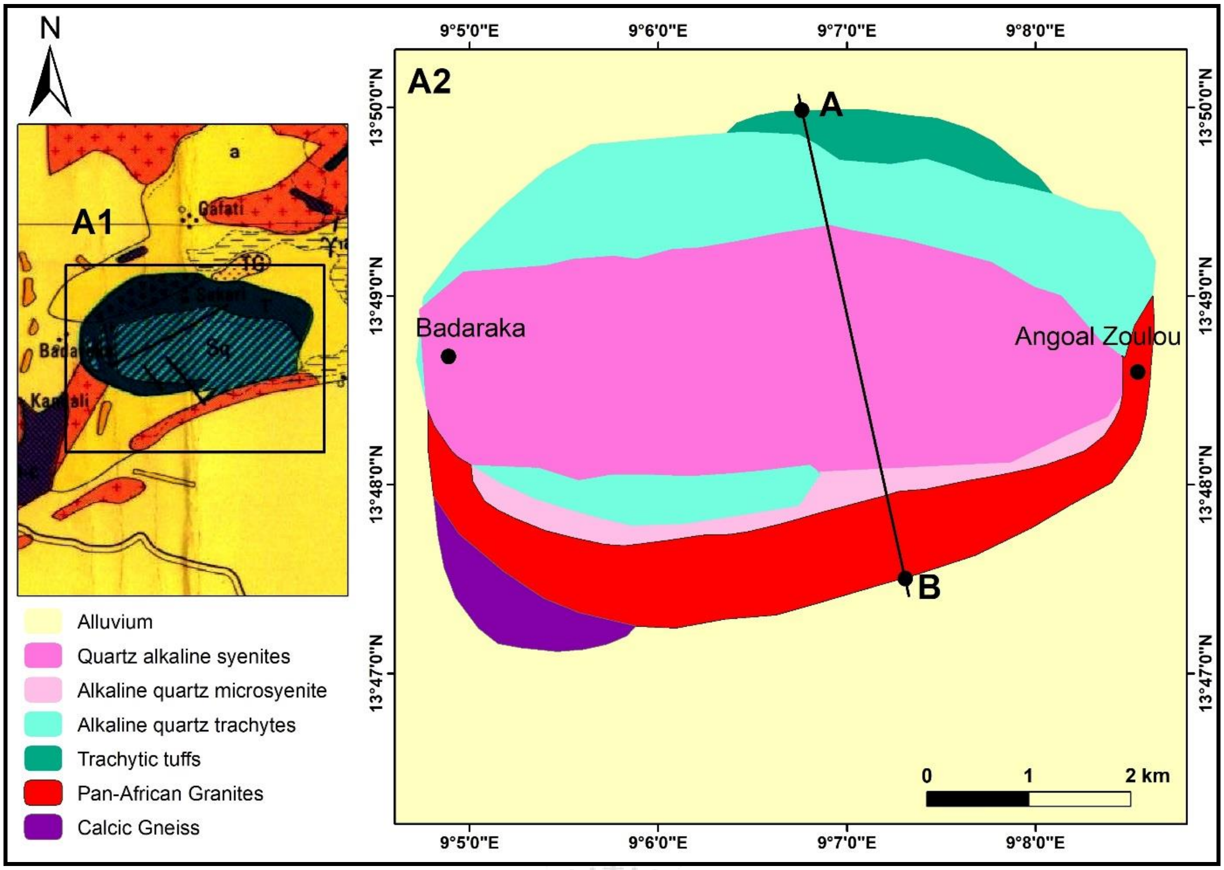

Figure 3: Location map of the Badaraka A1, A2 elliptical complex (from map[9], modified).

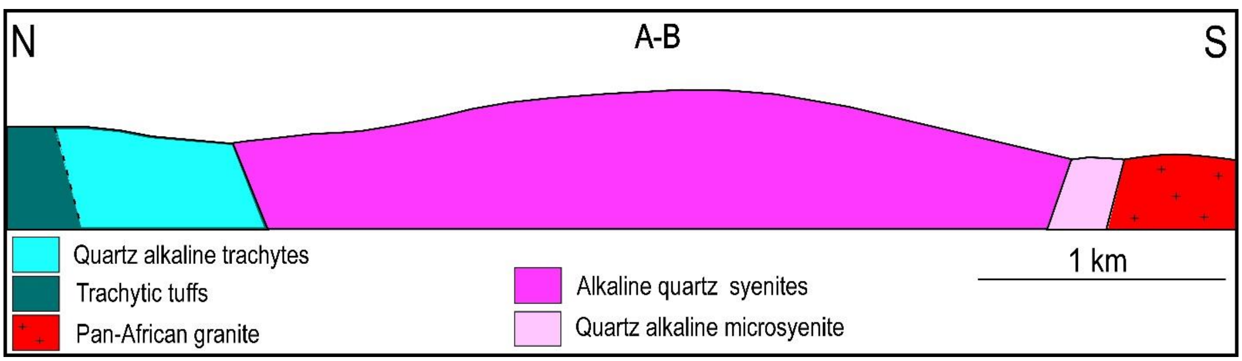

Figure 4: N-S Geological section of the Badaraka elliptical complex.

The macroscopic and microscopic analysis of all the sampled rocks shows a mineralogical composition represented by a dominant potassium feldspar. The latter appears in the form of perthitic orthose in the crystallized rocks and sanidine in the volcanic facies. Some minerals are also added quartz, sodium amphibole of arfvedsonite type, pyroxene of acmite type, biotite, and oxides. This mineralogical association gives to the Badaraka magmatic complex an alkaline character saturated to supersaturate in silica.

IV.2 Petrographic data

IV.2.1. Petrographic characteristics of the volcanic phase

The volcanic phase is represented by trachytic tuffs and quartz alkaline trachytes which outcrop along the northern and southern edges of the complex in an average east-west direction. These rocks show an average dip of N60° converging towards the center of the complex. The trachytic tuffs outcrop at the northern end of the complex in the form of whitish to milky blocks (Figure 5B). Their fluid texture is made of sanidine and quartz crystals, and it is devoid of colored minerals (Figure 5C). The sanidine and subangular quartz crystals present the mechanical macle giving them the sub-automorphic form: this reflects an explosive eruption.

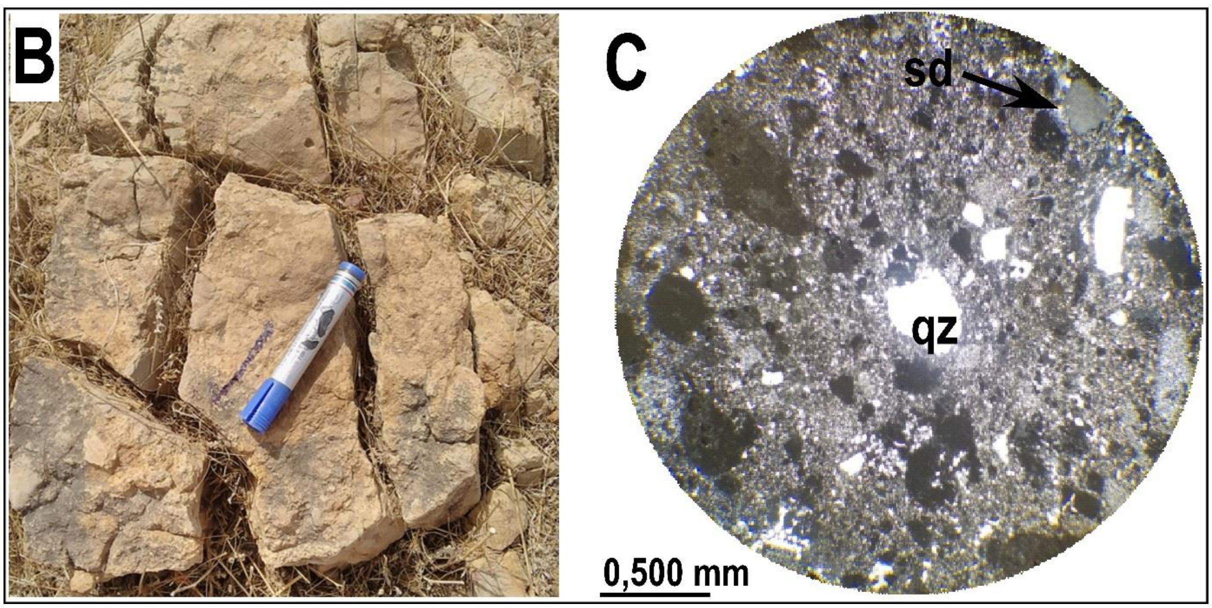

Figure 5: Photograph (B) and microphotograph (C) of trachytictuffs. Sd : Sanidine ; qz : quartz.

The trachytes (Figures 6D, and F) show a variation in color and texture from the edge to the center of the complex. The trachyte changes from a brownish, microlitic, quartz alkaline trachyte (T1) with sanidine up to 80% associated with rare quartz crystals (Figure 6E) to a blackish, porphyritic, supersaturated quartz alkaline trachyte (T2), with less sanidine but richer in quartz, biotite and chlorite with incidental oxides (Figure 6G). The oxides and chlorite are the alteration products of biotite. Besides, the T1 trachyte shows a kind of fracture schistosity corresponding to the lateral compression due to the emplacement of the central syenite (Figure 6D). Mineralogically and texturally, the transition from T1 to T2 is marked by a decrease in alkalinity (sanidine) and an increase in quartz and biotite. This variation in trachyte facies reflects a zonation between a periphery that has undergone a T1 quenching effect (Figure 6D), and a core that cooled more slowly, T2 (Figure 6F).

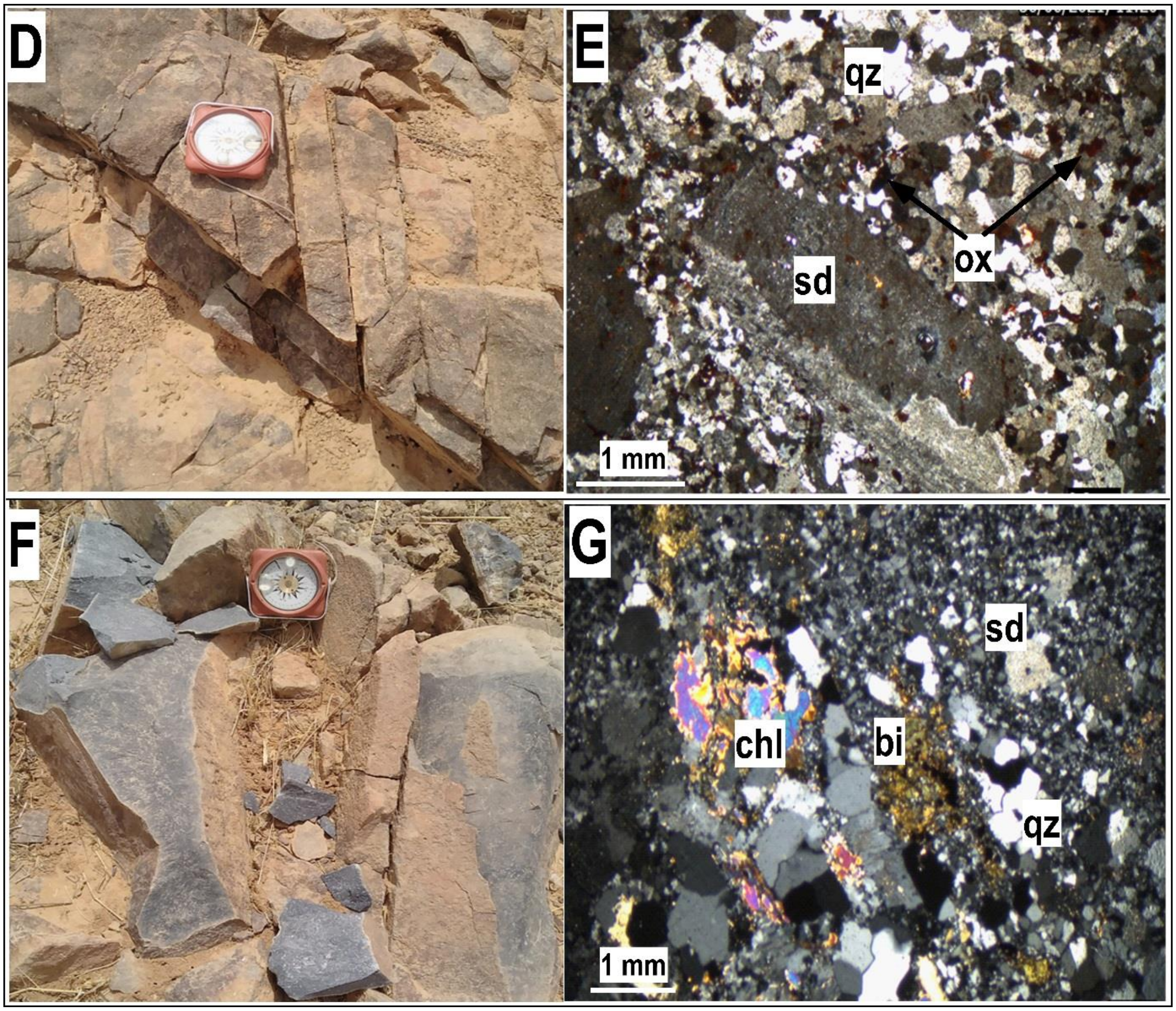

Figure 6: Photograph (D and F) and microphotographs (E and G) of trachytes. Sd : sanidine; qz : quartz; bi: biotite; chl : chlorite ; ox: oxide.

IV.2.2. Petrographic characteristics of the hypovolcanic phase

The hypovolcanic phase is represented by quartz alkaline microsyenites(Figure 7H) with a porphyritic microgritty texture and a pinkish color that outcrops along the southeastern edge of the complex. It is an N100° trending vein with an average dip of N60°W (Figure 4). Mineralogically, the microsyenites are composed of dominant orthoclase crystals (Figure 7I and J) associated with quartz and biotite, which are not very abundant. The orthoclase crystals are of medium size with the Carlsbad macle well observable. These characteristics are those of second-generation orthoclase.

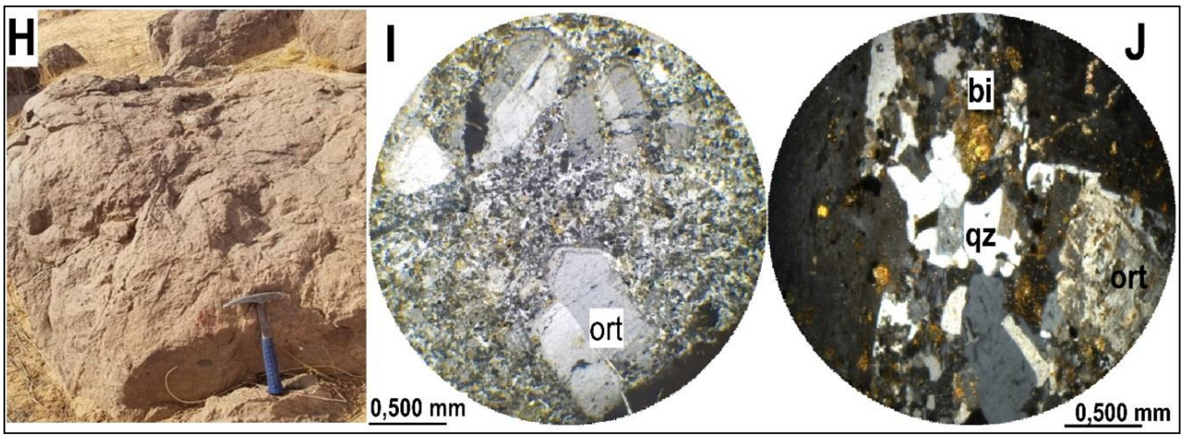

Figure 7: Photograph (H) and microphotographs (I and J) of microsyenitis. Sd : sanidine ; qz : quartz ; bi : biotite.

IV.2.3. Petrographic characteristics of the plutonic phase

The syenites outcrop in the center of the complex (about 6 km) from the east of the village of Badaraka to the west of the village of AngoalZoulou, intruding the tuffs, trachytes, and Pan-African granite (Figure 3). The same textural zonation as the trachytes is noted. The texture changes from gritty to porphyritic gritty from the periphery to the core of the complex. The Sy1 (Syenite 1) edge quartz syenite (Figure 8K) has a gritty texture and a light pink color. It contains perthitic potassium feldspar, myrmekites, sparse quartz, arfvedsonite, biotite, and acmite (Figure 8 L and M). Acmite is recognized by its hourglass-shaped macle (Figure 8M). The quartz syenite Sy2 (Syenite 2) is greyish and has a porphyritic grey texture (Figure 8N) containing perthitic potassium feldspar, quartz, arfvedsonite, acmite, and biotite crystals (Figures 8O and P). The presence of myrmekites in the perthitic feldspar reflects the leaching of potassium and enrichment of the potassic feldspar in sodium and silica. The transition from Sy1 to Sy2 is marked by an enrichment of the biotite content and an increase in the content of arfvedsonite and acmite.

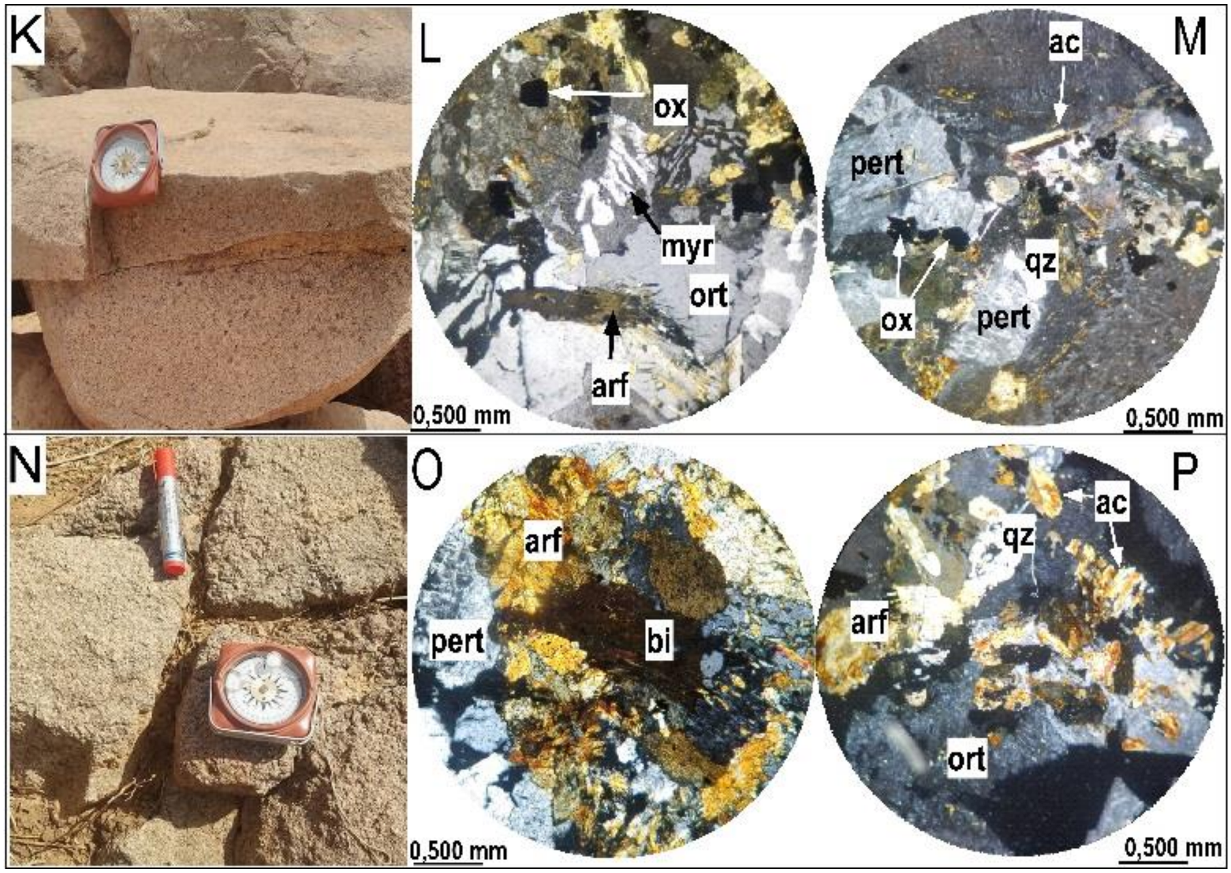

Figure 8: Photograph (K and N) and microphotograph (L, M, O, P) of quartz alkaline syenite. Ort: orthoclase; pert: perthite; bi: biotite; arf: arfvedsonite; myr: myrmekites, ac: acmite.

The elliptical shape of Badaraka is typical of the "compression" emplacement model, where the stresses are low enough that the deformation is not penetrative. This configuration explains the asymmetry of the complex: the trachytes do not outcrop to the east and west; the microsyenite appears only to the south. The first phase of emplacement begins with the explosive release of applies with mineral debris followed by the dome-shaped trachytes through the cold walls of the Pan-African granite and gneiss Neoproterozoic. The second phase sees the injection of microsyenite in an arc in the southern part of the complex after the collapse of the trachytes towards the center of the magma chamber. The third phase corresponds to the intrusion of the syenite that cuts all the rocks.

CONCLUSIONS

This study aims to determine the petrographic characteristics of the 'Younger Granites' of Badaraka through a new geological mapping. The results of the petrographic analysis show that the Badaraka complex is characterized by an alkaline petrographic sequence saturated to supersaturated in silica. This petrographic sequence consists of volcanic rocks (trachytes and trachytic tuffs), subvolcanic rocks (microsyenite), and plutonic rocks (syenites). All these rocks have undergone processes of leaching potassium into sodium justified by the presence of perthite, which gives a sodic character to the complex. Also, four types of textures have been identified from the edge to the heart of the complex. These are the trachytic texture of the tuffs, the microlitic to microlitic porphyry texture of the trachytes, the microgritty texture of the microsyenites, and the gritty to gritty porphyry texture of the syenites. The evolution of the different textures from the periphery to the core of the complex as well as the geometric relationships suggests a model of a superficial magma chamber that releases rocks by jerks. The presence of sub-automorphic crystals of trachytic tuffs indicates an explosive eruption. The asymmetry observed on the complex results from its elliptical shape due to its emplacement in a weakly shearing context.

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