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Petrographic characteristics of the younger granites of Tirmini (southeastern Damagaram, Niger)

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Abstract: This work focuses on the petrographic characterization of the Tirmini anorogenic ring complex (southeastern Niger). The latter in the pan-African province of Damagaram-Mounio, corresponding to the northeastern termination of the Benin-Niger Shield. Very little geological data is available on the Tirmini complex. The only lithological data available are those of Mignon (1970). The aim of this study is to present the new petrographic data obtained at Tirmini to clarify the magmatic suites. The methodology used is based on macroscopic and microscopic (optical) data, supported by scanning electron microscopy (SEM) data. The petrographic results obtained revealed two magmatic lineages: (i) alkaline and (ii) peralkaline. The first lineage is characterised by a petrographic sequence ranging from alkaline rhyolite to alkaline microgranite, alkaline granite, and alkaline quartz syenite. The second lineage of peralkaline chemism, evolves from comenditic rhyolite to peralkaline microgranite and peralkaline granite. This petrographic evolution reflects the three-phase emplacement of younger granites, typical of a subsidence petrogenetic model: volcanic phase, hypovolcanic phase and plutonic phase. The mineralogical results (MO and SEM) obtained include orthoclase, aegirine, arfvedsonite, annite and quartz associated with accessory minerals (ilmenite, fluor-apatite, zircon, and monazite). The mineralogical evolution from the alkaline line to the peralkaline line is marked by an increase in the content of sodium minerals (arfvedsonite and aegyrine).

Keywords: Younger granites, Tirmini, Damagaram-Mounio, Niger-Nigeria province, lineage.

I. Introduction

The Paleozoic to mesozoic province of Niger-Nigeria is an impressive example of continuous anorogenic complexes over 1300 km in a continental environment, with a progressive decrease in age from the Aïr in the north to the Jos plateau in the south [1]-[10]. The intraplate felsic magmatism of the Damagaram-Mounio province, emplaced along the submeridian lineaments of Raghane [8], forms an important link between the younger granites of the Aïr in the north and those of Nigeria in the south. Paleozoic magmatism in Damagaram began in the Carboniferous with the emplacement of the Badaraka, Zinder and Zarnouski younger granites and ended in the Permian with the emplacement of the Gouré younger granites [10]-[12]. Like the Damagaram younger granites, another alkaline to peralkaline complex was emplaced in the Permian in a purely extensive anorogenic context [11]. The petrographic characteristics of this alkaline-peralkaline complex remain undefined or very sketchily known. This study aims to present new petrographic data on the younger granites of Tirmini to clarify their mineralogical compositions and magmatic suites.

II. Geological context

The Damagaram-Mounio province is the northeastern terminus of the Benin-Nigeria shield [13], [14]. It corresponds to the southern segment of the pan-African trans-saharan chain, which extends from the Hoggar in the north to the Gulf of

Benin in the south [15]. According to the work of [15], this Pan-African chain comprises numerous elongated north-south blocks separated by shear zones, resulting from the Pan-African collision between the West African Craton and the eastern mobile belt. The Damagaram province consists of metamorphic rocks of Neoproterozoic age, including migmatites, gneisses, metamorphic conglomerates, phyllades and quartzites (Figure 1) [16], intruded in the Pan-African by syn-tectonic calc-alkaline and post-tectonic tardi-alkaline granites [14], [16]-[18]. This Damagaram-Mounio province was affected by intraplate magmatism of the alkaline to peralkaline type between 344 and 287 Ma, setting up younger granites in ring complexes [10]-[12]. The Damagaram province covers an area of 3,600 km^2 and has around twelve ring complexes with diameters ranging from 2 to 15 km, the best known of which are the Zinder, Gouré and Zarnouski complexes [11], [12], [19].

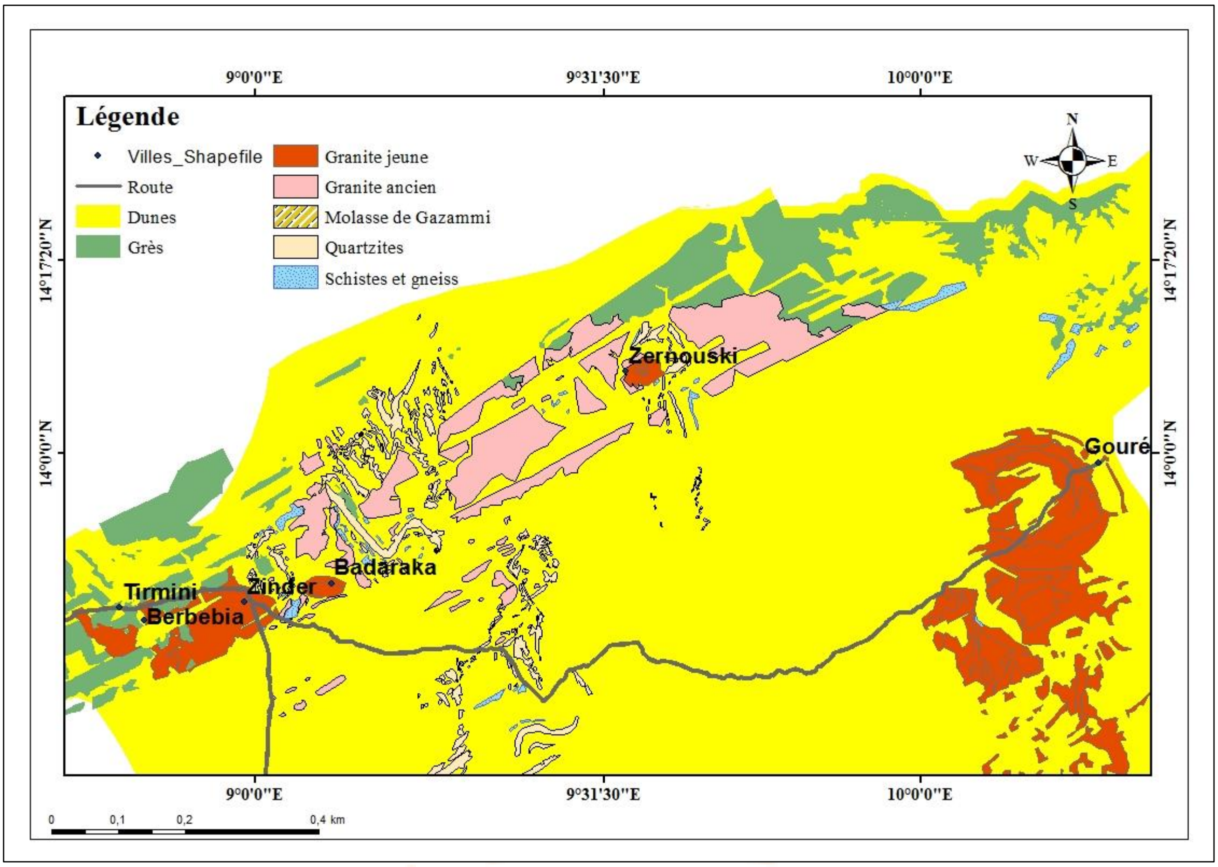

Figure 1: Geological map of the Damagaram-Mounio province [17].

III. Methodology

Several field campaigns were carried out in the study area as part of this study. Thirty (30) representative samples were selected for the production of thin sections and polished sections. The thin sections were made at the ''Centre des Recherches Géologiques et Minières'' (CRGM) and the observations at the Ground Water and Georessources laboratory at Abdou Moumouni University. The polished thin sections were produced at the Thin Section Geoscience and Environment Laboratory in Toulouse, France. The SEM study aimed to determine the micro-morphology and chemism of both the fragments and the polished thin sections. The fragments were fixed on aluminium stubs with double-adhesive carbon tape, while thin sections were positioned on a flat aluminium support after being coated with carbon about 10 nm thick under a vacuum evaporator, observed by SEM and analysed by EDS. The following conditions were adopted: electric current of 15kV, filament current of 50 to 100µA, variable spot size and working distance of 20mmEDS based on an Oxford Automated Qualitative Elemental Analysis (INCA) mode. The Tirmini geological map was updated manually.

IV. Results

IV.1 Mapping

The lack of agreement between the geological map produced by [17] and the new petrographic data (macroscopic, polarising microscope and scanning electron microscope observations) obtained in the course of this work meant that the geological map of the Tirmini complex had to be updated. Two magmatic lines were identified: (1) an alkaline line consisting of alkaline rhyolite, alkaline microgranite, alkaline granite, and alkaline quartz syenite, and (2) a peralkaline line consisting of comenditic rhyolite, peralkaline microgranite, and peralkaline granite (Figure 2). According to [17], the Tirmini ring complex consists of a single alkaline line comprising rhyolite, microgranite, and alkaline granite.

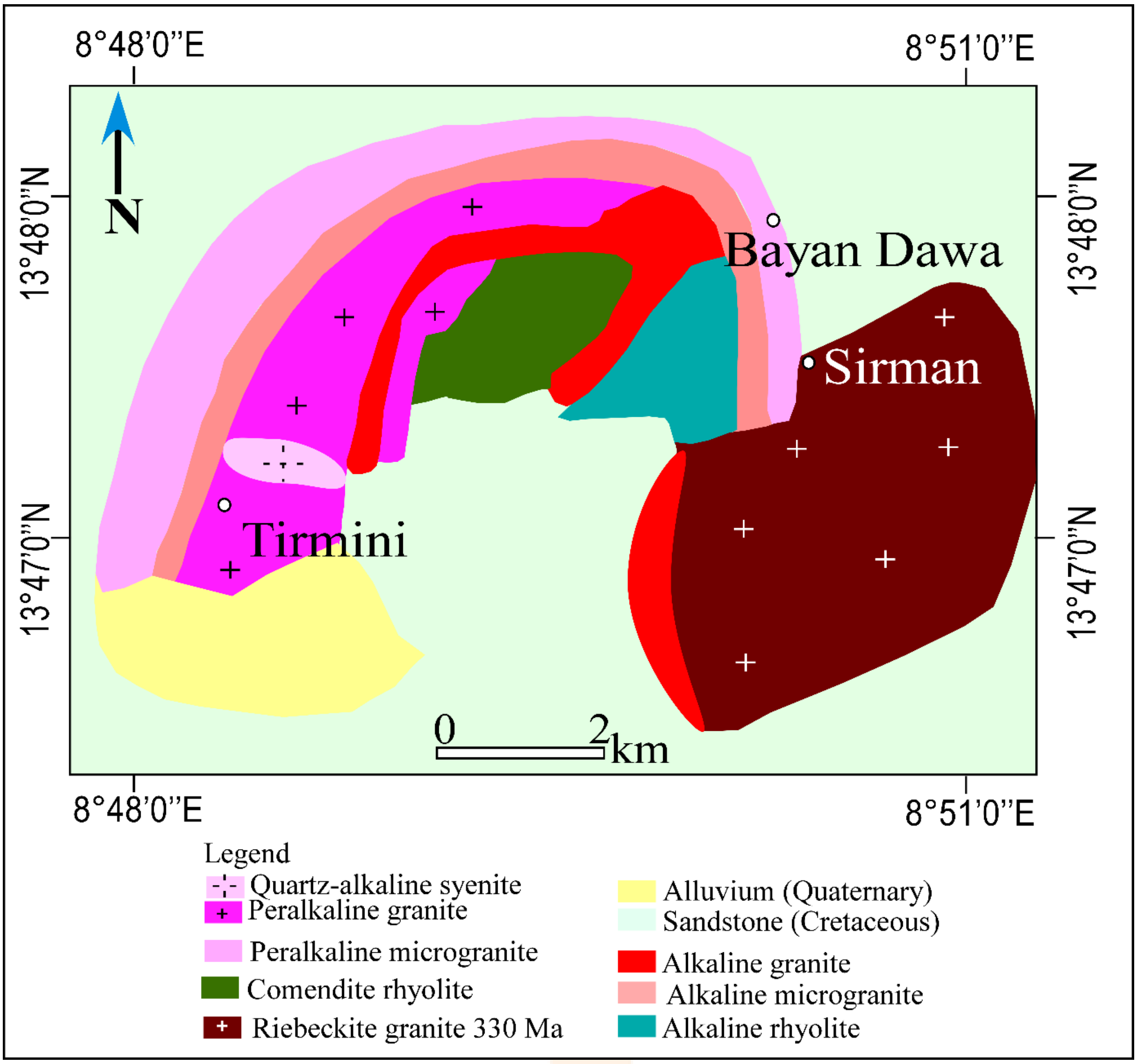

Figure 2: Updated geological map of the Tirmini ring complex.

IV.2 Petrographic analyses

The Tirmini alkaline line corresponds to a petrographic suite consisting of alkaline rhyolite, alkaline microgranite, alkaline granite, and alkaline quartz syenite. Its mineralogical composition comprises perthitic orthose (Figure 3a, b, c and d), quartz and arfvedsonite. Alkaline rhyolite outcrops to the west of the village of Sirman (Figure 3a). It has a porphyritic and fluid microlitic texture. The alkaline microgranite (Figure 3b) represents the edges of the ring complex (Figure 2). The alkaline granite outcrops towards the heart of the complex, where it cuts through the rhyolites (Figure 3c). This alkaline sequence ends with the emplacement of alkaline quartz syenite (Figure 3d). The second line (peralkaline) consists of comenditic rhyolite, peralkaline microgranite, and peralkaline granite. The mineralogical composition of this line is marked by enrichment in peralkaline minerals (arfvedsonite and aegirine). The comenditic rhyolite has a porphyritic to fluid spherulitic hyalomicrolithic texture (Figure 3e). The peralkaline microgranite (Figure 3f) has a greyish colour and a porphyritic microgritty texture. Finally, this peralkaline suite ends with the emplacement of peralkaline granite, which corresponds to the most widespread facies of the Tirmini ring complex (Figure 3f).

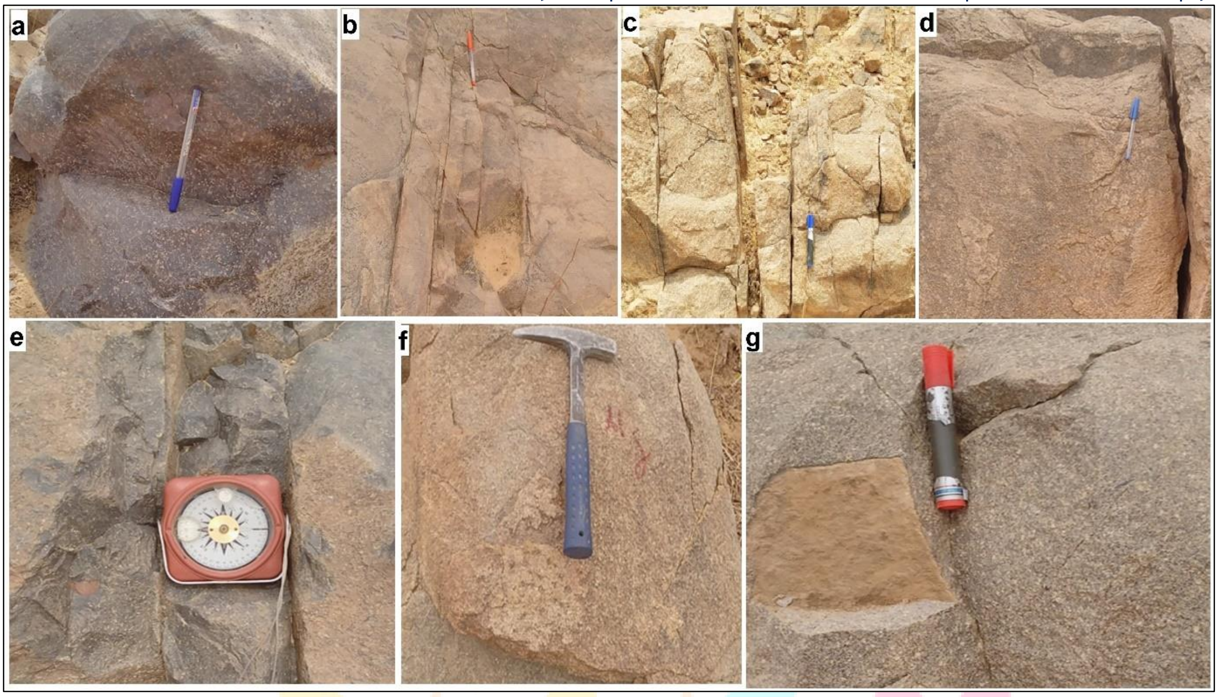

Figure 3: Younger granites of Tirmini; a: alkaline rhyolite; b: alkaline microgranite; c: alkaline granite and, d: alkaline quartz syenite; e: comenditic rhyolite; f: peralkaline microgranite and g: peralkaline granite.

Optical microscopy shows crystals of perthitic orthoclase, arfvedsonite (annite alteration), aegirine, rounded quartz and albite laths in exsolution (Figure 4). Orthoclase is most often marked by the Carlsbad macle (Figure 4a). Quartz has a positive uniaxis and appears in the form of short bipyramidal prisms with a subhexagonal cross-section, rarely angular (Figure 4b). This morphology is the result of incomplete growth of these crystals in a felsic magma. Quartz shows blunt angles underlining high-temperature crystallisation (Figure 4b), typical of quartz-ß polymorphs. Arfvedsonite appears as elongated pleochroic crystals (Figure 4d). It is derived from the alteration of annite crystals (ferriferous biotite), which allowed the crystallisation of secondary minerals such as magnetite and ilmenite (Figure 4d). Aegirine crystallises in the interstices of orthoclase crystals, underlining its late-stage nature (Figure 3c). The magmatic evolution from alkaline to peralkaline is marked by an increase in the relative proportion of arfvedsonite and aegirine. This increase can be explained by the low presence of alumina (Al_2O_3) necessary for the formation of orthoclase, which favours the crystallisation of sodium minerals such as aegirine and arfvedsonite.

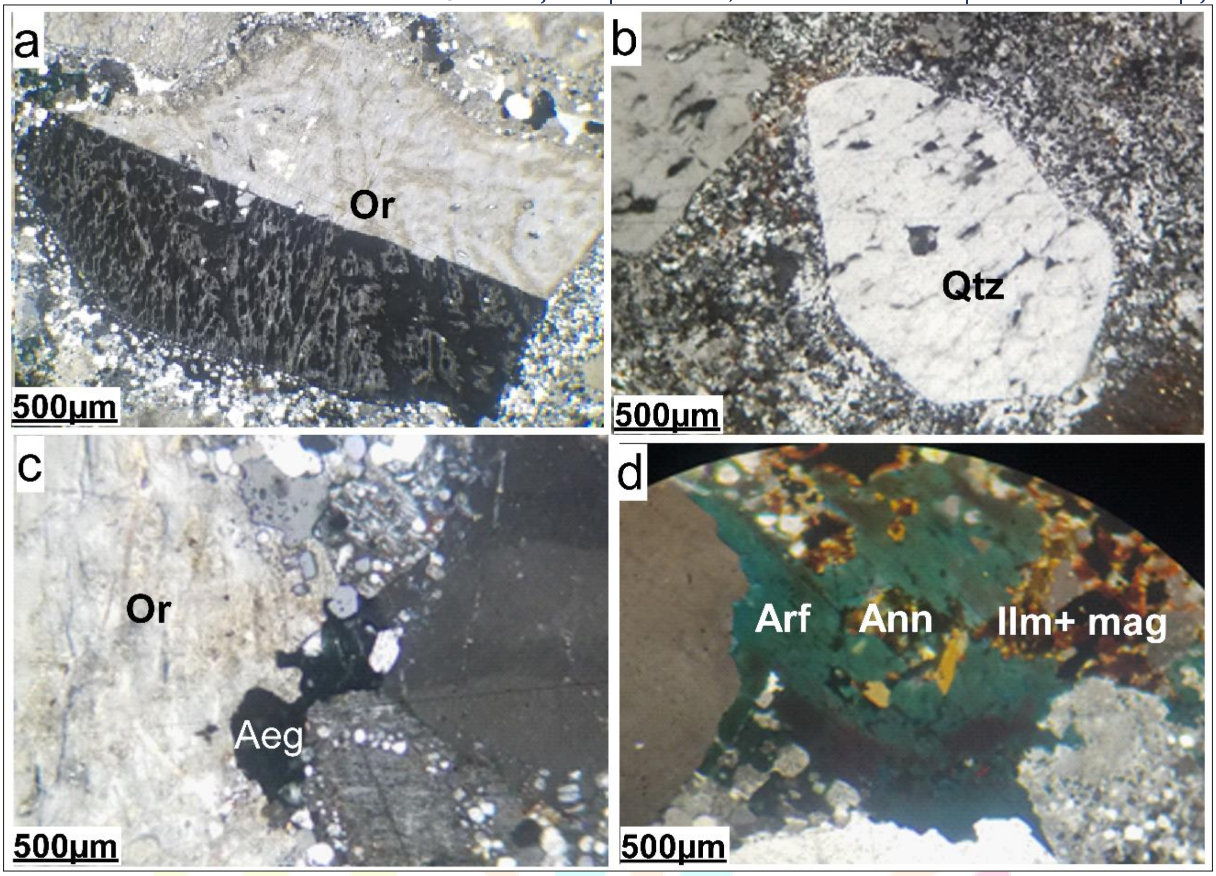

Figure 4: Microphotographs (a, b, c, and d) of the younger granites of Tirmini. Or: perthitic orthoclase; qtz: quartz; arf: arfvedsonite; aeg: aegirine; ann: annite; ilm: ilmenite and mag: magnetite.

Under the scanning electron microscope (SEM), the secondary and accessory minerals obtained include ilmenite ($FeTiO_3$), zircon ($ZrSiO_4$), fluoro-apatite ($Ca_5(PO_4)_3F$) and monazite (Figure 5). Ilmenite is present in all lines and appears as large xenomorphic crystals (Figure 4a) several tens of micrometres in size, up to 100 µm. Zircon has a quadratic cross-section and appears as inclusions in orthoclase crystals (Figure 5b). Fluoro-apatite crystallised early, in the form of squat or elongated, limpid prisms with high relief (Figure 5c). Fluoro-apatite and monazite have only been observed in granites (alkaline and peralkaline). They contain some uraninite inclusions (U, Th, Nb).

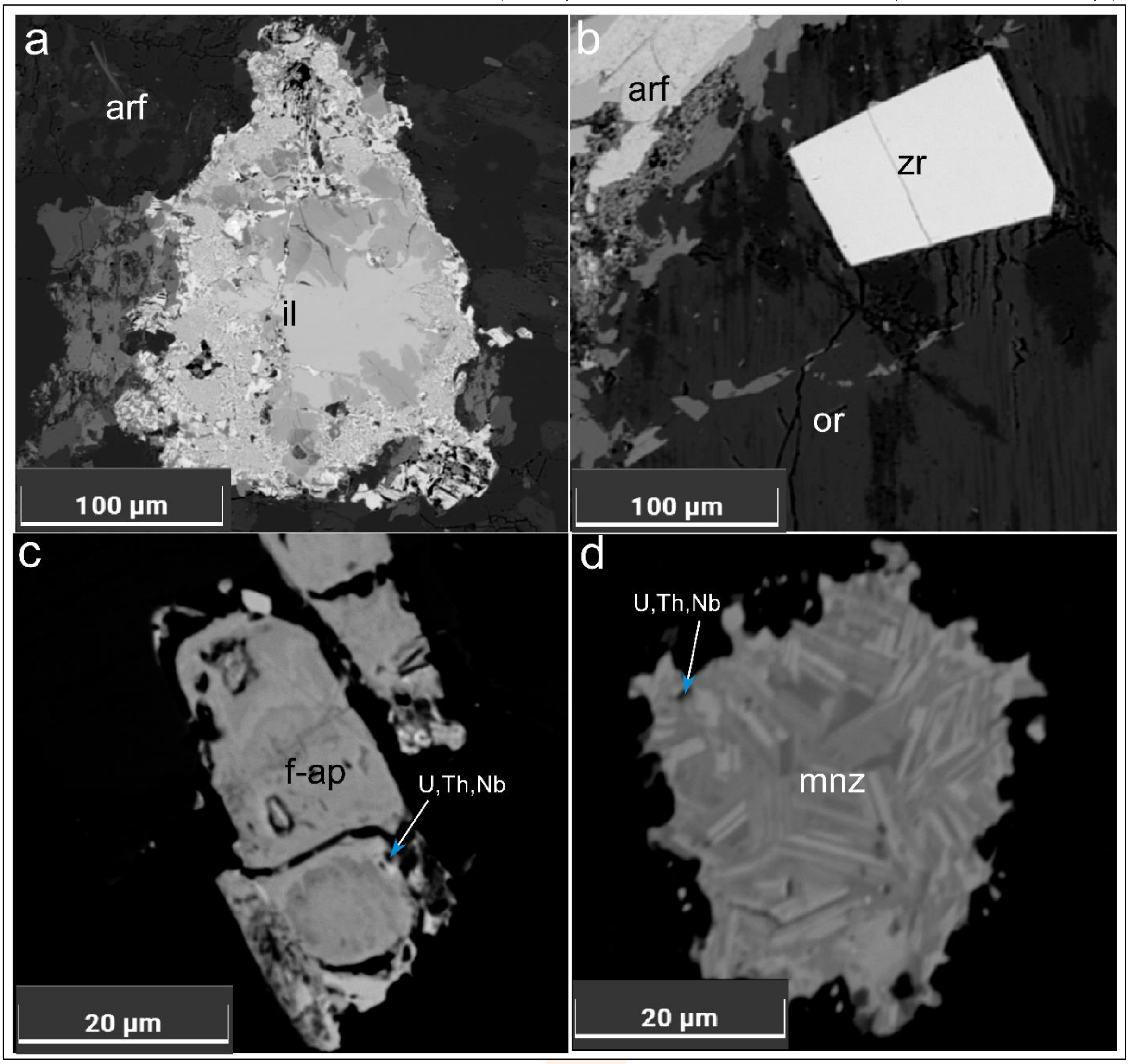

Figure 5: SEM microphotographs of accessory and secondary minerals. Ilm: ilmenite; arf: arfvedsonite; or: orthoclase; zr: zircon; f-ap: fluoro-apatite; mnz: monazite; U, Th, Nb: uraninite.

IV. DISCUSSION

The petrographic sequence obtained for each lineage at Tirmini is typical of a petrogenetic model of [20] and [2]: volcanic phase, hypovolcanic phase and plutonic phase. The same sequence has been demonstrated in certain Aïr complexes [6]. Similarly, at Mounio and in northern Nigeria, the same petrogenetic model has been demonstrated [4], [21]. These examples support a common petrogenetic model for the ring complexes of the Niger-Nigeria province. The magmatic evolution from the alkaline lineage to the peralkaline lineage is marked by an increase in the relative proportion of arfvedsonite and aegyrin. This increase can be explained by the low presence of the alumina (Al_2O_3) needed to form orthoclase crystals, leading to the crystallisation of other sodium minerals, notably aegyrin and arfvedsonite [11]. Mineralogical results obtained by optical microscopy show that the percentage of orthoclase contained in the feldspar can be estimated at around 92-97%. This underlines the fact that the Tirmini younger granites are persolvus rocks. In such situations, [22] showed that the exsolution dome in the albite-orthose system was well separated from the solidus and that the orthose which has undergone exsolution of the albite should have a composition of 95% orthose plus or minus 2%. [23] and [24] have shown that in persolvus rocks the 95% orthoclase content of alkali feldspar occurs at at least 400°C, the temperature at which orthoclase enters the microcline stability range. This shows that the orthose-microcline transition did not occur in all Tirmini rocks: hence the absence of microcline.

Conclusion

Petrographic analysis has revealed two lineages: (1) alkaline and (2) peralkaline. The alkaline lineage has a petrographic sequence consisting of alkaline rhyolite, alkaline microgranite, alkaline granite and alkaline quartz syenite. The peralkaline line evolves from comenditic rhyolite to peralkaline microgranite and peralkaline granite. The mineralogical composition revealed by optical microscopy includes orthoclase, quartz, arfvedsonite and aegyrin. The presence of sodium minerals (aegyrine and arfvedsonite) marks the transition from the alkaline line to the peralkaline line. The accessory minerals (ilmenite, annite, fluoro-apatite, monazite, and zircon) were observed using scanning electron microscopy (SEM).

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