https://dx.doi.org/10.4314/ijs.v25i1.5

MICROSTRUCTURAL INTERPRETATION OF THE GARNET-SILLIMANITE-BEARING GRANITE GNEISS OF IKARE AREA, SOUTHWESTERN NIGERIA

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(Received: 7th January, 2023; Accepted: 22nd March, 2023)

ABSTRACT

This study presents microstructures from the granite gneiss of the Basement complex of southwestern Nigeria. The granite gneiss of Ikare area comprises of the mineral assemblage; garnet, biotite, K-feldspar, quartz, plagioclase, sillimanite and opaque minerals. K-feldspar porphyroblasts have cuspate interstitial quartz grains, also quartz grains are included in K-feldspar. Most K-feldspar grains are highly strained and in some cases are fractured. Prismatic and fibrolite-type sillimanite are both present. Biotite is closely associated with fibrolite-type sillimanite. Sillimanite was observed to mimic the foliation produced by biotite. K-feldspar is the dominant mineral and could have formed by the dehydration reaction of biotite + plagioclase + quartz + sillimanite → garnet + K-feldspar + melt. Microscopic structures such as strained feldspar grains, micro-fractures in K-feldspar, simple twinning in K-feldspar, myrmekite, mimicking textures, microperthitic intergrowth and cuspate volumes of quartz surrounding K-feldspar are indicative of melt-bearing and solid-state deformation of regional metamorphic rocks.

Keywords: Microperthitic intergrowth, Fibrolite, Myrmekite, Microcline.

INTRODUCTION

The Precambrian rocks of Nigeria are located in a region that was impacted by the Pan-African Orogeny 600–150 Ma ago, northwest of the Congo Kasai Craton and east of the West African Craton (Rahaman *et al.*, 1983, 1991; Bruguier *et al.*, 1994). Oyawoye (1964) reported that the Nigeria Basement Complex is made up of three main rock types: Ancient Metasediments; gneisses, migmatites, and older granites; and the Newer Metasediments. In the past, Ikare area which is part of the Precambrian Basement complex of southwestern Nigeria has been mapped as variably migmatized, undifferentiated, biotite and biotite-hornblende-gneiss with intercalated amphibolite (Dempster, 1966). Rahaman (1976) in a study, reviewed the geology of Ikare area in which migmatite-gneiss of the Precambrian complex was identified as the main rock unit. The migmatite-gneiss complex as identified by Rahaman (1976) comprises of; biotite and biotite hornblende gneisses; quartzites and quartz schist and; calc-silicate rocks which occur as small lenses. Upper amphibolite facies metamorphism has been suggested for the Precambrian basement of southwestern Nigeria based on field evidences, petrology as well as structural analyses (Oyinloye, 1992). The Precambrian migmatite gneiss-quartzite complex has an age of 2700-2000 Ma. Rocks of the Archean age have been clearly identified in the basement from southwestern (Rahaman and Ocan, 1988). Rahaman and Ocan (1988) consider that granulite facies metamorphism is pre-Pan-African in age. In recent times, effort has been made to map the various rock units of Ikare area (Oziegbe, 2016; Ugwuonah, 2018; Oyawale and Ocan, 2020). These studies have reported the following rock units; pelitic gneiss, grey gneiss, granite gneiss, charnockitic gneiss, quartzite, porphyritic granite and mafic intrusive. In northern part of Ondo State southwest Nigeria, where the gneisses and related supracrustals are extensively exposed (Figure 1). Significant bands of supracrustal rocks that is up to 1 km along strike can be observed in Ikare region (Rahaman and Ocan, 1988; Oziegbe, 2016).

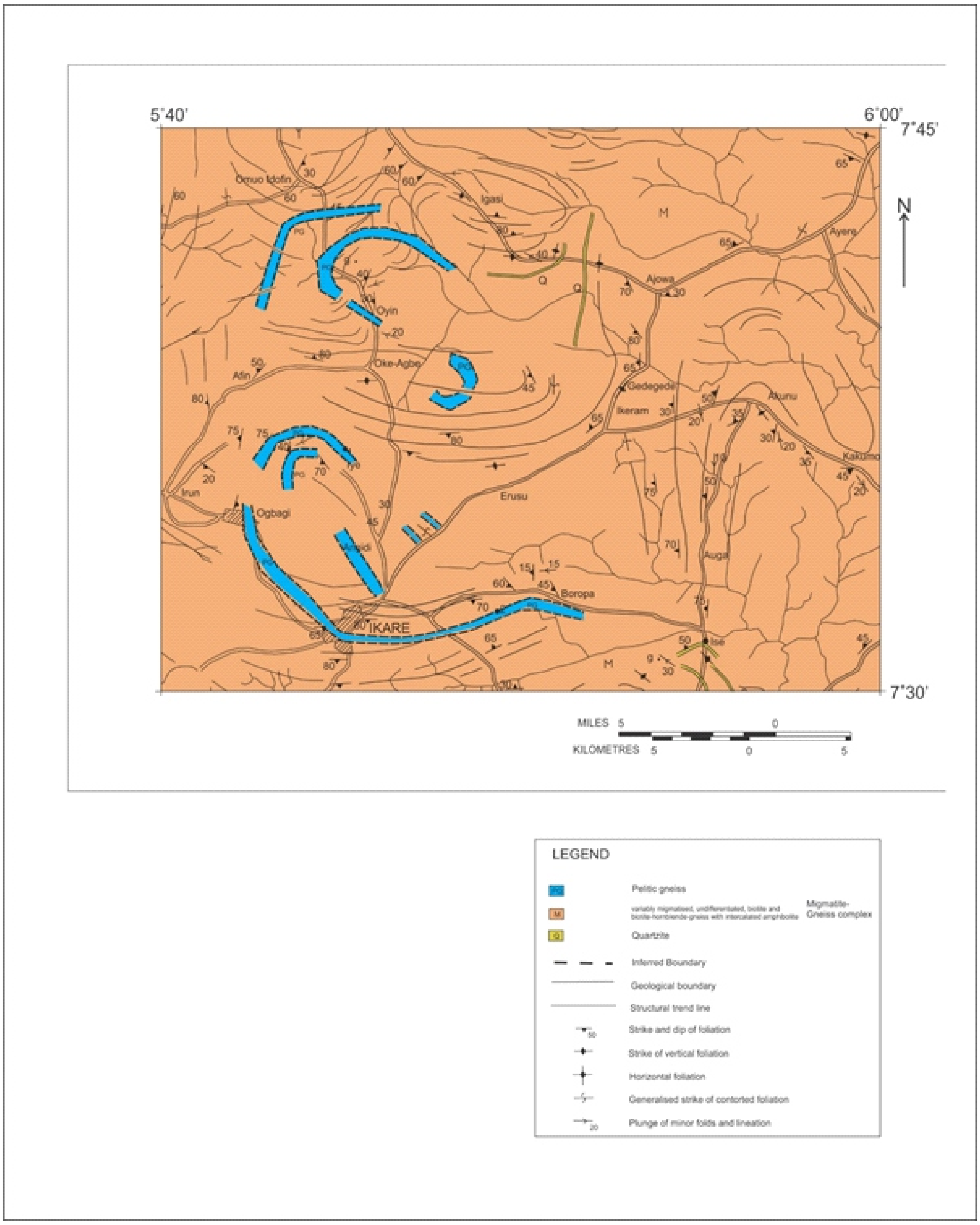

Figure 1: Geological map of the study area (Modified after Dempster, 1966; Oziegbe, 2016)

Rocks of Ikare area have been reported to have undergone four episodes of deformation and a minimum of three episodes of metamorphism (Oyawale and Ocan, 2020). Evidence of transition from the upper amphibolite facies to granulite facies has been documented in Ikare area. Also, retrograde processes have been reported in both charnockitic and pelitic gneisses in this area (Oziegbe *et al.*, 2020, Oyawale and Ocan, 2020). The granite gneiss under study is light coloured coarse grained with porphyroblasts of brownish garnet (Figures 2a & 2b). There is an abundance biotite schlieren on the surface of granite gneiss (Figure 2a). The main purpose of this paper is to use microstructures to interpret the metamorphic evolution of granite gneiss of Ikare area, southwestern Nigeria.

MATERIALS AND METHODS

Thin sections were prepared at the laboratory of the Department of Geology, Obafemi Awolowo University. The thin sections were studied using a polarizing microscope at the Department of Geosciences, University of Lagos and photomicrographs of areas of interest were taken using a digital camera.

RESULTS

Petrography

Porphyroblasts of garnet occur in the matrix of K-feldspar and quartz (Figures 3a & 3b). Garnet grains has numerous fractures and also have inclusions of quartz making the grains poikiloblastic towards quartz. Xenoblastic biotite is greenish-brown in colour and is in most cases surrounded by fibrolitic sillimanite (Figure 3c & 3d). Fibrolites of sillimanite mimic the texture left behind by biotite (Figures 3e & 3f). Some of these mimickitic structure show folded structure (Figures 3e–4b). Prismatic sillimanite occurs at the edges of altered biotite and in some cases surrounds fibrolitic sillimanite (Figures 4c–4e). Both fibrolitic and prismatic sillimanite occur at the edges of K-feldspar (Figures 4e & 4f).

Figure 2: (a) Field photograph of granite gneiss at Ikare showing brownish porphyroblasts of garnet. Take note of the preferred alignment of dark-coloured mineral (biotite). (b) Field photograph showing porphyroblasts of garnet in granite gneiss, where dark specks of biotite are not aligned

K-feldspar occur as porphyroblasts, and in most cases are strained (Figure 3d). K-feldspar grains in some cases show cross-hatched twinning (Figure 5a) and also microperthitic intergrowth (Figures 4e & 5c). Quartz grains fills the spaces between porphyroblasts of K-feldspar (Figures 4f–5e) and in some cases occur as inclusions in porphyroblasts K-feldspar (Figures 5a & 5d). Symplectic intergrowth exists between quartz and plagioclase feldspar (Figures 5c). Plagioclase feldspar is surrounded by both grains of K-feldspar and quartz (Figure 5e). Opaque minerals (ilmenite) surrounds sub-idioblastic grains of biotite (5f).

DISCUSSION

The rocks of Ikare can be said to have been subjected to ductile deformation. Structural trend (curved) around Ogbagi, Oke-Agbe and Oyin Akoko (Figure 1) are evidences of ductile deformation on a large scale. Two major foliation trends can be recognized; the N-S trending foliation and E-W trending foliations (Figure 1), which could have resulted from two different episodes of deformation (D1 & D2). The E-W foliation trend stretches from Iboropa through Ikare areas, and across Igashi, while the N-S foliation trend extend from Auga through Gedegede to Ajowa, and Ogbagi through Irun to Oyin Akoko (Figure 1). Evidences of multiple fold episodes have also been reported in Ikare area (Oziegbe, 2016; Oyawale and Ocan, 2020). Authors have suggested two phases of folding of the Pan African Orogeny for the Nigerian Basement Complex (McCurry, 1976; Fitches *et al.*, 1985). Also, domes and basins structures have been reported from Ikare area (Oziegbe 2016; Oyawale and Ocan, 2020) which could have resulted from the interference of two folds of different axial plane directions (Rahaman *et al.*, 1991). Consequently, Ikare area has undergone at least two stages of regional deformation (Oyawale *et al.*, 2020).

The textural relationship in Figures 3d-3f, is an indication that unstable biotite breaks down to a more stable K-feldspar and sillimanite, and this can be represented by equation (1) (Kretz, 1964):

Biotite + Plagioclase + Quartz + Sillimanite ⇨ Garnet + K-feldspar + Melt (1)

There is a high reduction of biotite grains as observed in the thin section study. The reduction in the amount of biotite grains is an indication that the equilibrium shifts to the right-hand side of equation (1) at high temperatures and an indication of granulite facies (Kretz, 1964). K-feldspar-sillimanite has been reported to occur in higher grade of regional metamorphism with biotite greatly reduced (Vernon, 1987). Quartz inclusion in K-feldspars (Figures 5a & 5d) suggests quartz as a prograde mineral. The strains on most of the K-feldspar might be a result of ductile stretching. Since there are opaque minerals (ilmenite) then equation (2) (Kretz, 1964) will take care of the titanium in biotite:

Biotite + Quartz ⇨ Ilmenite + K-feldspar + Sillimanite + H_2O (2)

Figure 3: Photomicrographs showing: (a) porphyroblasts of garnet with numerous fractures, PPL (b) porphyroblasts of garnet (Grt) with inclusions of quartz (Qtz), surrounded by K-feldspar. XPL (c) fibrolitic sillimanite (Sil) at the edges of brownish biotite (Bt), PPL (d) K-feldspar mantling biotite (Bt), sillimanite (Sil) and quartz (Qtz), PPL (e) folded trails of sillimanite (Sil), PPL (f) fibrolitic sillimanite (Sil) mimicking foliation left by biotite (Bt), PPL

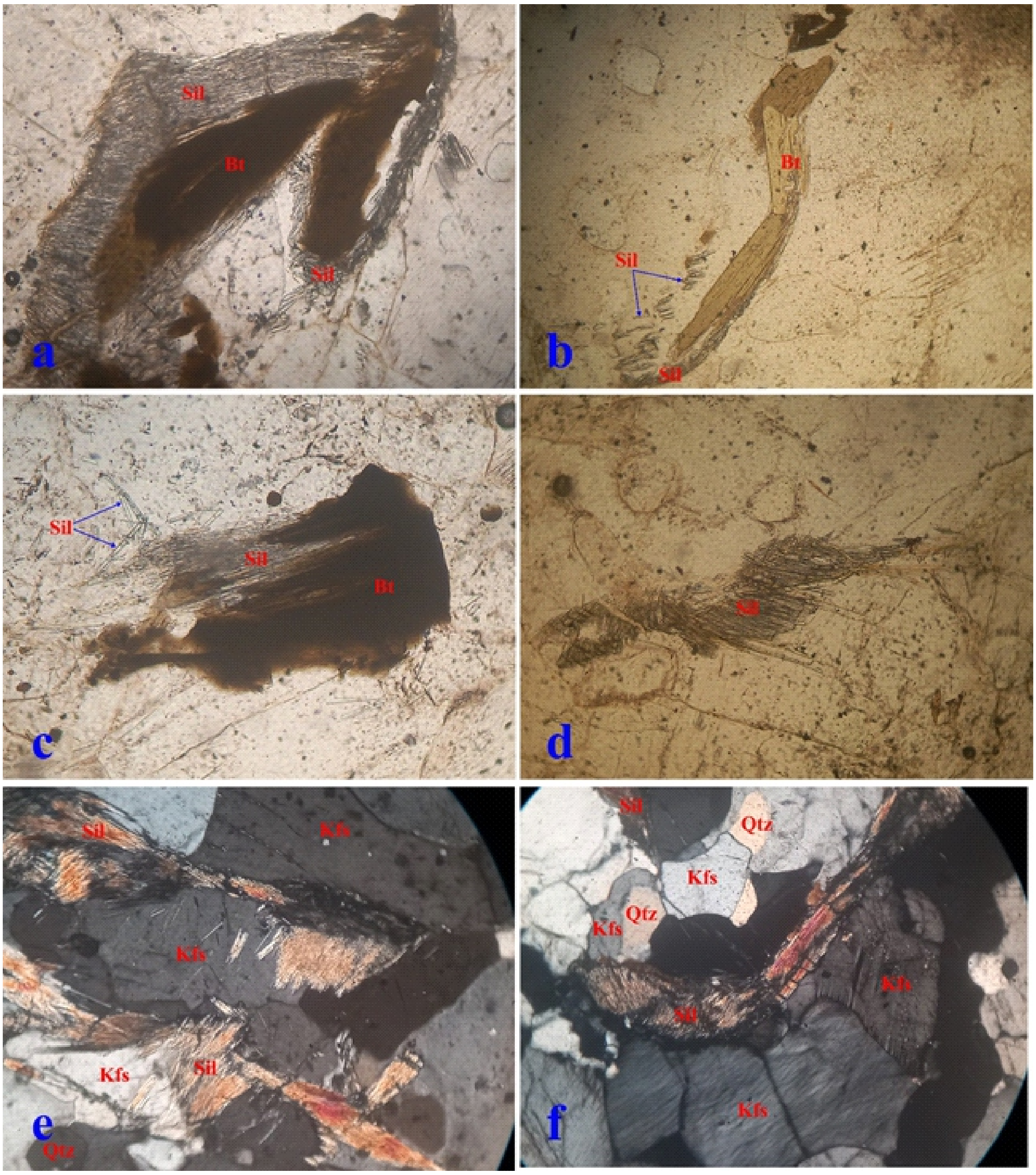

Figure 4: Photomicrographs showing (a) parallel to sub-parallel aggregates of fibrolitic sillimanite surrounding biotite, PPL (b) sillimanite (Sil) aligned in the same direction as biotite (Bt), PPL (c) prismatic sillimanite (Sil) concentrated along the edges of biotite. PPL (d) prismatic euhedral sillimanite (Sil) concentrated around fibrolitic sillimanite (Sil), PPL (e) sillimanite occurring at the edges of K-feldspar (Kfs), with some occurring as needles in K-feldspar (Kfs), K-feldspar also show microperthitic intergrowth, XPL (f) quartz (Qtz) and sillimanite (Sil) filling the spaces between grains of K-feldspar (Kfs), XPL

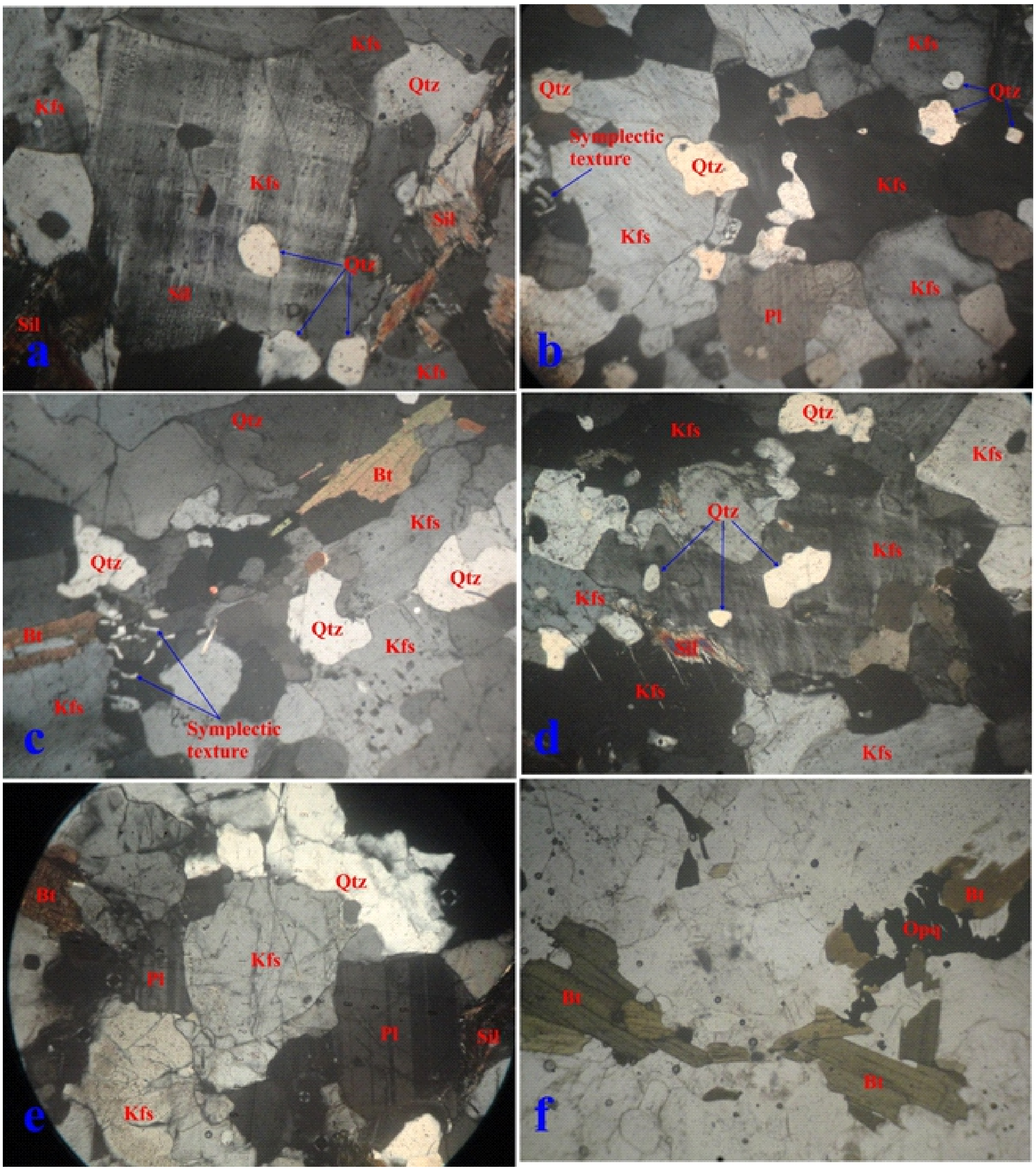

Figure 5: Photomicrographs showing (a) inclusions of quartz (Qtz) in K-feldspar (Kfs), tartan twinning well developed in K-feldspar (Kfs), XPL (b) quartz (Qtz) grains at the edges of porphyroblasts of K-felspar (Kfs), XPL (c) symplectic (wormy-like) intergrowth between quartz and plagioclase, take note of the microperthitic intergrowth on the K-felspar (Kfs), XPL (d) smaller grains of quartz (Qtz) at the edges of porphyroblasts of K-feldspar (Kfs), inclusions of quartz grains in K-feldspar, XPL (e) plagioclase (Pl) surrounded by quartz (Qtz) and K-feldspar (Kfs), K-feldspars has numerous fractures, XPL (f) opaque minerals surrounds sub-idioblastic grains of biotite (Bt) PPL

The above reaction is a form of biotite dehydration melting reaction. Biotite-dehydration melting (biotite + quartz + plagioclase + sillimanite = melt + garnet + K-feldspar) occurs at temperatures of 760–800 °C (Breton and Thompson, 1988). The marginal replacement by myrmekite (Figure 5c) is evidence of gneisses derived from the solid-state deformation of granitoid (Simpson and Wintsch, 1989). The reaction between K-feldspar and plagioclase produces blebs of quartz. The microstructure showing K-feldspar between two plagioclase grains (Figure 5e) is an example of pseudomorphs of melt along grain boundaries of unlike phases, and is indicative of crystallization from melt (Holness and Sawyer, 2008). Rectangular grains of K-feldspars are pieces of evidence of phenocrystic source (Vernon, 1986). The contact of the minerals quartz, K-feldspar and plagioclase grains (Figure 5e) is indicative of simultaneous crystallization from melt (Clemens and Holness, 2000; Vernon *et al.*, 2004). Microstructure involving these three minerals is a reliable criterion for the identification of former melt in regional migmatites (Vernon, 2011). Quartz grains included in porphyroblasts of K-feldspar (Figures 5a & 5d) are not as strained as those within the matrix (Vernon, 1990). The sillimanite concentrations (Figures 3e & 3f) may be due largely to 'fibre sliding' which is the ability of fibrolite aggregates to undergo strong non-coaxial deformation by grain-boundary sliding (Vernon, 1987). The curving of fibrolitic sillimanite observed (Figures 3e & 3f) are evidence of non-coaxial strain (Simpson and Schmid, 1983; Vernon, 1987). The folded trail of sillimanite is called mimickitic texture and is evidence of post tectonic metamorphism, that is, metamorphism after the folding episode that produced the biotite. The original foliation defined by biotite could have resulted from D1, while the folding of the biotite grains could have developed from D2. Since the folded sillimanite grains (Figures 3e & 3f) mimics the biotite grains, with no bent grains, they can be described as post-tectonic. A series of deformational and evolutionary episodes had previously been reported in the granite gneisses of southwestern Nigeria (Oyinloye, 2011). Mimicking textures have been previously reported in the gneisses of Ikare area (Oyawale and Ocan, 2020). Some authors have proposed the growth of fibrous sillimanite from biotite (Chinner, 1961; Homam *et al.*, 2002), as indicated in equation (2). Melt-residue back reaction was proposed for the fibrolitic sillimanite which surrounds biotite in the pelitic gneiss of Ikare area (Oziegbe *et al.*, 2021). A similar assemblage Grt + Sil + Kfs + Qtz + Bt + Pl obtained in this study, has been reported as the peak metamorphic assemblage in aluminous gneiss of Khondalites (Wang *et al.*, 2011).

CONCLUSION

Biotite dehydration dry melting can be said to have occurred in the granite gneiss of Ikare area. The abundant K-feldspar could have formed by the dehydration melting reaction of biotite + plagioclase + quartz + sillimanite → garnet + K-feldspar + melt. Quartz included in porphyroblasts of K-feldspar are free of deformation. The folia sillimanite can be interpreted as post-deformational. Textural evidences suggest fibrolitic sillimanite replacing biotite. Microscopic structures such as strained feldspar grains, micro-fractures in K-feldspar, simple twinning in K-feldspar, myrmekite, mimicking textures, perthitic intergrowth and cuspate volumes of quartz surrounding K-feldspar are indicative of melt-bearing and solid-state deformation of regional metamorphic rocks.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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