Evidences of Metasomatic Processes During the Emplacement of Pan-African Granites in the Eastern End of the West African Craton.

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Abstract
Pan African Orogeny has been linked with pervasive potash metasomatism that has affected most parts of the Precambrian Basement Complex of Nigeria. The Nigerian Basement Complex is characterized by several granitoid intrusives marking the Pan-African orogeny (600 Ma). They are seen emplaced within schists and migmatites. These rocks reflect syn- to post collisional environment.The Ilesha schist belt is studied to investigate which of metasomatic or magmatic processes is the more dominant process that affected the emplacement of rocks of the Nigerian basement complex.Aluminium saturation index (ASI) shows that these granites range from metaluminous – peraluminous. Tectonic model reveals that they are calc-alkaline products of continental collision events. Petrographic studies show typical composition of quartz, alkali feldspar, biotite and hornblende as the major mineral phases. Both geochemical and petrographic data infer phase changes that may be connected with potash metasomatism.
Key words: Older granites, Potash metasomatism, Microcline, Pan African orogeny and Ostwald ripening)

Introduction

The Nigerian Basement Complex is characterized by several granitoid intrusives marking the Pan-African orogeny (600 Ma). They are seen emplaced within schists and migmatites. These rocks reflect syn- to post collisional environment. The term 'older granite' is used to refer to rocks formed before the Paleozoic and therefore predates the Mesozoic anorogenic alkaline suite known as the younger granites (Falconer, 1911). Porphyritic granite gneisses of Eburnean age (2205 ± 70 Ma) occur together with Pan-African porphyritic granites (750 and 450 Ma) within the Precambrian Basement Complex of Nigeria. Mullan (1979), however, believes that this rock suite is Eburnean and possibly Kibaran. The intrusive nature of the Pan-African older granites has been linked to the mineralization of rejuvenated basement, mobilization, dissemination and concentration of gold in geosynclinal older mineralized schist belts (Chuku, 1988). Mineralization within the schist belt localized in the western half of Nigeria may be products of subaerial volcanism in an oxidizing environment (Elueze, 1977, Olade and Elueze, 1979). Earlier understanding of the evolution of this Complex suggests a single Pan-African cycle of deposition, deformation and metamorphism (Truswell and Cope, 1963). However several authors opined against a monocyclic basement complex. Records of Liberian as well as Eburnean orogenies make them believe that the Nigerian Basement Complex suffered multiple deformation episodes, hence polycyclic. Evidence of ionic diffusion during emplacement of these rocks is presented in this paper as a possible source of K-metasomatism that is wide spread within the Basement Complex of Nigeria.

The Older granite rocks are slightly peraluminous with normative corundum and acidic with low Fe/Mg ratio. The origin of these bodies may be from anatexis of the host gneisses rather than differentiation of parent magma (Olarewaju and Rahaman, 1981). Geochemical data from older granites in the Akure, Ado-Ekiti points to enrichment in light rare earth elements (LREEs) with depletion in heavy rare earth elements (HREEs) (Olarewaju, 1981). The composition of the older granites is varied ranging from dioritic and tonalitic through granodioritic to true granites, pegmatites and syenites (Rahaman, 1988). A common mineralogy is found consisting of qtz + alk-fds + plg + bt + opaques ± hrn ± musc.

Based on their tectonic nature of emplacement, the older granites have been classified into three groups (McCurry, 1988). The older granites from the Ilesha schist belt, southwestern Nigeria, belong to the syn- to post tectonic granites class. The southwestern part of the Nigerian Basement is characterized by complex structural styles. Cooray (x) attributed this to high degree of metamorphism, faulting and the absence of well defined younger schist. Northward plunging anticlinorium with a migmatitc core and associated synclinorium of metasediments is the prominent style in the area. Quartzite bands in gneisses around Ibadan exhibit major folding with NW axial trace. This structural style is consistent with the trend observed for the granite batholith north of the Ilesha schist belt. Foliation and schistosity are therefore thought to be of tectonic-origin and not due to original compositional differences.

Geochemical and petrographical data from granites within the Ilesha schist belt were used to investigate phase changes in their mineral composition. Silica-potassium metasomatism has been suggested to have affected the basement complex of Nigeria (Oyawoye, 1964). This may not be unconnected with alteration of minerals to yield new ones in events associated with dynamic metamorphism (Elueze, 1981). The Pan African orogeny (ca 600 Ma) is established as a granite emplacement period that witnessed the intrusion of older granites into the migmatite gneiss – quartzite complex, Eburnian granitoids and associated schist terrains within the Nigerian Basement Complex. The occurrence of microcline in the mineralogical suites of granites suggests low temperature metamorphic conditions during evolution (McBirney, 1993). The pan-African orogeny has been reported as a thermotectonic event that presupposes elevated temperatures to favour the emplacement of rocks of granulite facies, such as the Ado-Ekiti charnockites. Partial melting is favoured with emplacement of collisional granites (Freeth, 1970) and this may account for ionic diffusion of elements. Bi-metasomatism or feldspathization as possible cause for silica-potassium metasomatism is investigated.

Geology of the Ilesha Older granites

North of the Ilesha schist belt, in the heart of the Nigerian rain forest vegetation, is a prominent Granite batholith (Fig. 1). This batholith spans a total area of 120 Km^2. Image of the area on Landsat 7 (Fig. 1) reveals the whole rock body as one discreet body, with several out shoots as inselbergs. Elevations may reach close to 670m (Igbajo, south Imesi-Ile). Like many bodies around the Ifewara/Zungeru fault line (Fig. 1) this batholith trends in the NW/SE. This makes it a discordant body to the Ifewara fault line.

The granitic rock is observed to be severally intruded by criss-cutting quartzofeldspathic veins with preferred trends in the NE/SW and NW/SE directions as well as dolerite dykes that trend mainly NNE-SSW. The characteristic setting within migmatite-gneiss-quartzite complex with infolded schist is typical (Fig 1). They occur as concordant bodies with sharp contact with the metasediments. Migmatitic gneisses bounding this batholith to the south and east are separated by thick sequences of quartz muscovite schist. Migmatites occur as vestigial crystalline rocks.

Mafic-ultramafic xenoliths are conspicuous around Otan-Ile to Igbajo. These inclusions show sharp contacts with their host. Some of these inclusions show evidences of macro internal schistocity which McCurry (1988) described as swirling foliation for those mapped in the northern part of the country. Rotated xenoliths are not uncommon. This suggests intense deformation associated with their emplacement. Several dolerite dykes with width averaging 30cm occur as criss-crossing veins. Also cutting are minor aplite dykes evident around the southern part of the rock. The abundance of biotite flakes gives the rock a biotite granite gneiss nature.

The rock exhibits a weakly foliated fabric. Biotite, quartz and alkali-feldspar exhibiting antirapakivi texture are observed from hand specimen. Grains are quite large with biotite flakes reaching 0.6cm by 0.8cm especially near pegmatitic intrusions south of Igbajo. The alkali feldspar exhibits Carlsbad twinning and size averages 1cm by 2.4cm. Pinkish alkali feldspars are more prominent at the centre of the batholith. Thin section slides reveal biotite, quartz, plagioclase (oligoclase) and microcline. Several grain to grain contacts reveal annealing/ostwald ripening.

Methodology

Field mapping exercises were conducted between January and April (i.e. the dry periods of the year) as most land would be laid bare in preparation for the planting season. This period facilitates easy access as well as good exposures of outcrops.

Eleven samples were selected from fifty five rock samples obtained from the granite batholith north of Ilesha schist belt. Several thin sections were made to reveal the mineralogy. The thin sectioning was performed at the Obafemi Awolowo University, Ile-Ife and University of Ibadan, Ibadan.

To obtain whole rock geochemical data, from these samples, sizeable fractions were pulverized and subjected to Inductively Coupled Plasma Mass Spectrometry (ICP-MS) at the ACME laboratories in Vancouver, Canada. Prepared sample is mixed with $LiBO_2/LiB_4O_7$ flux. Crucibles are fused in a furnace while cooled beads are dissolved in ACS grade nitric acid. Loss on ignition (LOI) was determined by igniting a sample split then measuring the weight loss was done,

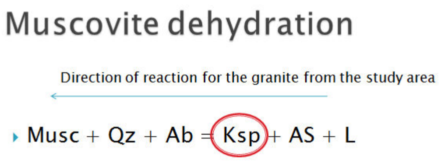
Analysis of major element was performed using Petrograph® while observation of the minerals in thin sections was done with a petrological microscope and a camera for photomicrographs.

Results

The result of the geochemistry of the granite is presented in Table 1. The SiO_2 concentration ranges from 63.3 – 77.25wt% with a mean concentration of 69.35wt%. The average values of concentration for other oxides such as Al_2O_3, Fe_2O_3, MgO and CaO are 14.31wt%, 3.29 wt%, 0.65wt% and 2.53wt% respectively. This study regards Fe2O3 as the total Fe (i.e. FeO_{tot}The concentration of Na_2O and K_2O ranges from 2.44 – 3.77wt% and 2.91 – 6.87wt% respectively while their respective mean values are 2.95wt% and 5.25wt%. The Na_2O/K_2O ratio is

0.56wt% while the FeO/FeO+MgO index is 0.835.
Mineral identification in slides reveals quartz grains displaying undulose extinction, the biotite with speckles that are characteristic of bird's eye biotite (Fig.). The alkali feldspars are identified as microcline as they display their characteristic tartan twinning while albite twinning is evident in plagioclase suspected to be oligoclase in composition (McCurry, 1988) (Fig. a and b). Muscovite is seen around annealed margins of biotite and quartz. Common hornblende is seen as prismatic and green.

Discussion
From the geochemical data, change in mineral phase is suggested by variation plots of SiO_2 vs K_2O, SiO_2 vs CaO and SiO_2 vs Total Alkali (Figs. 2a and b). These plots infer a differentiating magma characterized by the appearance or disappearance of a phase rich in alkali (McBirney, 1993). The granite metaluminous to peraluminous with Aluminium Saturation Index (ASI) of ca 1.00 computed for the peraluminous pinkish microcline rich samples obtained at the core of the batholith while values less than 0.97 is recorded for those samples obtained elsewhere. This change in mineral phase is therefore consistent with geochemical results. Samples plot in the calc-alkaline field (Fig. 3) of Irvine (1971). The older granites of Nigeria have been widely accepted as syn-post collisional that implies a subduction zone for their emplacement.
Three waves of metasomatism affected the rocks of the basement complex of Nigeria during the Precambrian. Potash metasomatism is by far the most common. In granites of the Ilesha schist belt evidence of this is bold. Oyawoye (1970) linked these waves of metasomatism to temperature gradient and considered the potash metasomatism as lower in temperature. The formation of myrmekite and muscovite (Fig.4) present sources of K+ ions that diffuse and pervade rocks during the Pan African orogeny. Equation 1 shows muscovite dehydration that may possibly occur during the thermotectonic orogeny.



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The replacement of microcline (Fig. 4e) during the formation of myrmekite (Fig. 4c) releases K+ which may then become available for the formation of muscovite in the presence of quartz and albite. The possibility of feldspathisation is unlikely as crystals of microcline and quartz do not show strong intergrowth (Fig. 4d).
Large crystals of alkali feldspar are characteristic of the older granite and granites of the Ilesha schist belt is no exception. It is believed that the temperature at which these rock body is emplaced may not favour crystallization of such large crystals. Evidence of Ostwald ripening is presented as possible explanation for their growth and relationship with quartz grains.

Conclusion
Inflexion from the variation plots SiO_2 vs K_2O and SiO_2 vs Total alkali show change in mineral phase. The presence of myrmekite shows that K+ is released as Quartz and plagioclase is formed and Alkali feldspar is consumed. This reaction may be responsible for the formation of muscovite grains observed both in thin section and some portions of the granite at Imesi-Ile, a town within the Ilesha schist belt. Although aureoles have not been established around these intrusive batholiths evidences from this reactions suggest bimetasomatism.

Table1: Major Oxide composition for the porphyritic Granite north of Ilesha

	SiO2	Al2O3	Fe2O3	MgO	CaO	Na2O	K2O	TiO2	P2O5	MnO
S1	73.19	12.76	2.99	0.24	1.27	2.69	5.53	0.31	0.08	0.03
S2	77.25	11.13	2.39	0.22	1.06	2.47	4.51	0.24	0.08	0.03
S3	70.18	13.79	3.66	0.2	1.45	2.76	6.27	0.34	0.07	0.03
S4	72.31	13.16	2.77	0.14	1.38	2.86	5.77	0.27	0.06	0.03
S5	73.84	12.61	2.53	0.1	1.24	2.6	5.64	0.23	0.05	0.03
S6	72.11	13.38	2.54	0.11	1.08	2.44	6.87	0.28	0.04	0.03
S7	64.54	15.37	4.5	1.31	4.38	3.48	3.95	0.78	0.28	0.1
S8	63.3	16.08	4.58	1.78	4.64	2.95	4.79	0.45	0.22	0.09
S9	64.88	17.1	2.84	0.74	3.28	3.29	5.95	0.5	0.19	0.05
S10	64.66	15.33	4.63	1.53	5.12	3.77	2.91	0.78	0.15	0.12
S11	66.6	16.67	2.77	0.8	2.99	3.09	5.59	0.36	0.19	0.04

a

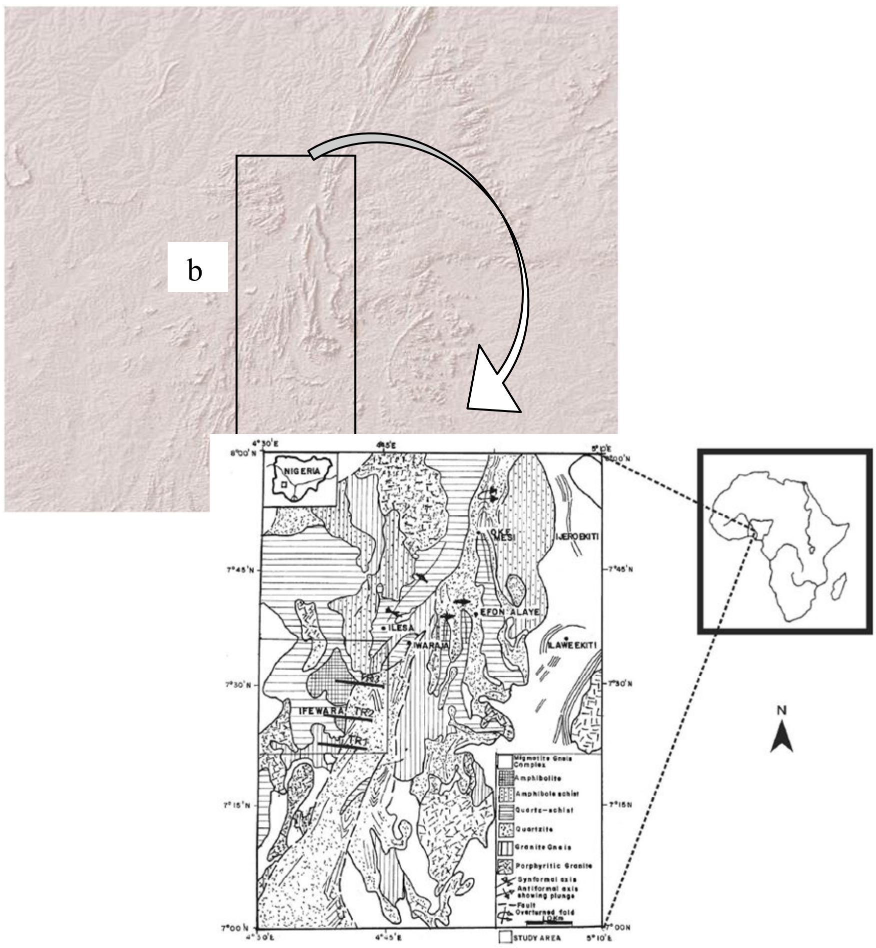

Figure 1: a) Shaded relief of southwestern Nigeria. b) Geological map revealing the litho-structural setting of rocks within the Ilesha schist belt of Nigeria.

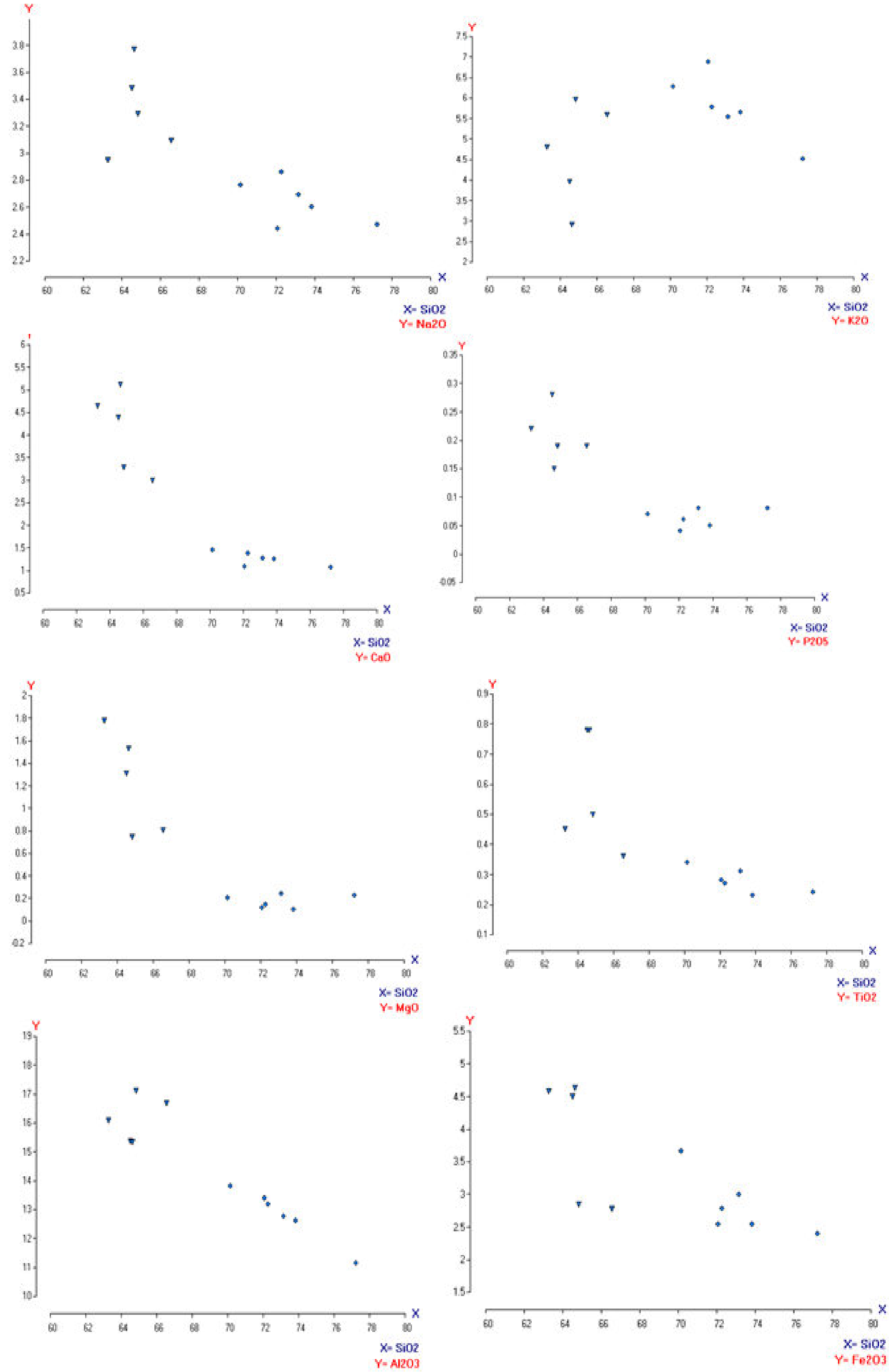

Figure 2a: Harker's plot revealing marked change in linearity in plots of SiO_2 vs K_2O.

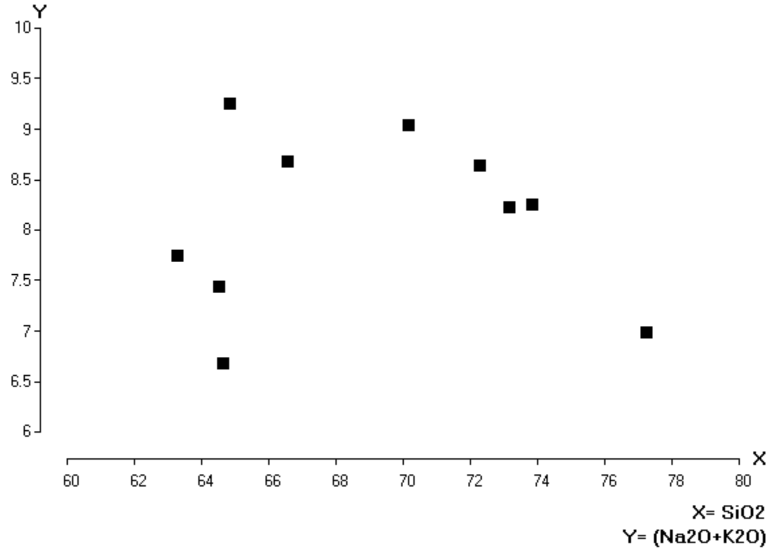

Figure 2b: Curved trend is also observed in SiO_2 vs (Na_2O + K_2O) (modified after Kuno et al. 1957).

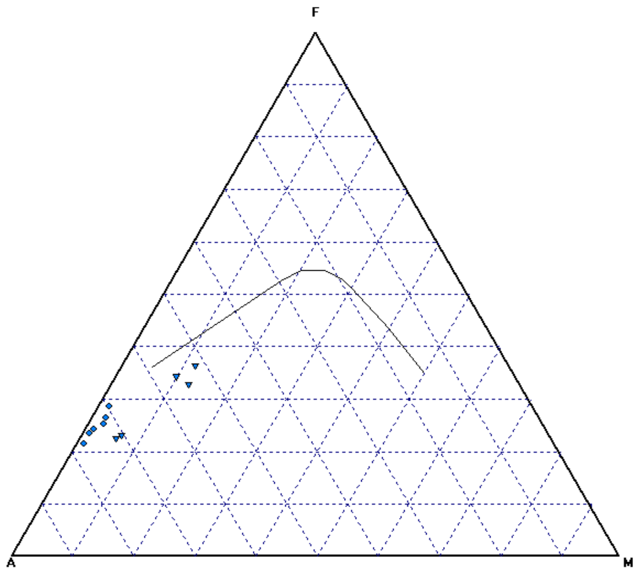

Figure 3: Granites plot in the calc-alkaline field (Adapted after Irvine Baragar, 1971).

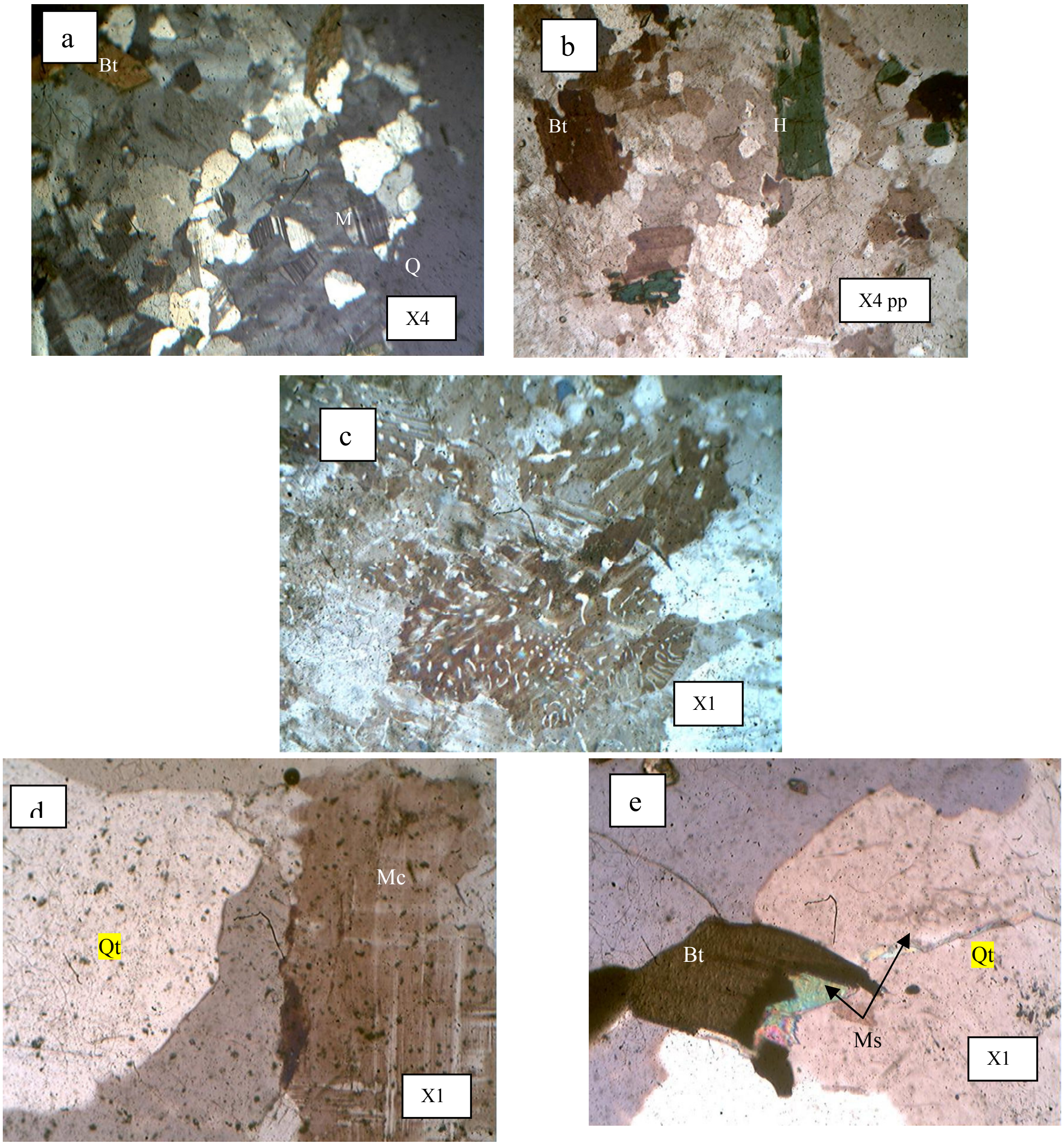

Figure 4: Mineralogical composition of quartz, biotite and microcline is revealed in a and b. In c myrmekitic texture shows blebs of quartz. No evidence of intergrowth between alkali feldspar and quartz in d. Possible alteration of biotite to muscovite is observed in e.

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