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Morphology and microstructure of migmatite rocks around Zaranda, Bauchi

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ABSTRACT

The study area covers Zaranda village and environs within latitudes 10°16'00"N & 10°13'00"N and longitudes 9°39'21"E & 9°42'35"E. In the northern Precambrian basement, the area comprises mainly of pan-African migmatites, based on previous literatures. 15 samples of rocks have been subjected to geochemical and petrology studies after carrying out the geological mapping technique. The rock samples are found to contain high amounts of silicon oxides and low major oxides. The minerals identified are biotite, ilmenite, silimanite, garnet, quartz, and feldspar (plagioclase orthoclase). Microstructures were observed under cross- and plane-polarized light, indicating rock forms and resulting in partial melting of structures: melting of feldspar in quartz and vis-é-vis and cleavages in plagioclase feldspar. The paleosome appears finer and lighter as observed in the field. The remains of metasedimentary rocks as evident by quartzite rock are observed at a point within the study area. This work shows sodium-rich plagioclase and has successfully categorized the homogeneous and inhomogeneous migmatite into metatexite, mesocratic, and leucocratic diatexites.

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1. Introduction

Detailed field studies were carried out within latitudes 10°16'00"N & 10°13'00"N and longitude 9°39'21"E & 9°42'35"E, on a scale of 1:25,000, which falls on the Bauchi migmatites and on major road to plateau state; all exposures studied are connected with foot paths.

Migmatites is a Greek word which literary means “mixed rock”. It was first introduced into the geological literature in 1907 by Jakob Johannes Sederholm. Migmatite is a result of partial melting also known as anatexis. It is divided into metatexite and diatexite; the difference between the two are the late preserved pre-anatectic structure, whereas no pre-anatectic is preserved in diatexite, which is a result of balance between the degree of partial melting and melt fraction (Tasco and Moraes, 2019). Diatexite rocks may contain light-colored minerals called leucosome or dark-colored minerals called melanosome; migmatites can also be mesosome. Terminologies such as homogeneous and inhomogeneous are used to classify parts of the diatexite rock sample where the dark and light colors are observed.

Generally, leucosomes have igneous characteristics and melanosome have metamorphic characteristics (Milord et al., 2001). So many perspectives exist about the origin of the heat responsible for the partial melting such as radiogenic heating, hot geotherm, and

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additional heat from mafic magma in the continental margin.

Oyawoye (1961) concluded that probably most of Nigeria was covered by sedimentary rocks which experienced regional metamorphism, such as quartzite, amphibolite, schist, and calc-silicate in the Precambrian period. These rocks are still found in places where is not covered by the cretaceous sedimentary (sedimentary basin).

Geochemical studies on the rocks are fundamental to classify rock types in terms of major oxides and minor/trace elements together with petrographic observation from thin sections; we will look at the petrogenesis and evolution of the rocks as follows:

- The thermal and barometric conditions in which the primary magma was formed;
- The magmatic processes that might be involved in the evolution of igneous rocks;
- The geotectonic environment in which igneous rocks might have been formed (Sawyer and Brown, 2008).

2. Methodology

2.1. Desk study

The desk study involved an extensive and in-depth review of previously published accessible unpublished works on the study area.

(a) Literature review: the literature review of the Nigerian basement complex and its tectonic settings will be carried out by studying both published and unpublished reports.

(b) Remote sensing: interpretation through analysis of satellite images.

2.2. Field mapping

The first step of the field mapping involved the reconnaissance survey which was carried out to have an overview of the geology of the area on a scale of 1:50,000. Areas of interest such as out crop and river channel were delineated from the survey and mapped on the scale of 1:25,000.

2.3. Field equipment

1. Measuring tape.
2. Compass and clinometer.
3. Hammer.
4. Hand lens, including; Global Positioning System (GPRS), field notebook, pen, masking tape, sample bag, etc.

2.4. Mode of data collection

A total of 32 samples were collected during field studies and sorted into groups; later, three to four samples were selected to represent each of the groups. The samples were broken into approximately 2–3 cm and labeled for pulverization and whole rock geochemical analysis using X-ray fluorescent spectrometer at the Nigerian Geological Survey Agency, for major oxides and trace/minor elements. The result were used in plotting alkaline iron and magnesium diagram, spider diagram, hacker variation, feldspar plot, total alkali, and tectonic discrimination diagram using GCD kit and PETROGRAPH software.

2.5. Laboratory sample preparation

Rock samples were collected on the fields at the taken coordinates, naming the sample with the use of masking tape and permanent marker. The sample is described in the field notebook for geochemical analysis and petrographic studies. The sample was prepared for thin section.

2.6. Geochemical analysis

Geological field mapping covering the whole study area was conducted by climbing the most low-lying outcrops, and taking notes and observation of all rock exposures were the important things done; fresh sample collection, taken with point coordinates, description of color, textures, and composition of rock samples were carried out on the field. This also includes the study of lithology of rocks revealed in river channels.

Samples were named and described in field notebooks; the labeled samples were taken to the laboratory in sample bags for geochemical (Table 2) and petrology analysis. Rollinson and Pease (2021) and Sawyer and Brown's (2008) first- and second-order classification principles were used as a guide in the classification of rocks.

2.7. Geology of the study area

The older granite is known to be deep-seated, and is often concordant or semi-concordant and intruded during the pan-African orogeny of late Proterozoic to early Paleozoic age. They are believed to have culminated from extensive granitization which modified earlier rocks, resulting in the formation of migmatites (Fig. 1) and wide spread granitic rocks of the basement complex, with distinctions from the highly discordant tin-bearing granites (younger granite) of Northern Nigeria. Older granite rocks are subdivided into pre-, syn-tectonic, post-tectonic rocks and basic, intermediate rocks which cut across the migmatite–gneiss–quartzite complex and the schist belts. Older granite is the best representation of the pan-African orogeny (Dada, 2006; Kröner and Mainz, 2005; Rahaman and Ocan, 1978; Rahaman, 1988).

Oyawoye (1961) concluded that the name Bauchite is used to denote a dark greenish fayalite-bearing rock of quartz syenite to andemallite (Oyawoye, 1961), which is exposed along Jos, Bauchi, consisting mainly of anatectic, metapelitic, gneisses, and metatexites sheets of diatexite (Ferré and Caby, 2007; Obaje, 2009). Older granite is found to be overlain by undeformed acid and basic dykes, younger granite basement areas, and cretaceous sediments in the sedimentary basin areas.

The study area is covered by the migmatites part of the older granite, exposed in some points and river channel as observed.

3. Results and Discussion

3.1. Field relationship and morphology of the migmatites

The study area is underlain by crystalline rocks members of the older granite (Isah et al., 2020; Kachalla and Haruna, 2020; Yahuza et al., 2020); it is accessible through the major road linking Bauchi to Jos; the few outcrops are accessible through minor roads and footpaths that crisscross the area and river channel (Fig. 1). This work deals with the study of the litho-morphological units as they occur, with detailed petrography.

3.2. Metatexite

The rocks retain a low melt structure (Figs. 2 and 3) and there is evidence of partial melt movement. The rocks consist of properties of the rock (protolith) rather than that of the magma, different from the diatexite which has a lost pre-anatextic texture and structures such as bedding. The metatexites of the study area fall within the banded orthogneiss and the stromatic migmatite as in Sawyer and Brown's (2008) classification.

3.3. Macroscopic studies of metatexite

Part of the study area is occupied by metatexite, with structures observed In (Fig. 3b), however this structures disappeared in about 3,505 meters southern part (Fig. 1) of the geological map, living the rocks (Fig. 5) a simple form at sampling location S22 and S15. a net structure occurrence shows a point having more residuum than melts, this sample (Fig. 3) contains more rafts or schollen; it's basically a two systematic orientation of darker minerals that is of the paleosome, and lighter mineral of neosome, the constituent minerals of the paleosome melted less than that of the neosome. Indicating a transition point of metatexite and diatexite migmatites, this is a clear evidence of partial melting.

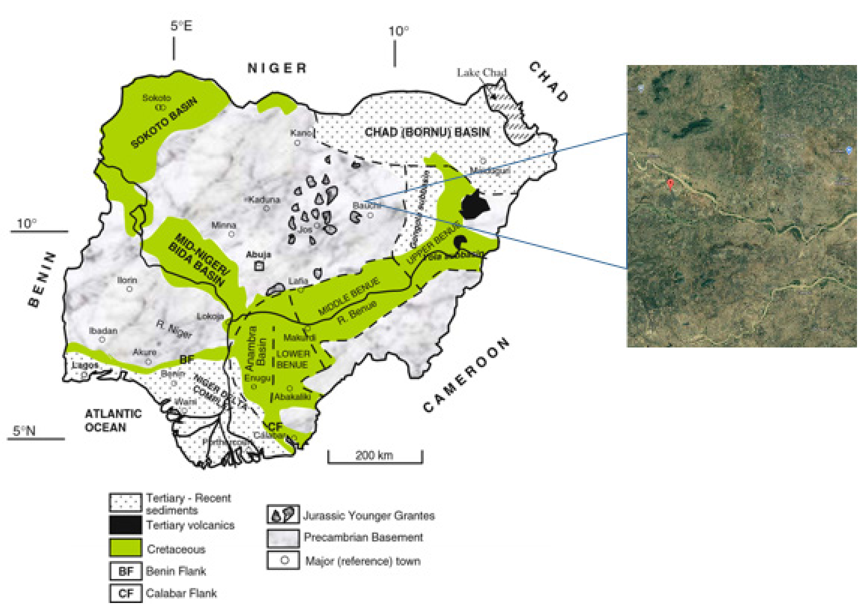

Figure 1. Geological map of Nigeria and satellite image of the study area (Obaje, 2009).

3.4. Mesocratic diatexite

This migmatite (Fig. 4) also has a fine-grained texture and is composed of plagioclase, biotite, microcline, and quartz. Predominantly, the ferromagnesian minerals are the darkest of the samples among the diatexite group, and biotite is greater than 30% volume of the rock. Quartz grains are large and irregular, and modal composition shows that orthopyroxene is the predominant proportionate to the plagioclases and exhibits strong pleochroic halos.

Figure 4 shows the microscopic photo of mesocratic diatexite

3.5. Leucocratic diatexite

Petrographic analysis shows that the rock has a coarse texture (Fig. 5) and is predominantly felsic minerals—quartz, plagioclase, K-feldspar, and small amount of biotite—which exhibit strong pleochroic halos. The quartz occurs principally in large irregular masses and in some cases it shows strain effects. The microcline exhibits a crosshatched twinning, and it sometimes occurs as interstitial grains.

3.6. Macroscopic study of leucocratic diatexite

The net structure disappears from the transition point at the metatexite and diatexite migmatite (Fig. 3a–c) to the result of this (Fig. 4), to create a simpler appearance diatexite migmatite that are all neosome (Fig. 4).

leucocratic diatexite is medium to coarse grain size comprising quartz, plagioclase, biotite, K-feldspar, apatite, zircon, ilmenite, and graphite (Milord et al., 2001). The figures shows biotite, quartz, and plagioclase well foliated, indicating clearly the direction of magma flow (Tasco and Moraes, 2019).

4. Microstructures

Some microstructures (Figs. 7 and 8) show indications of metamorphism. The following are the two microstructures observed.

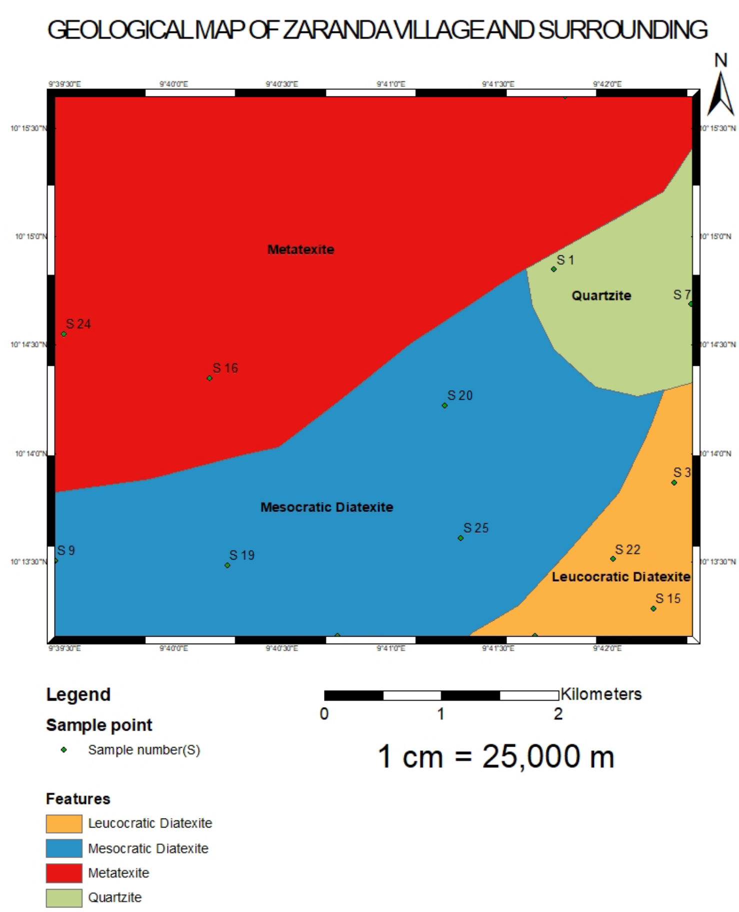

Figure 2. Geological map of the study area.

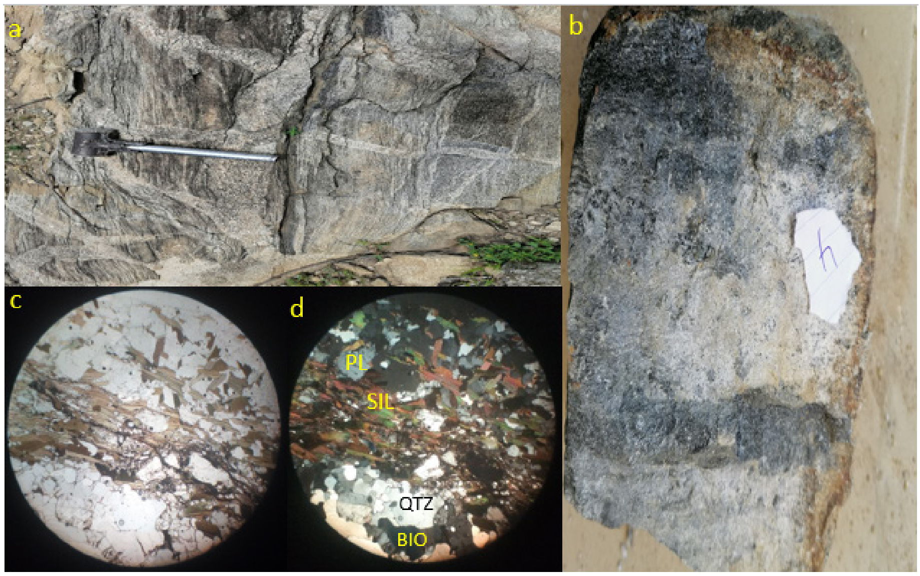

Figure 3. Metatexite (a) field photograph (b) rock sample (c) under plane- and (d) under cross polarised light (×10 magnification), showing quartz grains and exhibiting undulose extinction and bulging of grains into one another. BIO = biotite, PL = plagioclase, QZ = quartz, and MC = microcline.

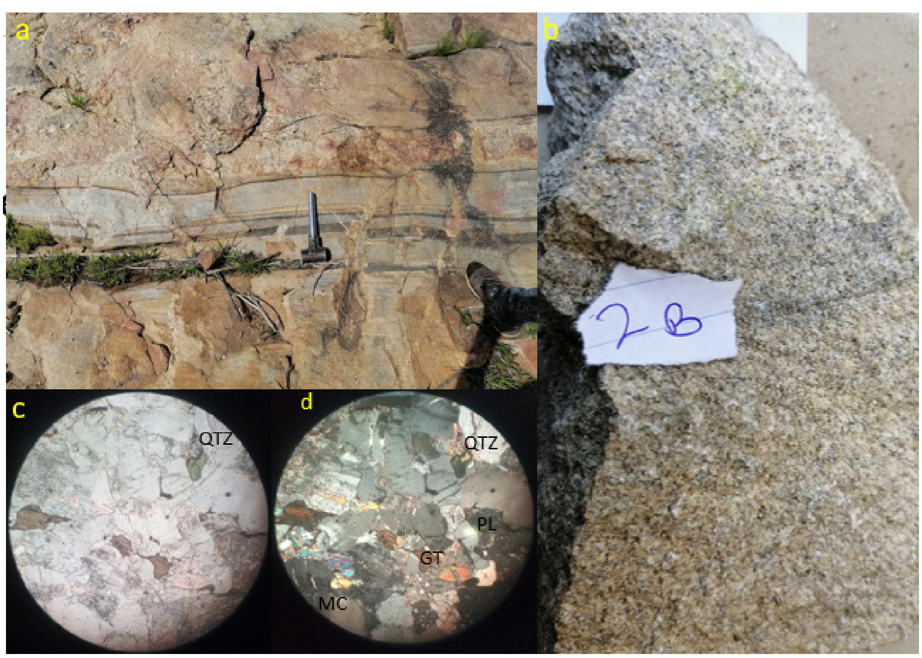

Figure 4. Mesocratic diatexite (a) field photograph (b) rock sample (c) under plane- and (d) cross-polarised light. BIO = biotite, PL = plagioclase, QZ = quartz, and GT = graphite.

4.1. Antiperthite

Antiperthite is a name given to an intergrowth of K-feldspar; in this case, "antiperthite" is observe with a patchy/lamellar texture (Fig. 7) point labeled "M" because the K-feldspar is in a plagioclase host, indicating exsolution of the K-feldspar from plagioclase upon cooling of an original higher temperature.

4.2. Myrmekite

Quartz intergrowth in plagioclase occurrence of this is an indication of somewhat metasomatism in conjunction with tectonic deformations (Fig. 8), the mechanism for the melt differentiation and also differential solid and liquid faces.

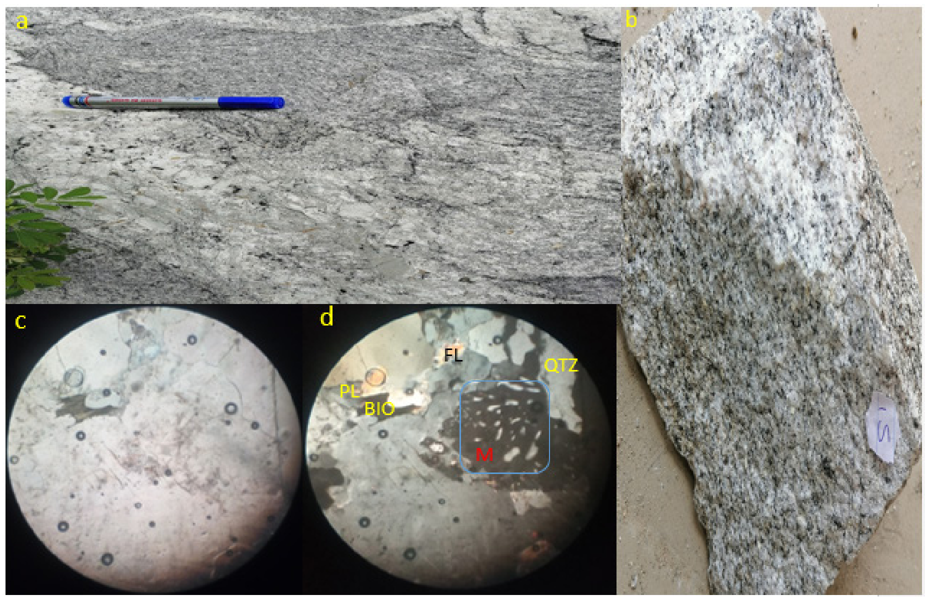

Figure 5. Leucocratic diatexite. (a) field photo, (b) Rock sample, (C) under cross, and (d) plane polarised light with a quintessential-structure as observed in a and b, the structure disappears away to metatexite migmatite point with a net-structure.

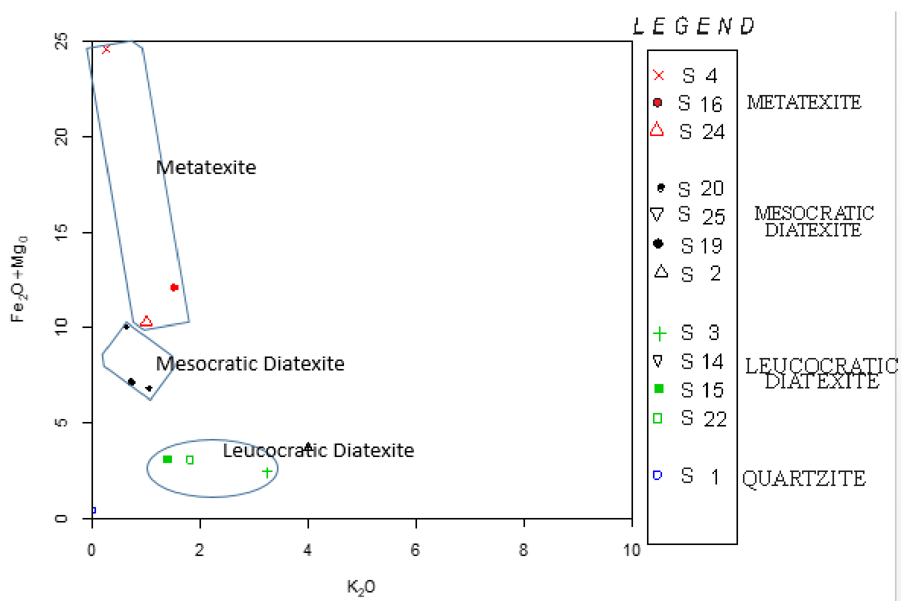

Figure 6. Plot of FeO + MgO versus K_2O showing the compositional field of metasediments, metataxite, and diatexite (after Patino Douce and Harris, 1998).

5. Petrographic Model

Metasediments subjected to heat in the upper crust at lower temperature mineral will start melting, causing partial melting as the temperature continues rising, and mesocratic is formed (Haruna, 2016; Hasalová et al., 2008).

- Metatexite is the residue left after extraction of up 40% volume melt from partial molten metasedimentary remains;
- Mesocratic diatexite is the melt-enriched part of the migmatite containing 5%–50% residue (Fig. 9);
- Leucocratic diatexite is part of the migmatite that has no residue left; it is all melts (Table 1).

6. Conclusion

The paleosome (metasedimentary remains) appears to be finer than the neosome (migmatites) found within the metatexite. This work has categorized the

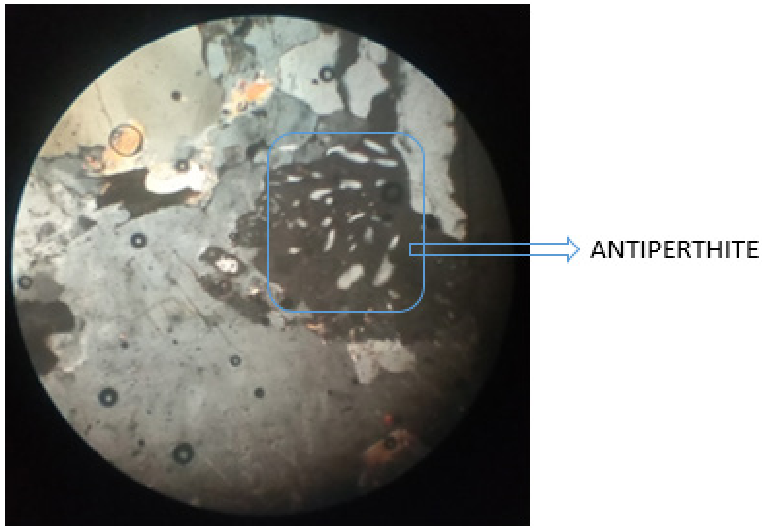

Figure 7. Rock sample showing the antiperthite structure.

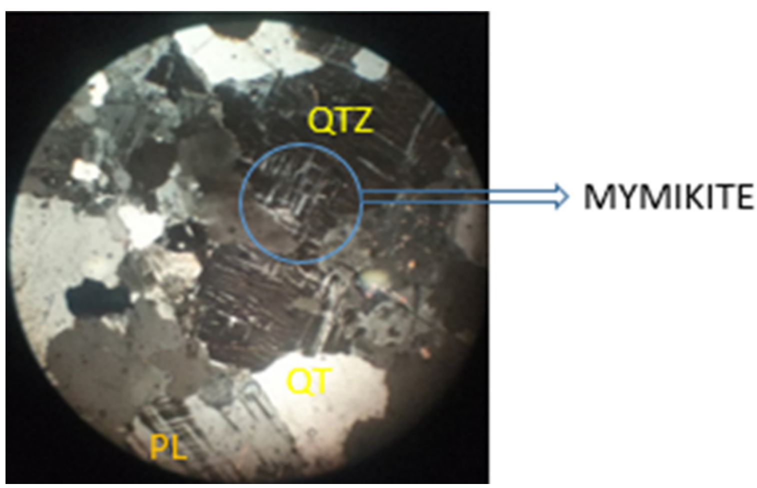

Figure 8. Rock sample showing myrmekite structure.

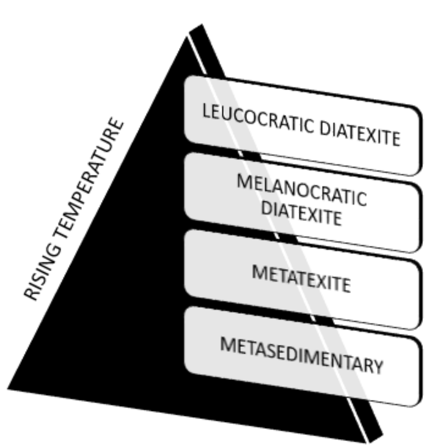

Figure 9. Rising temperature of rock products (Milord et al., 2001; Sawyer and Brown, 2008).

rocks in the study area into four: metatexite, melanocratic and leucocratic diatexites, and quartzite; metatexite migmatites possess a structure called net; diatexite appears simple and is called quintessential. This work further concludes as follows:

- Geological field mapping of the study area at the scale of 1:25,000 shows that the area is composed of metatexite, diatexite (leucocratic and mesocratic), and quartzite.
- Biotite and quartz are mineral constituents of the rocks, the contacts between the rocks are gradational. The rock host enclaves' perthite and myrmekite. Partial melting is identified as one of the mechanism responsible for the melt differentiation and metasomatism in some places as evident by the presence of myrmekite.

Table 1. SiO_2 rock sample groupings.

Migmatite group	SIO_2 contain (%)	Number of samples
Metatexite	50–70	3
Mesocratic diatexite	71–73	1
Leucocratic diatexite	74–76	3

Table 2. Geochemical analysis result.

	Quartzite	Metatexite			Mesocratic diatexite				Leucocratic diatexite			
ID	S 1	S 4	S 16B	S 24	S 2	S 19	S 25	S 20	S 3	S 15	S 22	S 14
SiO_2	98.61	57.81	68.11	70.11	72.32	73.4	73.1	71.21	76	75.14	76	73.24
CaO	0.01	0.32	0.1	0.62	0.73	0.2	0.02	0.7	0.21	0.28	0.16	0.06
MgO	0.001	0.18	2.84	3.12	0.24	0.03	ND	2.02	0.01	0.06	0.07	ND
SO_3	ND	0.06	1.24	0.13	0.03	0.02	ND	0.11	ND	ND	ND	ND
K_2O	0.02	0.26	1.51	1	4	0.73	8.45	0.62	3.24	1.4	1.81	8.6
Na_2O	0.04	1.03	1.84	2.1	1.04	1.28	0.62	1.46	1.6	2.06	2.02	1.62
TiO_2	0.04	2.41	1.13	1.46	0.23	0.84	0.21	0.4	0.63	0.43	0.48	0.06
MnO	0.001	0.32	0.21	0.03	0.06	0.19	0.004	0.03	0.08	0.03	0.02	ND
P_2O_5	ND	0.01	0.01	0.1	0.12	ND	ND	0.16	ND	ND	ND	ND
Fe_2O_3	0.43	24.39	9.21	7.18	3.46	7.07	1.16	8	2.4	3.01	3.01	1.06
Al_2O_3	0.32	12	12.82	12.06	13.01	12.4	14	12.12	12.6	13.84	13.81	12.7
H_2O+	0.74	2.02	2	2.12	2.64	2.6	2.16	2.21	1.7	2.01	1.6	2
V	201.01	660	501.5	601	401	601	420	482	4,182	603	386	510
Cr	118.02	316	246.19	346.29	145.29	346.29	210.4	245	245	325	145	230.19
Cu	480	380	354	334	334	334	280	334	330	290	310	310
Sr	1,890	1,830	1,220	1,220	1,220	1,220	1,000	2,031	2,030	290	2,030	1,440
Zr	5,720	1,200	1,200	1,200	1,200	1,200	1,000	1,520	1,500	720	1,500	1,000
Ba	680	2,010	3,100	3,100	3,100	3,100	600	1,810	1,800	100	1,800	930
Zn	100	370	97	97	97	97	160	56	560	60	560	40
Ce	30	63	50	50	50	50	80	44	54	45	54	42
Pb	75	56.09	26	26	26	26	580	867	867.5	17	867	25
Bi	0.344	5	0.099	0.099	0.099	0.099	3.98	0.873	0.871	0.219	0.873	1.89
Ga	34.02	5.09	39	39	39	39	6	42	22	17.4	12	32
As	22	3	7.02	7.02	7.02	7.02	0.46	17.3	17.2	7	17	15
Y	10	4.3	15	15	15	15	26	3.92	3.9	39.1	3.9	14
Ir	5.1	2.02	20	20	20	20	3.8	6.07	6.09	3.1	6.09	3.1
Au	0.67	0.2	0.22	0.22	0.22	0.22	1.6	0.468	0.448	0.014	0.488	0.224
Ni	0.056	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.038
Rb	21.6	36	29	29	29	29	62	30	30.4	9.84	30	30
Mo	15	0.009	32.01	32.01	32.01	32.01	0.008	81	83	14	83	48
Co	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.998	0.21	0.213	0.01	0.21	0.02
Cd	0.09	0.005	0.034	0.034	0.034	0.034	<0.001	1.094	1.192	<0.001	1.094	0.998
Ru	0.032	1.23	0.005	0.006	0.015	0.006	0.98	0.001	0.001	<0.001	<0.001	0.002
Eu	0.65	340	0.14	0.12	0.22	0.12	23	2.06	2.06	0.82	2.06	1.24
Re	160	<0.001	170	180	180.5	180	0.004	36	36.02	101	34	120
Nb	20.22	42	20.22	40/10	17.02	30	60	25.87	20.35	14.3	24.87	20.12
Ag	0.6	0.54	0.11	0.41	0.41	0.41	1.12	0.09	0.09	0.67	0.09	1.12

Continued

	Quartzite		Metatexite			Mesocratic diatexite				Leucocratic diatexite		
Ta	70.2	55	42.10	42.10	42.10	42.10	101	60	64.2	63	64	36
W	12	5.06	0.891	0.891	0.891	0.891	5.62	1.46	1.46	13.3	1.46	0.96
Hf	39.45	24	33	33	33	33	28	21	21	16	21	20
Yb	2.14	0.46	4.14	4.04	4.04	4.04	0.19	6.9	6.9	1.76	6.9	2.11
In	9.72	2.23	2.1	2.1	2.1	2.1	2.8	0.09	0.09	3	0.09	1.9
Se	0.2	0.28	<0.001	0.001	<0.001	0.001	0.22	0.012	0.012	0.28	0.012	0.21
U	0.201	<0.001	0.001	<0.001	<0.001	<0.001	0.025	0.007	0.007	<0.001	0.007	0.022
Th	0.21	0.31	1.5	2.5	2.5	2.5	0.09	2.2	2.2	0.22	2.2	0.86
Sb	8.01	3.3	7.03	7	7.03	7	2.24	14	14	12	14	6.13
Ge	14.01	4.36	24	24	20	24	18.8	40	41	14	40	4
Sn	61.22	19.88	21.06	30.26	31.06	30.26	47.03	21.12	19.12	9.88	20.12	17.03
Apatite	0	0.02	0.02	0.24	0.28	0	0	0.38	0	0	0	0
Chromite	0.03	0.07	0.05	0.07	0.03	0.07	0.05	0.05	0.05	0.07	0.03	0.05
Zircon	1.15	0.24	0.24	0.24	0.24	0.24	0.2	0.31	0.3	0.14	0.3	0.2
Ilmenite	−0.02	0.64	0.41	0.01	0.11	0.36	−0.02	0.03	0.14	0.02	0.02	−0.03
Sphene	0.11	0	0	0	0	0	0	0	0	0	0	0
Orthoclase	0.12	1.54	8.92	5.91	23.64	4.31	49.93	3.66	19.15	8.27	10.7	50.82
Albite	0.34	8.72	15.57	17.77	8.8	10.83	5.25	12.35	13.54	17.43	17.09	13.71
Anothite	0.63	2.51	1.45	3.44	3.85	2.01	0.54	3.44	2.05	1.5	1.8	0.94
Corundum	0	9.1	7.63	6.26	5.56	8.77	3.64	7.79	5.71	8.39	7.87	0.38
Hematite	0.43	24.39	9.21	7.18	3.46	7.07	1.16	8	2.4	3.01	3.01	1.06
Hypersthene	0	0.45	7.07	7.77	0.6	0.07	0	5.03	0.02	0.15	0.17	0
Quartz	97.62	49.39	46.69	47.85	48.86	62.17	36.86	55.75	53.29	57.01	56.34	30.43
Rutile	0	2.07	0.91	1.45	0.17	0.65	0.22	0.39	0.56	0.42	0.47	0.08

- There is mineralogical, chemical, and morphological continuity of all the migmatites in the study area.
- Hydrothermal alteration is responsible for the emplacement of the quartz veins in the fractured basement during the pan-African orogeny, which later has been metamorphosed into quartzite.

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