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The Geology and Petrography of the Pyroxene-Microdiorite of Eziator Hill, Eastern Nigeria

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With 1 figure in the texte

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Summary

Eziator Hill is formed by an igneous intrusion into a Cretaceous sedimentary sequence. The intrusion occurred between the Cenomanian stage and the Santonian substage of the Cretaceous, and is probably a sill.

The igneous rocks are predominantly altered pyroxene-microdiorite. One altered quartz microdiorite, characterised by a micropegmatitic intergrowth of primary quartz and feldspar, was recorded. Alteration products are described, alteration reactions and a mineral succession are suggested, and some remarks made on the genesis of the rocks.

I. Introduction

The first description of the intrusions into the Cretaceous sediments of Eastern Nigeria was given by Wilson and Bain (1925); they termed

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them dolerites and made some general remarks about the petrography of the Lokpauku dolerite sill.

The present paper is the first detailed description of the petrography of any of these intrusions, and is based on the study of samples from shallow borehole cores from Eziator Hill. Eziator is a hillock almost astride the boundary between Onitsha and Owerri Provinces, about four miles south-south-west from Ndeaboh railway station, at Latitude 5° 58′ North, Longitude 7° 32′ East. It is one of several hypabyssal bodies south and south-east of Awgu, intruded into a sedimentary succession.

Thirteen specimes collected by BUCHANAN (1955) are described by A. W. Günthert, and the geological notes are supplied by H. J. Richards. The microscopical work has been carried out at Kaduna, in the headquarters of the Geological Survey of Nigeria, after H. J. Richards had visited Eziator Hill.

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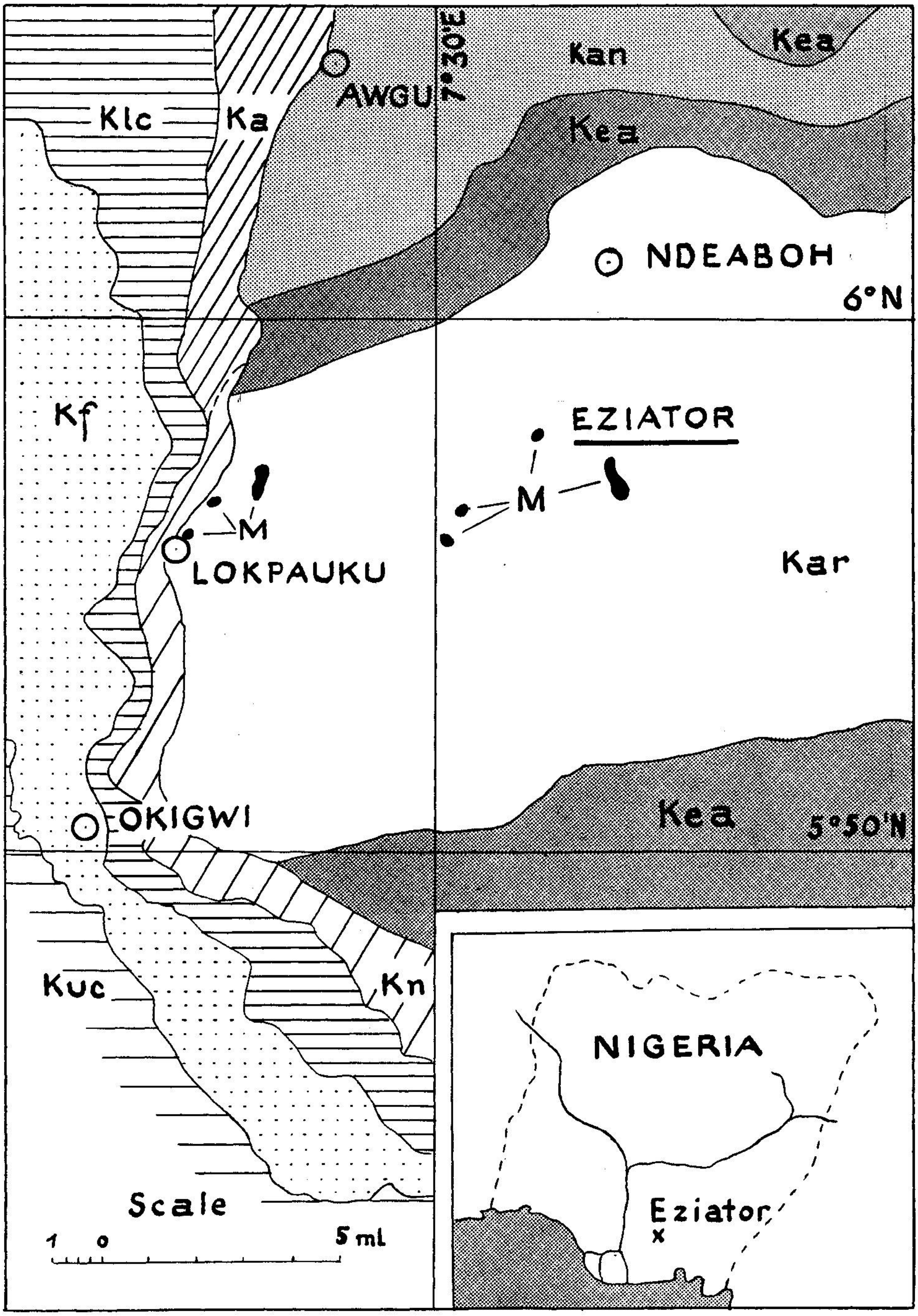
Fig. 1. Geology of the Awgu-Okigwi area, Eastern Nigeria.

Stratigraphical Unit		Cretaceous Stage
Kuc	Upper Coal Measures	Maestrichtian
Kf	Falsebedded Sandstones	
Klc	Lower Coal Measures	
Kn, Ka	Nkporo Shales and Awgu Sandstones	
Kan	Awgu-Ndeaboh Shales	Senonian
Kea	Eze-Aku Shales	Turonian
	? present	Cenomanian
Kar	Asu River Group	Upper Albian
M	Intrusions of Microgabbro	


Klc
Ka
AWGU
7°30'E
Kan
Kea
Kea
NDEABOH
6°N
Kf
EZIATOR
M
M
LOKPAUKU
Kar
OKIGWI
Kea
5°50'N
Kuc
Kn
NIGERIA
Eziator
Scale
1 0 5 ml

II. General Account of the Geology

This intrusion appears in the shales of the Asu River Group, the lowest member of the Cretaceous succession exposed in the area. There do not appear to be any intrusions into the succeeding formations, so those exposed result from intra-Cretaceous igneous activity which occurred certainly in post-Cenomanian and probably pre-Santonian times. Fig. 1 is a sketch map of the geology of the area.

The Asu River Group is predominantly argillaceous with some sandstones and thin, shelly limestones, and may reach 10,000 ft. at its maximum thickness. Overlying this group, apparently conformably, are the Eze-Aku Shales and Awgu-Ndeaboh Shales, the former reaching perhaps 2,000 ft., the latter 3,000 ft. in thickness, and both made up of shales with thin sandstones and shelly limestones. These rocks have been folded along the Okigwi-Abakaliki anticlinorium, which pitches west-south-west, and eroded.

The Eziator microdiorite was intruded during, or soon after, the folding. Over the axis of the uplift Nkporo Shales rest unconformably on Asu River Shales, the unconformity becoming less away from the axis.

In form Eziator Hill appears to be a sill, formed by one of many

G. S. N.[1]) borehole and sample number	Depth below surface		Depth to bedrock (Buchanan, 1955)	
	ft.	in.	ft.	in.
1330/MB. 23	14	6	16	5[2])
1330/MB. 24	38	6		
1332/MB. 25	18	0	9	7
1332/MB. 25a	24	1		
1334/MB. 26	23	0	16	3
1334/MB. 26a	36	10		
1335/MB. 27a	36	10	21	2
1336/MB. 28	9	0	6	4
1336/MB. 29	25	0		
1337/MB. 30	12	0	13	3[2])
1337/MB. 31	25	0		
1339/MB. 32	32	0	28	4
1339/MB. 32a	49	0		

[1]) Geological Survey of Nigeria.

[2]) Sample of weathered rock.

offshoots of a deeper-seated igneous mass. Its ground plan is roughly elliptical, its vertical cross section asymmetrical with the steeper face on the south-east, and its longer axis is approximately parallel to the strike of the country rock. The upper surface of the intrusion has pushed up the shales, and altered, baked shale weathered a dull rusty brown is exposed to the top of the hill on the north and north-west slopes of the feature, and around the eastern margin.

The specimens described are detailed above, and were obtained from boreholes put down on the east and south sides of the intrusion.

III. Petrography

In hand specimen the light greenish-grey, fine- to medium-grained, partially amygdaloid rocks are characterised by coarse prisms of more or less altered pyroxene and radiating needles of ilmenite set in a groundmass of fine- to medium-grained aggregates of pyroxene and feldspar, or their alteration products.

Microscopically the rocks are characterised by a holocrystalline, hypidiomorphic texture which is intergranular to slightly sub-ophitic. The feldspar is in excess and the other constituents fill the interstices between the divergent radiating feldspar laths.

The structure and texture of the rock and the composition of the plagioclase — determined on the universal stage — are typical of a microdiorite to meladiorite as defined by HATCH and WELLS (1949, p. 257—259, 264). The absence of ophitic texture and the occurrence of coarse to medium-grained laths of acid to intermediate plagioclase, of phenocrysts of pyroxene and of needles of ilmenite are not typical of a dolerite or diabase.

The examined pyroxene-microdiorite is olivine-free with the exception of a few relics. All but No. 25a have no primary quartz and represent leucocratic to mesotype microdiorites, the colour index of the series varying between 20 per cent and 60 per cent, the estimated average being 35 per cent. (For the separation of hornblende-free pyroxene-diorites from olivine-free pyroxene gabbros the colour index appears to be less important than the composition of the feldspar in excess as shown by the colour index of relevant mesotype diorites and leucocratic gabbros respectively.) Specimen No. 25a was found to be an altered leucocratic quartz microdiorite bearing primary quartz.

a) The Altered Leucocratic to Mesotype Microdiorites

All specimens except No. 25a show the following ranges of composition:

	Estimated volume per cent
plagioclase	40 to 80
pyroxene	5 to 30
serpentine	3 to 30
ilmenite + leucoxene	3 to 5
carbonate	0 to 20
zeolite	0 to 30
secondary quartz	0 to 10
talc	0 to 10

The following minerals are present in accessory amounts or as alteration products:

magnetite, pyrite, chalcopyrite, sphene, sericite, chlorite, biotite, phlogopite, saussurite, zoisite, clinozoisite-pistacite (epidote), apatite, prehnite, phillipsite, laumontite, thomsonite, natrolite, green hornblende (uralite), actinolite-tremolite, aragonite, calcite, quartz, clayey matter.

Plagioclase

The plagioclase forms unorientated subhedral to euhedral laths up to 3 mm. in length. The feldspar is always in excess, with the other constituents filling the angular interstices between the feldspar laths. Most of the feldspar is turbid because of incipient sericitization and saussuritization. Some of the clear and less turbid crystals were determined on the universal stage using the method described by REINHARD (1931). Individual crystals are of one plagioclase but collectively they range from albite to andesine.

Albite is present throughout the whole series while oligoclase is less common and andesine was detected in only two samples (MB 31, MB 32). The albite has a content of 2 per cent to 10 per cent anorthite and is characterised by albite and pericline twinning; the anorthite content of oligoclase varies from 10 to 12 per cent. The measured optic axial angles of the plagioclase range from $2V_z = 81°$ to $92° \pm 2°$, indicating a low-temperature formation of the plagioclase according to TUTTLE and BOWEN (1950, fig. 4). This agrees with the origin of the albite and oligoclase present (see below). The andesine has a content of 33 per cent to 35 per cent anorthite, and shows optic axial angles ranging from $2V_x = 74°$ to $82° \pm 2°$.

Pyroxene

The length of the lath-shaped pyroxenes ranges from 0.4 mm. to 1.5 mm. in the groundmass and from 2.5 mm. to 7 mm. in the phenocrysts. Generally there is no intergrowth between the pyroxene and the plagioclase, but some of the terminations of the plagioclase crystals are enveloped by pyroxene, giving rise to a sub-ophitic texture. Only three thin sections showed isolated examples of plagioclase surrounded by pyroxene. Of the two types of pyroxene found to be present diopsidic augite predominates over pigeonite. While some speciments contain both types of pyroxene others had only one. Measurements on the universal stage and by oil immersion methods gave the following details of the pyroxenes.

(i) *Diopsidic augite (leucaugite)*, as defined by HESS (1949), and accepted by WINCHELL (1951). This mineral shows an extinction of Z : c = 46° to 49°, its optic axial angles ranging from +2V = 56° to 64°. Pleochroism varies as follows:

X = colourless to pale yellow,
Z = pale green, light brown to brown.

Zoning is parallel to the prism faces and hour-glass structure may be occasionally observed.

(ii) *Pigeonite* shows an extinction of Z : c = 31° to 44°, its optic axial angles lying between +2V = 0° and 32°

$nX' > 1.690 \qquad nZ' < 1.736$

The pigeonite is colourless to weakly pleochroic with

X = pale yellow,
Z = light brown, light brownish grey, or olive green.

The subhedral pyroxene is corroded by plagioclase and has different alteration products. The alteration begins around the periphery where a rim of serpentine, talc, α and β-chrysotile or antigorite is developed. Margins of incipient uralitization and chloritization were also observed. The uralite is composed of common green hornblende or actinolite-tremolite, which mantles the pyroxene or develops along cleavages in it. In only one specimen is diopsidic augite partially altered to brownish chlorite. The alteration is completed by serpentine, pseudomorphous after pyroxene, either through replacement by antigorite (bastite), or by chrysotile, or both.

Talc and serpentine develop together along cleavage and fracture planes of the pyroxene from the margins towards the core of the grains.

Olivine was detected as a primary relic in only one specimen (MB 25) and is almost entirely replaced by serpentine.

Bars of ilmenite up to 5 mm. in length and displaying trigonal symmetry are found in all specimens and are in places intergrown with sphene or magnetite. Some of the ilmenite is altered to leucoxene and both are at times slightly corroded by feldspar.

Zeolite

The zeolites are alteration products of calcic plagioclase which is no longer present. Its former existence can be inferred from the lath-shaped pseudoperthitic structure of zeolitised plagioclase. In many cases the albite and oligoclase are partially intergrown with the calcic zeolites, which suggests that these feldspars are of secondary origin. (The mode of intergrowth is described below.) The following zeolites were observed:

Laumontite is found as spherulitic aggregates of colourless fibres, or intergrown with plagioclase in either lath- or flame-like form, or as irregular patches, and is partly pseudomorphous after plagioclase. It forms about 25 per cent of specimen MB 24. In this and in specimens MB 26a and MB 27a, divergent columnar or fanlike *prehnite* is developed as a rim to albite or as a constituent of serpentine-quartz aggregates. It is also embedded in the mantle of albite and chrysotile that surrounds marginally serpentinized pyroxene, and occasionally shows typical "bow-tie" structure. Prehnite occurs exclusively between grains of plagioclase and serpentine as a result of the following reaction:

basic plagioclase + augite + water $\rightarrow$ serpentine + prehnite + albite

Colourless, radiating *phillipsite*, and *natrolite*, as well as fibrous and plumose *thomsonite* occur in specimens MB 24 and MB 29. Thomsonite and natrolite may occur as secondary aggregates which radiate outwards from the plagioclase prism faces and end faces respectively.

Quartz of secondary origin occurs in several specimens and is always associated with other secondary minerals such as zeolitised plagioclase (albite-oligoclase), chlorite, chrysotile, calcite, actinolite, and turbid (clayey?) matter.

Secondary *carbonate* — chiefly calcite — is present in most of the samples filling interstices or amygdules, and occasionally enveloping mica and serpentine. In MB 26 calcite and antigorite form an aggregate which is pseudomorphous after pyroxene. The carbonates generally amount to less than 1 to 5 estimated volume per cent. A higher content of carbonate was found in MB 30 only, bearing up to 20 estimated volume per cent of calcite.

The *amygdules*, which reach a maximum diameter of 16 mm., vary in structure and composition. They may be hollow or filled with radiating fibres of actinolite-tremolite. Zoned examples were observed (MB 32) in which the core, consisting of calcite or aragonite, is followed by fine-grained concentric layers of (a) albite and quartz, (b) pyroxene, serpentine and actinolite, (c) serpentine and ilmenite. Albite and quartz are corroding and marginally replacing calcite and aragonite. Calcite is orientated with X sub-parallel to the longer axis of the amygdule. Coarse-grained aragonite showed $-2V = 20°$.

b) The Altered Leucocratic Quartz Microdiorite, MB 25a

This rock differs essentially from the leucocratic to mesotype micro-diorites in the micropegmatitic intergrowth of quartz and feldspar. Such a graphic implication structure appears to be eutectic and, therefore, the quartz is probably of primary origin. Hence the name, "quartz microdiorite". Micropegmatitic feldspar was the last primary feldspar to form, and either fringes euhedral feldspar grains or is moulded upon, and radiates from, subhedral and euhedral feldspar. The constituents of the micropegmatitic intergrowth are quartz, slightly sericitized albite, oligoclase (6 to 12 An, $-2V = 82°$ to $86° \pm 2°$), and potash feldspar. The remainder of the feldspar is of secondary origin and of sodic composition; it forms about 60 per cent of the rock by volume, and has inclusions of pyroxene and serpentine.

The pyroxene is diopsidic augite with $Z:c = 46°$ and $+2V = 56°$, forming about 10 per cent of the rock by volume. It is marginally altered to colourless actinolite-tremolite and to serpentine, especially when bordered by ilmenite. Some of the latter is intergrown with serpentine, forming a lattice-like structure. When found occurring with ilmenite and leucoxene the fringes of the augite crystals are altered to brown biotite, which in turn has suffered further alteration to antigorite and actinolite. Ilmenite is embayed by pyroxene and both are marginally corroded by feldspar.

c) Stages of Alteration

The following characteristic alteration products have been observed, the predominant products being in italics:

ilmenite	→ leucoxene
ilmenite + pyroxene	→ serpentine
ilmenite + biotite	→ actinolite + antigorite
augite and pigeonite	→ *serpentine* (chrysotile and antigorite) ± actinolite-tremolite
	→ *antigorite* (bastite) ± calcite
	→ talc + serpentine
	→ biotite → antigorite + actinolite
	→ *actinolite-tremolite* (uralite)
	→ delessite and jenkensite (chlorites)
diopsidic augite	→ brownish chlorite
olivine	→ *serpentine*
phlogopitic biotite	→ antigorite
intermediate plagioclase	→ *sericite* ± calcite
	→ saussurite ± sericite ± epidote
	→ *albite, oligoclase* ± prehnite ± quartz
	→ *albite + oligoclase + laumontite + sericite + quartz*
	→ thomsonite ± calcite
albite	→ natrolite

There are, of course, combined alteration reactions as shown by the following example of closely aggregated constituents:

intermediate plagioclase + augite → *albite + serpentine* (chrysotile), or
uralite + chlorite ± prehnite ± laumontite ± phillipsite

The secondary calcite and quartz which are usually present throughout have, to some extent, filled the interstices and are also intergrown with the alteration products.

d) Mineral Succession

On the basis of crystal shape, inclusions, corrosion and alteration, the following general succession is inferred.

(i) ilmenite, apatite, zircon
(ii) ilmenite and olivine
(iii) ilmenite, leucoxene and sphene
(iv) ilmenite and plagioclase
(v) plagioclase
(vi) plagioclase and pyroxene
(vii) pyroxene
(viii) pyroxene and biotite
(ix) sodic plagioclase, sericite, serpentine, uralite, prehnite, zoisite, epidote, chlorite, secondary quartz, zeolite
(x) micropegmatite and quartz
(xi) secondary quartz and albite (interstitial and in amygdules)

(xii) secondary quartz (interstitial and in amygdules)
(xiii) zeolite (interstitial and in amygdules)
(xiv) carbonate (interstitial and in amygdules)

IV. Petrogenesis

The presence of albite-oligoclase, of pigeonite and diopside augite, the almost complete absence of olivine, as well as the bulk composition of the rocks, is characteristic of a saturated magma probably of the composition of a subaluminous soda-diorite or diorite to meladiorite, as definied by SHAND (1949) and HATCH and WELLS (1949) respectively.

A slight oversaturation occurred occasionally and gave rise to eutectic, late-magmatic, quartz-feldspar solutions which never played a dominant role. These solutions led to micropegmatite occurring only interstitially and containing albite, which probably represents a second generation of sodic plagioclase.

Whether the first generation of albite is of primary (magmatic) or secondary (autometamorphic albitization) origin, is difficult to decide. This problem concerns the main feldspar content of the microdiorite in the area and the composition of the original magma.

The coexistence of andesine and albite-oligoclase in some of the specimens shows that plagioclase of at least intermediate anorthite content is of primary origin, and that part of the albite and oligoclase is secondary.

Several specimens contain albite-oligoclase without the more basic plagioclase. Their sodic plagioclase may be of primary origin, having crystallized from a watery and carbonic residual magma. Excess solutions and vapours from the magma may have altered the already crystallized constituents. As REINHARD and WENK (1951), p. 79) have pointed out regarding relevant rock genesis, "rocks of primary, and those of autometamorphic, epi-mineral, composition... occur next to, and merge into, one another. Genetically they are correlates and owe their origin to the same rock-formative process."

Most of the other alteration products seem to be due to late magmatic (autometamorphic) hydrothermal solutions. This view is supported by:

(i) occurrence of zeolites which were found only in fresh rocks below the zone of weathering (MB 24, 26a, 27, 29),

(ii) zeolitized plagioclase which often shows a patchy to pseudoperthitic structure with little or no saussuritization,

(iii) absence of secondary. iron oxides, iron hydroxides and opal in the examined rock specimens.

Further evidence of hydrothermal activity is found in the minerals filling the amygdaloidal cavities. These show a regular sequence of crystallization and corrosion from the wall to the core (as described above) which can be correlated with decreasing temperature of crystallization and increasing solubility in watery solutions.

Part of the serpentine, uralite, calcite, saussurite and sericite may be due to reactions with hydrothermal solutions, or to weathering, since both processes yield similar products in certain cases.

Other possible methods of alteration, such as postmagmatic low-grade metamorphism or postmagmatic metasomatism, are unlikely to have taken place since the country rocks have been baked only by the intrusion.

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