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PRELIMINARY GEOLOGICAL AND RADIOMETRIC STUDIES OF GRANITOIDS OF ZING-MONKIN AREA, ADAMAWA MASSIF, NE NIGERIA

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ABSTRACT

Zing-Monkin area is part of a large basement complex of the Adamawa Massif in eastern Nigeria characterised by extensive exposures of granitoids. Field mapping and radiometric survey of the area at a scale of 1:50,000 shows that the area is underlain by moderately radioactive biotite-hornblende-granodiorite, migmatites, equigranular granites, porphyritic granites, and highly radioactive fine-grained granite with subordinate pegmatites. Composed of hornblende, plagioclase, biotite, perthitic microcline, quartz with accessory apatite, sphene, and zircon, these rock units host enclaves of various shape and are separated from one another mostly by gradational contacts.

The paucity of foliation, the mafic hornblende-bearing enclaves and the gradational contact relation between the rock units have led to a conclusion that the granitoids are probably I-type, genetically related to a common source by fractional crystallisation of hornblende, plagioclase, biotite, microcline and accessory apatite, sphene and zircon. The distribution of enclaves throughout the granodiorite unit, their sub-rounded shape and diffused contacts are consistent with their igneous texture that the enclaves are syngenetic probably representing remnants of pre-existing rocks from which the granitoids were derived.

The enhanced radiometric counts in fine-grained granite and pegmatite may be related to uranium occurrences of magmatic/hydrothermal nature around Mika, Jada and Nyaza.

KEY WORDS: Granitoids., Geology., Radiometry., Zing-Monkin.

INTRODUCTION

Adamawa Massif is one of the three massifs in eastern Nigeria that share a long border with the Republic of Cameroon (Fig. 1). It is the largest of the three massifs bordering the Benue Trough in which pockets of uranium occurrences have been discovered. The other two are the Hawal Massif to the north and the Oban Massif to the south. The three massifs form the eastern sector of the Nigerian Basement Complex and constitute one of the three major basement segments in the country. Within the eastern basement, only the Oban Massif has been studied in details (Ekwueme and Onyeagocha, 1985a, b, 1986; Ekwere and Ekwueme, 1991; Ekwueme et al., 1988, 1997; Ekwueme, 2003; Odigi and Okonny, 1987). Unlike its Oban equivalent, knowledge of the geology of Adamawa Massif lags behind consequently; there is always a tendency to infer the geology of Adamawa Massif from that of the well documented Oban Massif which sometimes leads to erroneous conclusions.

Zing-Monkin occupies an approximate area of 345km^2 and lies between longitudes 11º40'E, 11º48'E and latitudes 8º48'N, 9º.00'N in the northern part of Adamawa Massif (Fig. 1), providing diversity of topographic forms that are hardly compared with that of the neighbouring areas. Apart from the fine-grained granites that are found as low-lying intrusions and enclaves in some rock units, the porphyritic granites, equigranular granites and migmatites combine with the swampy plains to form some of the attractive scenery.

The geological features of the area are mostly demarcated by their topographic forms. The various rock units form prominent rocky hills with some of the hills reaching 3000m. Most of the rugged hill country underlain by these rock units is developed in the southwestern, eastern and northeastern parts of the area. Here, elongate and sub-circular isolated hills of granodiorite and granites are found in Kobon Tolegbeng, Koleng and Kozonthchi. The most outstanding among these is the Kobon Tolegbeng, an extensive granitic body that extends from southeast of Monkin beyond the study area to the neighbouring Toungo area. The scarcity of volcanic rocks in this area is easily noted.

This paper utilises field and petrographic characteristics to gain some insight into the origin, evolutionary processes and possible uranium mineralisation potentials of the granitoids. Inferences drawn from this study do not preclude the use of petrochemical data for same study in the same area.

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Fig. 1 Geological map of Adamawa Massif and the adjoining Benue Trough (modified after the Geological Survey of Nigeria Map, 1994 edition).

Field Procedure

The field mapping exercise was conducted concurrently with samples collection and radiometric measurements along traverses planned to run across the rock outcrops. The sampling exercise was guided by changes in texture, colour and macro-scale mineralogy of the rocks. Samples representing a wide spectrum of texture, colour and minerals were carefully collected. Great care was taken to ensure that weathered samples were not collected. So, the collected fresh samples were properly labelled and transported to the petrology laboratory of Geology Department, Federal University of Technology, Yola where they were thin sectioned and petrographically studied using a high magnification polarising microscope. Canada balsam was used as the mounting medium.

Radiometric survey was carried out using a McPhar model TC-33A portable gamma ray scintillometer specifically designed for use in uranium prospecting. The gamma ray detecting principal lies in the sodium iodide crystal. Gamma rays entering the crystal interact with the crystal atoms resulting in free electrons and light emissions. The optically coupled photomultiplier converts the light emission to electrical pulses. The number of electrical pulses bears a relationship to the quantity of radioactive material in the rock. Based on this principle the instrument detects, counts and displays the number of gamma rays which are trapped by the crystal detector. Using the scintillometer, over 80 numerical data on radiation intensities emanating from the different rock units in the area were collected (see appendix 1). From the data, average radiometric counts for each rock unit were calculated and tabulated.

RESULTS

Petrology, Petrography and Radiometry of the Rock Units

The major rock units of the study area include granodiorites, migmatites, equigranular granites, porphyritic granites and fine-grained granites, with pegmatites as the only minor rock unit (Fig. 2). These rocks show considerable variation in mineralogy, texture and structure as well as contact relationships. Volcanic rocks are virtually absent in the area.

Granodiorite

This rock belongs to a group of feldspathised, intermediate and basic rocks with a wide range in composition from basic granodiorite to quartz monzonite or adamellite. It is distinguished from other rock units in the field by its high mafic mineral content, giving it a greyish colour. This greyish appearance strongly contrasts with the pink and pale red of the granites.

Two varieties of granodiorites are texturally distinguishable in the field. These are the medium- to coarse-grained (measuring 2mm x 3mm to 3mm x 4mm in size) and porphyritic (30mm x 30mm) varieties. The medium-grained variety occurs as inselbergs north of Wuro Alkali and occasionally as marginal masses of larger fairly porphyritic granodiorite bodies around Kobon Tolegbeng in the southern part of the area. The coarse-grained to porphyritic variety occupies most of the eastern part of the area occurring as sub circular to large elongate plutonic bodies spanning some tens of kilometers. Though widely distributed in the eastern part of the area, individual occurrences are small except in the northeastern and southeastern parts where they occur as large elongate bodies.

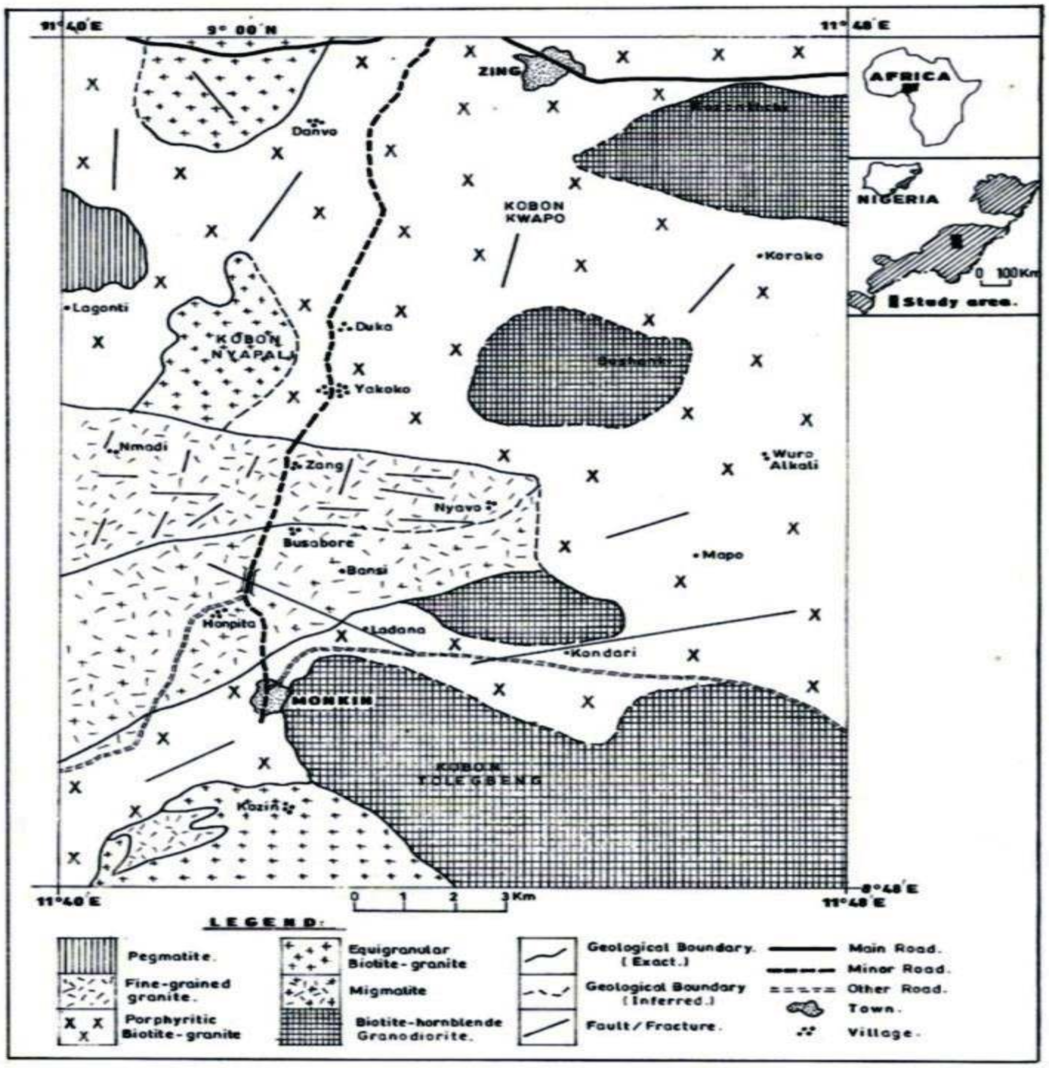

Fig. 2 Geology of Zing-Monkin area (present work).

Outcrops are mostly massive (Plate 1a) and almost restricted to the eastern part of Zing-Monkin area. Large bodies of the rock occur in Kobon Tolegbeng and Kozonthchi. Between the two localities, massive subcircular granodiorite bodies form the inselbergs around Bushanki and Kondari. The rock displays a variety of relationships with the granites ranging from mostly transitional to discordant and cross-cutting in a few localities. Contact between the two variety of granodiorite (medium- and coarse-grained) is mostly gradational.

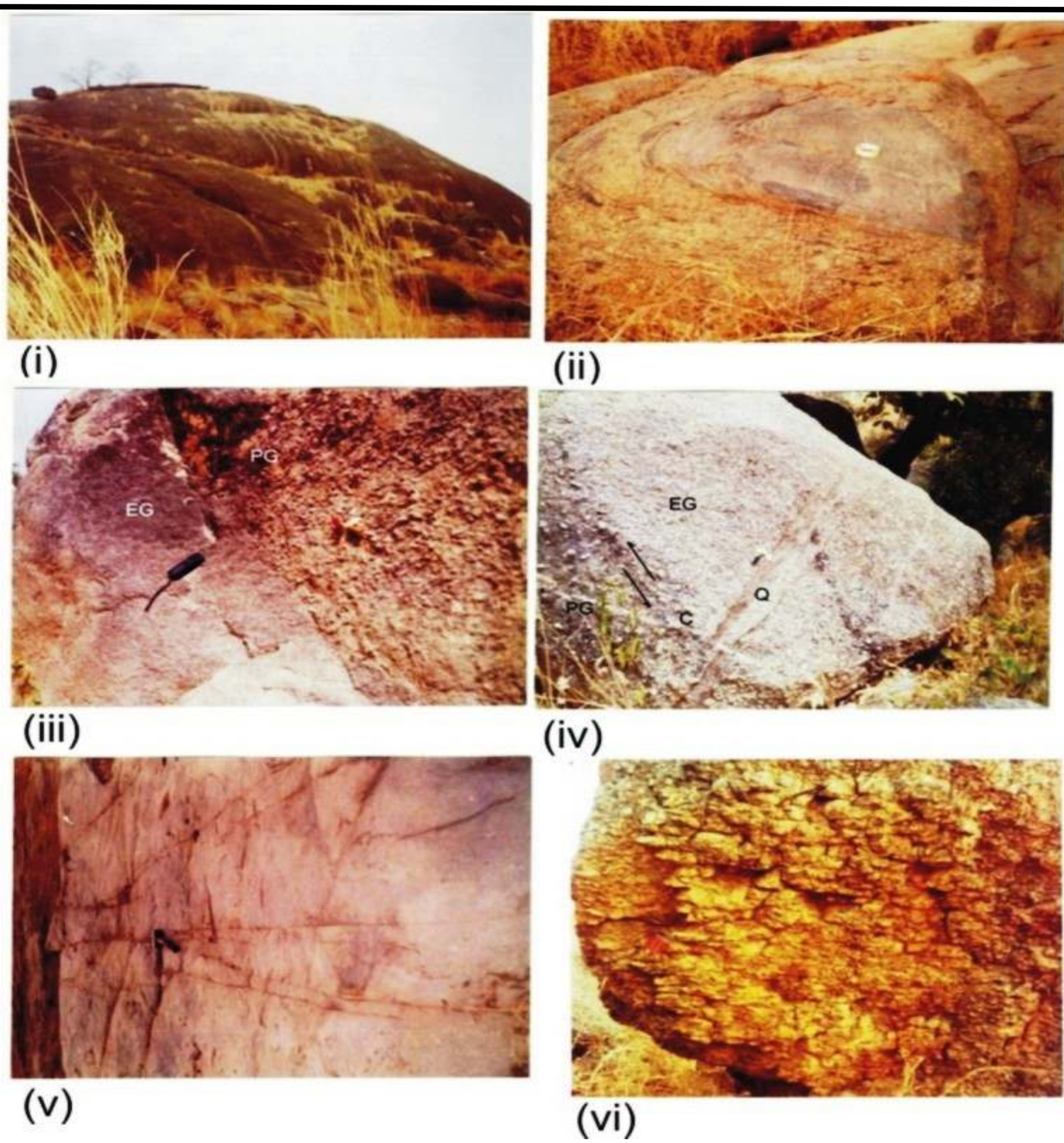

Plate 1 Field occurrences and relationships of various rock units in the study area: (i) massive body of granodiorite at Bushanki; (ii) Migmatite with xenoliths of mafic rock and patches of granitic material near a bridge south of Busabore; (iii). Equigranular granite (EG) in contact with Porphyritic granite (PG) at a locality south of Monkin. (c) Sharp contact between equigranular granite and Porphyritic granite at a locality south of Monkin; (iv) One of the many gradational contacts between porphyritic granite (PG) and equigranular granite (EG) with a quartz vein (Q) displaced at the contact region (C) in a locality west of Danyo (v) Fine-grained granite with numerous fractures/faults at Nmadi locality south of Yakoko; (vi) A pegmatite body southwest of Danyo.

Foliation in granodiorite is scanty, defined by stretched biotite crystals and almost restricted to border facies. Radiometric measurements in this unit range between 130 and 154cps with an average of 151.4cps (Table 1).

Table 1: Summary of Radiometric Counts for the various Rock Units in the Study Area

Rock Unit	**Range**	**Average**
Granodiorite **(n=81)**	130 - 165	140.5
Fine-grained granite **(n =81)**	280 - 320	300.8 (310)
Migmatite **(n=81)**	130 - 155	151.40
Equigranular granite **(n=81)**	140 - 170	160.4
Porphyritic granite **(n=81)**	140 - 175	160.12
Pegmatite **(n=79)**	235 - 260	249.40

n = number of readings/measurements taken

The granodiorite unit hosts a lot of mafic enclaves. The enclaves have very little or no variation in texture and are mineralogically similar to the granodiorite which composed essentially of plagioclase, biotite, hornblende, quartz, feldspar and accessory apatite, zircon, sphene and opaques (Table 2).

Table 2: Modal composition of the granitoids of Zing-Monkin area, Northeastern Nigeria

	Granodiorite	Migmatite	Equigranular Granite	Porphyritic Granite	Fine-grained Granite
Quartz	13	23	18	24	21
Microcline	4	6	11	8	7
K-Feldspar	13	19	43	41	48
Plagioclase	39	20	17	14	13
Biotite	15	18	5	6	5
Muscovite	5	9	2	1	-
Hornblende	6	2	-	-	-
Apatite	1	-	-	2	1
Zircon	1	-	1	1	2
Sphene	1	1	2	1	1
Opaque	2	2	1	2	2

Migmatite.

Migmatites, are of restricted occurrence, occurring between Yakoko and Monkin. Unlike the fine-grained granites however, migmatites are composite rocks consisting of granitic units alternating with biotite-enriched mafic components. They are poorly foliated, mostly leucocratic, coarse-grained and show considerable variations in structure, texture and mineralogy.

All phases of transition are observed between the variants which reflect the composition and physical conditions of the original country rock and various degrees of granitisation. The hornblende, biotite and iron ore minerals occur as ragged crystal much corroded by quartz. Pegmatitic segregations, patches of granites and xenoliths of mafic rocks are very conspicuous in the migmatites (Plate 1b). The granitic portion of the migmatite is often leucocratic and medium- to coarse-grained.

The migmatite appears to be injection type. Penetration of the country rock by granitic material appears to have given rise to the migmatite varying in appearance and structure. A tract of country north of Ladana extending westward through Bansi to Honlipa and beyond is underlain by migmatite. At a bridge south of Busabore, the migmatite is well exposed and best studied at this locality. Radiometric measurements over the migmatites range from 140 – 150cps with an average of 140.5cps (Table 1). The mineral composition of the migmatite is given in Table 2.

Equigranular Granite

Equigranular granites are next in abundance to porphyritic granites in the area. They are medium-grained and include a diverse series of granites varying in texture, structure and mineralogy. Contacts between the various types are mostly gradational. The equigranular granites are massive in some places and foliated in others. The foliation is expressed by elongate feldspar and to lesser extent quartz crystals.

Blocks of equigranular granites are frequently found within the porphyritic granites implying that the former were emplaced earlier than the latter. In some localities where the two rock units lie side by side they are separated by a sharp contact (Plate 1c). Patches of migmatites are sporadically found within the equigranular granite, suggesting that the equigranular granites were emplaced after the formation of the migmatites. Late fluid segregation is represented by quartz-feldspar pegmatite

Just like the granodiorite, two varieties of equigranular granites are distinguishable in the field. These are the pinkish or red and the fairly grey varieties.

Small subcircular stocks of equigranular granite run from north to south along the eastern border of the study area. The southern hills of Kozin are formed by equigranular granite. The most important development of equigranular granite occurs north of Danyo where they form rugged hills. The greater part of the hilly country at Kobon Nyapali is formed by equigranular granites. Radiation intensity ranging between 150 – 172cps with an average of 160.4 (Table 1) was recorded over the equigranular granite.

Under the microscope, equigranular granite, like migmatite, appears hypidiomorphic-granular in texture with readily identifiable potassium feldspar, microcline, quartz, plagioclase, biotite with accessory zircon, sphene and opaques (Table 2).

Porphyritic Granite

The most striking characteristic of porphyritic granites is their porphyritic texture consisting of phenocrysts of microcline (measuring 20mm x 30mm to 35mm x 40mm) set in a medium- to coarse-grained mineral matrix ranging in size from 2mm x 3mm to 4mm x 5mm. They are relatively homogeneous, having predominantly gradational and restricted sharp contacts with the equigranular granites and migmatite (Plate 1d). These rocks are mainly potash granites, which grade into a fairly basic variety at the margins of the intrusions. Ferromagnesian minerals are mainly biotite. Composition and texture of porphyritic granite changes as one traverses the intrusions from the center to the borders (margins). At the center, feldspar phenocrysts are crowded and the rock appears to be homogeneous biotite granite. This composition gradually changes towards the edges where the density of feldspar phenocryst is less. Porphyritic granites exhibit mostly gradational contact relationship with other rock units in the area.

Porphyritic granites contain less inclusion of other rock materials. However, within the marginal facies, patches of basic rocks and migmatites consisting of large microcline crystals are observed in some localities. Acid segregation such as pegmatites, aplites and quartz vein are less frequent in these rocks than in the equigranular granites.

Widespread and extensive development of porphyritic granite occurs throughout the study area. The greater part of the hilly country between Mapo and Korako, the country north of Yakoko, the southwestern part of Monkin and the hills southwest of Danyo are underlain by porphyritic granites. Radiometric measurements in the rock range between 140 and 160cps with an average of 160.12cps (Table 1)

Mineralogically, porphyritic granite contains principally of microcline, quartz, plagioclase, biotite and K-feldspar (Table 2).

Fine-grained Granite

The fine-grained granites are pale brown to grey and show little variation in appearance. The rock consists of predominantly quartz, microcline and plagioclase. Similar rock forms enclaves which occur as irregular bodies and as vein-like lenses within the equigranular granites with a sharp contact relationship. In some places veins of fine-grained granite interfinger and penetrate the porphyritic granites.

Fine-grained granite, like the migmatite, is of subordinate occurrence in the study area. It occurs only in two locations: around Nmadi and at Kozin. At Nmadi the rock occurs as low lying intrusive body with numerous fractures (Plate 1e). At Kozin it is found cross cutting the host equigranular granite. The highest radiometric measurement was recorded over this rock unit with a range of 250– 320cps and an average of 300.8cps (Table 1).

The fine-grained granite consists essentially of microcline, K-feldspar, quartz, plagioclase, biotite and accessory apatite, zircon sphene, and opaque (Table 2).

Pegmatite

Pegmatite does not form an independent or mappable rock unit in the study area except at a locality southwest of Danyo where it occurs as a small hill consisting of graphic intergrowth of quartz and potash feldspars (Plate 1f). At this locality, the rock takes the form of quartz-feldspar body a few tens of meters in length. In other rock units, especially the equigranular granites, pegmatite takes the form of irregular cross cutting vein-like bodies. Sporadically, they form concentrations along the granite contacts.

The analysis of lineaments in the study area shows that lineaments strike principally in NW-SE direction with few subordinate N-S and NE-SW trends (Fig. 3). Radiometric measurements over the pegmatite body southwest of Danyo range between 230 – 265cps with an average of 249.4cps.

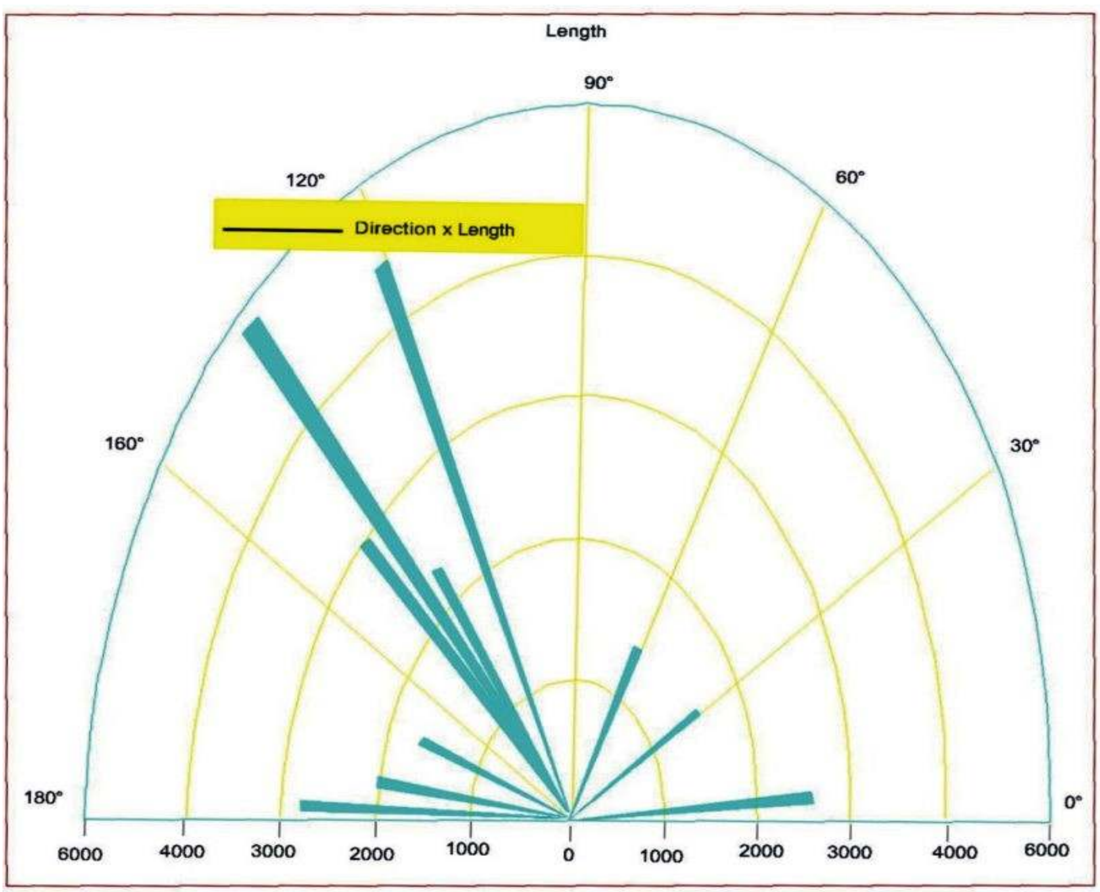

Fig. 3 Trend of Lineaments in Zing-Monkin area

DISCUSSION

Mineral Paragenesis

The granitic units have similar mineralogy except for the significant abundance of certain mineral phases in granodiorite and their extreme paucity in the granites. The granites on the other hand, possess the same mineralogy and same as the migmatites but in different proportions. Consequently, paragenesis of minerals in the granitoids can be conveniently discussed in terms of the two rock units – granodiorite and the granites.

In granodiorite, hornblende and biotite are the sole mafic minerals. Plagioclase and biotite are hosted by microcline. This shows that the latter post-dates both plagioclase and biotite. Quartz occurs interstitial to both plagioclase and microcline and as inclusions in microcline and biotite suggesting that crystallisation of quartz commenced at the same time as microcline and biotite but after significant plagioclase precipitation. The close association of apatite, sphene, zircon and magnetite with biotite shows that they probably appeared at the same time. The presence of zoned plagioclase with an andesine core ($An_{35\pm3}$) in the granodiorite indicates the presence of early ferromagnesian mineral, hornblende. The breakdown of such hornblende probably resulted to biotite-magnetite-sphene-zircon assemblage. In summary the sequence of crystallisation of minerals commenced with precipitation of ferromagnesian minerals + plagioclase (An_{35+3}). This early phase was followed by a more sodic plagioclase ($An_{20\pm2}$) with biotite and probably zircon, sphene and apatite. Microcline and quartz are probably the last major phases to precipitate.

The order of precipitation of the minerals of the granites is similar to that described for the granodiorite. Plagioclase ($An_{39\pm3}$) which started precipitating early in the granodiorite continued in the granite units increasingly becoming more sodic ($An_{20\pm2}$ to $An_{14\pm3}$). Quartz, microcline and the accessory minerals crystallised later as the cooling of the magma continued. That microcline and quartz appeared late in the solidifying magma is buttressed by the replacement of oligoclase by microcline and quartz and the interstitial occurrence of the latter. In summary, the sequence of crystallisation of the various mineral phases of this unit is conveniently expressed in terms of early formed plagioclases and late assemblages of microcline, quartz and accessory apatite, zircon and sphene. Alteration of these minerals led to formation of secondary phases such as chlorite. The irregular outline and cloudy appearance of microcline crystals points to replacement as the dominant process in the generation of the textures observed in the rock units.

Origin of the Granitoids of Zing-Monkin Area

Mantle and crust are two end member sources of granitoids. However, the two sources are not mutually exclusive. While most granitic rocks originate by contribution from both sources, some are derived purely from the end member sources (Clarke, 1996; Pearce, 1996).The composition of the source and the physico-chemical processes that affect this source and the melt therefore control the chemistry of granitic rocks. Such chemical characteristics have been described by Chappell and White, (1978).

Chappell and White, (1978) recognised two types of granites (each, related to a particular orogenic belt) – the I-type granite (which is compositionally expanded) and the S-type granite (which is compositionally restricted). Both granites have calc-alkaline characters and distinctive petrochemical characteristics which reflect the differences in the sources of the magmas. The I-type granites are derived from a basic igneous source by remelting of deep seated igneous material or the mantle, while the S-type granites are derived from melting of metesedimentary source materials. The fundamental distinguishing mineralogical and field characteristics of the different sources, as recognised by Chappell and White, (1978) are compared with those of Zing-Monkin granitoids in Table 3. Such comparison shows that the Zing-Monkin granitoids have I-type characteristics and support the model of its derivation by partial melting of basic source rock of mantle origin. The granitoids of Zing-Monkin area probably formed by partial melting of basic rocks (most likely derived from igneous source) in the uppermost mantle and/or lower crust. As the magma made it way from the zone of generation to the sites of emplacement, it differentiated by progressive fractionation of hornblende, plagioclase, biotite, potassium feldspar, apatite and zircon leading to compositional and mineralogical variation from granodiorite to the granites.

Table 3: I- and S-type granite characteristics (after Chappell and White, 1978) compared with those of Zing-Monkin Granitoids

Criteria	I-type	S-type	Zing-Monkin Granitoids
Field	Massive, with little or no foliation. Contains mafic hornblende-bearing xenoliths	Usually foliated. Contains metasedimentary Xenoliths. May be associated with regional metamorphism; more likely to be found near their source and shows evidence (migmatite, regional metamorphism).	Little foliation. Contains Mafic enclaves in the granodiorite.
Mineralogical	Hornblende and biotite + accessory magnetite	Muscovite + accessory ilmenite	Hornblende and biotite + accessory magnetite
Chemical	High oxygen fugacity, high Na_2O, >3.5% in felsic rocks decreasing to >2.2% in more mafic types.	Low oxygen fugacity, low Na_2O; normally <3.5% in rocks with approximately 5% K_2O decreasing to >2.2% in rocks with approximately 2% K_2O.	NA*
Isotope	δ^{180} <10% SMOW $^{87}Sr/^{86}Sr$ = 0.704 - 0.706 $\delta^{34}S$ = 3.6 – 5.0%	δ^{180} >10% SMOW $^{87}Sr/^{86}Sr$ = >0.7061 $\delta^{34}S$ < - 5.00%	NA*
Ore Association	Porphyry copper, Mo	Tin	No porphyry copper, no Mo.

NA* = Not investigated

The textural, mineralogical and field features of the observed enclaves in the investigated area are further evidences that the granitoids probably formed by partial melting of basic rocks of igneous origin in the uppermost mantle and/or lower crust. Mafic enclaves in granitoids have been variously documented (Clarke, 1996; Pearce, 1996; El-Nisr et al., 2001). According to El-Nisr et al., (2001), enclaves (restites) that are indicative of partial melting of a basic source are often mafic in appearance, small in size, devoid of rapikivi texture and normally have gradational contacts with the host rock (similar to the mafic enclaves in the granodiorite of Zing-Monkin area). Didier (1973) had earlier detailed the distinguishing features of the various enclaves in granites and the criteria for differentiating their various origins. Didier's features were later modified by Maurey et al., (1978) who summarised the characteristics that distinguish enclaves of igneous from those of sedimentary origins. The workers also distinguish congeneric enclaves (cognate enclaves) from foreign (xenolithic enclaves) of igneous origin in the granitoids. Using the characteristics presented by these workers, the enclaves observed in the granitoids of Zing-Monkin area are compared with enclaves of igneous and sedimentary origins in Table 4, and with congeneric and foreign enclaves in Table 5. From the Tables, it is clear that the textural, mineralogical and field features of enclaves in the granitoids of Zing-Monkin area do not support xenolithic origin for the enclaves. The features appear to suggest that these enclaves represent remnants of igneous rocks connected with the source of the granitoids of Zing-Monkin area. They probably represent pre-existing rocks from which the granitoids of Zing-Monkin area were derived.

Table 4: Some distinguishing characteristics of enclaves of sedimentary and igneous origin in granites (modified from Didier, 1973)

Criteria	**Enclaves of sedimentary rocks**	**Enclaves of igneous rocks (including meta-igneous rocks)**	**Enclaves in Zing-Monkin Granitoids**
Distribution	Concentrated about the periphery of the granite body	Concentrated centrally (if of congeneric origin)	Distributed throughout the pluton. More at the centre.
Texture	Perfect granoblastic (with banding sedimentary bedding) common	Variety of igneous rocks textures (and modification thereof) according to type; banding rare	Igneous texture with less directional fabric including banding
Petrofabric analysis	Results comparable with those of the surrounding rocks	Results comparable to those of granites (if enclave is of congeneric origin)	NA*
Chemical composition	That of sedimentary rocks	That of igneous rocks	NA*
Shape	Tends towards angularity	Angular (if xenolithic in origin); Rounded (if congeneric in origin)	Shapes are varied ranging from sub-angular to sub-rounded
Zircon shape	Irregular or rounded edges and corners	Prismatic	NA*
Nature of plagioclase twin	Untwinned or very weakly twinned	Pronouncely twinned on various laws. Twin on 010 dominate over others. Abundant albite twin (if enclave is magnetic or thermally metamorphic)	Both twinned and untwined crystals present
Presence of large feldspar (phenocrysts or porphyroblasts)	Rare	Common	Observed in many enclaves

NA* = Not investigated

Table 5: Some distinguishing features of congeneric and xenolithic enclaves of igneous origin in intrusive granites (modified from Didier, 1973)

Criteria	Enclaves of earlier and independently formed igneous rocks	Congeneric igneous enclaves = cognate enclaves	Enclaves in Zing-Monkin Granitoids
Distribution	Particularly in proximity to country rock composed of earlier formed igneous rock	Throughout the pluton but with local concentrations where chilled margins or earlier dikes have been dislocated	Observed throughout the granodiorite units
Shape	Angular; sharp contacts with host granite	Rounded; diffused contacts with host granite	Sub-rounded; both sharp and diffused contacts observed
Texture	Metamorphic	Normal igneous	Igneous texture with very few directional fabrics observed
Mineral composition	Independent of the granite. There is thermal disequilibrium between enclave and host; hence different mineralogy	Similar to that of granite. There is strong resemblance between minerals of enclaves and those of host granite evidence of thermal equilibrium	Mineral composition of enclaves very similar to that of host granodiorite
Feldspathisation	Rare	Very common	Observed in many localities
Granitisation	Rare	Very common	Observed in many localities
Chemistry	Drastically different chemical composition from the host. There is no consanguinity between enclave and host.	Chemical composition deviates only very slightly from that of host. Tend to be slightly more basic than host.	NA*

NA* = Not investigated

Uranium Potentials

Graphical presentation of average radiometric measurements (Fig. 4) indicates a progressive increase in radioactivity from granodiorite through migmatites to the granites with the highest intensities recorded in fine-grained granites. The radiometric count is generally above 100cps and over 245cps in two localities. This result has been compared with that of similar study conducted in Damara Orogen, Namibia. Paul et al (2001) divided the sheeted leucogranites of the Damara Orogen, Namibia into six distinct types (A-F) based on radiometric measurements and considered those above certain radiometric counts as U-enhanced. Table 6 below, summarises the radiometric characteristics of Zing-Monkin granitoids and compares them with those of the sheeted leucogranites.

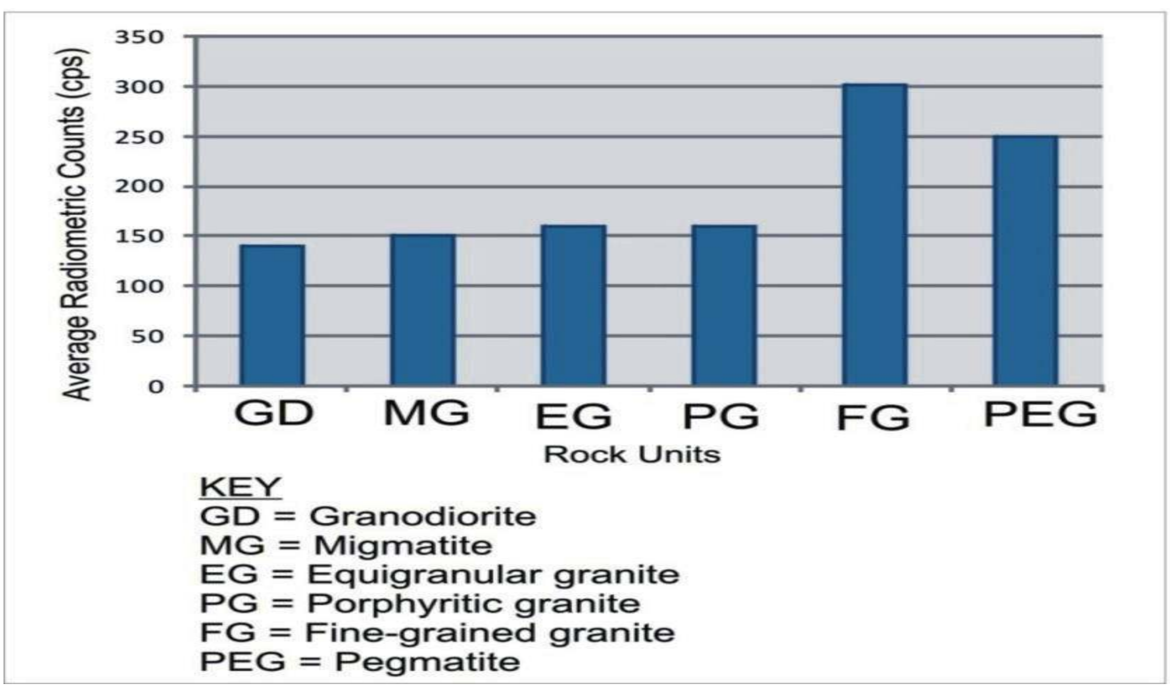

Fig. 4. Plot of Average Radiometric Measurements in Zing-Monkin area.

Table 6. Average Radiometric counts (cps) of Zing-Monkin granitoids compared with sheeted leucogranites. Numbers in brackets are the maximum scintillometer counts for U-enhanced type.

Zing-Monkin Granitoids			Sheeted Leucogranites
Rock Unit	**Range**	**Average**	
Granodiorite **(n=81)**	130 - 165	140.5	A, <20
Fine-grained granite **(n =81)**	280 - 320	300.8 (310)	B, <20
Migmatite **(n=81)**	130 - 155	151.40	C, 10-20 (200)
Equigranular granite **(n=81)**	140 - 170	160.4	D, 100 (400)
Porphyritic granite **(n=81)**	140 - 175	160.12	E, 30 (300)
Pegmatite **(n=79)**	235 - 260	249.40	F, <20

n = number of readings/measurements taken

From the table, it is clear that two rock units: the fine-grained granite and the pegmatite are uranium-enhanced. The enhanced radiometric counts in fine-grained granite and pegmatite may be suggestive of uranium occurrences. It has been suggested that such uranium is normally magmatic with little hydrothermal contribution. For instance, Jacob (1974a, b), Bunting (1977) and Jacob et al (1986) suggested that most uranium mineralization is essentially magmatic with little hydrothermal influence. However, recent fluid extraction studies indicate significant post-magmatic enrichment in the Rossing pit, South Africa (Herd 1996; Nex et al 2002). The data corroborates those of NUMCO uranium exploration findings (1979-1982) with uranium prospects of interest in nearby Mika, Jada and Nyaza.

CONCLUSION

The paucity of foliation, the mafic hornblende-bearing enclaves and the gradational contact relation between the rock units have led to a conclusion that the granitoids are I-type, genetically related to a common source probably by fractional crystallisation of hornblende, plagioclase, biotite, microcline and accessories such as apatite, sphene and zircon. The distribution of enclaves throughout the granodiorite unit, their sub-rounded shape and diffused contacts are consistent with their igneous texture that the enclaves are congeneric probably representing remnants of pre-existing rocks from which the granitoids were derived.

The enhanced radiometric counts in fine-grained granite and pegmatite may be suggestive of uranium occurrences. Such uranium is normally magmatic with little hydrothermal contribution.

REFERENCES

Chappell, B.W. and White, A.J.R., 1978. Granitoids from the Moonbi district, New England batholiths, Eastern Australia. Journ. Geol. Soc. Australia, 25: pp. 267-283.

Clarke, D.B. 1996, Two centuries after Hutton'sTheory of the Earth: the status of granite science. Transaction Royal Society Edinburg Earth Sciences 87, 353-359.

Didier, J. 1973, Developments in petrology 3: Granites and their enclaves: Elsevier Scientific Publishing Company, New York.

Ekwere, S.J. and Ekwueme, B.N. 1991, Geochemistry of Precambrian Gneisses in the Eastern part of the Oban Massif, Southeastern Nigeria. Geol. Mijnb. 70, 105-114.

Ekwueme, B.N. 2003, The Precambrian geology and evolution of the southeastern basement complex. Univ. Calabar Press. P. 135.

Ekwueme, B.N., Caen-Vachette, M. and Onyeagocha, A.C. 1988, Rb-Sr geochronology of metasedimentary schist and gneisses in the Oban Massif, southeastern Nigeria. J. Min. Geol., 24, 249-255.

Ekwueme, B.N., Itaya, T. and Yabe, H. 1997, K-Ar ages of intrusive rocks in the Oban-Obudu Massif and their significance for the plutonic history of southeastern Nigeria. The Island Arc, 6, 353-360.

Ekwueme, B.N. and Onyeagocha, A.C. 1985a, Metamorphic isograds of Uwet area, southeastern Nigeria. J. Afr. Earth Sci. 3, 443-454.

Ekwueme, B.N. and Onyeagocha, A.C. 1985b, Petrology of intrusive rocks in Uwet area, Oban Massif, Southeastern Nigeria. J. Min. Geol. 22, 71-78.

Ekwueme, B.N. and Onyeagocha, A.C. 1986, Geochemistry of metasedimentary rocks of Uwet area, Oban massif, Southeastern Nigeria. Geol. Rundsch; 75, 411-420.

El-Nisr, S.A., El-Sayed, M.M. and Saleh, G.M. 2001, Geochemistry and petrogenesis of Pan-African Late- to post-orogenic Younger granitoids at Shalatin-Halaib, Southeastern Desert Egypt. Journ. of Afri. Earth Sci. 33, 261-281.

Herd, D.A. 1996, Geochemistry and mineralisation of alaskite in selected areas of the Rössing Uranium Mine, Namibia. Unpubl. M.Sc Dissertation, University of St. Andrews, Scotland, p144.

Jacob, R.E. 1974a, Geology and metamorphic petrology of part of the Damara orogen along the lower Swakop river, south west Africa. Bulletin 17 Chamber of Mines, Precambrian Research Unit, university of Cape Town.

Jacob, R.E. 1974b, The radioactive mineralization in part of the Central Damara Belt, South West Africa, and its possible origin. Report PIN-234(BR), Pelindaba, Atomic Energy Board, South Africa.

Jacob, R.E., Corner, B. and Brynard, H.J., 1986. The regional structural and geological setting of the uraniferous granite provinces of South Africa. In: Anhaeusser, CR; Maske, S. (Eds) mineral Deposits of South Africa, Vol.II. Geological society of South Africa, Johannesburg, PP. 1807-1818.

Maury, R.C., Didier, J. and Lameyre, J., 1978. Comparative magma/xenoliths relationships in some volcanic and plutonic rocks from the French Massif Central: Contributions to Mineralogy and Petrology, 66: 401-408.

NEX, P.A.M., Herd, D.A, and Kinnaird, J.A., 2002. Fluid Extraction from quartz in sheeted leucogranites as a monitor to styles of uranium mineralization: an example from the Rossing area, Namibia. Geochemistry Exploration Environment Analysis (in press).

Odigi, M.I. and Okonny, I.P., 1987. Application of radar imagery to structural and geological studies in Oban Massif, southeastern Nigeria. J. Afr. Earth Sci., 6, 275-280.

Paul, A.M.N; Judith, A.K, and Graham, J.H.O., 2001. Petrology, Geochemistry and uranium mineralization of post-collisional magmatism around Goanikontes, southern Central Zone, Damaran Orogen, Namibia. Journal of African Earth Sciences, 33: 481-502.

Pearce, J.A., 1996. Sources and settings of granitic rocks. Episode 9: 120-125.

Appendix II: Radiometric Measurements (cps) for various rock units in the study area.

S/N	GD	MG	EG	PG	FG	PT
1	160	130	170	140	310	250
2	160	130	170	160	310	250
3	140	135	165	150	300	250
4	150	130	165	145	300	240
5	150	135	145	155	300	245
6	150	135	145	160	320	260
7	150	140	155	170	330	260
8	150	155	150	160	330	260
9	150	155	140	175	280	260
10	160	140	160	140	280	260
11	165	140	160	170	290	260
12	165	140	160	165	285	255
13	160	145	170	160	285	255
14	165	145	150	165	285	250
15	165	140	150	165	290	250
16	145	140	150	170	300	250
17	150	140	160	145	305	250
18	145	140	165	140	300	250
19	140	150	165	150	300	250
20	165	130	165	150	305	250
21	165	130	170	155	300	255
22	160	140	160	160	300	255
23	160	140	170	155	300	240
24	160	155	170	155	305	240
25	150	135	145	155	310	260
26	150	150	150	155	310	260
27	150	130	155	165	310	250
28	155	140	155	160	320	260
29	145	130	155	140	320	250
30	145	130	160	140	320	250
31	145	130	155	145	290	250
32	160	145	160	155	300	240
33	160	145	140	150	310	245
34	155	140	170	150	300	250
35	160	145	165	160	290	240
36	165	150	160	160	300	240
37	165	150	160	160	300	240
38	165	155	160	165	300	240
39	145	155	165	160	310	235
40	145	155	170	155	305	240
41	130	130	165	170	290	245

S/N	GD	MG	EG	PG	FG	PT
42	150	140	170	155	310	260
43	155	150	170	150	310	250
44	155	150	165	155	295	250
45	155	150	160	140	285	250
46	150	140	160	155	280	255
47	150	135	160	145	295	255
48	150	140	150	145	295	260
49	155	140	155	175	295	255
50	155	145	155	175	295	255
51	155	135	155	170	295	250
52	150	145	160	150	300	250
53	150	150	165	170	290	250
54	150	140	140	170	300	250
55	140	145	160	160	300	250
56	160	155	160	160	300	250
57	150	135	160	170	310	255
58	150	130	165	170	310	260
59	140	140	160	170	320	260
60	155	130	160	165	315	260
61	150	140	160	165	315	240
62	150	140	145	165	315	240
63	150	140	140	170	315	245
64	150	135	140	170	315	240
65	160	150	160	170	300	240
66	155	150	165	165	300	250
67	165	140	155	160	300	250
68	160	140	160	170	305	240
69	150	140	160	170	300	240
70	150	140	160	170	300	240
71	165	135	165	160	305	260
72	150	150	150	160	310	255
73	150	145	160	165	300	245
74	130	140	160	170	300	240
75	140	140	170	165	300	255
76	135	145	170	170	300	240
77	135	140	170	170	290	240
78	135	130	170	165	295	240
79	140	135	165	165	285	240
80	140	135	170	160	290	---
81	135	135	170	170	290	---

KEY: GD = Granodiorite, MG = Migmatite, EG = Equigranular granite, PG = Porphyritic granite, FG = Fine-grained granite, PT = Pegmatite.