NSUK Journal of Science & Technology, Vol. 7(1): pp. 100-110, 2020 Print: ISSN: 2756-696X
On-line: ISSN 2756-6951
Website: www.nsukjst.org.ng

GEOLOGICAL AND GEOCHEMICAL EVALUATIONS OF GRANITIC ROCKS FROM ISAN EKITI AREA, SOUTHWESTERN NIGERIA

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ABSTRACT
Geologic and geochemical features of granitic rocks in Isan Ekiti southwestern Nigeria was investigated and reported. The geochemical study which adopted ICP-MS presents major, trace and rare earth elements composition and geotectonic implications of the rock. Isan Ekiti area is underlain by charnockite, porphyritic granite and fine to medium-grained granite. The charnockite is coarse-grained in texture and comprises of poikilitic texture of hypersthenes surrounded by fine grained matrix of biotite and quartz. Porphyritic granite consists of large euhedral crystals of microcline occurring in a finer matrix of quartz, biotite and plagioclase. The fine to medium-grained granite comprises of microcline occurring in the interstitial spaces between quartz, biotite and orthoclase. In the SiO_2 versus total alkali diagram, the granitic rocks plot in the calc-alkaline field. In the Rb versus SiO_2 discrimination diagram for tectonic setting, the granitic rocks plot in the syn-collisional and volcanic arc granite fields. Porphyritic granite and fine to medium-grained granite show similar REE patterns with charnockite. The granitic rocks show high fractionation with steep patterns of LREE fractionation relative to HREE depletion. The observed similarities in the REE patterns of the granitic rocks suggest similar origin. The lower values of Ba/Rb and Ba/Sr ratios in porphyritic granite and fine to medium grained granite than in charnockite is an indication of high fractionation through magmatic differentiation.
Keywords: fractionation, crustal contamination, crystallization, magmatic and differentiation

INTRODUCTION

Isan Ekiti area is located in the northern part of topographical Sheet 244 on southwestern sector of Nigerian Basement Complex (Fig. 1) while location map of Isan Ekiti area is shown in Figure 2. The geotectonic setting is polycyclic, having been affected by tectono-metamorphic events (Dada, 1998; Rahaman, 1988; Fitches et al., 1985). The Pan-African Orogeny resulted in extensive over-printing of pre-existing structures by plutonism, widespread metamorphism and polyphase folding (Boher et al., 1992; Olarewaju, 1988; Rahaman, 1988). Variations in the trace and rare earth elements are of significance in granitic studies (Emmermann et al., 1975; Obiora and Ukaegbu, 2010).

Several studies have been carried out on Isan Ekiti clay (Bolarinwa, 1992; Elueze and Bolarinwa, 1995; Ojo and Adeyemi, 2003) while limited research has been done on the crystalline basement rocks. Due to limited documentation on the geological, geochemical features and genetic origin of the granitic rocks of Isan Ekiti area, the present study focuses on geological and geochemical evaluations of the granitic rocks of the area.

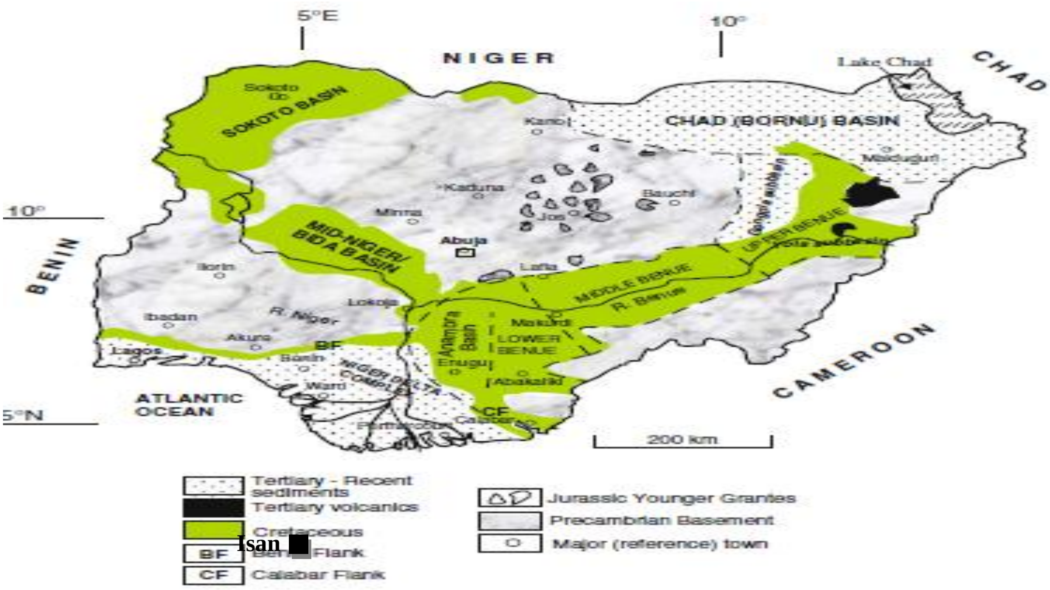

Fig. 1: Geological map of Nigeria showing location Isan Ekiti area (after Obaje et al., 2004)

Fig. 2: Location map of Isan Ekiti area showing the roads and drainage

METHODOLOGY

Fieldwork was carried out for about one month around Isan Ekiti area. During the fieldwork, exposed rocks were mapped and structural data were collected. Isan area was traversed using existing footpaths and river channels. Fresh rock samples were collected from the outcrops with geological hammer and were properly labelled in the field. GPS was used for exact location of outcrops. Lithological descriptions together with data from measurement of attitude of the rocks and other relevant information were obtained and recorded on the map.

Representative rock samples obtained from the fieldwork were used for the production of thin sections and productions of photomicrographs of thin sections were also produced at University of Jos, Nigeria. Whole rock geochemical analyses of two samples of porphyritic granite, one sample of charnockite and one sample of fine to medium grained granite were carried out at Acme Laboratory, Canada.

GEOLOGY OF THE STUDY AREA

Isan Ekiti area is underlain by three rock units namely: charnockite, porphyritic granite and fine to medium grained granite (Fig. 3).

Charnockites

Charnockites are hypersthene-bearing granite. The presence of hypersthene gives charnockite greenish colouration which distinguishes it from granite. It covers about forty percent (40%) of Isan area (Fig. 3). Charnockite occurs as low-lying outcrops in northern part of the area. Due to the occurrence of charnockites as xenoliths in the porphyritic granite and geochronology data according to Rahaman (1988), the charnockites are likely to be emplaced before porphyritic granite which occurs as batholithic intrusions. Charnockite is dark greenish in colour and highly rich in bluish quartz and greenish feldspar. The greenish colouration appears in hand specimen. The texture is usually medium and randomly oriented thus the rock has no foliation.

The thin section shows that the charnockite composed of quartz that is colourless and occur in interstitial spaces between hornblende, hypersthenes and plagioclase feldspar (Fig. 4). Biotite crystals exhibit one directional cleavage and are dark to light brown in color in plane and crossed polars. The charnockite is coarse grained in texture and comprises of poikilitic texture of hypersthenes surrounded by fine grained matrix of biotite and quartz. The alkali feldspars are mesoperthitic while the plagioclase has composition in the andesine range with subordinate labradorite. The modal compositions of charnockite include quartz (25%), andesine (20%), hornblende (10%), biotite (15%), hypersthenes (23%) and accessory garnet (3%).

Porphyritic granite

Porphyritic granite occurs as well exposed outcrop, but in some locations it occurs as inselbergs. Porphyritic granite comprises of phenocrysts of K-feldspar in a matrix of fine grained quartz and biotite. There is a localized deformation of the porphyritic granite and the foliations are not well defined. Porphyritic granite consists of quartz, microcline and biotite. The microclines are mainly large euhedral crystals in a finer matrix of quartz, biotite and plagioclase (Fig. 5). The thin section shows modal composition of quartz (20%), microcline (45%), biotite (20%) and plagioclase (15%). The quartz appears as colourless, the biotite is brownish in colour and shows pleochroism. Quartz crystals are angular in shape and is grayish in color when viewed in plane and crossed polars.

Fine to medium grained granite

Fine to medium grained granite occurs as lowlying outcrop and pinkish colour depicts high content of K-feldspar. The rock is medium grained in texture and comprises of microcline occurring in the interstitial spaces between quartz, biotite and orthoclase (Fig. 6). In thin section, the modal composition is quartz (25%), plagioclase (15%), microcline (30%), biotite (20%) and orthoclase (10%). Anhedral crystals of quartz occur within the plagioclase. Biotite which is brown in colour has been partially replaced by chlorite while crystals of plagioclase exhibit albite twinning and is partially replaced by sericite.

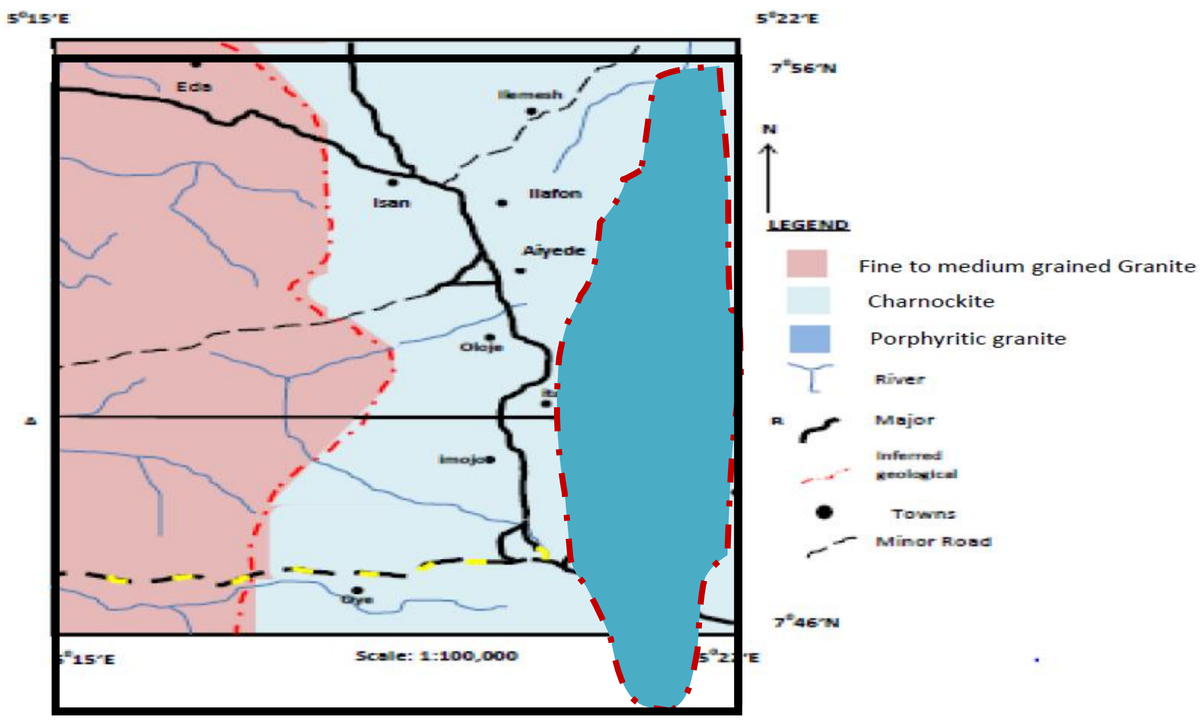

Fig. 3: Geological map of Isan Ekiti area

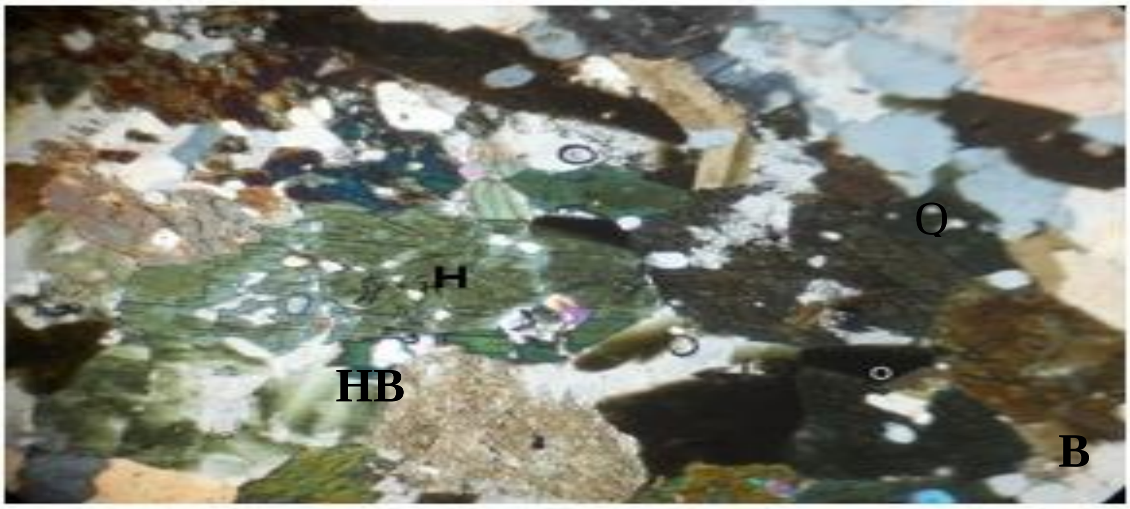

Fig. 4: Photomicrograph of charnockite from Isan Ekiti. 40X magnification showing H=Hypersthene, HB=Hornblende, B=Biotite and Q=Quartz

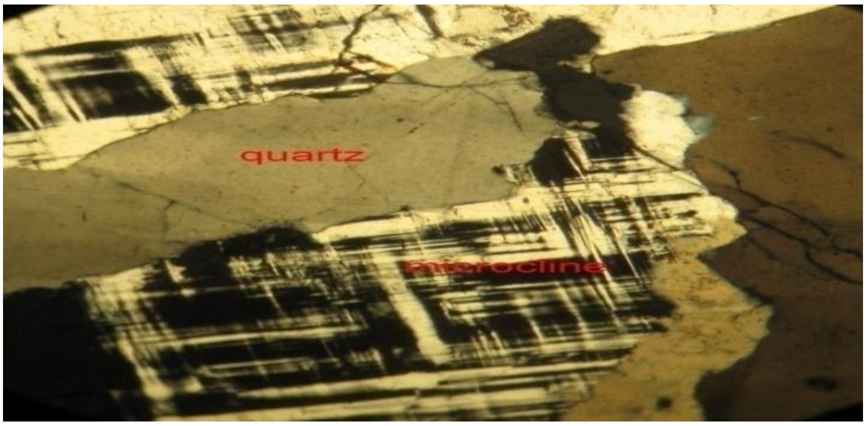

Fig. 5. Photomicrograph of porphyritic granite from Isan Ekiti using 40X magnification

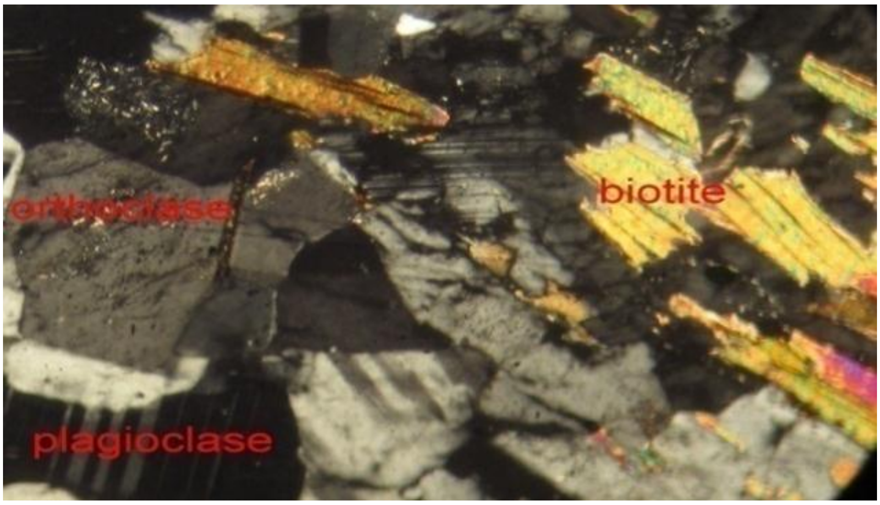

Fig. 6. Photomicrograph of fine to medium-grained granite from Isan Ekiti cpl 40X

RESULTS

The results of geochemical analysis of rocks samples comprising of major oxides is presented in Table 1, trace elements is presented in Table 2 and rare earth elements is presented in Table 3. The Porphyritic granite has SiO_2 content ranging from 69.93 to 72.07wt%, Al_2O_3 value ranges from 13.87 to 14.56 wt%, Fe_2O_3 content varies from 2.53 to 2.82wt%, MgO value ranges from 0.26 to 0.43wt%, CaO value ranges from 1.46 to 1.68 wt%, Na_2O content ranges from 2.95 to 3.11 wt% and K_2O value ranges from 5.34 to 6.67 wt% respectively.

The major oxide compositions of charnockite include SiO_2 (63.74wt%), Al_2O_3 (15.21 wt%), Fe_2O_3 (6.9wt%), MgO (0.24wt%), CaO (2.5 wt%), Na_2O (3.33 wt%) and K_2O (6.36 wt%) while major oxide composition of fine to medium grained granite comprises of SiO_2 (67.87wt%), Al_2O_3 (15.20 wt%), Fe_2O_3 (3.81wt%), MgO (0.71wt%), CaO (1.92 wt%), Na_2O (3.20 wt%) and K_2O (5.54 wt%) respectively.

The granitic rocks of Isan Ekiti area have Ba value ranges from 597 to 1513ppm, Rb content varies from 93.6 to 285.7ppm, Sr value ranges from 142.3 to 244.3 ppm, Th content ranges from 13.6 to 71.6 ppm, Zr content ranges from 229.5ppm to 1188.6ppm and Zn content ranges from 8 to 65ppm respectively (Table 2).

Table 1: Major oxide compositions (wt%) of Isan Ekiti granites

Major oxides	RT 1A Porphyritic granite	RT 1B Porphyritic Granite	RT 2 Charnockite	RT 3 Fine to medium grained granite
SiO_2	72.07	69.93	63.74	67.87
Al_2O_3	13.87	14.56	15.21	15.2
Fe_2O_3	2.53	2.82	6.9	3.81
MgO	0.43	0.26	0.24	0.71
CaO	1.46	1.68	2.5	1.92
Na_2O	3.11	2.95	3.33	3.2
K_2O	5.34	6.67	6.36	5.54
TiO_2	0.31	0.29	0.64	0.6
P_2O_5	0.06	0.05	0.1	0.15
MnO	0.03	0.04	0.13	0.04
Cr_2O_3	<0.002	<0.002	<0.002	<0.002
LOI	0.6	0.5	0.4	0.6
Sum	99.83	99.76	99.55	99.65
TOT/C	0.04	0.03	0.03	0.03
TOT/S	<0.02	<0.02	<0.02	<0.02

Table 2: Trace element compositions (ppm) of the granitic rocks from Isan area.

Trace elements	RT 1A Porphyritic granite	RT 1B Porphyritic granite	RT 2 Charnockite	RT 3 Fine to medium grained granite
Ni	<20	<20	<20	<20
Sc	3	12	13	4
Ba	597	1207	1513	1091
Be	4	2	2	5
Co	3.4	1.6	2.2	5.2
Cs	1.1	0.5	0.4	0.6
Ga	18.3	18.7	20.4	20.3
Hf	6.4	6.9	25.9	13.6
Nb	22	20.7	37.5	31.8
Rb	93.6	177.9	128.9	285.7
Sn	1	<1	<1	2
Sr	159.7	149.4	142.3	244.3
Ta	2	1	1.7	1.9
Th	42.9	13.6	23	71.6
U	5.7	1.7	1.6	4.8
V	15	14	<8	31
W	<0.5	<0.5	<0.5	0.7
Zr	229.5	245.2	1188.6	537.6
Y	12.6	34.6	30.8	16
Mo	2.4	1.3	2.5	0.9
Cu	4.2	4.2	13	7.2
Pb	3.8	1.4	1.8	6.5
Zn	37	8	64	65
Ni	3.3	1.3	1.6	3.4
As	<0.5	<0.5	0.6	0.9
Cd	<0.1	<0.1	<0.1	<0.1
Sb	<0.1	<0.1	<0.1	<0.1
Bi	<0.1	<0.1	<0.1	<0.1
Ag	<0.1	<0.1	<0.1	<0.1

Au	<0.5	<0.5	<0.5	<0.5
Hg	<0.01	<0.01	<0.01	<0.01
Tl	0.3	<0.1	<0.1	0.4
Se	<0.5	<0.5	<0.5	<0.5
Ba/Sr	3.74	8.08	10.63	4.47
Ba/Rb	2.93	6.79	11.73	3.82
Rb/Sr	1.28	1.19	0.91	1.17
Rb/Zr	0.41	0.73	0.11	0.53

Table 3: Rare earth element (ppm) compositions of Isan Ekiti granites

	RT 1A	RT 1B	RT 2	RT 3
Rare earth elements	Porphyritic granite	Porphyritic granite	Charnockite	Fine to medium grained granite
La	78.8	62.6	176.7	195.6
Ce	155.8	125.9	317.5	375.1
Pr	14.04	15.64	35.36	37.08
Nd	43.4	61.4	122.5	109.8
Sm	5.98	12.1	16.42	12.4
Eu	0.85	2.5	3.6	1.53
Gd	4.1	10.3	11.85	7.12
Tb	0.51	1.52	1.4	0.69
Dy	2.64	7.72	6.94	3.19
Ho	0.43	1.39	1.15	0.53
Er	1.15	3.42	3.27	1.39
Tm	0.18	0.49	0.47	0.21
Yb	1.08	2.79	2.87	1.21
Lu	0.16	0.42	0.52	0.17

DISCUSSION

Porphyritic granite and fine to medium grained granite are more enriched in SiO_2 than the charnockite while the Fe_2O_3 concentration is higher in the charnockite than porphyritic granite and fine to medium grained granite (Table 1). Figure 7 shows the discrimination diagram of SiO_2 versus total alkali (Le Maitre, 1989), this indicates that the granitic rocks of Isan Ekiti area plot in the calc-alkaline field.

However, the granitic rocks have relatively similar Al_2O_3 contents with different SiO_2 content (Fig. 8). With increasing SiO_2 contents, Fe_2O_3, MgO, and CaO (Figs. 10, 11 and 12) contents reduce with increasing rates of crystal fractionation as observed in the area while K_2O contents (Fig. 9) increase with increasing crystal fractionation (Levinson, 1980).

The geochemical compositions of Isan Ekiti granites show high concentration of Ba and Zr (Table 2), this indicate the presence of barites as observed in the field and zircon as possible economic minerals in the area (Levinson, 1980). The incompatible trace element concentrations of Rb and Th (Figs. 16 and 18) increase with fractionation while compatible trace element concentrations of Ba, Sr and Ga (Figs. 15, 17 and 19) decrease with fractionation. The variations in SiO_2 (index of differentiation) with Al_2O_3, Fe_2O_3, CaO, MgO, Na_2O and K_2O (Figs. 8-13) suggest that the porphyritic granite, fine to-medium grained granite and charnockite originated through similar process of fractional crystallization.

The variation diagrams of SiO_2 versus K_2O (Fig. 9); and SiO_2 versus Zr, Rb, Th and Ga (Figs. 14, 16, 18 and 19) slightly deviate from smooth trends of variation of the components. The similarities in the contents of these trace elements in the granitic rocks seem to suggest that there was crustal contamination associated through the process of fractional crystallization.

The Rb/Sr ratio in the porphyritic granite ranges from 1.19 to 1.28, fine to medium-grained granite (1.17) and charnockite (0.91). The Ba/Sr ratio in porphyritic granite ranges from 3.74 to 8.08, fine to medium grained granite (4.47) and charnockite (10.63). Ba/Rb ratio in porphyritic granite varies from 2.93 to 6.79, fine to medium grained granite (3.82) and charnockite (11.73) as shown in Table 2. The lower values of Ba/Rb and Ba/Sr ratios in the porphyritic granite and fine to medium grained granite than charnockite further suggests fractionation trends (Taylor, 1965; Rajesh, 2007; Obiora and Ukaegbu, 2010).

In the Rb versus SiO_2 diagram (Fig. 20) of tectonic setting (after Pearce et al., 1984), the charnockite, porphyritic granite and fine to medium-grained granite plot in the syn-collisional and Volcanic arc granite fields. The chondrite normalized rare earth elements diagram of Isan granites is shown in Fig. 21. Porphyritic granite and fine to medium-grained granite show similar patterns with charnockite. There is light rare earth elements fractionation relative to heavy rare earth elements depletion. The similarities in the REE patterns of porphyritic granite and fine to medium-grained granite with charnockite suggest similar origin.

The overlap REE pattern (Fig. 21) observed in the study area indicates crustal contamination (Davidson, 1987). The values of incompatible elements of Rb/Zr ratio varies from 0.41 to 0.73 in porphyritic granite, charnockite (0.11) and fine to medium grained granite (0.53). This wide variation in Rb/Zr ratio indicates crustal contamination and ratio of incompatible elements observed in Isan area significantly change which is associated with crustal contamination.

CONCLUSION

The crystalline rock units identified in Isan Ekiti area include charnockite, porphyritic granite and fine to medium grained granite that are Calc-alkaline in composition and produced by-Syn-collisional and Volcanic arc magmatism. The incompatible trace element concentrations of Rb and Th increase with fractionation while compatible trace element concentrations of Sr, Ba and Ga decrease with fractionation. The values of incompatible elements Rb/Zr ratio in the granitic rocks of Isan Ekiti area ranges from 0.11-0.73. This wide variation in Rb/Zr ratio indicates crustal contamination.

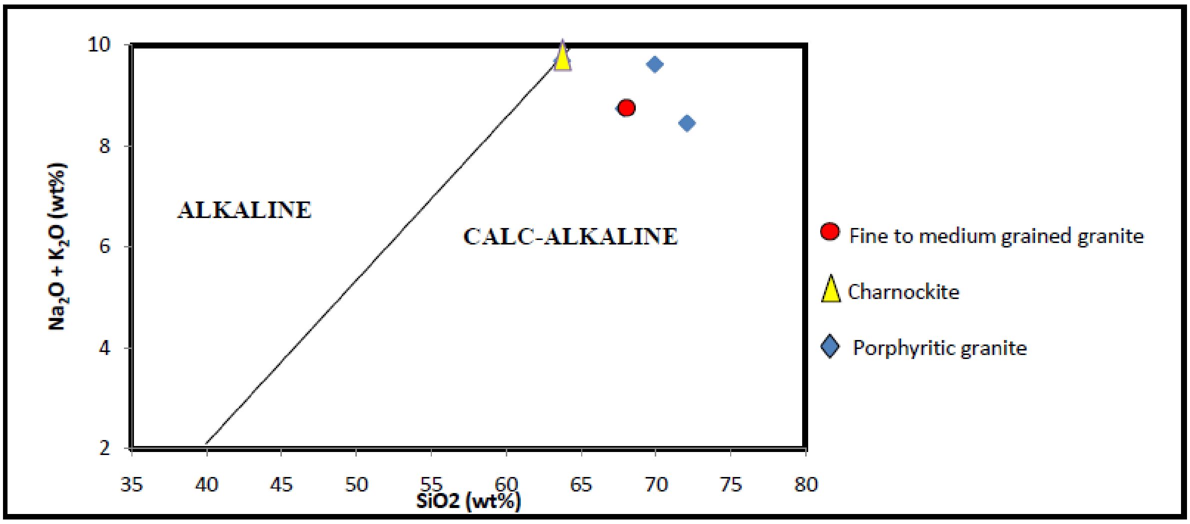

Fig. 7: Total alkali versus silica oxide diagram for the granitic rocks of Isan Ekiti area (adopted from Le Maitre, 1989)

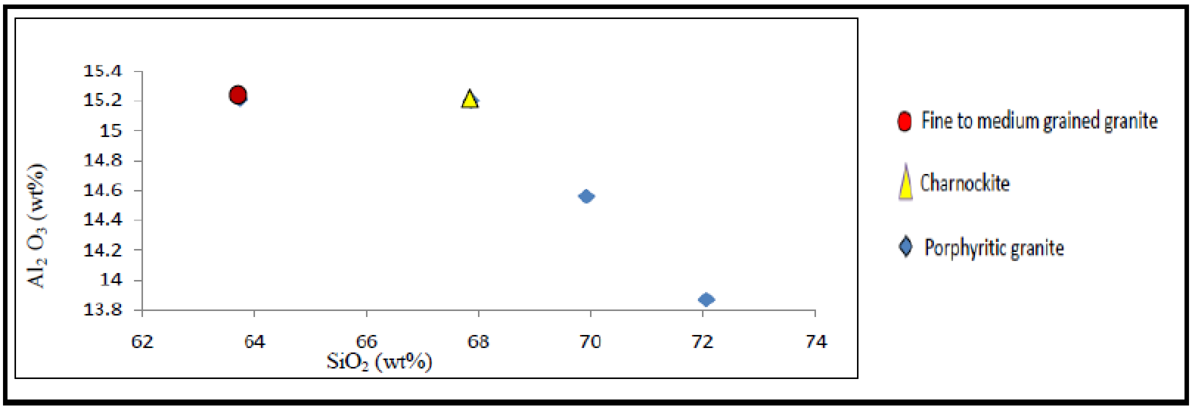

Figure 8: SiO_2 (wt%) versus Al_2O_3 (wt%) variation diagram

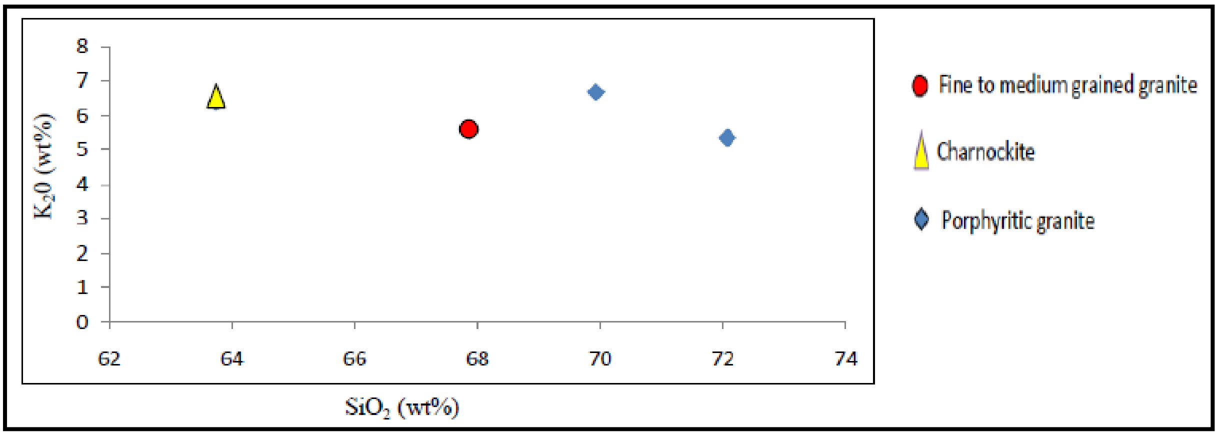

Figure 9: SiO_2 (wt%) versus K_2O (wt%) variation diagram

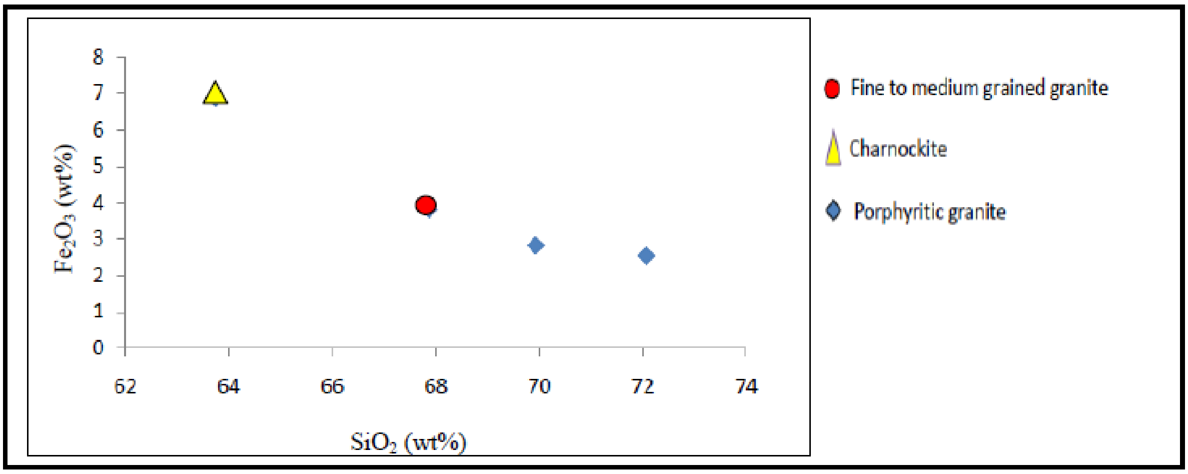

Figure 10: SiO_2 (wt%) versus Fe_2O_3 (wt%) variation diagram

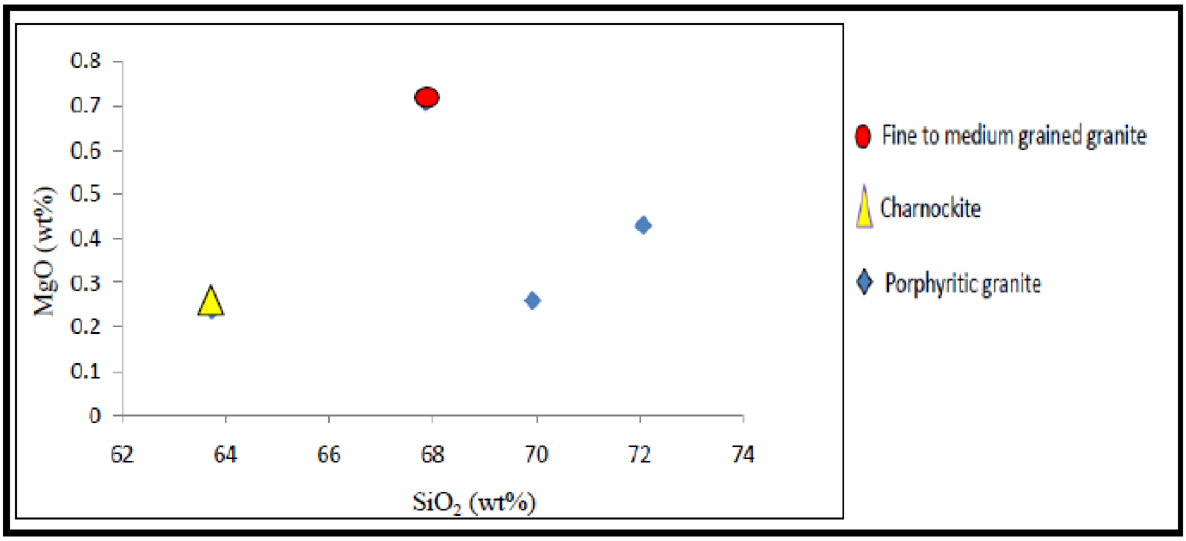

Figure 11: SiO_2 (wt%) versus MgO (wt%) variation diagram

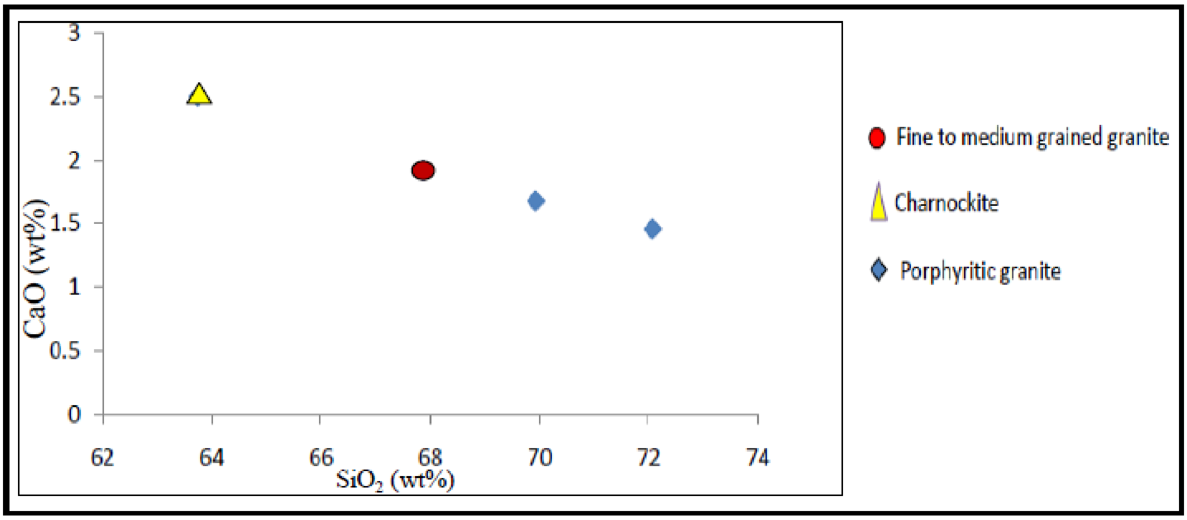

Figure 12: SiO_2 (wt%) versus CaO (wt%) variation diagram

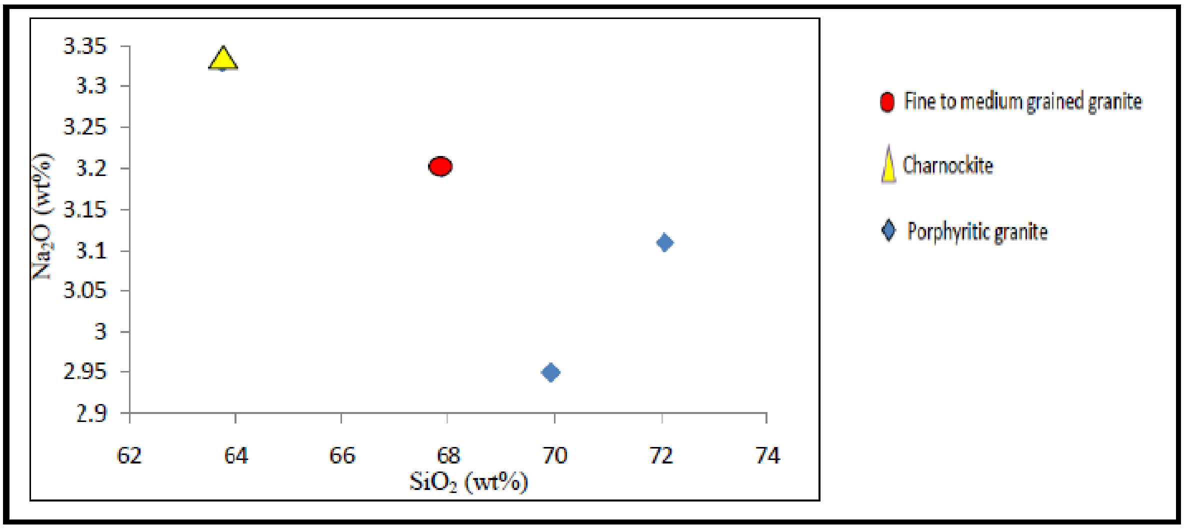

Figure 13: SiO_2 (wt%) versus Na_2O (wt%) variation diagram

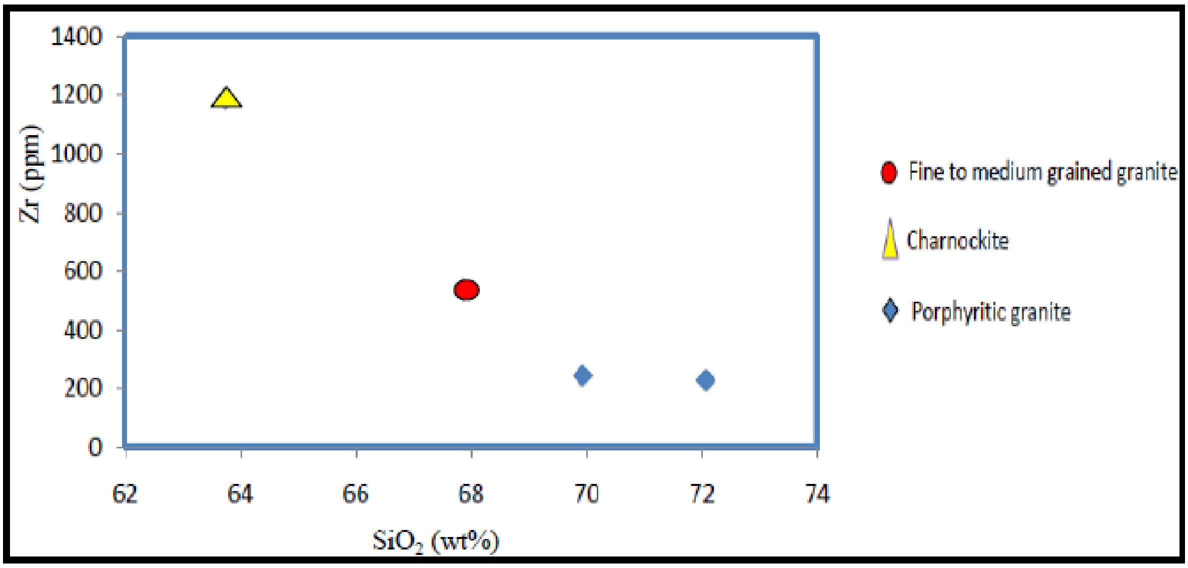

Figure 14: SiO_2 (wt%) versus Zr (ppm) variation diagram

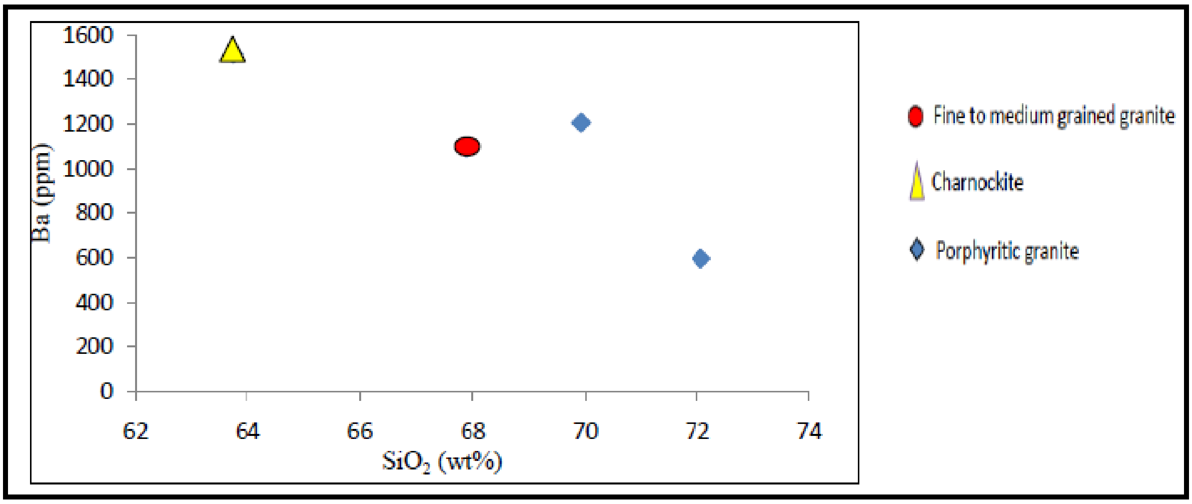

Figure 15: SiO_2 (wt%) versus Ba (ppm) variation diagram

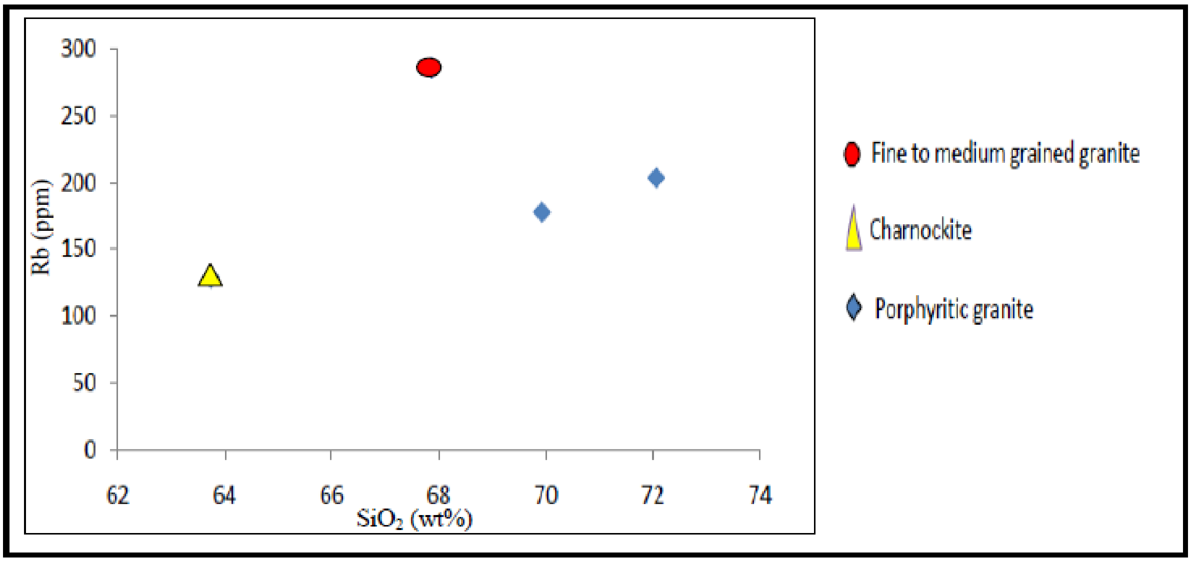

Figure 16: SiO_2 (wt%) versus Rb (ppm) variation diagram

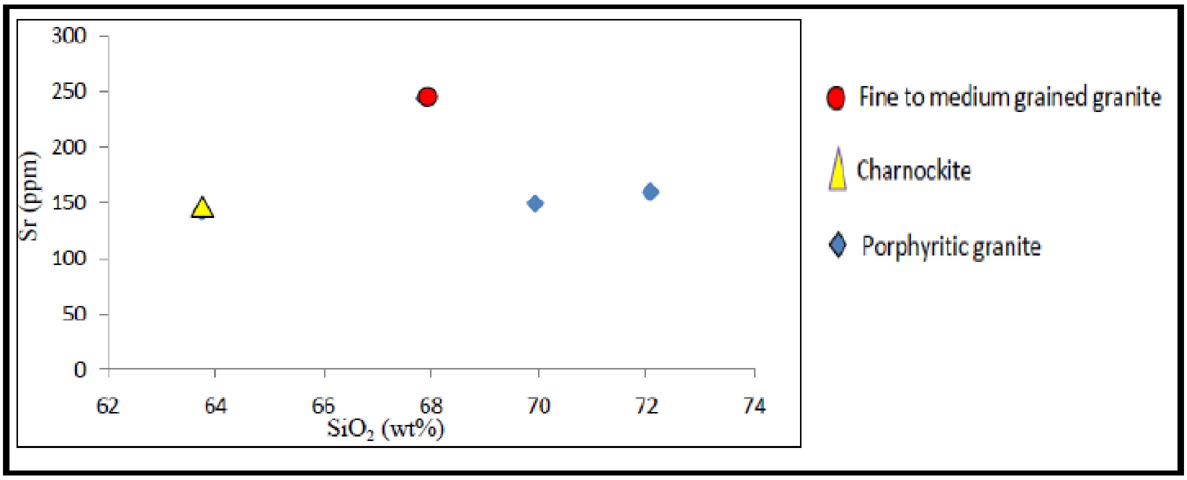

Figure 17: SiO_2 (wt%) versus Sr (ppm) variation diagram

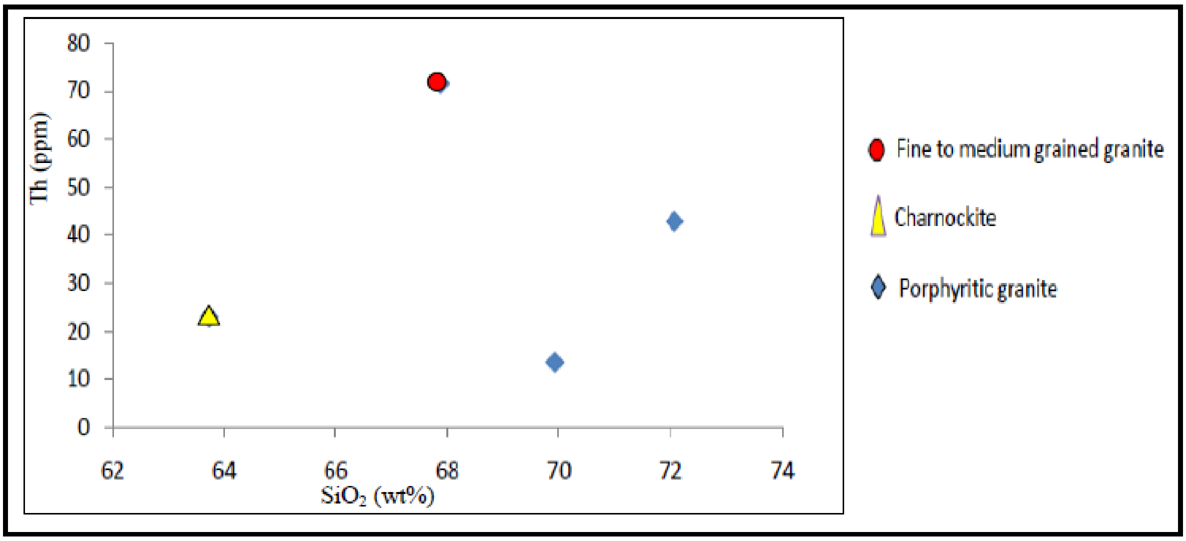

Figure 18: SiO_2 (wt%) versus Th (ppm) variation diagram

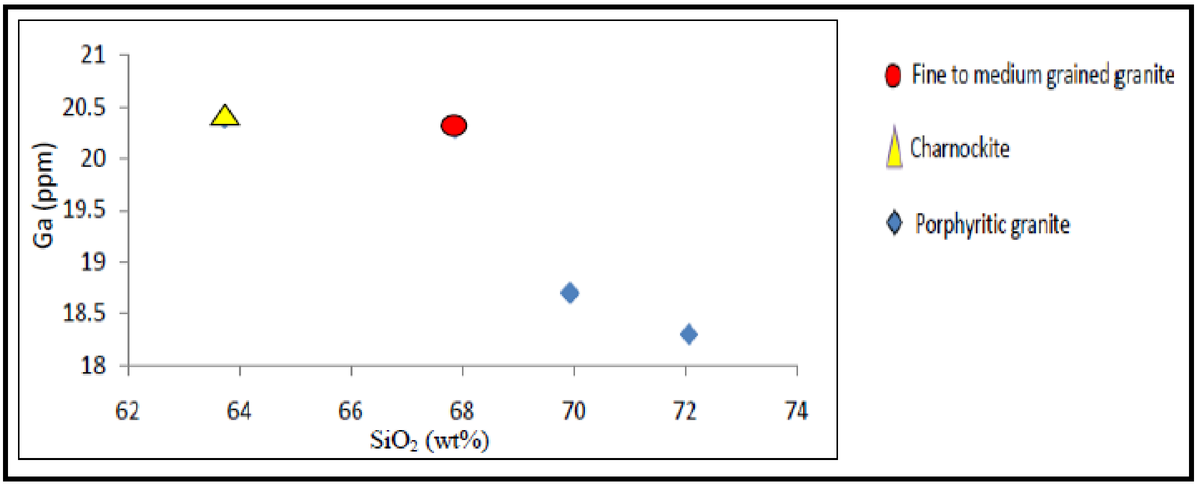

Figure 19: SiO_2 (wt%) versus Ga (ppm) variation diagram

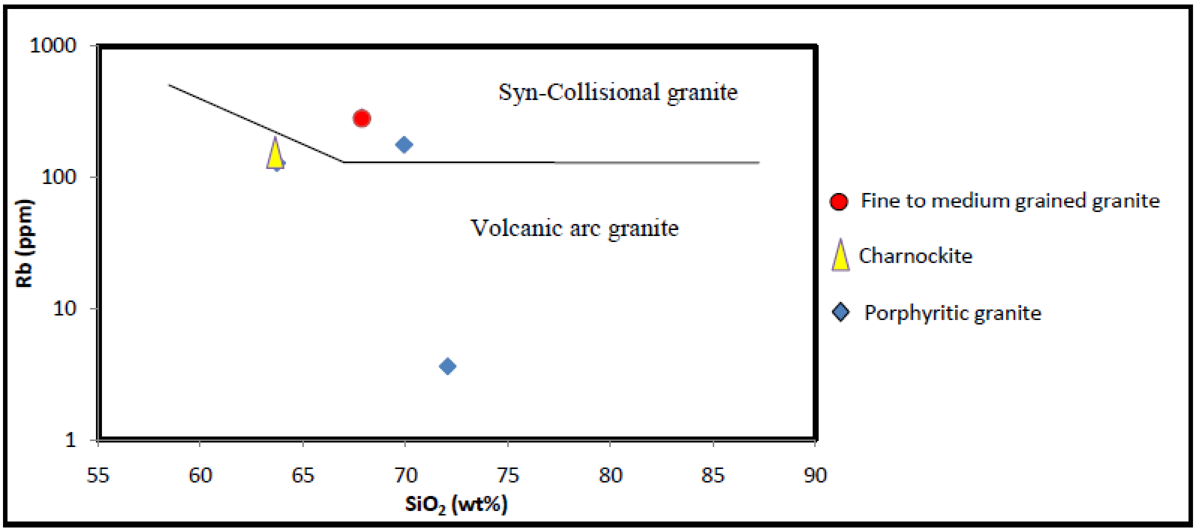

Fig. 20: Rb versus SiO_2 plot for granitic rocks of Isan area (adopted from Pearce et al, 1984)

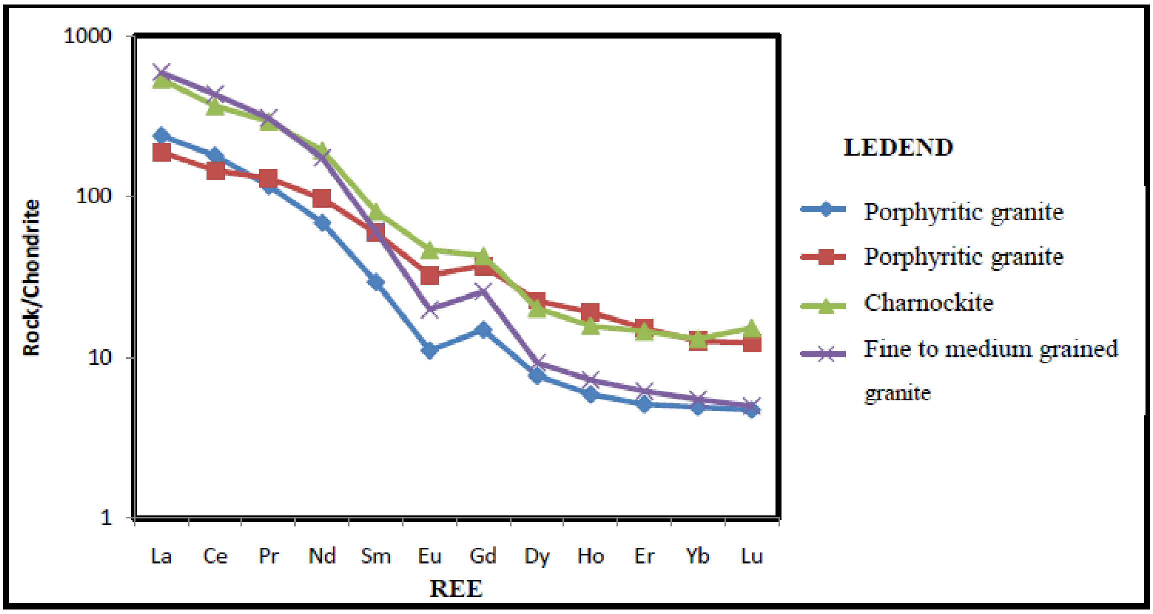

Fig. 21: Chondrite normalized REE plot of the granitic rocks from Isan area

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