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Petrochemical Characteristics and Age of Rare Metal (Ta-Nb) Mineralization in Precambrian Pegmatites, Komu, Nigeria

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Abstract. The Precambrian pegmatites of Komu area intrude semi discordantly older rock types, such as biotite gneiss, amphibolites and pelitic schists. The pegmatites occur as near flat lying bodies. This study aims at elucidating the geological setting, petrography, geochemical features and age of mineralization of these pegmatite bodies, with a view to classifying them and knowing their economic potential. The petrographic analysis shows that the pegmatite samples contain mainly quartz (35%), plagioclase (15%), microcline (10%) and muscovite (12%) with accessories like tourmaline, tantalum, niobium and illmeno-rutiles. Geochemical analysis of the muscovites extracted from pegmatites show that these rocks are enriched in silica (>60%) and Al_2O_3 (>12%) and depleted in Fe_2O_3, MgO and TiO_2. Trace element analysis shows that the pegmatites contain rare metals with moderately high Ta, Nb, Sn, Rb, Li and Cs values and depleted in Ti, Ba and Zr. Elemental ratios indicate low ratios of K/Cs, Th/U and K/Rb. Variation plots of Ta/(Ta+Nb) versus Mn/(Mn+Fe) show that the pegmatites plot in the complex (beryl subtype) field. The Na/K versus Sn, Nb, Rb variation plots show that the pegmatites of Komu area are mineralized and compare favourably with those of other mineralized pegmatite areas like Egbe and Ijero in southwestern Nigeria. The variation plots of Ta versus K/Cs, and Ta/W versus Cs, also confirm rare metal mineralization of Komu pegmatites, which plot over the mineralized line of Beus and Gordiyenko. The K/Rb versus Rb, Cs and Sn plots indicate low K/Rb ratios indicating moderate differentiation. The Rare Earth Elements (REE) show high heavy REE values and lower light REE values with prominent positive Ce anomaly and negative Eu anomaly from normalized chondrite plots. K/Ar dating of the age of mineralization of muscovites extracted from the pegmatite yielded late Pan-African ages between 502.8±13Ma and 514.5±13.2Ma. This period represents the cooling ages of the muscovite and suggests that the pegmatites may not be cogenetic with the surrounding Pan-African granitoids.

Introduction

The Komu area is located between longitude 3°00' E to 3°05' E and latitude 8°15' N to 8°25' N (Fig.1). Over the past thirty years, there has been an extensive research work on the pegmatite all over the world because of its unique composition and economic potential. In Nigeria, the study of pegmatite has aroused interest over the years. Jacobson and Webb (1946) were among the first to work on the pegmatites of Nigeria, especially in Wamba area (Central Nigeria) in a 400 km NE-SW trending belt. Other workers like Matheis (1979, 1987) studied the geochemical exploration for Sn-Nb-Ta in southwestern Nigeria. While, Matheis and Caen-Vachette (1983) studied the pegmatites of Pan-African reactivation zone covering areas of Egbe, Ijero and Wamba, and also distinguished mainly between the barren and mineralized pegmatites. Matheis et al. (1982) further discussed the trace element geochemistry of tin bearing pegmatite of southwestern Nigeria, while Ajibade et al. (1987) documented the metallogeny of the Nigerian basement complex rocks including the pegmatites. Matheis and Kuster (1989) worked on the geochemical exploration guides for rare metal bearing pegmatites with case studies of Ijero and Wamba. Further, Kuster (1990), Okunlola and Ocan (2002), Okunlola and Ogedengbe (2003), Garba (2003), Okunlola and King (2003), Okunlola and Somorin (2005) and Okunlola (2004) have also contributed to the better understanding of southwestern and northern Nigeria pegmatite bodies and concluded that the pegmatites were not confined to the earlier proposed 400 km long NE-SW trending belt. Further, compositional features, geologic and tectonic controls and rare metal evaluation potentials of these pegmatite bodies have also been studied in detail by these workers.

Geochronology data of the Precambrian pegmatites is rare except for the work of Matheis and Caen-Vachette (1983) on the Rb/Sr ages of the Egbe and Ijero areas. The Komu area in south western Nigeria is prolific in terms of occurrence of pegmatite veins, which has not been documented before. This study aims at studying the geological setting, petrography, geochemical features and age of the pegmatites of the area, with a view to classifying them and thereby elucidating their economic potential.

Materials and Methods

Fresh samples of rocks were collected both from excavations and the surface for petrographic studies. The rock samples were cut and mounted on a glass slide

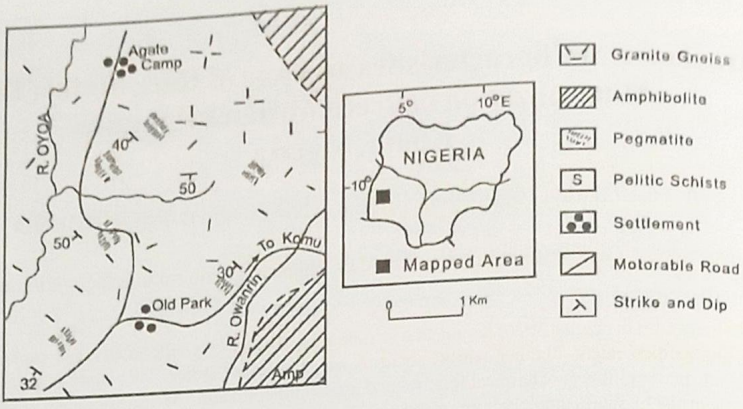

Fig. 1. Geological map of Komu area, southwestern Nigeria.

and then reduced to a thickness of about 30 microns. The muscovite extracts of the rock samples were analyzed for major, minor, trace and rare earth elements using atomic emission spectrophotometry (ICP-AES) but for geochronology, the noble gas mass spectrophotometry was used.

Regional Geologic Setting

Nigeria is underlain by Precambrian basement complex rocks, younger granites of Jurassic age and Cretaceous to Recent sediments. The basement rocks occupy about half of the land mass of the country. The Nigerian basement complex is a part of the Pan-African mobile belt lying between the west African and Congo cratons (Black, 1980). There are contrasting documentations of the evolution of the basement rocks. However, the basement is divided lithostratigraphically into three following major groups.

- Migmatite-gneiss quartzite complex comprising of biotite and biotite hornblende gneisses, quartzites and quartz schists.

- Schist belts consisting of paraschists and meta-igneous rocks, which include schists, amphibolites, amphibole schists, talcose and epidote rocks, marble and calc-silicate rocks. These are mainly N-S to NNE-SSW trending belts of low grade supra-crustal (and minor volcanic) assemblages. Other secondary rocks used in delineating them are carbonates, calc-gneiss and Banded Iron Formation (BIF).

- Older granites, which include granite, granodiorite, diorite-charnockite, pegmatites and aplites.

The migmatite-gneiss complex of Nigeria comprises of biotite and biotite hornblende gneisses, quartzites, quartz schists and lenses of calc-silicate rocks. Three types of gneisses can be distinguished, banded gneiss, granite gneiss and semi-banded gneiss that form the transition between banded and granite gneiss. The gneisses are in general biotite or biotite hornblende gneisses.

The schist belt includes slightly migmatised to unmigmatised paraschists and meta-volcanic rocks, which consist of pelitic schists, quartzites, amphibolites, talcose rocks, meta conglomerates, marble and calc-silicate rocks. These rocks occur in northerly trending belts within the basement extending west of the 8°E meridian (Elueze and Okunlola, 2003).

The principal rock types are quartz-muscovite-biotite schists, which grade laterally into coarse grained plagioclase bearing mica schists. Others include, phyllite, meta-conglomerates and marble, all occupying N-S trending synclinal belts (Elueze, 1981; Turner, 1983). According to Jones and Hockey (1964) there are three main groups of granites. An early phase comprising of granodiorite and quartz diorite, a main phase consisting of coarse porphyritic hornblende and syenite and lastly coarse porphyritic biotite granite. These are followed by a late phase comprising homogenous granite, pegmatite dykes and aplites. The early and late phases are widely distributed.

Results and Discussion

The study area is underlain by granite gneiss, amphibolite, pelitic schist and pegmatite. There are also quartz veins intruding the larger rock bodies. The granite gneisses are predominant in the study area, which are mainly composed of biotite, quartz and ferromagnesian minerals, as observed megascopically. In thin section study, minerals identified are quartz, biotite, microcline and plagioclase feldspars. The average modal composition is quartz (48%), biotite (18%), plagioclase (14%) and microcline (20%). These are mostly dark greenish rocks comprising hornblende, quartz and plagioclase.

The pelitic schistose rocks are mainly composed of biotite and feldspars. Most of the outcrops are weathered, which are observed in the northern portion of the study

area. The pegmatites occur as coarse grained rocks with euhedral crystals of quartz, feldspars and tourmaline. Megascopically, it is observed that pegmatites are made up of large crystals of quartz, K-feldspar, micas and schorl. These pegmatites are widely distributed, occurring as veins, intruding the amphibolites and gneisses. Some of the veins extend to about 500 m and are 50 m wide. The contact between pegmatite intrusions and the host rock is usually gradational. Lepidolite is also observed in the pegmatite, especially close to mineralization of gemstones. Thin section studies of the pegmatites show quartz (25-40%), K-feldspar (5-15%), muscovite (5-12%), biotite (5-8%) and some other minerals, which are believed to be rare elements (Table 1).

Quartz was observed with a low positive relief. It showed some intergrowth with feldspars, which were easily identified with their characteristic twin extinctions and habit. Some of the pegmatite samples are rich in microcline and plagioclase feldspars, mainly albite. Perthitic texture was also observed. Muscovite was noted with its characteristic high relief. Some of the muscovite showed dark haloes indicating alteration. Some other minerals were also observed, which remained dark on rotation of the stage.

Geochemical Features and Rare Metal Potential

The analytical results of major, trace and rare elements are shown in Tables 2 and 3. The major element composition of the pegmatite of the area shows SiO_2 content ranging from 60.35 to 76.00%, Al_2O_3 (12.28–19.80%), Fe_2O_3 (0.22–4.42%), K_2O (0.69–10.33%) and Na_2O (0.70–6.45%). There is a depletion in the percentage of the elements of TiO_2 (0.07–0.47%) and P_2O_5 (0.01–0.04%). The trace elements data (Table 3) show that pegmatites are rich in rare metals with moderately high Ta, Nb and Sn. Tantalum ranging from 54 to 500 ppm, niobium (25–390 ppm), rubidium (59-1000 ppm) and strontium (7–588 ppm).

Table 1. Ranges and average modal composition of the pegmatites

Minerals	% Composition	
	Range	Average
Quartz	25 – 45	35
Orthoclase	5 – 15	10
Plagioclase	10 – 20	15
Biotite	5-8	6
Muscovite	7-12	14
Others (opaques)	5-10	8

Following the classification criteria of pegmatites based on bulk chemistry, geochemical signatures of Cerny (1989) and the Ta/(Ta+Nb) versus Mn/(Mn+Fe) plot, the Komu pegmatites are of the rare and complex pegmatite type belonging to LCT petrogenetic (Li, Rb, Cs, Be, Ga, Sn, Ta > N (B, P, F) family and of the beryl subtype (Fig. 2).

From major element data, the pegmatites are of peraluminous bulk composition (A/CNK>1, where A:Al_2O_3, CNK: CaO+Na_2O+K_2O). Cerny (1982) states that the LCT family has a mild to extremely peraluminous parent granitic composition. Following this, the possibility that Komu pegmatites are derived from the anatexis of undepleted upper to middle crustal protoliths is high. Using K/Rb/Cs plots, the pegmatites in Komu area are classified as rare metal bearing (Fig. 3).

The low values of Mg, Ti, Ba and Zr with high Rb, Li, Cs and Y contents indicate high fractionation of the pegmatites. The moderately high Cs values of the pegmatites indicate moderately high alkali metal fractionation of the Komu pegmatites (Cerny, 1982, 1989). The K/Rb versus Cs variation plots show a consistent trend (Fig. 3), which compares favorably with the mineralized pegmatites of Noumas, South Africa (Moller and Morteani, 1987). However, these pegmatites are not as mineralized as that of Tanco, Canada (Cerny, 1982; Moller and Morteani, 1987; Garba, 2003).

There is a clear enrichment of Nb, Ta, Sn, Rb and depletion of Sc and Co, which also confirms mineralization of

Table 2. Major elements of the pegmatites

Elements	1	2	3	4	5	6	7	8	9	10
SiO_2	65.74	76.00	62.67	65.56	66.25	60.35	66.10	66.96	76.19	76.78
Al_2O_3	12.56	14.22	13.90	12.78	13.74	19.80	12.28	12.97	13.55	14.40
Fe_2O_3	1.94	1.12	0.64	4.18	4.42	3.43	1.36	1.86	0.22	0.35
MnO	0.09	0.07	0.10	0.16	0.37	0.16	0.05	0.06	0.21	0.30
MgO	2.13	0.19	2.35	2.44	2.85	0.26	2.05	2.48	0.05	0.07
CaO	1.40	0.44	0.73	2.60	2.86	0.02	1.10	1.46	1.39	1.80
Na_2O	4.32	6.45	4.22	2.17	2.99	0.70	2.84	3.38	3.39	3.77
K_2O	7.71	0.69	4.96	2.96	3.00	10.33	3.43	3.80	4.67	4.80
TiO_2	0.20	0.09	0.18	0.36	0.47	0.20	0.12	0.21	0.07	0.09
P_2O_5	0.03	0.04	0.02	0.03	0.04	0.02	0.04	0.03	0.01	0.02
A/CNK	0.94	1.88	1.40	1.65	1.55	1.79	1.67	1.50	1.43	1.39

Table 3. Trace and rare earth elements of the pegmatites

Elements	1	2	3	4	5	6	7	8	9	10
Sc	23.90	10.00	23.50	13.60	-	10.00	14.50	17.90	-	21.90
Ni	44.60	Nd	23.80	180.00	486.00	Nd	81.60	84.10	24.70	44.80
V	19.00	-5.00	210.00	497.00	566.00	13.00	577.00	588.00	314.00	340.00
Cr	-	-20.00	9.50	306.00	466.00	-20.00	399.00	420.00	359.00	368.00
Co	56.70	23.00	28.70	153.00	262.00	-1.00	163.00	168.00	39.30	59.80
Cu	43.40	Nd	-	68.00	21.60	Nd	61.60	64.00	32.20	38.20
Zn	136.00	48.00	43.00	103.50	168.00	338.00	105.00	106.00	34.50	34.60
Bi	118.00	116.00	189.00	213.00	-	419.00	401.00	339.00	230.00	410.00
Cs	156.00	1.80	45.00	5.00	90.00	195.00	145.00	165.00	190.00	65.00
W	220.00	228.00	350.00	19.80	25.60	14.00	228.00	320.00	310.00	28.00
Sn	777.00	0.05	790.00	3.10	5.20	1.10	1.15	0.09	235.00	210.00
Nb	72.00	390.00	78.00	48.30	58.60	381.00	246.00	230.00	25.50	45.60
Ta	104.00	500.00	118.00	175.00	385.00	76.20	108.00	100.00	54.60	84.60
Ga	41.00	33.00	31.00	31.10	34.40	283.00	51.30	54.30	97.20	98.20
Rb	574.00	59.00	387.00	570.00	481.00	1000.00	470.00	486.00	8040.00	5840.00
Sr	55.00	10.00	9.00	338.00	588.00	7.00	35.3	35.80	12.50	28.50
Th	17.00	10.60	9.00	12.30	8.70	0.20	1.90	12.00	10.20	0.90
U	15.00	14.50	18.00	11.90	5.60	0.40	4.50	13.00	14.90	1.80
Zr	28.10	15.00	11.00	81.70	64.80	3.00	10.30	16.80	2.91	3.94
Ba	18.80	12.00	25.54	12.50	13.00	32.00	23.00	15.80	28.00	32.00
Be	8.80	8.00	14.70	20.10	17.60	21.00	8.70	21.00	8.00	19.80
La	9.80	19.20	13.40	19.00	0.90	0.30	14.80	11.00	1.80	0.90
Ce	13.00	14.50	0.95	12.50	1.20	0.90	3.20	5.60	6.50	11.20
Pr	1.70	1.79	1.60	1.10	0.09	0.07	1.10	1.45	1.20	0.08
Nd	7.80	9.90	9.05	5.60	2.80	0.20	1.80	0.90	0.86	0.40
Sm	2.50	3.00	3.50	1.70	0.70	-0.10	0.40	0.10	3.70	-0.15
Eu	0.03	0.05	-0.05	0.02	-0.05	-0.05	0.45	0.05	-0.05	-0.08
Tb	0.50	0.35	0.30	0.25	0.50	-0.10	0.10	-0.10	0.50	0.10
Dy	2.10	2.00	2.10	1.10	2.10	-0.10	0.10	-0.10	2.10	-0.15
Ho	0.30	0.23	0.30	0.20	0.30	-0.10	0.15	-0.80	0.30	-0.10
Er	0.90	0.79	0.90	0.90	0.90	-0.10	0.10	-0.10	0.90	0.20
Tm	0.17	0.15	0.17	0.13	0.12	-0.05	0.09	0.05	0.17	-0.05
Yb	1.30	1.20	1.30	1.10	1.30	-0.10	0.10	-0.10	1.30	0.10
Lu	0.20	0.12	0.20	0.15	0.20	-0.04	0.04	0.07	0.20	-0.04
Y	17.00	11.00	9.00	17.00	28.60	-1.00	9.79	8.80	76.90	86.00

* The numbers 1,2,3 represent sample numbers.

the rare metal columbite-tantalite (Moller and Morteani, 1987). The samples are relatively higher in Ta content than Nb, which suggests that the pegmatites in Komu area are more enriched in tantalite than columbite. The K/Rb ratios of the pegmatites of the study area are low, indicating progressive fractionation and possible mineralization (Kuster, 1990). Figure 4 shows low ratio of K/Cs and Th/U typical of mineralized pegmatites (Garba, 2003).

According to Matheis (1987), the degree of albitization (Na/K) versus Ta, indicates that the pegmatites of Komu area compare favorably with those of other pegmatite mineralized areas, like Egbe and Ijero in southwestern Nigeria (Fig. 5).

Chondrite normalized plot of the rare earth element (REE) shows high heavy REE (HREE) (La, Ce, Pr) values and lower light (LREE) (Er, Lu, Yb) values (Fig. 6). This negative signature suggests fractionation and indicates late metasomatic effect. The positive Cerium (Ce) anomaly observed may also suggest that the rare metal pegmatites may not be cogenetic with the associated granitoids.

Mineralization Ages

Based on K/Ar isotopic data, the age of mineralization of the pegmatite ranges between 502.8+/-13.0 and 514.5+/-13.2 Ga (Table 4).

These mineralization ages of pegmatite are close to those ages documented by Matheis and Caen-Vachette

Table 4. K/Ar isotopic data of the pegmatites

Sample	% K	$^{40}Ar_{rad}$, nl/g	$\%^{40}Ar_{air}$	Age, Ga
OF1	7.49	170.03	3.2	514.5±13.2
OF11	7.51	170.10	3.1	510.2±12.1
OF2	7.94	175.46	3.0	502.8±13.0
OF21	7.60	172.05	3.1	506.7±13.1
OF3	7.52	170.60	3.2	511.3±10.2
OF31	7.51	170.15	3.0	514.0±10.3

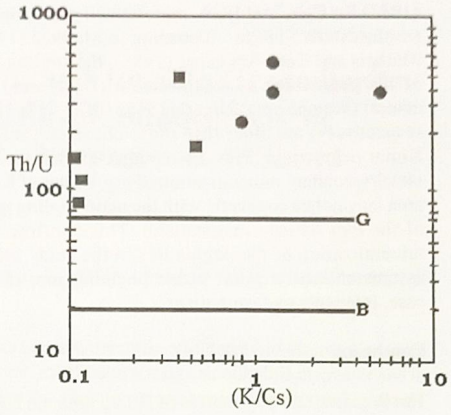

Fig. 4. Plot of ratio of K/Cs and Th/U elements.

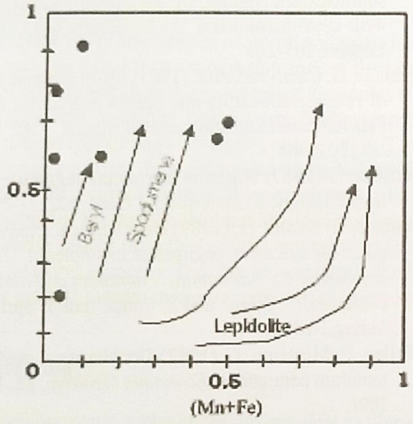

Fig. 2. Relationship plots of major, trace and rare earth elements of pegmatites.

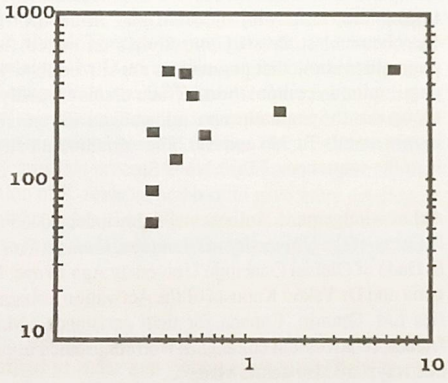

Fig. 5. Plot of relationship between Na/K and Ta elements.

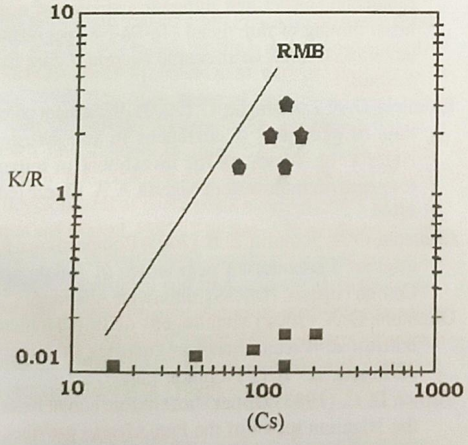

Fig. 3. Plot of relationship among K, Rb and Cs elements.

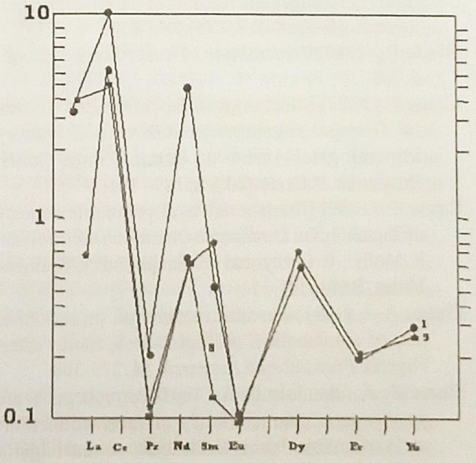

Fig. 6. Chondrite normalized plot of the rare earth elements (REE).

(1983) for Egbe and Ijero, mineralized pegmatites of southwestern Nigeria. According to Matheis (1987), Matheis and Caen-Vachette, (1983), the cooling ages of the pegmatites of southwestern (Egbe area) and central (Wamba area) Nigeria (545±10Ga, 537±12Ga, respectively) are older than those observed for these Komu pegmatites. This again suggests that the rare metal/secondary mineralization of pegmatites of Komu area may not be cogenetic with the main cooling phase of the Pan-African magmatisim. This confirms that mineralization of the pegmatites in the study area is associated with a latter phase phenomenon, in this case, intensive metasomatism.

Conclusion

The Precambrian pegmatites of Komu area are hosted by the biotite gneiss and amphibolites with some pelitic schists. Thin section petrographic analysis shows that pegmatites contain mainly quartz, plagioclase, microcline and muscovite with accessories like tourmaline, tantalum, niobium and illmenorutiles. Geochemical studies of muscovites extracted from pegmatites show that pegmatites are siliceous, with a peraluminous composition. Trace elements analysis shows that the pegmatites are mineralized and enriched in rare metals Ta, Nb and Sn. The enrichment pattern is in the sequence of Ta>>Nb>>Sn.

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(1983) for Egbe and Ijero, mineralized pegmatites of southwestern Nigeria. According to Matheis (1987), Matheis and Caen-Vachette, (1983), the cooling ages of the pegmatites of southwestern (Egbe area) and central (Wamba area) Nigeria (545±10Ga, 537±12Ga, respectively) are older than those observed for these Komu pegmatites. This again suggests that the rare metal/secondary mineralization of pegmatites of Komu area may not be cogenetic with the main cooling phase of the Pan-African magmatisim. This confirms that mineralization of the pegmatites in the study area is associated with a latter phase phenomenon, in this case, intensive metasomatism.

Conclusion

The Precambrian pegmatites of Komu area are hosted by the biotite gneiss and amphibolites with some pelitic schists. Thin section petrographic analysis shows that pegmatites contain mainly quartz, plagioclase, microcline and muscovite with accessories like tourmaline, tantalum, niobium and illmenorutiles. Geochemical studies of muscovites extracted from pegmatites show that pegmatites are siliceous, with a peraluminous composition. Trace elements analysis shows that the pegmatites are mineralized and enriched in rare metals Ta, Nb and Sn. The enrichment pattern is in the sequence of Ta>>Nb>>Sn.

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