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Uranium-Bearing Niobotantalate (Petscheckite) – A New Mineral in Nigeria

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ABSTRACT

The occurrence and physicochemical characteristics of uranium bearing niobotantalate (UBN) in a zoned pegmatite around Okene-Lokoja-Kabba roads junction, Kogi State Nigeria are investigated. The mineral occurs in the intermediate zone of the pegmatite in association with quartz, microcline and muscovite. Other associated minerals include beryl, columbite and tapiolite. The mineral found in the area has a very high radioactivity greater than 40x1500 counts per second (CPS). The uranium-bearing niobotantalate (UBN) mineral is generally brownish in colour with subvitreous luster and high specific gravity (4-5g/cm^3). The specimens were analysed on microscan 9 wavelength dispersive electron probe analyzer at 20kv. The results show the oxides of: U(24.40-27.40% UO_2), Nb(15.40-32.95%Nb_2O_5), Ta(11.64-34.47% Ta_2O_5), Th(2.44-3.06% ThO_2), Pb (1.47-1.87%PbO) and Fe(6.13-8.41 FeO) respectively. The minor to trace elements include the rare earth, Al, Si, Ti, Mn, and W. The uranium-bearing niobotantalate is affected by a late stage uranium-rich fluid resulting in the crystallization of highly uraniferous veinlets within the mineral. A comparison of the chemical composition of the uranium-bearing niobotantalate mineral with that of petscheckite clearly indicates that the minerals belong to the same family and that the specimen investigated represents the occurrence of pescheckite in Nigeria.

Keywords: *Occurrence, Uranium-bearing niobotantalate, Petscheckite.*

1. INTRODUCTION

The samples of the unusual uranium-bearing niobotantalate (petscheckite?) were discovered in an exterior pegmatite located less than 100m north-east of the Okene-Lokoja-Kabba roads junction Kogi State. (Fig1) The Pegmatite of the South-western Nigeria belongs to the Older granite suite of the Precambrian Basement Complex of Pan-African (500 +100 million years), (Rahaman 1988). The Nigerian Basement was affected by the 600 Ma Pan-African Orogeny and it occupies the reactivated region which resulted from plate collision between the passive continental margin of the West African craton and the active Pharusian continental margin (Obaje, 2009). The pegmatite in the study area runs northwest to south east and it is discondantly emplaced in gneissic host rock which strikes 342^o. The oval or elliptical shaped pegmatite body is deeply weathered with a strike of 310^o and having a length of about 110m and a breadth of 39m in the middle portion (fig 2). Mining activities for beryl, muscovite and kaolinite are evidently going on around the deposit.

1.1 Zoning and Mineralogy

The pegmatite from Okene-Lokoja-Kabba is a complex type which exhibits strong evidence of zoning in spite of its deeply weathered state (Fig 2). The border and the wall zones are not easily identified, but the intermediate zone consisting of microcline, quartz and muscovite with a width of approximately 20m is prominent. This zone is very coarse with feldspar of about 1m across and muscovite of about 40cm in width. Microcline feldspar is strongly weathered to kaolinite. Within this intermediate zone are beryl, columbite and uranium bearing niobotantalate (under investigation).

Beryl occurs as large greenish to yellowish euhedral crystals often reaching up to 25cm in width. The columbite crystal identified weighed approximately 80g while the uranium bearing niobotantalate crystals weigh up to 132g. Quartz occurs as large glassy almost transparent to grayish (smoky) irregular masses, The core of the pegmatite is essentially large with massive milky quartz of about 61m in length and 16m breadth. Beryl is the only accessory mineral identified in the core zone and which occurs as emerald green to aquamarine blue euhedral hexagonal crystal of about 20cm width. The glassy nature of beryl crystal from the quartz gives it its gem quality.

1.1.1 Physical Characteristics

Appearance

The uranium-bearing niobotantalate mineral is brownish in colour and the luster is sub vitreous. Some of the samples obtained are tabular in shape and sometimes

cleave in a particular direction. This mineral is easily identified by its density which is generally higher than those of other major pegmatite mineral such as quartz and feldspar. The weight of the sample collected range between 9.0 and 157.00g.

Specific Gravity

The specific gravity of the specimen was determined with the aid of a spring balance. Both the weight of the specimens in the air and water were determined at room temperature (25^{o}C). The results show the variation in specific gravity of the specimens as between 4.0 and 5.0. The increase in specific gravity from 4 to 5 uranium-bearing niobotantalite may be ascribed to the increased tantalum content of this group of minerals. Niobo-tantalum minerals are generally noted for the increase in specific gravity with increase in tantalum content (Fadipe, 1989a, 1989b).

Radioactivity

The radioactivity of the pegmatite body was carried out by the researcher with the aid of Strat SSPP2. NF. Gamma Ray Scintilometer. (see plate). The country rock (gneiss) in which the pegmatite is found has a radiation level of 10-12 x 500 cps (count per second). The pegmatite itself has a variable radiation levels which are characteristics of the different zones. The intermediate zone generally has values ranging between 25-35 cps. However, higher values up to 40 x 1500 cps were recorded in the areas with high concentrations of radioactive uranium-bearing niobotantalates.

The quartz core is generally less radioactive with radiations ranging between 5 – 10 x 500 cps.

2. MATERIALS AND METHODS

The Geiger Muller Counter, (a Gamma-ray Scintilometer, Strat SSPP2 NF model), being a radioactivity sensitive instrument was used to detect the presence of uranium-bearing niobotantalate in the pegmatite outcrops around Okene-Lokoja-Kabba road junction. The hand held equipment (Plate 1 and 2) easily detected the niobotantalate which were picked wherever radiation level rises above 20 x 1,500 cps. Twenty rock samples were collected from the deposits and were classified as LKJ1 and LKJ 2 with ten samples each. Their mean values were determined as presented in Table 1

The bulk composition and trace element determination were carried out by the use of Electron Microprobe analytical method. In this probe, tiny spots of materials were sampled. The rock specimen polished and carbon coated were analysed using the Wavelenght Dispersive micro-analyser (MK9) at 20 KV and 25nA (specimen current) on the Faraday cage at the Natural History Museum in London.

The calibrations of the various elements were carried out using the following standards:- Wolastonite-ca and Si: Rutile-titanium pure Uranium metal – U: pure Thorium metal – Th; Galena – Pb; synthetic Sodium Niobate-Nb and Na.

However, correction for mass absorption were carried out with the aid of computer programmes as several points were also analyzed on microprobe analyzer.

3. RESULTS

Table 1 shows the results of the major components of the two varieties of Niobotantalate minerals represented by LKJ 1 and LKJ 2. They are niobium (15.40-32.95%Nb_2O_5), tantalum(11.64-34.47% Ta_2O_5), uranium (24.40-27.40% UO_2), iron (6.13-8.41% FeO), thorium (2.44-3.06% ThO_2), calcium (2.30-3.20%), lead (1.47-1.87%PbO), yittrium (2.20-3.21%), and tungstein. The rare earth elements (REE.), silicon aluminium and manganese constitute the minor trace elements.

The results reveal that the two varieties of uranium-bearing niobotantalates are present in the pegmatite body. LKJ 1 is the Niobium-rich variety while LKJ 2 represents the tantalum-rich type. The mean niobium content in LKJ 1 is 32.95% and 15.40% in the LKJ 2 while the tantalum value in the LKJ 2, is 34.42% and 11.64% in the LKJ 1. The uranium contents in the two varieties are 24.40% in LKJ 1 and 27.40% in the LKJ 2 respectively. Both varieties have low values of Light rare earth elements (LREE) such as La (0.05% in both varieties). Ce (0.12 and 0.15% in LKJ 1 and LKJ 2) and Nd (0.18 and 0.13% respectively). Some Middle rare earth elements (MREE) like Sm and Dy have values that are less than 1 and 2 respectively.

Yittrium shows an enrichment in both varieties. The heavy rare earth elements (HREE) ytterbium (Yb) and Erbium (Er) have values that are less than unity. The low values of the totals (<100%) in the two varieties are due to the presence of water in the structure of the mineral which was not determined in the analytical method adopted in the study. Table 2 compares the compositions f E(UO_2, ThO_2, PbO) with that of petscheckite (40.50 UO_2) supports the assertion that the specimens investigated belong to the petscheckite family.

Though Mucke and Struntz (1978) presented only the analyses of UO_2, it is the belief of the present author that this component includes the ThO_2, PbO and REE_2O_3 contents as the addition of this components with UO_2 clearly makes up the slight fall in UO_2 contents of the specimens investigated.

The high radioactivity of the intermediate zone especially in the area of higher concentrations of uranium-bearing niobotantalate shows that the distribution of the U-rich rest fluid of the pegmatitic magma was unevenly distributed during the closing stages of the pegmatitic crystallization. The quartz core has the lowest radioactivity and carry no trace of uranium-bearing niobotantalate.

The association of the uranium bearing niobotantalate with columbite, tantalite and tapiolite clearly indicates the enrichment of niobium, tantalum, iron, manganese in the intermediate zone. The inclusion of columbite, tantalite and tapiolite in the uranium-bearing niobotantalate shows that the mineral crystallized much later than the other niobiumtantalate minerals.

The presence of veinlets of a more uraniferous phase (Figure 3 and Table 3) in the uranium-bearing niobotantalate indicates that the mineral was infiltrated by late stage uranium-rich hydrothermal solution. It is probable that the rest fluid in the host pegmatite is richer in uranium as manifested in the veinlets of specimen LKJ 1.

The totals of the various components determined may be attributed to the presence of some amounts of water in the structure of the specimens studied. Mucke and Struntz (1978) analysed already treated samples before chemical analyses. If these workers had analysed their sample before heating, they could have recorded lower totals which could easily be compared with that of the present study.

4. CONCLUSION

The present study has examined the occurrence and chemical composition of uranium bearing-niobotantalate around Okene-Lokoja-Kabba roads junction. The mineral is suggested to have occurred in the area of high radioactivity in the intermediate zone of the pegmatite. The mineral occurs in association with other niobotantalate minerals such as ferrocolumbite, ferrotantalite and tapiolite and it is also the last to crystallize among niobium bearing minerals. Tapiolite (Fe, Mn) (Ta, Nb)$_2O_6$ is associated with uranium bearing niobotantalate while ferrocolumbite (Fe,mn)(Nb,Ta)$_2$0$_6$ is associated with uranium-tantaloniobate. The study has also shown that the specimens occur as brown glassy mineral with relatively high specific gravity (4-5g/cm^3). The results show that the niobium, tantalum, thorium, iron and lead constitute the major mineral while the rare earth elements and others constitute minor to trace elements. Two varieties of the mineral have been identified Viz: the uranium-bearing niobotantalate the uranium-bearing tantaloniobate. The uranium-bearing tantaloniobate is found to have been affected by a late stage uranium-rich fluid resulting in the crystallization of highly uraniferous niobate as veinlets within it.

The results show that the uranium-bearing niobotantalate from Okene-Lokoja-Kabba roads junction is comparable in composition with petscheckite reported by Mucke and Strunts (1978) and may possibly be regarded as a second occurrence of the mineral in the worldof the Uranium-bearing Niobotantalates investigated with that of Petcheckite of Mucke and Struntz (1978) which are of the same family. Table 2 reveals great similarities in the values obtained. While the values of Nb_2O_5+Ta_2O_5 of Mucke and Struntz (1978) is 45.99%, those of the two varieties are 44.59% and 49.82% for LKJ1 and LKJ2 respectively. The values of the E(UO_2,ThO_2, PbO and REE_2O_3) obtained from this study compare favourably with that of UO_2 reported by Mucke and Struntz (1978). Contrastingly, the value of the E(FeO,Fe_2O_3, MnO) in Mucke and Struntz (1978) is 11.43% and those of the two varieties are 8.65 and 6.50% for LKJ1 and LKJ2 respectively.

Table 3 presents the compositions of other Niobium-tantalates found in association with the Uranium bearing Niobotantalates. The Nb-rich variety (LKJ1) is associated with niobium-rich columbite (Fe, Mn) (Nb,Ta)2O_6 while the tantalum-rich variety is associated with tapiolite (Fe Ta_2O_6). This association between the columbite and tapiolite with uranium-bearing niobotantalate does not appear to be a replacement type.

It was observed from the present study that a veinlet of high uranium-rich phase occurs in Uranium-bearing Niobotantalates as shown in fig 3. Analytical results of the veinlets in (Table 3) shows that UO_2 (46.08%), Nb_2O_5(25.46%), Ta_2O_5 (7.20%), PbO(4.59%), and FeO (3.76% and ThO_2 (1.01%) constitute the major components while minor amount of A1, Si, Ca, Ti, REE, W and Sc are present.

Figure 3 shows the X-ray distribution map of some of the elements present in the veinlets in comparison with that of the host Uranium-bearing Niobotantalate LKJ 1. Table 4 presents the field and elements microprobe study of the pegmatite body indicating the association of the Uranium-bearing Niobotantalate with minerals like ferro-columbite, ferro-tantalite and tapiolite as analysed in LKJ2.

5. DISCUSSION AND CONCLUSION

The results obtained from the present investigation show the Uranium-bearing Niobotantalate to have some similarities in composition with the mineral called Petscheckite (Mucke and Struntz, 1978).

The uranium-bearing niobotantalite specimens investigated have sub-vitreous luster similar to those of euxenite and fergusonite and whose minerals are known to be metamict in nature. However the structures of the two specimens studied were not investigated during this study, it is likely that the mineral occurs in the metamict state. Mucke and Strunts (1978) conducted their studies in

treated sample of hydroxyl petscheckite (a possible analog of the uranium-bearing niobotantalite investigated and observed two phases (uranpyrochlore (U^{4+}(Nb,Ta)$_2O_7$ and oxy-petscheckite). It is not unlikely that if uranium-bearing niobotantalite is heated, similar product may be produced.

The variation in niobium and tantalum in the specimens investigated as shown in Table 1 conforms with those of other groups of niobium-tantalum minerals as both elements naturally substitute for one another in nature. This leads to the classification of LKJ1 as uranium-bearing tantaloniobate and LKJ2 as uranium-bearing niobo-tantalate. The similarity in the niobium-tantalum contents with those of petscheckite (Mucke and Struntz, 1978) strongly indicates that the specimens investigated belong to this group of minerals.

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Table:1 The Statistical Data of Oxides of the Elements Present in the two varieties of the Niobotantalate Mineral

LKJ 1 Analyses				LKJ 2 Analyses			
Oxide	Range	Mean	Standard Deviation	Oxide	Range	Mean	Standard Deviation
Al_2O_3	0.02-0.47	0.09	0.11	MgO	0.02-0.27	0.11	0.11
SiO_2	0.38-3.47	1.40	0.64		0.04-0.90	0.48	0.33
CaO	0.01-6.00	3.20	2.04		0.17-4.94	2.30	1.61
Sc_2O_3	0.02-0.14	0.06	0.02		0.37-0.44	0.41	0.02
TiO_2	0.12-0.25	0.20	0.03		0.79-1.02	0.91	0.05
MnO	0.01-0.96	0.51	0.24		0.14-0.67	0.37	0.16
FeO	5.18-12.36	8.41	1.64		4.08-8.58	6.13	1.16
Y_2O_3	0.32-4.75	3.21	0.89		1.50-3.92	2.20	0.63
Nb_2O_5	24.84-37.39	32.95	1.80		13.20-16.35	15.40	0.85
La_2O_3	0.01-0.17	0.05	0.04		0.01-0.08	0.05	0.02
Ce_2O_3	0.02-0.32	0.12	0.06		0.02-0.22	0.15	0.06
Nd_2O_3	0.01-0.29	0.18	0.07		0.08-0.18	0.13	0.03
Sm_2O_3	0.16-0.94	0.17	0.17		0.14-0.83	0.40	0.21
Gd_2O_3	0.22-1.36	0.88	0.18		0.38-1.44	0.75	0.27
Dy_2O_3	0.34-1.89	1.34	0.36		0.82-2.11	1.20	0.32
Er_2O_3	0.01-0.57	0.34	0.12		0.10-0.61	0.36	0.13

Yb_2O_3	0.06-0.83	0.49	0.16		0.21-0.55	0.38	0.11
Ta_2O_5	10.20-15.39	11.64	0.96		31.47-36.42	34.42	1.27
WO_3	0.89-3.03	1.91	0.44		1.05-2.40	1.36	0.37
PbO	0.94-4.31	1.87	0.68		0.79-1.89	1.47	0.38
ThO_2	2.20-3.51	2.44	0.28		2.82-3.38	3.06	0.17
UO_2	17.59-26.64	24.40	1.77		24.38-30.11	27.40	1.58
Total		95.86				99.44	

Table: 2 Comparison of the varieties of Niobotantalate mineral (under study) with the Petscheckite of Mucke and Struntz (1978).

Elements in Oxide	Varieties (%)		Mucke & Struntz 1978 (%)
	LKJ 1	LKJ 2	
Nb_2O_5+Ta_2O_5	44.59	49.82	45.99
UO_2+ThO_2+PbO+REE_2O_3	38.00	39.32	40.50
FeO+Fe_2O_3+MnO	8.65	6.50	11.43
CaO	3.20	2.30	0.49
SiO_2	1.40	0.48	-
Al_2O_3	0.09	-	0.71
MgO	-	0.11	-
ZrO_2	-	-	0.42
K_2O	-	-	0.05
TiO_2	0.20	0.91	-

Table: 3 Showing the composition of Uranium – rich mineral occurring in veinlets in Uranium bearing Niobotantalate (see fig. 3)

Oxide	Range	Mean %
Al_2O_3	0.28-0.42	0.35
SiO_2	0.69-.098	0.87
CaO	0.30-0.37	0.33
Sc_2O_3	0.02-0.03	0.02
TiO_2	0.12-0.20	0.11
MnO	0.04-0.08	0.06
FeO	3.46-4.14	3.76
Y_2O_3	0.32-0.69	0.56
Nb_2O_5	24.84-25.85	25.41
La_2O_3	0.07-0.16	0.10
Ce_2O_3	0.26-0.32	0.29
Nd_2O_3	0.10-0.30	0.16
Sm_2O_3	0.41-0.53	0.48
Gd_2O_3	0.22-0.29	0.26
Dy_2O_3	0.49-0.63	0.57
Er_2O_3	0.01-0.22	0.17
Yb_2O_3	0.27	0.27
Ta_2O_5	6.60-8.15	7.20
WO_3	0.33-0.92	0.64
PbO	3.70-5.66	4.59
ThO_2	0.89-1.17	1.01
UO_2	44.66-46.89	46.08
Total		**93.29**

Table :4 Analytical results of Ferrocolumbite, Ferrotantalite and Tapiolite in association with Tantalite –rich Niobotantalate.

Oxide	Ferrocolumbite			Ferrotantalite			Tapiolite		
	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD
Na_2O	0.18-0.34	0.26	0.11	0.30-0.43	0.37	0.09	0.45-0.71	0.54	0.12
MgO	0.17-0.45	0.31	0.20	0.56-0.60	0.58	0.03	0.00-0.05	0.05	0.00
SiO_2	-	-	-	-	-	-	-	-	-
CaO	-	-	-	-	-	-	-	-	-
Sc_2O_3	0.13-0.60	0.37	0.33	0.19-0.22	0.22	0.04	0.33-0.35	0.34	0.01
TiO_2	0.69-2.31	1.50	1.15	1.47-1.62	1.55	0.11	2.11-2.83	2.53	0.31
MnO	3.22-3.87	3.55	0.46	2.84-3.12	2.98	0.20	0.20-0.44	0.34	0.11
FeO	12.86-14.36	13.61	1.08	12.43-12.73	12.58	0.21	14.19-14.81	14.53	0.30
Y_2O_3	0.01-0.07	0.04	0.04	-	-	-	-	-	-
Nb_2O_5	34.01-45.53	39.80	8.10	19.96-25.98	22.47	4.26	8.80-9.93	9.32	0.65
La_2O_3	0.01-0.07	0.04	0.04	0.05	-	-	0.01-0.02	0.02	0.01
Ce_2O_3	0.01-0.07	0.05	0.05	0.10-0.21	0.16	0.08	0.06-0.25	0.17	0.08
Nd_2O_3	0.05	-	-	-	-	-	0.01-0.06	0.04	0.04
Sm_2O_3	0.01-0.04	0.03	0.02	-	-	-	0.02-0.12	0.07	0.05
Gd_2O_3	-	-	-	0.11	1.14	0.04	-	-	-
Dy_2O_3	1.25-1.26	1.26	0.01	1.11-1.17	-	-	0.13-0.30	0.22	0.09
Er_2O_3	0.07-0.12	0.10	0.04	0.21	-	-	0.05-0.22	0.14	1.12
Yb_2O_3	0.16	-	-	0.10	54.11	-	0.25-0.30	0.28	0.04
Ta_2O_5	33.56-43.92	38.74	7.33	53-39-54.83	1.37	1.02	71-31-72.39	71.68	0.49
WO_3	0.47-1.32	0.90	0.60	0.79-1.95	0.19	0.82	0.54-0.82	0.68	0.16
PbO	0.01-0.09	0.05	0.06	0.02-0.35	0.03	0.23	-	-	-
ThO_2	0.02	-	-	0.02-0.04	-	0.01	-	-	-
UO_2	0.02-0.09	0.06	0.05	0.12		-	0.07-0.29	0.17	0.09
Total		100.67			97.75			101.12	