Geochemical Assessment of Tin-Tantalum Mineralization in the Precambrian Pegmatite Exposed at Agwan Rimi, Part of Sheet 208 NE, North Central Nigeria.

Y.S. Agunleti, M.Sc.*; E.A. Arikawe, Ph.D. (in view); and J.I.K. Okegye, Ph.D. (in view)

Department of Geology and Mining, Nasarawa State University, PMB 1022, Keffi, Nigeria.

E-mail: asylong@yahoo.com*

ABSTRACT

Angwa Rimi area is underlain by the basement complex rocks which comprise Schist and Biotite gneiss. These host rocks are intruded by veins, which could either be pegmatite, quartz, or quartzo-feldspathic veins. Pegmatite often hosts rare metals, micas, feldspar, and quartz; particularly the quartz rich ones could also be useful as materials for construction. The pegmatite occurs as an intrusion into the schist and as ridges in the biotite gneiss where they are exposed mostly with no direct contact with the host rock. A total of six (6) whole rock samples were analyzed for major, trace and rare earth elements using inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES) analytical technique. Petrographic analysis of both the biotite gneiss and amphibole schist reveals mineral quartz, plagioclase and biotite, in addition to the latter is the mineral amphibole and chlorite. Na/K ratio is less than (1.0) indicating poor albitization, however sample of pegmatite analyzed from the schist with the value (2.23) indicates a better albitization. Trace element analysis of Angwan Rimi pegmatites show fairly enrichment of Tantalum ranging from (13.7 to 185 ppm), rubidium (163.6 – 434.9 ppm) but low in niobium (6.6–37.3 ppm), Mean content of Ta (99.35 ppm) and Sn (105 ppm) are comparable to the rare metal pegmatites in Nigeria, although lower in Nb (21.95 ppm). Geochemical plots of Ta vs Cs, K/Rb vs Cs and K/Rb vs Rb indicate high potential for Tantalum mineralization especially those exposed at location 8.

(Keywords**:** tantalum, Angwan Rimi, Precambrian, albitzation, pegmatite)

INTRODUCTION

Angwan Rimi is located in the north-central part of Nigeria. The area is underlain by the basement complex rocks which comprise Schist and Biotite gneiss. These host rocks are intruded by veins, which could either be pegmatitic, quartz, or quartzo-feldspathic veins. Pegmatite often hosts rare metals, micas, feldspar, and quartz; particularly the quartz rich ones could also be useful as materials for construction. The research work is aimed at geological mapping of some part of Angwan Rimi sheet 208 NE so as to evaluate the tantalum mineralization potential of pegmatite intruding the host rocks.

The study area which covers some part of Angwan Rimi sheet 208 NE lies within latitudes 8°55′00″ - 9° 00′00″N and longitudes 7°47′00″E - 7° 50′00″E, with a total area extent of 34.56Sqkm. Accessibility to the study area is fair, but tough in the north central part due to thick forest. The area is generally flat and undulating in some places, pegmatite studied occurred as intrusion and in form of ridges. Depressions are sometimes drainage pathways and most of the outcrops where studied within the seasonal flowing stream. The study area falls within the hot climate region of north-central Nigeria characterize by short trees and grasses of the Northern Guinea Savannah zones with dendritic drainage system.

LITERATURE REVIEW

Previous Work in the Area

Pegmatite study of North-Central Nigeria has been documented by various workers (Figure 1). Pollard (1989) documented on the geochemistry of the granites associated with Tantalum and niobium mineralization with examples of the ring complexes of Northern Nigeria. Kinniard (1984) discussed on the contrasting styles of pegmatite of this area with respect to Sn-Nb-Ta-Zn mineralization.

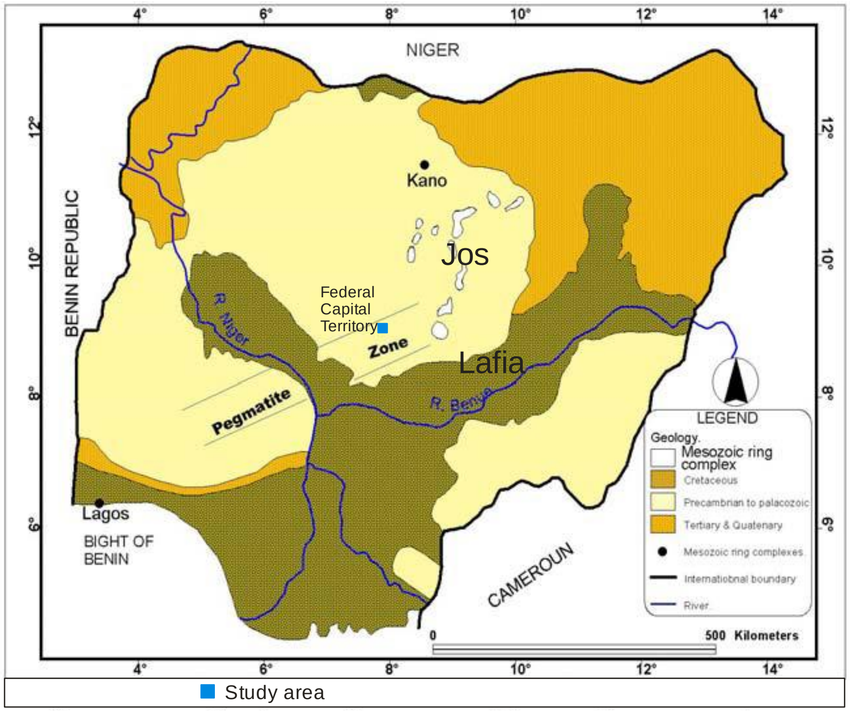


Figure1: General Geology of Nigeria showing the Location of the Study Area within the Pegmatite Zone (after Kinnaird, 1984).

Wright (1970), Jacobson and Webb (1946) were among the first researchers to document on the pegmatites of Wamba area in Nasarawa state, Central Nigeria.

Brief Regional Geology of Nigeria

The Nigerian basement complex forms a part of the Pan-African mobile belt and lies between the West African and Congo Cratons and south of the Tuareg Shield (Black, 1980). The basement complex is one of the three major litho-petrological components that make up the geology of Nigeria.

The Nigeria Basement Complex Basement is subdivided into the following division:

- Migmatite-gneiss quartzite complex comprising of biotite and biotite hornblende gneisses, quartzites and quartz schists
- Schist belts (Figure 2) 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.

MATERIAL AND METHODS

Rock samples were collected from the host rock using a hammer. Other tools used include the compass clinometers, to measure strike and dip and global positioning system Garmin map 76CXs (GPS) to correctly locate position on the topographic map, machete to clear the sampling points, the camera to take shots of features, a pen, pencil, eraser, etc. for documentation and the marker and tape to correctly label the rocks.

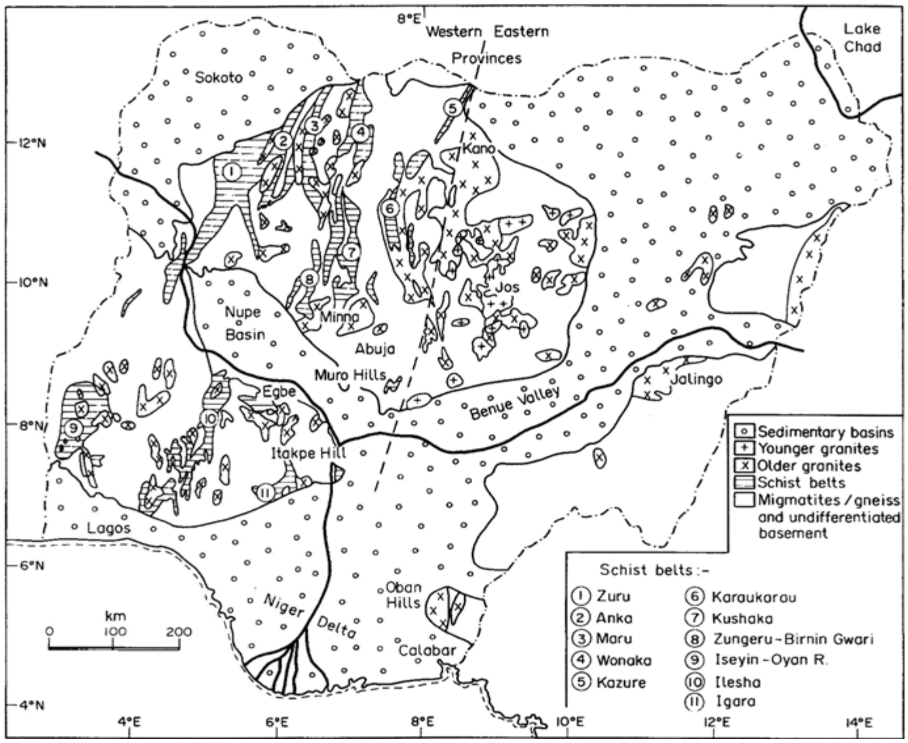


Figure 2: Schist Belt Localities within the context of Geology of Nigeria (after Woakes et al., 1987).

Petrographic studies and photomicrographs were prepared at Nigeria Geological Survey Agency (NGSA) Kaduna while samples for elemental analysis were pulverized, sieved on the 80 microns mesh and then about 10 grams put into clean sealed envelopes for geochemical analysis at Acme analytical Laboratory, Vancouver, Canada.

Field Geological Mapping

The study area is underlain by Schist and Biotite gneiss, (Figure 3). Both the Schist and the Biotite gneiss are intruded by large boulders of pegmatite within the study area. Pegmatites of Angwan Rimi occurred mostly as low lying intrusions into the Biotite gneiss (Figure 4) and as veins into the Schist (Figure 5). There is also quartz vein and quartzo-feldsphatic veins intruding the larger rock bodies (Figure 6)

Structural Analysis/interpretation

Veins: Veins are form when mineral constituents carried by an aqueous solution within the rock mass are deposited through precipitation. It also occurs as tabular or sheet like body of one or more minerals deposited in opening of fissures, as quartzo-feldspathic veins.

Veins are therefore of prime importance to mineral deposits, because they are the source of mineralization. Pegmatite veins of Angwan Rimi field were observed mostly as flat lying outcrops (Figure 4) within the study area and others occur as veins which range between 3cm-8cm in width and several thousand centimeters in length with general orientation between 012°-034°.

Figure 4: Showing a Flat Lying Pegmatite intruding the Biotite Gneiss of Angwan Rimi Area.

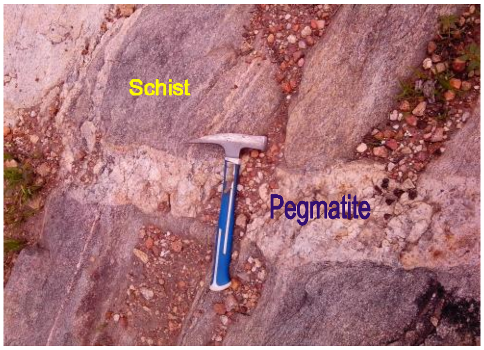


Figure 5: Showing Pegmatite Vein intruding the Schist of Angwan Rimi Area.

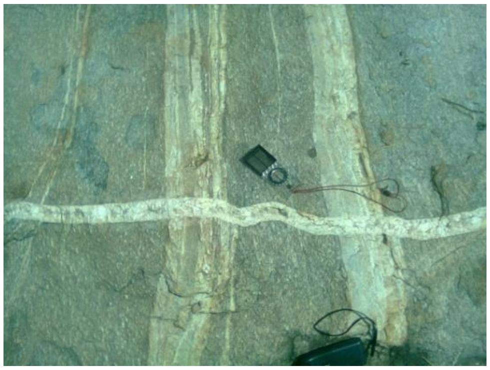


Figure 6: Quartz and Quartzo-Feldsphatic Veins intruding Biotite Gneiss of Angwan Rimi Area.

Foliation: This is a preferred orientation of minerals or mineral banding in rocks. The direction of foliation of the Schist and biotite gneiss of Angwan Rimi is generally in N-S direction (Figure 7 and 8), respectively.

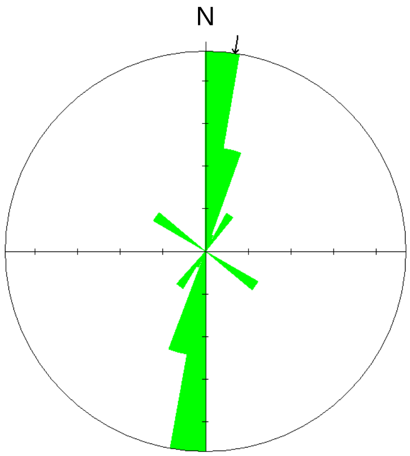


Figure 7: Rose Diagram of Foliation showing the N-S Dominant Trend in Schist of Angwan Rimi Field.

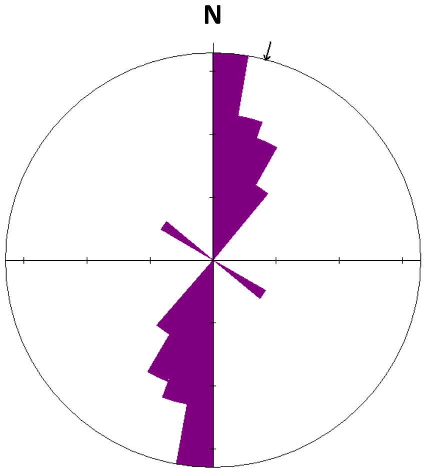


Figure 8: Rose Diagram of Foliation showing the N-S Dominant Trend in Biotite Gneiss of Angwan Rimi Field.

Joints: The major trend of joints in the Schist is ENE-WSW (Figure 9) and N-S in the Biotite gneiss (Figure 10) both studied in the Angwan Rimi field and are compared with the general N-S direction and those trending in the E-W direction within the basement complex rocks.

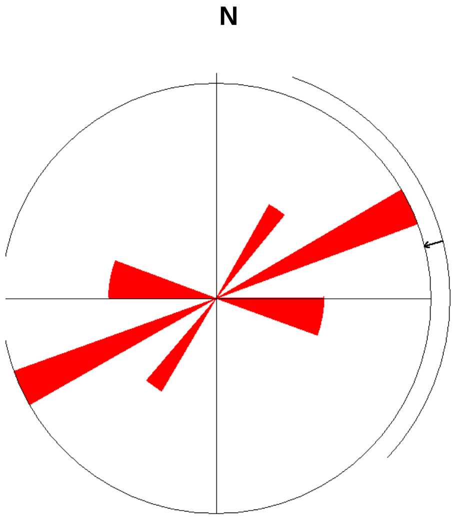


Figure 9: Rose Diagram of Joints showing the ENE-WSW Dominant Trend in Schist of Angwan Rimi Field.

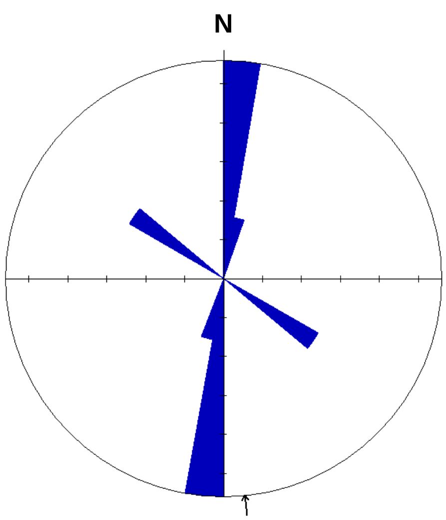


Figure 10: Rose Diagram of Joints showing the N-S Dominant Trend in Biotite Gneiss of Angwan Rimi Field.

Petrographic Study

Schist: These rocks form extensive bodies characterized by quartz rubbles and disaggregated mica over the area where they occur. They are dark to light grey in color, fine grained with large crystals of quartz. The schists are largely pelitic and contain very little feldsparthic minerals. The rocks display well-defined schistosity that makes it splits easily and contains mica flakes distributed in wavy lines which alternately meet and separate into sheets. In hand specimen the rocks are dark-grey in color, fine-to-medium grained and consist of plagioclase, quartz, microcline, biotite, chlorite, amphibole and opaque minerals. Under the microscope, quartz occurs as a colorless mineral usually cloudy and anhedral in shape with a low relief. It shows no cleavage, alteration and pleochroism. Biotite occurs as sub-hedral grains in between crystals of other minerals. It exhibits pleochroism, moderate relief and one direction of cleavage. Plagioclase occurs as a colorless mineral with a prismatic anhedral form. Chlorite and amphibole are other minerals seen under the microscope (Figure 11).

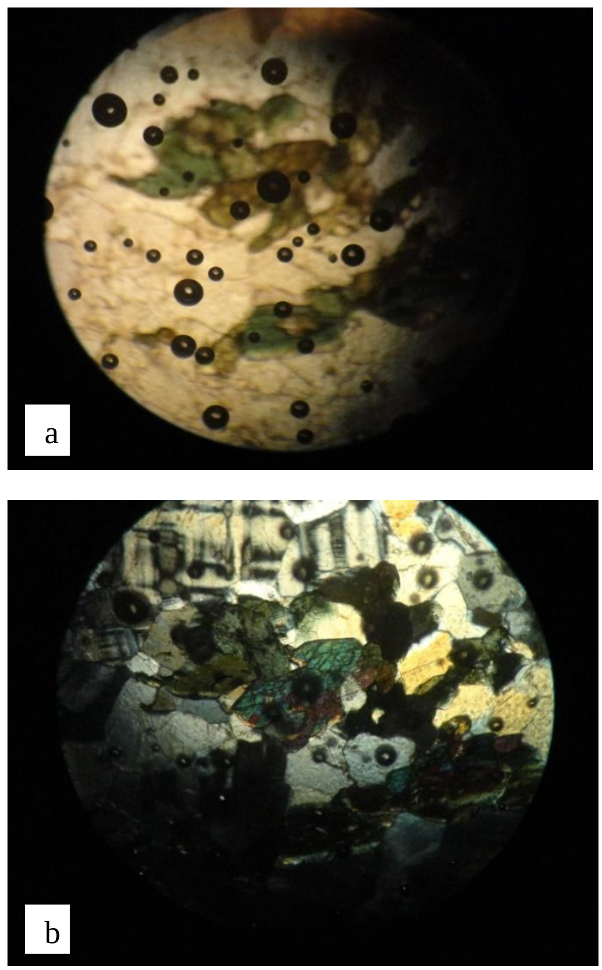
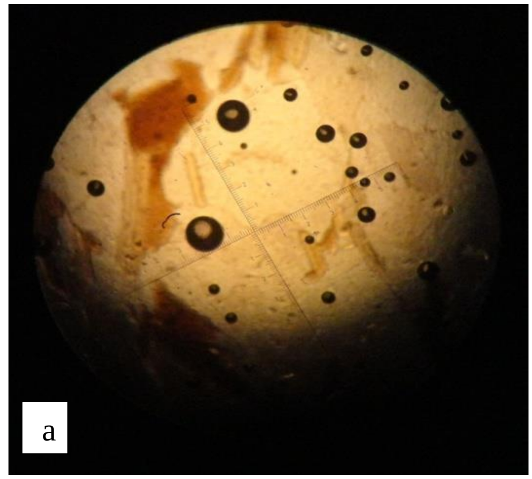
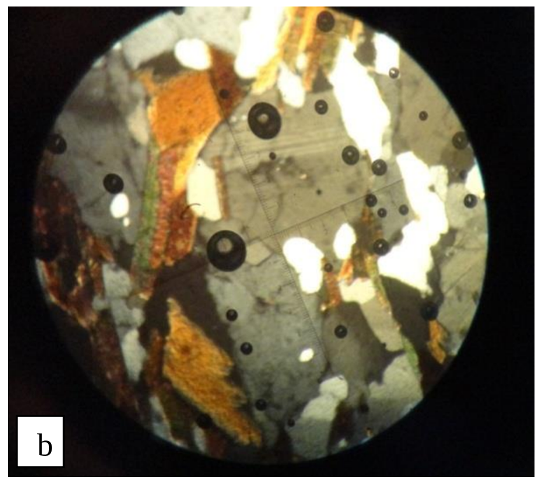


Figure 11: Photomicrographs of Schist under PPL (a) and XPL (b) showing Anhedral Crystals of Quartz, Feldspar, Biotite, Chlorite and some Opaque Minerals (black). The Quartz Exhibits Interference Colors from Grey to Brown.

Biotite Gneiss: Biotite gneiss studied in the area occurred as a medium-to coarse-grained foliated rocks with variable colors. It is banded with ferromagnesian minerals representing the dark bands. The dark bands contain biotite while the light bands are made up of quartz and muscovite and feldspar. In hand specimen the rock consists of quartz, feldspar, and biotite. Under the microscope, the rock shows variable grains of minerals closely packed showing preferred orientation. It displays an even texture though individual grains are irregularly shaped.

The following minerals can be distinguished- quartz, biotite and feldspar which occur under plane polarized light as colorless grains. Quartz occurs as a colorless mineral, sub-hedral in shape and shows no cleavage traces. Biotite is seen as large plates, brown to black in color and contains inclusions of some opaque minerals. The feldspar observed is a plagioclase and occurs as a colorless mineral, which is sub-hedral to euhedral in shape. It shows two directions of cleavage, low relief and has not been altered, thus exhibiting lamellar twining with oscillatory zoning (Figure 12)





Note: PPL= Plane polarized light, XPL= Cross polarizes light

Figure 12: Photomicrographs of Biotite Gneiss under PPL (a) and XPL (b).

RESEARCH RESULTS

Table 1 shows the representative samples selected for analysis in Angwan Rimi area. Four (4) Pegmatite, Biotite gneisses, and Schist samples at different locations were used for geochemical analysis. The samples were studies for their major oxides only (Table 1) and trace elements (Table 2).

DISCUSSION

Results from major, trace and rare elements are shown in Tables 1 and 2. The pegmatites of Angwan Rimi are fairly siliceous with SiO_2 contents ranging between 50.67% and 68.4% with an average value of 59.54%. This is compared to the barren pegmatites studied by (Elueze, 1982) around Ipetu Ijesha. Other major elements are Al_2O_3 (19.12–37.45%), Fe_2O_3 (1.53–1.98%) and K2O (2.01 –6.35%). However, there is depletion in the percentage of the elements of Na_2O (0.06–0.13%), TiO_2 (0.01–0.16%) and P_2O_5 (0.07–0.34%).

Bulk composition from major element data reveal that the Angwan Rimi pegmatites are of peraluminous. (A/CNK>1, where A: Al2O3, CNK: CaO+Na2O+K2O). Table 2 shows fairly enrichment of Tantalum ranging from (13.7 to 185 ppm) low in niobium (6.6–37.3 ppm), however rich in rubidium (163.6 – 434.9 ppm). Mean content of Ta (99.35 ppm) and Sn (105 ppm) of Angwan Rimi pegmatites are comparable to the rare metal pegmatites in Nigeria, although lower in Nb (21.95 ppm). Geochemical plots of Ta vs Cs, K/Rb vs Cs and K/Rb vs Rb indicate high potential for Tantalum mineralization especially those exposed at location 8 (Figures 13, 14 and 15) respectively.

Table 1: Major Element Data of Angwan Rimi Pegmatites in percent (%) ICP-AES.

Analyte	Unit	MDL	L1(Sc)	L5(Pg)	L6(Pg)	L8(BG)	L8(Pg)	L12(Pg)
SiO2	%	0.01	64.40	67.33	68.40	54.6	65.12	50.67
Al2O3	%	0.01	23.42	20.20	19.12	25.70	35.00	37.45
Fe2O3	%	0.04	1.77	1.84	1.53	9.74	1.98	1.72
MgO	%	0.01	0.63	0.10	0.06	1.66	0.13	0.30
CaO	%	0	0.72	0.65	0.13	0.35	0.23	1.22
Na2O	%	0.01	1.73	5.01	3.58	3.47	2.51	3.51
K2O	%	0.01	5.27	2.01	6.35	1.62	3.01	3.26
TiO2	%	0.01	0.15	0.02	0.01	0.26	0.03	0.16
P2O5	%	0.01	0.53	0.29	0.34	0.22	0.26	0.07
MnO	%	0	0.02	0.04	0.15	0.09	0.03	0.03
Cr2O3	%	0.002	0.005	<0.002	<0.002	0.002	0.003	<0.002
TOT/C	%	0.02	0.02	0.05	0.02	0.12	0.04	0.02
TOT/S	%	0.02	<0.02	<0,02	<0,02	<0,02	<0,02	<0,02
LOI	%	-5	1.10	1.3	0.2	2.0	1.7	1.4
Sum			99.80	99.2	99.94	99.83	99.90	99.75

Table 2: REEs and Trace Elements (ICP-MS). Pg = Pegmatite, Sc = Schist and BG=Biotite Gniess

S/N	Analyte	Unit	MDL	L1(Sc)	L5(Pg)	L6(Pg)	L8(BG)	L8(Pg)	L12(Pg)
1	Ba	ppm	1	472	35	56	26	31	96
2	Be	ppm	1	103.7	10	2	41	6	9
3	Cs	ppm	0.1	8.2	8.4	5.3	5.8	45.3	5.2
4	Ga	ppm	0.5	25.9	33.8	20.2	64.2	40.8	34.4
5	Hf	ppm	0.1	3.2	0.8	1	1.6	1.5	3.4
6	Nb	ppm	0.1	34.1	29.5	6.6	14.8	37.3	27.2
7	Rb	ppm	0.1	322	163.6	364.2	131.2	434.9	176.4
8	Sn	ppm	1	103	19	12	52	137	42
9	Sr	ppm	0.5	112.5	12.2	14	9.9	7.8	52.9
10	Ta	ppm	0.1	20.3	13.7	61	22.5	185	53.6
11	Th	ppm	0.2	2	1.1	0.4	0.8	0.7	2.5
12	Ce	ppm	0.1	16	6.3	2.3	2.5	2.8	10.5
13	La	ppm	0.1	8.6	3.3	1.2	1.3	1.3	3.8
14	Ni	ppm	20	34	<20	<20	<20	<20	90
15	Sc	ppm	1	3	2	<1	5	5	28
16	Co	ppm	0.2	4.6	0.6	1.9	2	1	31.2
17	U	ppm	0.1	2.8	2.5	2.1	2.2	1.4	3.8
18	V	ppm	8	26	<8	<8	<8	<8	219
19	W	ppm	0.5	3.2	2.7	1.3	3.4	6.9	1.6
20	Zr	ppm	0.1	64	15.7	14.6	24.8	10.7	179.7
21	Y	ppm	0.1	7.7	7.3	1.6	1.1	1	46.8
22	Pr	ppm	0.02	2.07	0.63	0.25	0.23	0.26	8.95
23	Nd	ppm	0.3	9.4	1.6	1	0.6	1.2	38.8
24	Sm	ppm	0.05	1.59	0.61	0.17	0.21	0.23	7.91
25	Eu	ppm	0.02	0.65	0.06	0.03	0.02	0.02	1.26
26	Gd	ppm	0.05	1.71	0.85	0.18	0.21	0.26	7.91
27	Tb	ppm	0.01	0.24	0.22	0.05	0.04	0.04	0.23
28	Dy	ppm	0.05	1.45	1.28	0.31	0.22	0.29	0.23
29	Ho	ppm	0.02	0.26	0.21	0.03	0.03	0.03	0.23
30	Er	ppm	0.03	0.72	0.59	0.09	0.1	0.06	0.57
31	Tm	ppm	0.01	0.11	0.09	0.02	0.02	0.02	0.09
32	Yb	ppm	0.05	0.84	0.53	0.16	0.16	0.13	0.58
33	Lu	ppm	0.01	0.12	0.07	<0.01	0.03	0.02	0.08
34	Mo	ppm	0.1	0.6	1.3	1	2.1	1.2	0.6
35	Cu	ppm	0.1	16.1	13.9	10.1	28.8	13.4	91.1
36	Pb	ppm	0.1	2.2	1.9	2.9	1.7	1.9	4.1
37	Zn	ppm	1	10	29	3	16	12	15
38	Ag	ppm	0.1	<0.1	0.1	<0.1	<0.1	<0.1	0.1
39	Ni	ppm	0.1	5.8	4.3	3.3	8.8	4.2	4.8
40	As	ppm	0.1	<0.5	0.9	0.6	1.3	0.5	0.6
41	Au	ppm	0.5	<0.5	<0.5	1	<0.5	<0.5	<0.5
42	Cd	ppm	0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1
43	Sb	ppm	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
44	Bi	ppm	0.1	0.2	5.7	5.6	0.1	<0.1	0.2
45	Hg	ppm	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
46	Ti	ppm	0.1	<0.1	0.2	<0.1	<0.1	0.4	1.4
47	Se	ppm	0.5	<0.5	<0.5	<0.5	<0.05	<0.5	<0.5

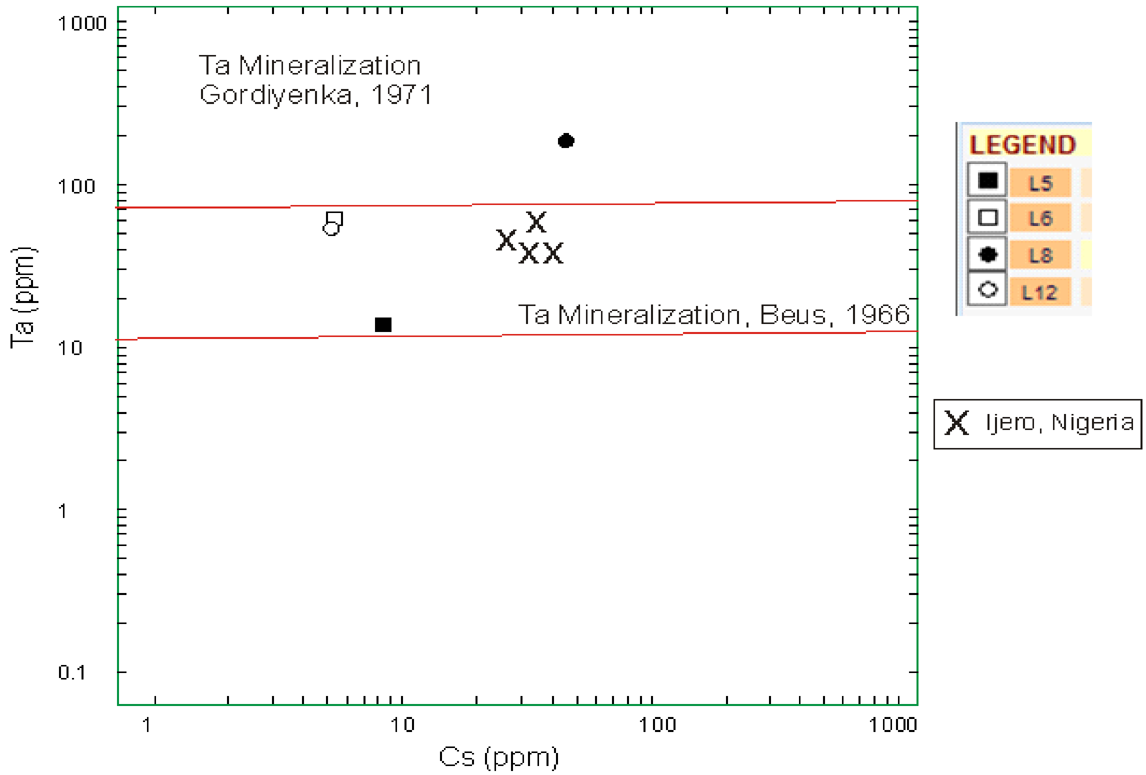


Figure 13: Ta vs Cs plot of Angwan Rimi Pegmatites. L8 falls with Ta mineralization of Gordiyenka while others plots within the Ta Mineralization of Beus which can be compared with those of Mineralized Ijero, Nigeria (After Moller and Morteani, 1987).

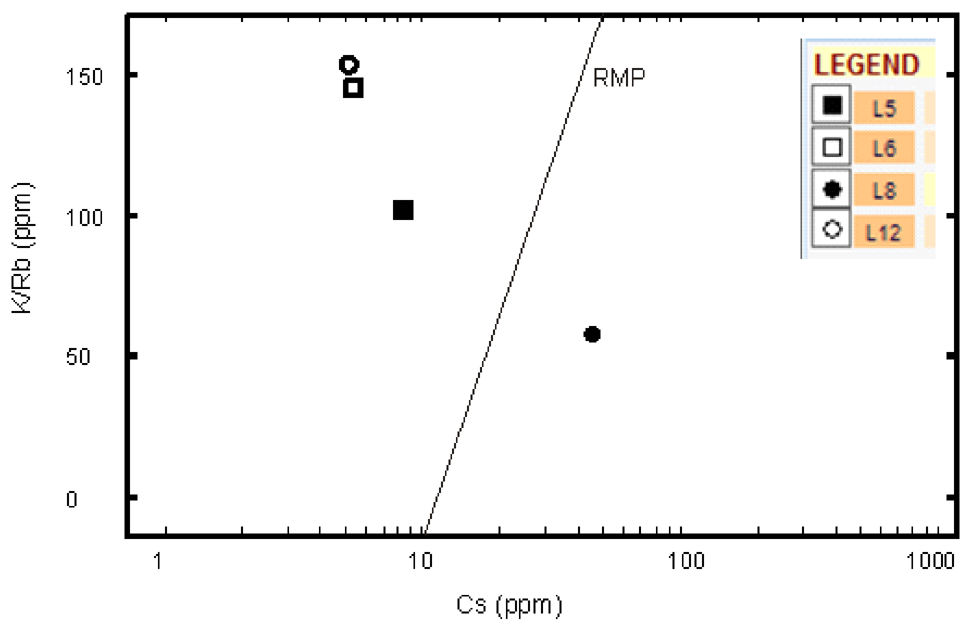


Figure 14: K/Rb and Cs plots of Angwan Rimi Pegmatite, the discrimination line RMP separates Mineralized from Non-mineralized Pegmatites. Only L8 of the pegmatites plot in the mineralized zone, (After Moller and Morteani, 1987).

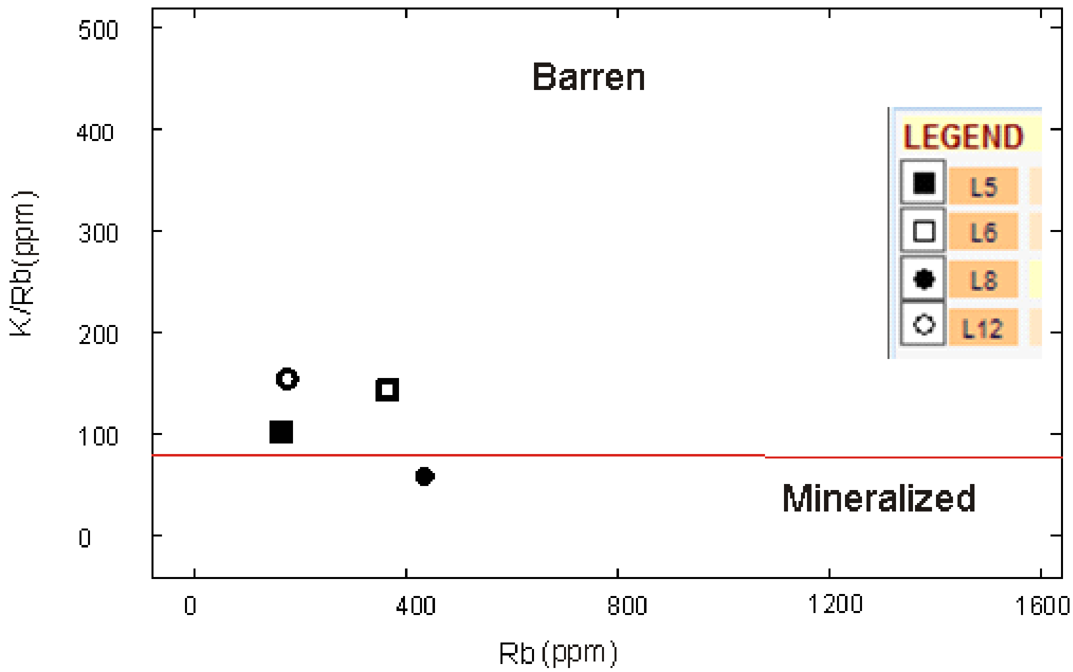


Figure 15: Sampled Pegmatites from Angwan Rimi Pegmatites show only L8 plotting within the Mineralized Zone from the plots of K/Kb Vs Rb (After Staurov et al., 1969).

The Rb/Sr ratio is moderately high and can be compared with other rare metal pegmatites of Nigeria (Matheis et al., 1982, Okunlola and Ocan, 2002, Garba, 2003). The Rb/Sr ratio of some pegmatite sample in the study area are moderately high and can be compared with the values of rare metal mineralized pegmatites of Nigeria (Matheis et al., 1982, Okunlola and Ocan, 2002, Garba, 2003, Okunlola, 2004).

Average K/Rb values (114.4 ppm) are significantly high and can be is compare with the rare metal mineralized pegmatites of Nigeria. The degree of albitisation usually examined through the Na/K ratio (<1.0ppm) is relatively low which shows a low degree of albitisation when compared with the Sn, Nb-Ta mineralized pegmatites which is usually more than 10 in most cases (De Kun, 1965). Figure 16 shows that Angwan Rimi pegmatites are more enriched with Sn-Ta-Nb around location 8 compared to other sampled locations.

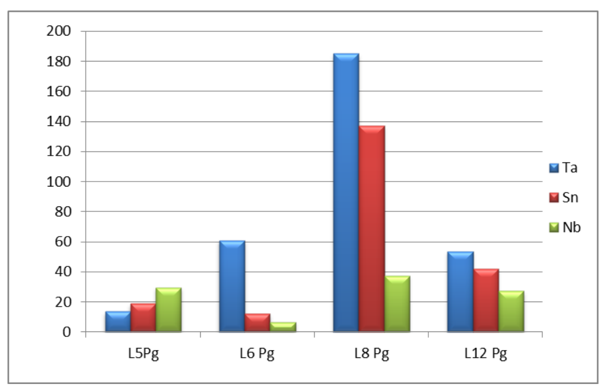


Figure 16: Average Concentrations of Sn-Ta-Nb (ppm) in Angwan Rimi Pegmatites.

CONCLUSION

The pegmatites of Angwan Rimi are hosted by the Biotite gneiss, Schist, and amphibole schist. Petrographic analysis of these rocks shows that it contains mainly quartz, plagioclase, biotite, microcline and muscovite. Whole rock geochemical studies indicate that the pegmatites are siliceous, with a peraluminous composition. Trace elements analysis reveals that the pegmatites are fairly rich in Ta and Sn mineralization.

Variation plots of Ta vs Cs, K/Rb vs Cs and K/Rb vs Rb has shown that Angwan Rimi pegmatites can be merged with those of Ijero southwestern Nigeria in term of mineralization. Further and continuous work has to be undertaken as a means of research and development, more especially in the area of mineralization.

REFERENCES

1. Black, R. 1980. "Precambrian of West Africa". *Episodes* 4:3–8.

2. De Kun, N. 1965. *Mineral Resources of Africa*. Elsevivier: Amsterdam, The Netherlands.

3. Garba, I. 2003. "Geochemical Discrimination of Newly Discovered Rare Metal Bearing and Barren Pegmatites in the Pan-African (600±150Ma) Basement of Northern Nigeria". *Trans. Inst. Min. Metall. Bull*. 112:287-292.

4. Jacobson, R.E.E. and J.S. Webb. 1946. "The Pegmatites of Central Nigeria". *Geol. Surv. Nig. Bull*. 17-61pp

5. Kinnaird, J.A. 1984. "Contrasting Styles of Sn-Nb-Ta-Zn Mineralization in Nigeria". *J Afr. Earth Sci* 2:81–90

6. Matheis, G., W.O. Emofurieta, and S.F. Ohiwerei. 1982. "Trace Element Distribution in Tin-Bearing Pegmatites of Southwestern Nigeria". In: *Metallization Associated with Acid Magmatism*. A.M. Evans (ed.), Wiley: London, UK. 205-220.

7. Moller, P. and G. Morteani. 1987. "Geochemical Guide for Tantalum Pegmatite". *Economic Geology*. 12:1885- 1897

8. Okunlola, O.A. 2004. "Metallogeny of Ta-Nb Mineralization of Precambrian Pegmatites of Nigeria". *Abstracts, 32nd IGC*. Florence, Italy

9. Okunlola, O.A. and O.O. Ocan. 2002. "The Expected Environmental Impact and Mitigation Studies of Organized Mining of Rare Metal (Ta-Sn-Nb) Pegmatites around Angwan Rimi, North Central Nigeria". *J. Env. Ext.* 3:64-68.

10. Pollards, C. 1989. "Geochemical Potential of Tantalum Mineralization". *Proceedings of Berlin workshop of Lanthanides, Tantalum and Niobium*. Moller, P., P. Cerny, and F. Sampe (eds). Society of Mineral Explorationist. 67-98

11. Staurov, O.D., L.S. Stolyarov, and E.I. Isochewa. 1969. "Geochemistry and Origin of Verkh Iset Granitoid Massif in Central Ural". *Geochem Intern*. 6:1138-1146

12. Woakes, M., M.A. Rahaman, and A.C. Ajibade. 1987. "Some Metallogenetic Features of the Nigerian Basement". *J Afr Earth Sci*. 6:54–64

13. Wright, J.B. 1970. "Controls of Mineralization in the Older and Younger Tin Fields of Nigeria". *Econ Geol*. 65:945–951.

ABOUT THE AUTHORS

Y.S. Agunleti, M.Sc., is a graduate of geology in the Department of Geology and Mining, Faculty of Sciences, Nasarawa State University, Keffi, also graduated as a Mining Engineer from School of Mines and Metallurgy, Kogi State Polytechnic, Lokoja, both in Nigeria. He specializes in geochemistry and structural geology, also found worthy in application of remote sensing for mineral and groundwater explorations with practices not limiting to mining.

E.A. Arikawe, Ph.D. (in view) is an Assistant Chief Geologist with National Agency for Science and Engineering Infrastructure (NASENI), currently on his Ph.D. study in Mineral Exploration and Mining from Nasarawa State University, Keffi. He specializes in geochemistry and economic geology.

J.I.K. Okegye, Ph.D. (in view) is a Lecturer in Nasarawa State Polytechnic, Lafia. He holds a Masters degree in Mineral Exploration and currently is on his Ph.D. in Mineral Exploration and Mining with Nasarawa State University, Keffi. He specializes in economic geology and mineral processing.

SUGGESTED CITATION

Agunleti, Y.S., E.A. Arikawe, and J.I.K. Okegye. 2014. "Geochemical Assessment of Tin-Tantalum Mineralization in the Precambrian Pegmatite Exposed at Agwan Rimi, Part of Sheet 208 NE, North Central Nigeria". *Pacific Journal of Science and Technology*. 15(1):415-425.

Pacific Journal of Science and Technology