Geochemical Investigation of Gemstone Specks within Complex Basement Rocks of Iwajowa Area of Oyo State, Southwestern Nigeria

B. S. Badmus, O. D. Akinyemi, *A. M. Gbadebo, P. Babatunde, S. A. Ganiyu and O. T. Olurin

Department of Physics, Federal University of Agriculture, Abeokuta, Nigeria.
*Department of Environmental Management and Toxicology, Federal University of Agriculture, Abeokuta, Abeokuta, Nigeria.
olurin@physics.unaab.edu.ng, stolurin@yahoo.com

Abstract: Geo-chemical analysis was carried out on complex basement rock samples serving as host rocks for tantalite, tourmaline and beryl, using Atomic Absorption Spectrophotometer (AAS). The AAS was used for the determination of major oxides, trace and rare earth elements. The results revealed the various mineral compositions of these rock samples both in part per million (ppm) and weight percentage (wt. %). The analyses revealed tourmaline to be a complex compound with high proportion of Boron (B), silica (SiO_2), Alumina (Al_2O_3), Iron (Fe_2O_3), Barium (Ba) and Titanium oxide (TiO_2) with little proportion of Mg_2O, Ca_2O, K_2O, Li, Mn, Cr, Co, V, Zr, Th, Ra, etc. Tantalite analysis revealed the presence of Iron oxide (Fe_2O_3), Tantalum oxide, Copper oxide, Niobium, Boron, and Barium with little proportion of Li, V, Ti and Cr. Beryl analysis also revealed high content of beryllium and iron with little proportion of Ti, Cr, B, Ni and Ba but with no content of Nb. Cr, Ni, V and Fe. This paper x-rayed the qualities of tantalite, tourmaline and beryl samples analyzed to be of low qualities but more importantly, it has revealed the host rock of the tourmalines and beryl to be gneissic-schist.

[B. S. Badmus, O. D. Akinyemi, A. M. Gbadebo, P. Babatunde, S. A. Ganiyu and O. T. Olurin. **Geochemical Investigation of Gemstone Specks within Complex Basement Rocks of Iwajowa Area of Oyo State, Southwestern Nigeria.** *Nat Sci* 2013;11(8):89-93]. (ISSN: 1545-0740). http://www.sciencepub.net/nature. 14

Key words: Chemical composition, Gem stones, Mineralized pegmatite, Gemstones

1.0 Introduction

Solid minerals are distributed unevenly across the globe, some are exogenic (seen at the surface of the earth) while some are endogenic (buried underneath the earth surface).Rare-metal pegmatite containing economic concentrations of columbite-tantalite ore minerals (coltan) are widespread in the Pan-African (600±150Ma) basement of Nigeria (Adekeye and Akintola, 2007). Pegmatite is an important source of precious and semi-precious stones (such as beryl, aquamarine, tourmalines). Until recently these pegmatites were known mainly from a broad 400km long NE-SW stretching from Wemba, Keffi and Nasarawa area (near the Jos plateau) through Isalu-Egbe in central Nigeria to Ijero, Aramoko and Ilesha areas of south-western Nigeria with a few occurrences in the Obudu and Oban massif of South-eastern Nigeria. A marked concentration of the mineralized pegmatite occurring in a broad belt extending for about 400km from Ago-Iwoye area in the southwest to Bauchi area in the Northeast Nigeria (Jacobson and Webb, 1946; Wright, 1970; Kinnaird, 1984 and Kuster, 1990). However Ekwueme and Mathias (1995) have also identified mineralized pegmatite in the Precambrian basement of southeastern Nigeria. This Pan-African belt continues southwest into northeast Brazil where analogous mineralized rare metal pegmatites also occur (Schuling, 1967). The pegmatites range in dimensions from a few metres to a kilometer in length while the width varies from a few centimeters to ten meters and more. Dykes with strike lengths between 300-700 meters are quite common. Although the majority of the pegmatites occur in the form of regular, tabular dykes with fairly constant dips and strikes, many of richly mineralized pegmatites occur as sill-like bodies with pronounce pinch and swell structures. Based on field relationship, the pegmatites in which mineralization is closely associated with late albitization have been genetically linked in Nassarawa area. Some of the rare earth metal mineralized fields occur in proximity to area previously known for hydrothermal gold mineralization (Garba, 2002). The rare earth metal pegmatite fields, which are all closely associated with NE-SW and NNE-SSW regional fault systems are enriched to varying degrees in ores of Li, Be, Sn, Nb, Ta, W, B and probably Ce. In 2006, Ertl et al successfully carried out geochemical analysis of tourmaline samples from Liddicoatite Elbaite series from Anjanabonoina, Madagascar to determine the mineral compositions both in weight (wt.%) and in ppm.

This paper revealed the mineral compositions of gemstone deposits of Iwajowa area of Oyo state, Southwestern Nigeria for exploration purposes. Mathies, 1979 suggested that special attention should be given to petro-genetic indicators of rare earth elements such as Li, Rb, Cs and Be and ratios of Mg/Li and K/Rb because they can be used as exploration aids in rare metal pegmatites. These gemstones include tourmaline and beryl. Tourmaline is a complex borosilicate mineral with varying amount of aluminum, iron, magnesium, sodium, lithium, potassium and sometimes other elements. It occurs in prismatic crystal (trigonal) form, commonly three-sided, six-sided or nine-sided and striated vertically. Tourmaline is a vari-coloured mineral, its colours ranging from red, pink, blue, green, brown, yellow, violet-red and black. Its hardness is between 7.0 -7.5 on mohs scale. Its general formula can be written as $XY_3Al_6(OH)_4(BO_3)_3(Si_6O_{18})$ where X may be Na or Ca and Y may be Al, Fe^{+3}, Li, Mg or Mn^{+2}.

Beryl is a major ore of beryllium, it is found in the same geological formation as tourmaline and its chemical formula is $Be_3Al_2Si_6O_{18}$ but has variable amount of Na, Li, Ce, Fe, V and Cr. It exists in different facies: green, blue, red, yellow, colourless and pink. Tantalite is a natural mineral which exist as columbite-tantalite (COLTAN) since pure tantalite is very rare.

1.1 Location of the Study Area

The study area lies within Oyo state which is bounded in the West by Benin Republic, in the South by Ogun state, in the North by Kwara and Osun State and in the East by Osun/Ondo state. It occupies a total area of 5km^2 of Iwajowa area with longitude between N07^{0}58'17'' and N07^{0}58'26'' and latitude between E003^{0}2'24'' and E003^{0}2'28''.

1.2 Geology of the Study Area

The basement complex of south-western Nigeria lies to the rest of the West African craton in the region of late Precambrian to early Paleozoic oogenesis. The basement complex rocks of Nigeria are composed predominantly of migmatitic and granitic gneisses; quartzite, slightly migmatised to meta-sedimentary schist and meta-igneous rocks; charnockitic, gabbroic, and dioritic rock; and the members of the older granite suit mainly granites and granodiorites and syenites.

1.3 Petrographic Characteristics of the Study Area

The rock types consist of pegmatite, quartz vein, dolerite dykes. The dolerite dykes are believed to be the youngest.

1.3.1 Pegmatite: These are composed of microcline and quartz; widely spread through the basement complex of the southern part of Nigeria. They vary in size from vein let to a few millimeters wide, to bodies of up to a few kilometers wide. Dolerite dykes are also widely spread in the basement complex of south-western, Nigeria. They are described in association with the gneiss and older granites, they occur as tabular, unmetamorphosized bodies cross cutting the foliation in most rocks. They are known to be the youngest member of the basement complex. Quartz veins and lenses occur in all the major rock types of a basement complex. They vary in thickness from a few millimeters to about a meter. They show great irregularities in their form and seen in a place to thin out, widen or turn their courses.

1.3.2 Migmatite: These are widely spread in the basement complex of the south western Nigeria, comprising; gneiss, quartzite and calc- silicate rocks and marble. The gneiss consists of early gneiss, mafic – ultramafic and granitic or felsic components.

1.3.3 Slightly Migmatised to Unmignatised Para-schist and Meta-igneous Rocks: This group of rocks comprises of all rocks which have been previously described as younger or newer meta-sediments. It consists of pelitic, quartzite and amphibolite, talcose rocks, meta-conglomerate, marbles and talc-silicate rocks.

1.3.4 Older Granites: The older granites range in size from plutonic batholitic. This includes: granites, granodiorites, quartz, granites, monozonotes, syenites, and pegmatite. Granitic-granodioritic, compositions are most common.

2.0 METHODOLOGY

Sampling: Eight rock samples were collected from the artisan pits within the study area and labeled A, B, C, D, E, F, Q_1 and Q_2 with their geographical points recorded with the aid of GPS (Table 1). These rock samples contain tantalite, tourmaline, and beryl, which are analyzed for composition.

Chemical analysis of the rock samples A, B, C, D and E was carried out to analyzed for Barium (Ba), Niobium (Nb), Nickel (Ni), Beryllium (Be), Boron (B), Titanium (Ti), Chromium (Cr), Copper (Cu) and Tantalum (Ta). In all the samples, Fe_2O_3 was majorly analyzed (Table 2). Also samples Q_1 and Q_2 (Pink tourmalines) were analyzed for major elements (Al_2O_3, TiO_2, SiO_2, Fe_2O_3, MnO_2, Mg_2O, Ca_2O, Na_2O and K_2O) as shown in Table 3. Trace and rare earth elements (Li, V, Ba, Co, Ni, Zr, Th, F and Ra) are shown in Table 4. All these analyses were carried out using Atomic Absorption Spectrophotometer (AAS).

Sample Preparation Technique

Hand picking of fresh chips and large rocks after the use of large steel hammers, hydraulic press and steel jaw crusher to prevent significant iron, chromium or nickel contaminations which resides mainly in finer dust. It has been recognized that tungsten carbide mills cause contamination with tungsten and cobalt and these elements are not analyzed. Niobium contamination has also been reported from tungsten carbide mills (Joron et al., 1990, Hickson and Juras, 1986).

These samples are crushed to about walnut-size in a commercial rock determine the presence of the following trace elements: Barium (Ba), Niobium (Nb), Nickel (Ni), Beryllium (Be), Boron(B), Titanium (Ti) and Chromium (Cr) while sample F was crusher, put through a commercial roller mill and reduced to about 8 – 10 mesh size. Mechanical grinder equipped with agate mortars and pestles reduce the samples to fine powders of about 200 mesh size; without contamination by new high-alumina ceramic buck board and miller (Bloon and Barnette, 1955); where the speed of grinding is faster than that of an agate mortal. Precision balances are also used.

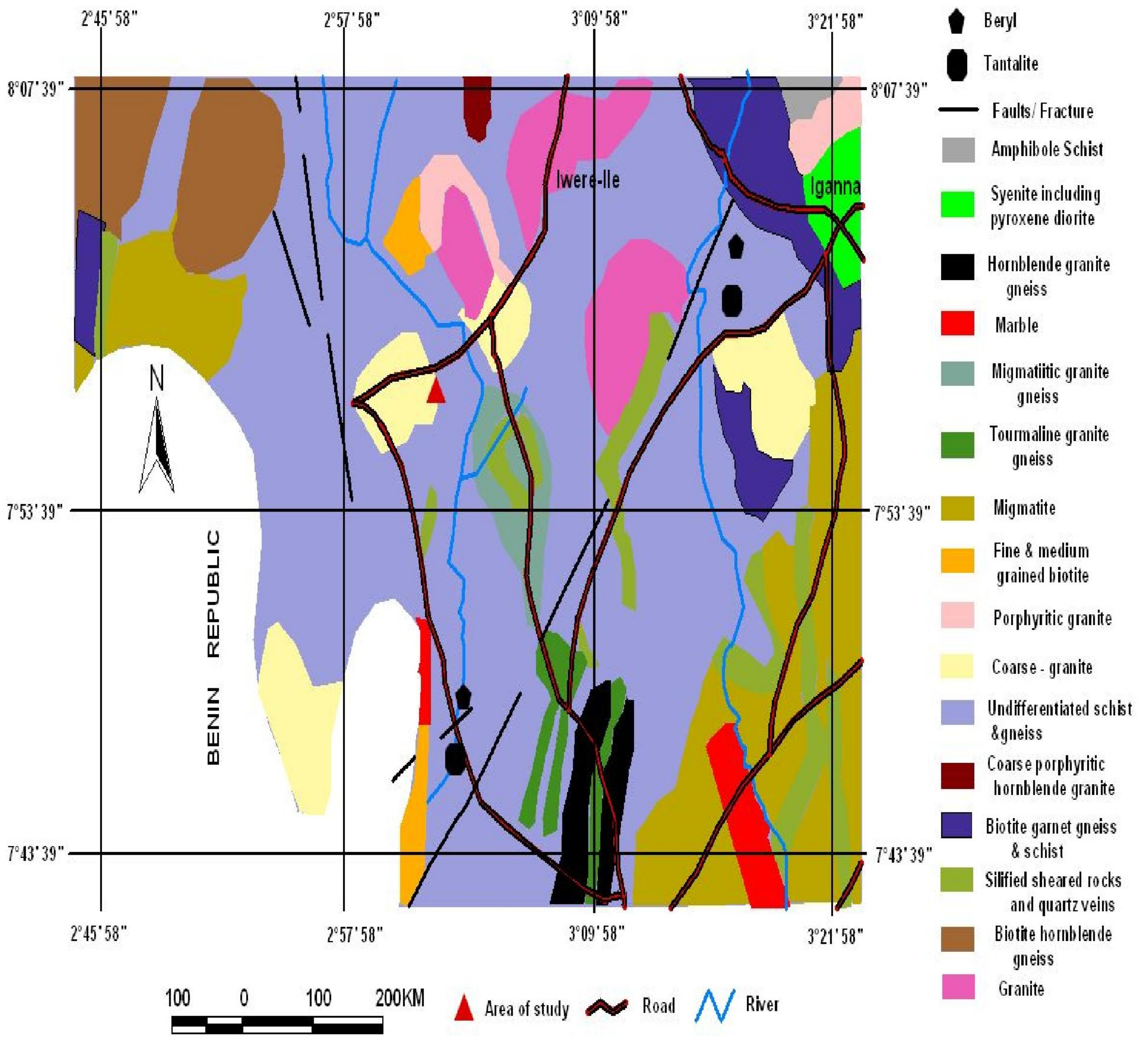

Figure 1 Geological Map of the Study Area

Table 1. Sampling and Locations

Samples	Locations

A	Lat: 07^{0}97'29'' N and Long: 003^{0}4'96'' E
B	Lat: 07^{0}97'28'' N and Long: 003^{0}4'95'' E
C	Lat: 07^{0}97'29' N and Long: 003^{0}4'96'' E
D	Lat: 07^{0}97'27' N and Long: 003^{0}4'11'' E
E	Lat: 07^{0}97'25'' N and Long: 003^{0}4'85'' E
F	Lat: 07^{0}97'28'' N and Long: 003^{0}4'95'' E
Q_1	Lat: 07^{0}97'26'' N and Long: 003^{0}4'109'' E
Q_2	Lat: 07^{0}97'26'' N and Long: 003^{0}4'109'' E

3.0 Results and Discussion of Geochemical Analyses

Results of Geochemical Analyses

Table 2. Geochemical Analysis of Trace Element in Some Samples

Species	A	B	C	D	E	F
Fe_2O_3	0.87%	7.51%	4.69%	4.23%	4.33%	4.51%
Ba	0	336	442	405	416	339
Nb	0	12	10	10	18	12
Ni	2	3	6	3	5	3
Be	68	6	4	3	6	5
B	1	171	162	159	168	177
Ti	1	2	2	4	9	3
Cr	4	4	1	4	6	3

Table 3. Major Elements in (wt %)

Samples	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O
Q1	59.99	2.17	25.35	4.02	0.01	0.06	0.03	1.17	0.58
Q2	58.48	2.20	18.65	3.36	0.03	1.26	0.46	0.48	0.87

Table 4. Some Minor and Rare Earth Elements in Pink Tourmaline in PPM

Samples	Li	V	Ba	Co	Ni	Zr	Th	F	Ra
Q1	4	1	42	2	1	8	5	1	1
Q2	2	1	64	3	1	11	3	1	0

4.0 Discussion

Samples A, B, C, D, E and F were analyzed for Fe_2O_3 (Table 2) where sample B has the highest content of 7.51%. Samples C, D, E, and F were almost of equal content between 4.23 and 4.69%. The trace elements analyzed were Ba, Nb, Ni, Cr, Ti, B, and Be. Sample A has the highest content of Be (468ppm) while other samples are between 3 and 6ppm in content (Table 2). Ti, Ni, Cr and Nb were present in small content while B and Ba were present in large content (Table 2). The content of Be in sample A suggested it to be a beryl. Other Samples have very low content of Be. Samples B, C, D E and F have about equal content of B with Sample A showing very low content of B. Nb is absent in sample A while in other samples, it is between 10 and 18ppm. Ni and Cr were relatively low in all the samples, found to be between 1 and 6ppm.

From the analysis of samples Q_1 and Q_2 (Pink Tourmalines), Silica, Alumina and iron were the most abundant minerals in the content of 59.99, 25.55 and 4.02% respectively while other major elements were present in small content (Table 3). Ba is the most abundant trace element between 42 and 64ppm as analyzed in Q_1 and Q_2 while other trace elements were present in small content (Table 3). Zr, Th and Ra were the rare earth elements analyzed with Zr having the highest content of 11ppm (Table 4). It was only in sample F that Cu and Ta were analyzed and the content of these elements in this sample was low between 16 and 38.9ppm respectively.

5.0 CONCUSION

The results of laboratory analyses have shown the mineral compositions of gemstone deposits found in Iwajowa area of Oyo State to be highly rich in silicon and aluminum with variable contents of rare earth elements such as boron, beryllium, zirconium, barium, tantalum, etc. The ratio of rare earth elements to major elements can serve as a basis for exploration of mineralized pegmatite especially those that are rich in gemstones.

Common method that is especially valuable for the detection and determination of the minor chemical elements in rocks, minerals/ores has been described. This method provides good detectability of elements present in very small amounts because a relatively large sample, as compared is consumed for analysis. It has also been used for the analysis of major constituents in areas where an insufficient sample makes a chemical analysis difficult and where chemical analysis is not feasible; as is true in the determination of the industrial rare-earth elements.

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6/5/2013