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***Research Article***

# GEOCHEMICAL STUDIES OF MINERAL BEARING ORES FROM NASARAWA EGGON AND UDEGE BEKI AREAS OF NASARAWA STATE, NIGERIA

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## ABSTRACT
Geochemical studies of mineral bearing ores from selected mining sites in Nasarawa-Eggon and Udege Beki areas of Nasarawa State, Nigeria using X-ray Fluorescence (XRF) method and magnetic/gravity beneficiation technique was carried out. Geochemical data obtained showed that the mineral ores contained some metals in exploitable quantities. Beneficiation result indicated that the following minerals can be exploited and concentrated to required specifications in sufficient quantities from these mining sites for various applications; Pb and Zn in ores of Nasarawa– Eggon to 95% and 26%, Nb, Fe and Sn in ore from Udege Beki to 55%, 58% and 50%, respectively. Values obtained showed that where there was deficiency in silica (under saturated) in the ores there was a corresponding enrichment in certain elements (Pb, Zn, Fe, Nb & Sn) and depleted in Ti, Sr, Cd, Th, Bi, Cr, As Ca, K and S elements. There compositional characteristics were consistent with their mineralogy. Result of element abundance correlation in ppm showed that most of the elements with values > x 1 shale or chondrite values were enriched while few of them with values < x 1 shale or chondrite are highly depleted. Major elements correlation result revealed a high % ratio of $Fe_2O_3$ to $K_2O$ and CaO in the ores.

***Key Words:*** *Geochemical, Minerals, Nigeria, Ores, Mines*

## INTRODUCTION
The term mineral in itself is a concentration of naturally occurring solid, liquid or gaseous material in or the Earth's crust in such a form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible (Ashano, 2000). According to Taylor and Steven (1985) the mineral resource potential of any locality can be identified as high, moderate or low. Prior to the emergence of petroleum in the mid nineteen seventies as a major foreign exchange earner, the solid mineral sector ranked second to the agricultural sector as a source of export earnings. During the period, Nigeria was known for the production of coal as an energy source for electricity, railway and for export. Nigeria was a major producer of tin and columbite, accounting for 94 % of world production at a certain point. The subsector also contributed substantially to the national output, accounting for about 10 % of gross domestic product (GDP) in 1970 (Kogbe and Obialo, 1976). However, with the exit of foreign multinational mining companies, the performance of the subsector began to dwindle. Annual production declined considerably, particularly in metallic minerals. The tempo of mining activities shifted to industrial non-metallic minerals needed for construction, building and industrial applications in domestic industries (Mallo, 2005).The decline of the solid mineral industries started with the discovery of oil which has, made Nigeria a mono product economy. Nigeria's economic development has witnessed trials and tribulations due to the nations over dependence on oil (Obaje, 2008).Abundant mineral deposits occur in all the components of the Nigerian geology (Basement, Younger granite, Sedimentary basins).The solid mineral deposits that are of economic significance include gold, Marble, iron, barytes coal, lead/zinc. Mineral ore deposits in Nigeria are found in igneous, metamorphic as well as sedimentary environments. Lead– zinc occurrences in Nigeria are associated with saline water intrusion or with fractures/shear zones. This mineralization is often associated with small amount of copper occurring in lodes filling the fractures

with the sedimentary rocks in the axial zone of the Benue Trough (Akande *et al.*, 1990). The Trough which is believed to have originated as a failed arm of an aulacogen at the time of opening of the South Atlantic Ocean during the separation of the African Plate and the South American Plate is partitioned into the lower, middle and upper region with lead– zinc mineralization occurring in almost the entire 800km length (Offodile, 1980 and 1989). Economic Pb–Zn mineralization is restricted to the Southern parts of the Trough, associated with the Pb–Zn ore are chalcopyrite, siderite, azurite, malachite and mascasite. Upward to the middle and upper regions of the Trough are important deposits of salt, baryte, limestone and fluorite as well as argentiferous galena and gypsum. All these deposits owe their genesis to aulacogen development which in turn is a tectonic plate (Ford, 1989). Tin occurs mostly as native metal, and in combined form as oxide ($SnO_2$). Fifteen other tin bearing minerals are known but these occur as trace minerals in rocks of appropriate composition (Moller and Morteni, 1987). Tin with the associated mineral deposit in Nigeria is located in the stable Precambrian which was intruded by the Younger Granites in Plateau, Nasarawa and Bauchi States, Nigeria. Most of the primary tin and columbite are found in the biotite granite phase and in pegmatites. Cassiterite ($SnO_2$) and columbite (Fe, Mn) $Nb_2O_6$ have geochemical affinity with the early volcanic phase of magmatism (Jacobson and Webb, 1946). Newman *et al.,* (1989) suggested that nearly all the primary cassiterite and most of the columbite are associated with and concentrated within the now eroded roofs (volcanic ejecta) of the biotite granites. The source of economic tin today is the accumulation of cassiterite eroded from the roofs and transported to the present sites where they form placer deposits in both ancient and modern stream channels. The columbite-tantalite minerals are ubiquitous in these deposits and constitute important by products. All other forms of mineral deposits found in Nigeria are largely due to some form of secondary processes which all occur in Nasarawa state (Obaje *et al.,* 2006).Despite the abundant mineral resource of the state, the poor knowledge of the geology of the state couple with low technical capacity to properly asses the reserves. The physicochemical properties, the industrial applications of these minerals resources have not been harnessed. The geochemical studies of some selected mining sites in Nasarawa state would enhance the development of these local raw materials for export and local sourcing to meet both local and international demand hence having a balance economy. With the dwindling reserve of oil in the country, in addition to the attendant challenges in the world order where alternative sources of energy are being desperately sought and all countries are making effort to stem the delibitating effect on their economies was what necessitated this studies. In a rapidly dynamic world economy, solid mineral sector diversification is the solution to the Nigerian situation. Adequate knowledge of Nigeria mineral sector is essential for planning with respect to any specific mineral commodity considered to be a reserve. Mineral deposit is physically exhaustible and irreplaceable, the metal extracted from the mineral ore is itself non-renewable (Bailly, 1982). This research is part of the on–going study on the need to diversify the country's economy from the oil to non–oil sector in order to avert the negative effect of over dependence on oil and gas revenues. The objective of the work is to enhance effective utilization of local solid minerals for economic development or for export as value added products.

## MATERIALS AND METHODS

### *Study Area*

Nigeria lies approximately between latitude $4^oN$ and $14^oN$ and longitude $3^oE$ and $15^oE$. The study area is Nasarawa State, one of the 36 States in the Federal Republic of Nigeria, located in the North–Central Geo–political zone of the country otherwise known as the middle belt region and covers an area of $300km^2$. The State is accessed by road through Kaduna–Plateau State, Taraba–Benue States and Kogi State – Abuja road (Fig. 1). The State is blessed with abundant mineral resources and for this reason it is tagged, "The Home of Solid Minerals in Nigeria". Prominent among the mineral deposits of the State are coal, barytes, salt, limestone, clays, glass sand, tantalite, columbite, cassiterite, iron ore, lead, and zinc.

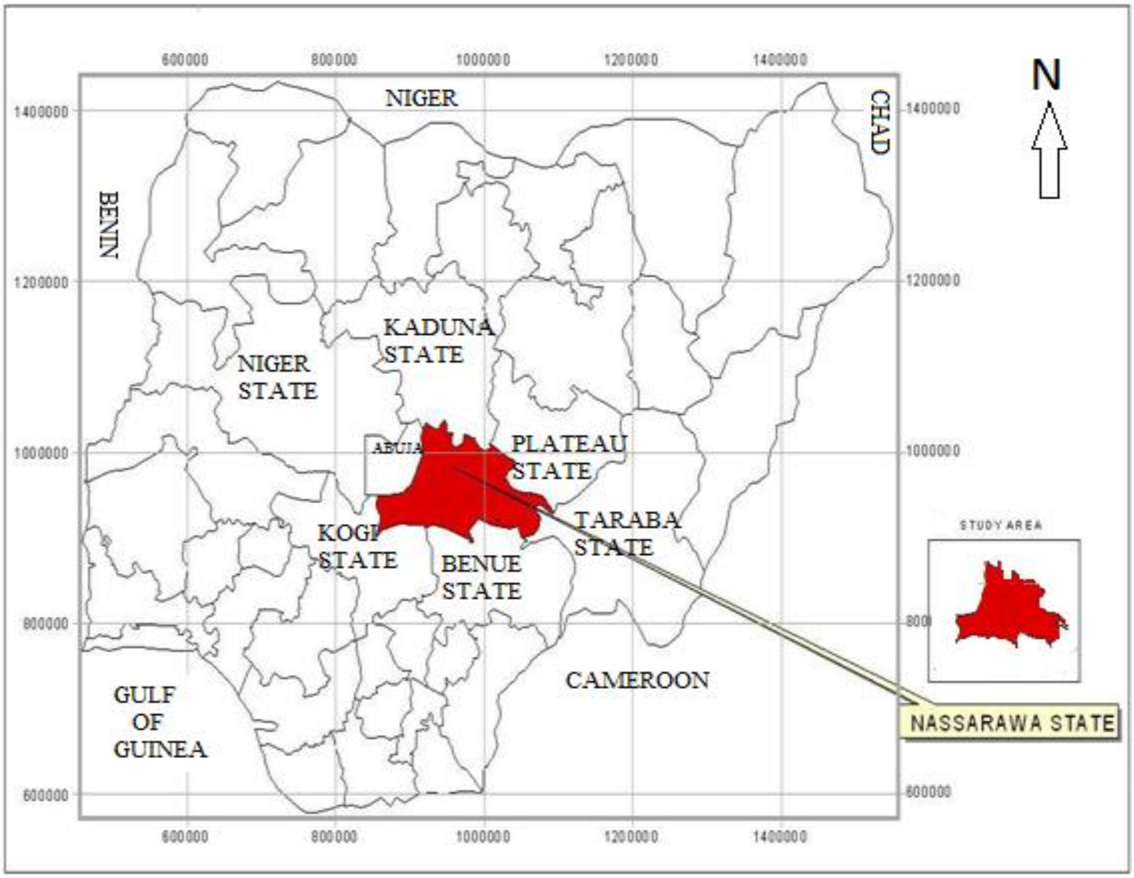


**Figure 1: Map of Nigeria Showing Nasarawa State the studied Area**

***Geology of the Study Area***

The area under study is located within the middle Benue Trough as the name infers the middle portion of the Nigerian Benue Trough. The Benue Trough itself is a riftbasin in Central West Africa that extends NNE–SSW for about 800km in length and 150km in width. The Trough contains up to 6000M of Cretaceous Tertiary Sediment of which those pre–dating the mid–Santonian Compression ally deformed (Benkhelil, 1989). The study area is covered with 60% Basement complex rocks while the remaining 40% is made up of sedimentary rocks of the Benue Trough. The Younger Granites intrude the Basement complex at Mada and Afu and therefore do not occupy any separate landmass of their own of the Basement complex. Magnetite–Gneisses along with the older granites accounts for about 70%, while rocks of Schistose Lithology and other sedimentary series (quartzite, marble, iron ores) in the areas around Laminga, Nasarawa and Gadabuke made up the remaining 30% .Nasarawa eggon is situated within the sedimentary basin while Udege beki fall within the younger granite location in the state (Obaje *et al.*, 2006) (Fig. 2).

***Sample Collection***

Mineral ores for this analysis were collected from active mining sites in Nasarawa–Eggon and Udege Beki mines in Nasarawa State with the assistance of miners. The Pb–Zn samples were collected from four different mines across Nasarawa–Eggon designated NE1–NE4 while cassiterite and niobium samples were collected from five mines located in Udege Beki town and were labeled UG1–UG5, respectively. In each case, the point of collectionof each ore sample differs from the other in a particular mining site (Fig. 3).

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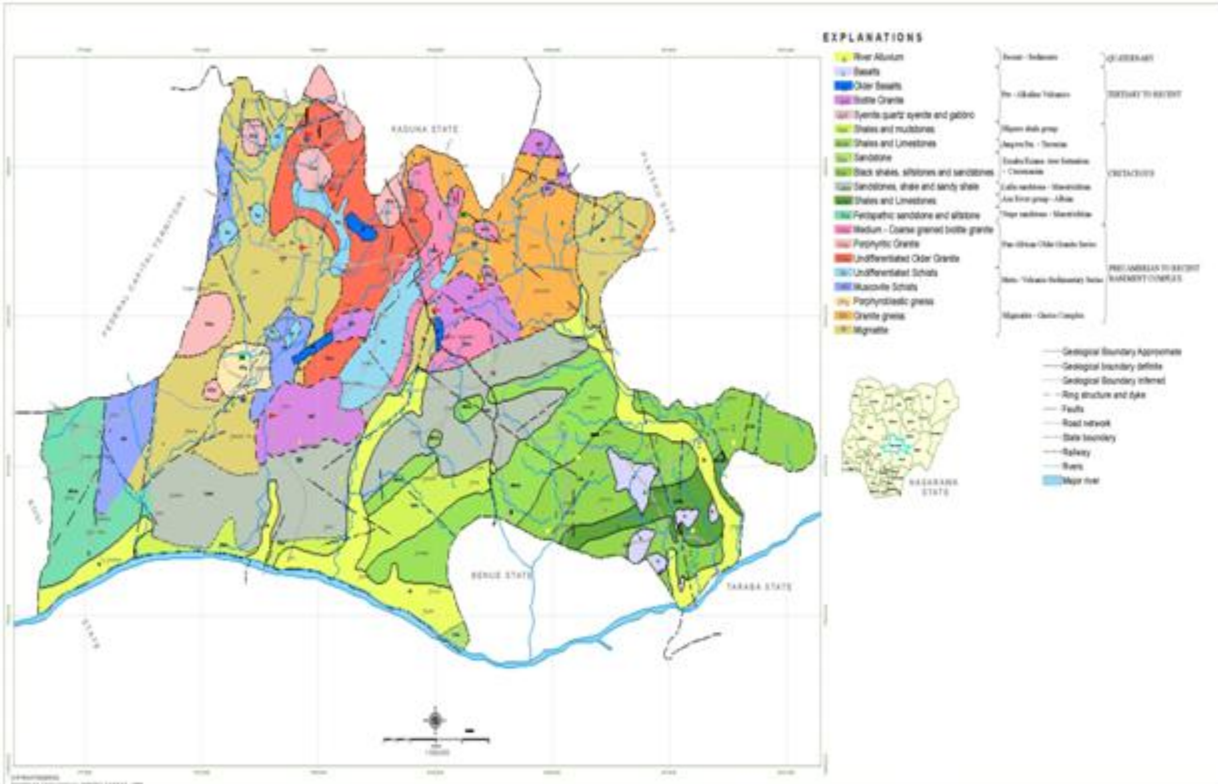


**Figure 2: An Outline Geological Map of Nasarawa State**


**Figure 3: Map of Nasarawa State Showing Research Towns**

***Sample Preparation and Analysis***

The samples were crushed and pulverized at National Metallurgical Development Company (NMDC), Jos plateau State, Nigeria. 20.00g of the ore sample is finely ground to pass through a 200 – 250 mesh sieve,dried in an oven at 105$^{o}$C for 1h and cooled. Thereafter, the sample was intimately mixed with a cellulose binder in a ratio of 5: 1repectively and pelletized at a pressure of 10-15 tons/ inch. Elemental analyses of the pelletized mineral ores sample were carried out using energy dispersive x–ray fluorescence spectrometer (ED–XRFS) [miniPAL 4 model (c) 2005]. The X–ray spectrometer is attached to a computer with software that has been programmed to show the results directly (Cooper, 1983).For the beneficiation, a representative sample of the mined ores weighing 50kg was taken randomly using a sample divider from the bulk of the sample obtained from the mining sites. It was then crushed and used for beneficiation employing magnetic and gravity separation techniques. The beneficiated mineral were then analyzed using the ED–XRFS analytical technique.

**RESULTS AND DISCUSSION**

The results of analysis showed that Al metal concentration from the ores were between 0.95 – 2.89% (Table 2). Though the ores contained this metal but are not in profitable quantities for economic extraction. The metal can only be considered a probable mineral resource (Bailly, 1982).Economic mine grade usually have the metal content between 25 – 35% (Australian Mining Consultants, 1997).Results of Si for all the samples ranged 2.51 – 13.2% (Tables 1 and 2) with trace amounts obtained in sample NE1 which could be due to the corresponding high concentration of Pb detected in the sampling location. The geochemical data obtained for the metal mineral from some sampling sites suggested that the compositional characteristics of the ores were consistent with their mineralogy indicating deficiency in silicon content (unsaturated) with corresponding enrichment in the ores of some incompatible elements (Ti, Zr, Sr, Nb and Th). Similar lower values for the metals were obtained by Lar and Tsalha (2005).

Potassium metal was only obtained in samples UG3 – UG5 with values between 1.54 – 1.71% (Table 2). Values obtained are indication that the ores were not rich in K. These values compared well with one obtained earlier by Arome (2009) for analysis of iron and copper deposits of Akiri within the same geological zone in the State. The metal may be intricately associated with Nb–Ta–Sn mineralized areas as suggested by Lar *et al.,* (2006). Similarly, all the ore samples showed very low concentrations of Ca metal (Tables 1 and 2) indicating that the metal deposit is not in quantities for economic extraction. Its applications include, making carbide, glass, soap paper, bleaching powder, etc.

Titanium concentration for all the samples ranged between 0.02 – 0.75% (Tables 1 and 2). These values are similar to those obtained by Arome (2009). However, Daspan and Ogezi (2006) reported distinct values from other geological zone in the country. The distinct values from these areas may be attributed to the difference in geological formations in the zone of mineralization. Geochemical result indicated poor content of the metal not in economic quantities for exploitation from the mines (Brookins, 1989). Typical ore grade for economic exploitation varies from between 3 – 25% depending on the associated minerals.

Values for Manganese (Tables 1 and 2) compared well with ones reported by Lar *et al.,* (2006) for the Nb–Ta–Sn distribution in the granitic geological locations of Biu plateau. Correlation result of those minerals showed a significant association of occurrence between Mn and Nb–Ta–Sn within the zone of mineralization. These may be attributed to the geological nature and ore forming bodies in the areas. A similar association of certain kinds of metals in ore deposits has been reported in south western U.S.A. (Rose *et al.,* 1979). However, Mn was not in exploitable quantities for economic consideration.Iron metal results (Tables 1 and 2) indicated high content of the metal in the ores from these mining sites for economic exploitation. These sampling sites may be classified as probable resource for exploitation. Obaje *et al.,* (2006) reported that the geology of these areas favors the mineralization of the metal. Mined ores containing 10% of the metal and upward are considered prospective mines depending on the associated minerals (Obaje, 2006).

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**Table 1: Result of Analysis of Lead Zinc Ore Samples from Nasarawa Eggon (%)**

| Location | Elements | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Al | Si | S | K | Ca | Ti | Cr | Mn | Fe | Ni | Cu | Zn | Sr | Ba | Zr | Pb | As | Cd |
| NE1 | ND | TR | ND | ND | 0.24 | 0.22 | 0.02 | 0.03 | 0.04 | 0.33 | 0.13 | 1.34 | ND | 0.31 | ND | 81.8 | ND | 7.33 |
| NE2 | ND | 10.3 | ND | ND | 0.22 | 0.22 | 0.10 | ND | 0.78 | 0.33 | 0.20 | 2.50 | ND | 0.30 | ND | 63.4 | ND | 2.90 |
| NE3 | ND | 3.65 | ND | ND | 0.24 | 0.22 | 0.10 | 0.09 | 2.36 | 0.05 | 0.25 | 10.40 | ND | 0.30 | ND | 67.24 | ND | 2.11 |
| NE4 | ND | 13.2 | ND | ND | 0.22 | 0.22 | 0.10 | 0.02 | 1.22 | 0.03 | 0.14 | 2.00 | ND | 0.40 | ND | 57.80 | ND | 2.50 |

*ND-Not Detected TR-Trace*

**Table 2: Result of Analysis of Cassiterite-Niobium Ore Sample from Udege Beki (%)**

| **Location** | **Elements** | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Al | Si | S | K | Ca | Ti | Cr | Mn | Fe | Ni | Cu | Zn | Sr | Ba | Zr | Pb | As | Cd | Nb | Ta | Sn | Bi | Th |
| UG1 | 0.95 | 3.28 | ND | ND | 0.11 | 0.33 | 0.12 | 0.23 | 40.1 | 0.02 | ND | 0.30 | ND | ND | 0.30 | 0.60 | ND | ND | 4.91 | 0.97 | 11.1 | 0.36 | 1.8 |
| UG2 | 1.13 | 2.51 | ND | ND | 0.10 | 0.13 | 0.10 | 0.13 | 57.7 | ND | 0.02 | 0.61 | ND | ND | 1.30 | 0.32 | ND | ND | 0.93 | 0.16 | 2.52 | ND | 1.2 |
| UG3 | 2.89 | 8.41 | ND | 1.71 | 0.37 | 0.36 | 0.02 | 0.34 | 6.10 | 0.02 | ND | 0.11 | ND | 0.20 | 20.0 | 0.40 | 0.01 | ND | 10.5 | 1.13 | ND | 0.1 | 1.7 |
| UG4 | 2.54 | 13.1 | ND | 1.54 | 0.52 | 0.38 | 0.02 | 0.10 | 2.85 | 0.02 | ND | 0.04 | ND | 0.10 | 34.6 | 0.14 | 0.01 | ND | 1.80 | 0.22 | ND | 0.1 | 1.4 |
| UG5 | 2.67 | 12.5 | ND | 1.68 | 0.44 | 0.20 | 0.04 | 0.10 | 2.40 | 0.02 | ND | 0.04 | ND | 0.03 | 37.9 | 0.12 | 0.01 | ND | 1.97 | 0.17 | ND | 0.1 | 0.1 |

*ND-Not Detected*

Nickel content in the ores was very poor (Tables 1 and 2) profitable mines with economic prospect usually contained between 3.2 – 10% Ni, as reported for Rosebery and Elua, mine in Australia (Rudenno, 2008). In contrast, in the present study with one reported by some workers in other parts of the country showed poor content of the metal in the ores (Daspan and Ogezi, 2006). Makenzie and Bilodeau (1984) reported that economic mineral grade can vary from 6 – 20% for sulphide ores and 1 – 3% for laterite ores.

Copper metal result ranged between 0.01 – 0.25%, perhaps these values are very low indicating that the metal cannot be concentrated from the ores (Tables 1 and 2).

The absence of the metal in Udege beki ores may be attributed to the ore forming process resulting in the deficiency of some metals which may be considered incompatible as earlier studies on the banded iron ores of Muro Toto within the same geological area by Obaje (2006) suggested. Cu mines as low as 0.5% of the metal with average Cu content not more than 2% has been concentrated (Wills, 1985). Economic mined grades for the metal can vary from a low 0.25 – 2% upwards for underground mines depending on the level of associated metals such as gold.

Zinc analysis showed high content of the metal in a significant quantity from Nasarawa_Eggon which correlated with ones reported for some mines in Ebonyi State and Plateau State, Nigeria with the metal averaging between 43.86–48.52% (Raw Materials, 2006). Offodile (1980) reported that there is occurrence of Pb–Zn in the ores from these zones due to mineralization in variable quantities depending on the geological formation and nature of occurrence of the ore deposits. There is strong occurrence of these metals as galena (Olade and Morton, 1980). Mineral grade can vary from a low of 5% – 20% per tonne (Runge, 1998). The ore may also be further concentrated by hydrometallurgical process to recover more zinc (Lejan, 1989).

Tin metal was only obtained in samples from Udege Beki (Table 2) with values between 2.52 – 11.10%. These mines have high prospect of the metal for exploitation in commercial scale. Lar *et al.,* (2006) obtained similar result for the distribution pattern of the metal in Granitic pegmatites of Nunku, Nasarawa State. This is an indication that Sn is intricately associated with granitic geological areas. The metal can be concentrated by beneficiation using gravity or magnetic separation or a combination of the two methods (Yaro and Oloche, 2001).

Bismuth and Thorium were in low quantities in the ores (Table 2). Bi is known to occur in veins associated with ores of Sn, Ag, Co, Ni and Cu (Nriagu, 1979). Thorium metal is a radioactive metal and a possible source of atomic energy (Reed, 1981).

Lead metal was detected in a very high concentration for economic exploitation (Table 2). Pb is often associated with some metals such as Zn and in some instances with Ba mineralization area when it is of hydrothermal origin, at times Cu, and other metals such as Cd, Fe are found in trace amount. The present study compared well with one earlier carried out by Raw Materials (2006) in Enyigba, Ameri and Ameka lower Benue Trough, Nigeria with average grade of between 60 – 80% of the metal with Pb–Zn ratio of 2:1. The content of a metal in an ore can be used to identify the ore type, for example Nyeba district of Nigeria Gossan collected over a known Pb–Zn deposit contained 4000ppm Pb and 500ppm Zn and was said to be a very poor site (Rose *et al.,* 1979).

Niobium and Tantalum result is presented in Table 1 and 2. Values obtained showed that the mines contained the metals in significant quantities. Geochemical analysis of Nb–Ta in Birnin Gwari north–western Nigeria and Oshogbo–Ibadan and Shaki (Okeogun) in South Western Nigeria gave values ranging from > 100ppm to > 120ppm (Ta + Nb), in most of the areas consistent grades of 250 – 500ppm were obtained over large areas. Cut off concentrate grade of the ore was reported to show a population of $Ta_2O_5$, $Nb_2O_5$ and $SnO_2$ of 15 – 45%, 6 – 18% and 2 – 35%, respectively. A strong geological occurrence of these metals concentrated into deposits in varying quantities is often observed within the zone of mineralization (Funtua, 1999). Average grades of Nb–Ta metals are mostly as by–product of Sn, economic grades are not relevant but for pegmatite operations the metal is recovered appreciably.

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Arsenic and cadmium results are presented in Tables 1 and 2. Arsenic is found native usually in association with other metals but never in sufficient quantity to repay working (Wills, 1985). These metals are in very low quantities, they are usually employed in the industry in small quantities.

Correlation results of ores (ppm) from Nasarawa–Eggon after Wood *et al.*, (1979) (Fig. 4) showed that Ti, Ni, Cr have values that are lower than the standard chondrite values of 645.000, 16500.000 and 3975.000 for metal elements which showed that the metals are highly depleted in the ores and are poorly distributed while the rest metals with values > 1 chondrite are in abundance. The observed behavior may be as a result of chemical changes upon the depositional environment. The bivariate correlation plot of the major elements in the ores (ppm) after Bhatia (1983) showed a higher proportion of iron oxide ($Fe_2O_3$) in all the ores with sample $NE_3$ having a higher concentration than the rest mines which means more iron can be recovered from that site while deficient in potassium as ($K_2O$) and insignificant in calcium as (CaO), this may be due to tectonic interleaving of different protolithic compositions which give rise to a rock of mixed parentage. Pb vs $SiO_2$ (Fig. 6) showed high silica content in $NE_4$and $NE_2$while the rest samples had very low amount as a result of high Pb content in them due to silica undersaturation in the ores. Pb/ Zn bivariate plot (Fig.7) showed that all the samples contained Pb in very significant concentration than Zn. However, mine $NE_3$have higher prospect than the rest mines due to its higher Zn concentration which could be mined together with Pb. Figure 8 is a plot ofPb–Zn vs $Fe_2O_3$correlation, the plot showed that in samples where high Pb content is observed a low Fe content was obtained ($Fe_2O_3$).

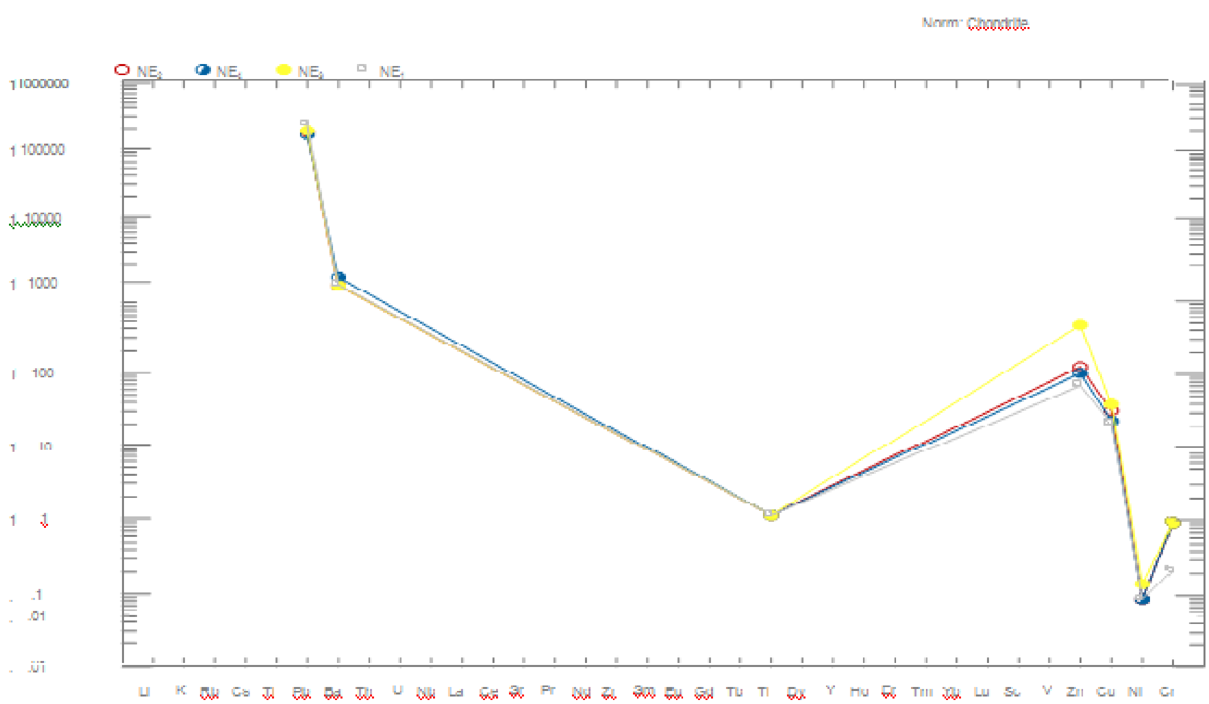


**Figure 4: Chondrite-normalized element abundance correlation diagram for Pb- Zn ores $NE_1$ – $NE_4$ (Source: Wood et al., (1979))**

Pb–Zn vs $TiO_2$ plot indicated that the ratio of $TiO_2$ in all the samples is the same (Fig. 9).On the other hand, chondrite–normalized element abundance correlation (ppm) after Wood *et al.*, (1979) (Fig. 10) indicated poor distribution of Ni and Cr because there values are lower than their standard values of 16500.00 and 3975.00 while the rest metal are well distributed in the ores and could be of interest for possible extraction. The behavior of these metals may be as a result of metamorphism governed by the melting process. Major element correlation after Bhatia (1983) indicated highiron content in samples $UG_2$ and $UG_1$ than the other ore samples while calcium and potassium are insignificant concentrations (Fig.

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11) implying poor content of Ca and K metals. Sn vs $SiO_2$ correlation plot showed that where there is deficiency in Si ($SiO_2$) there was a corresponding high concentration of Sn mineral which is consistent with the values obtained for all the ore samples (Fig.12). Sn vs $Fe_2O_3$ bivariate plot showed high Fe as$Fe_2O_3$and Sn in sample $UG_1$and $UG_2$ while the rest samples have insignificant concentrations of the two metals in the ores (Fig. 13). Similarly, Nb vs $Fe_2O_3$ plot (Fig. 14) exhibited the same trend with slight variation in sample $UG_3$ and $UG_1$ where niobium concentration was significant for economic consideration. Nb vs $SiO_2$ plot showed high silica content as$SiO_2$ in ores with lower content of either Sn,Fe or Nb in the samples, such mining sites with high silica content are not economically viable for recovering Nb (Fig. 15).

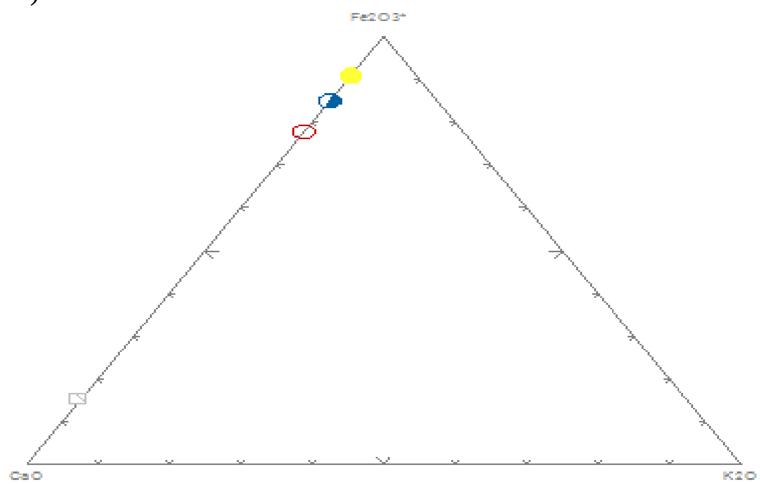


**Figure 5: Bivariate major elements correlation plot (ppm) for Pb-Zn ore deposit. After Bhatia (1983)**

Where: $NE_2$ $NE_4$ $NE_3$ $NE_1$

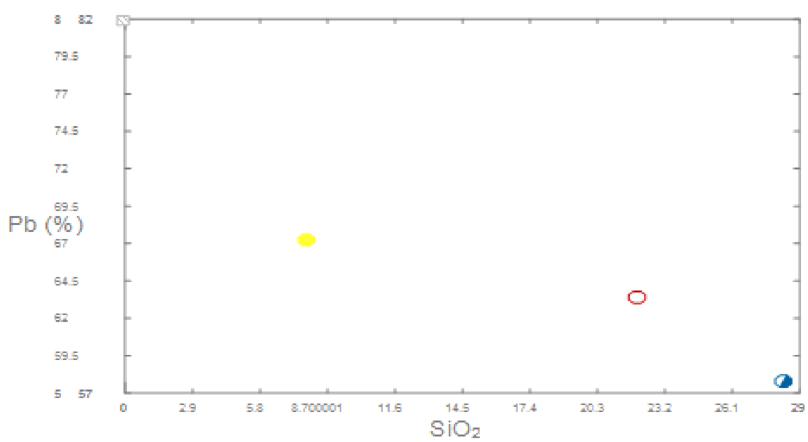


**Figure 6: Pb vs. $SiO_2$ bivariate correlation plot (ppm) for Pb- Zn ore deposit. After Bhatia (1983).**

Where: $NE_2$ $NE_4$ $NE_3$ $NE_1$

Beneficiation result obtained for all the ores from the mining sites showed a pre–concentrate assaying 95% Pb and 26% Zn from samples $NE_1$ – $NE_4$ in Nasarawa–Eggon areas and 55% Nb, 50% Sn and 58% Fe from ore samples $UG_1$ – $UG_5$ in Udege Beki area. This result compares well with one obtained by Yaro and Oloche (2001) for the Muro toto, Nasarawa State banded iron ore, with a pre–concentrate

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assaying 40.3% Fe produced from runoff mines using gravity separation technique. Further attempts have also been made on the Muro toto iron ore deposit using magnetic separation technique of beneficiation by Thomas (2002) with similar result obtained.

The state is therefore, strategic in terms of the availability of lead, zinc, and niobium, tantalite and cassiterite raw material mineral for exploitation, beneficiation and concentration for various industrial applications locally or for export as value added product. This will significantly generate revenue and also serve as a means of diversifying the economy from oil to non -oil sector.

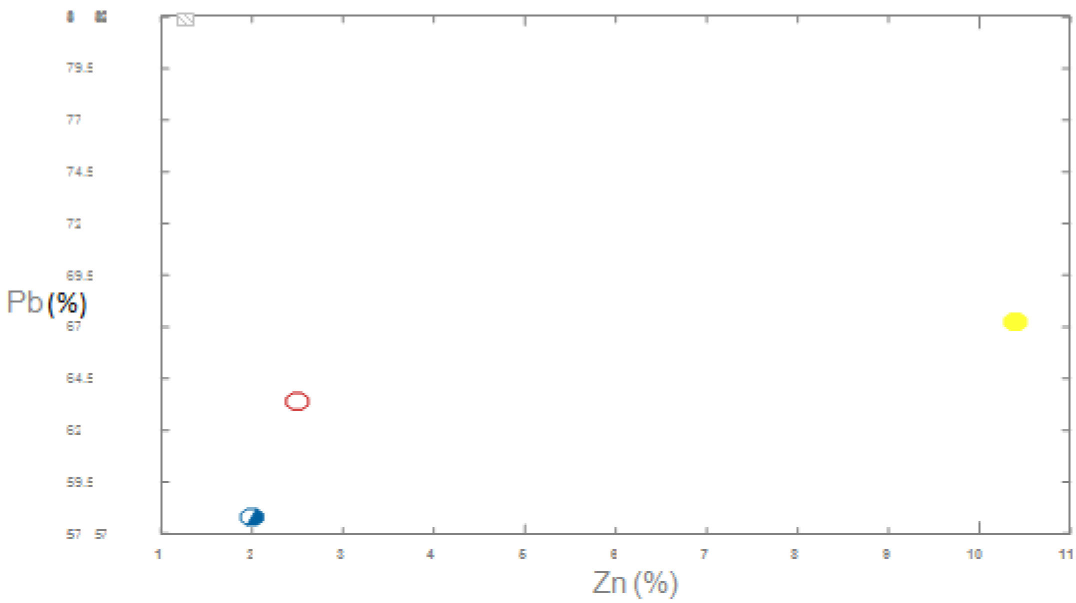


**Figure 7: Pb/Zn bivariate correlation plot (ppm) for Pb- Zn ore deposit. After Bhatia (1983)**

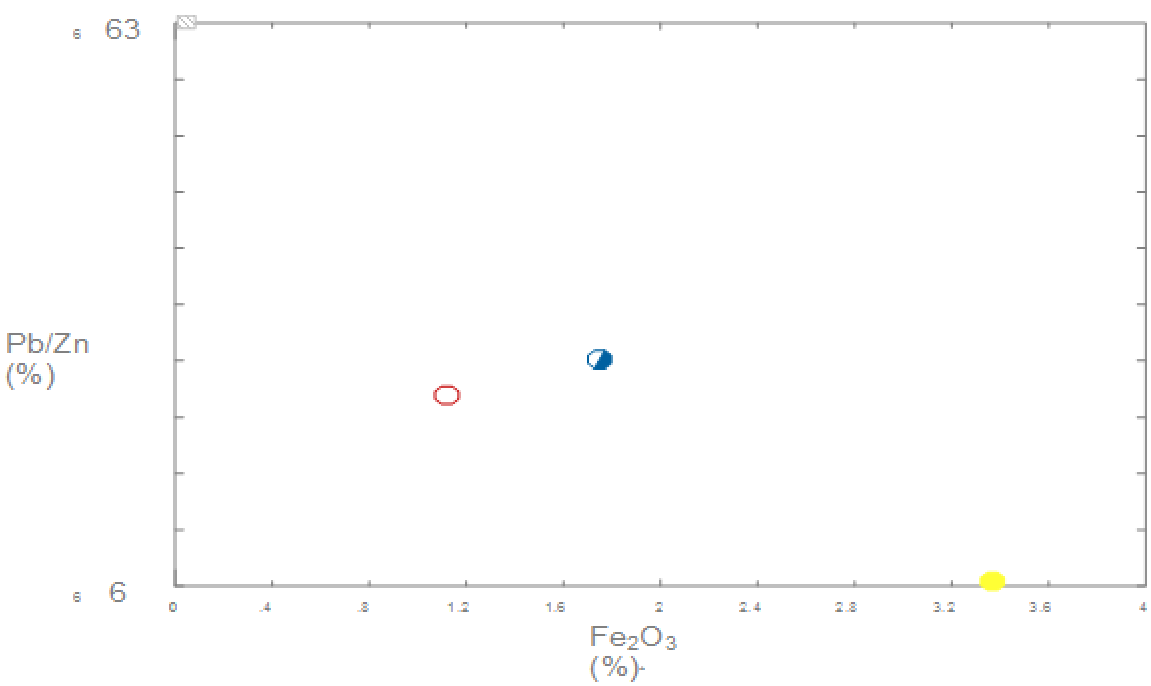


**Figure 8: Pb/Zn vs $Fe_2O_3$bivariate correlation plot (ppm) for Pb- Zn ore deposit. After Bhatia (1983)**

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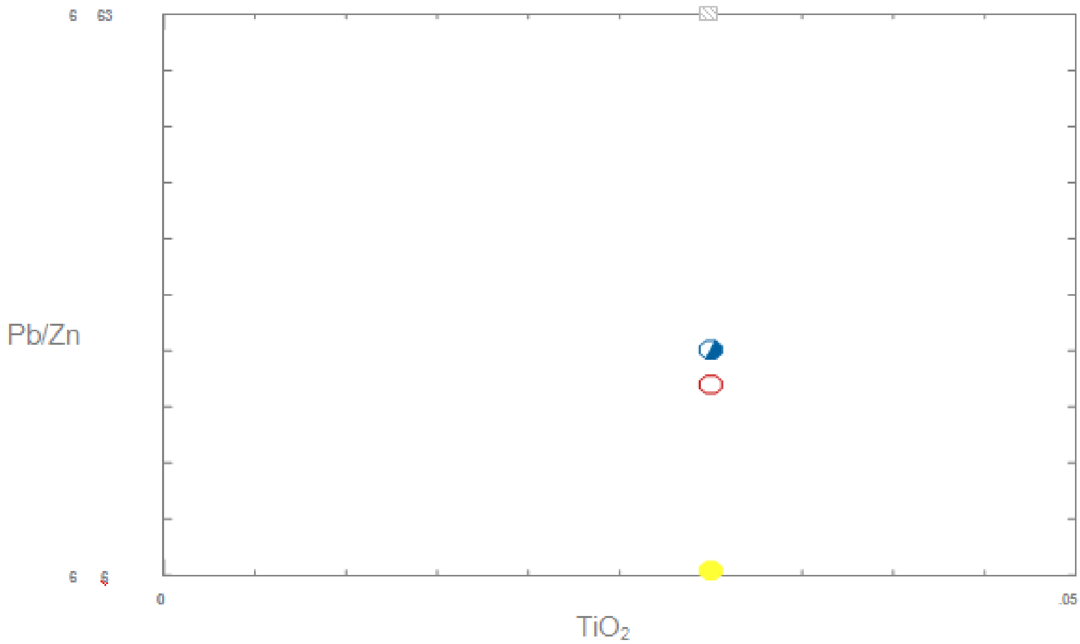


**Figure 9: Pb/Zn vs. $TiO_2$bivariate correlation plot (ppm) for Pb- Zn ore deposit. After Bhatia (1983)**
Where: $NE_2$ $NE_4$ NE $NE_1$

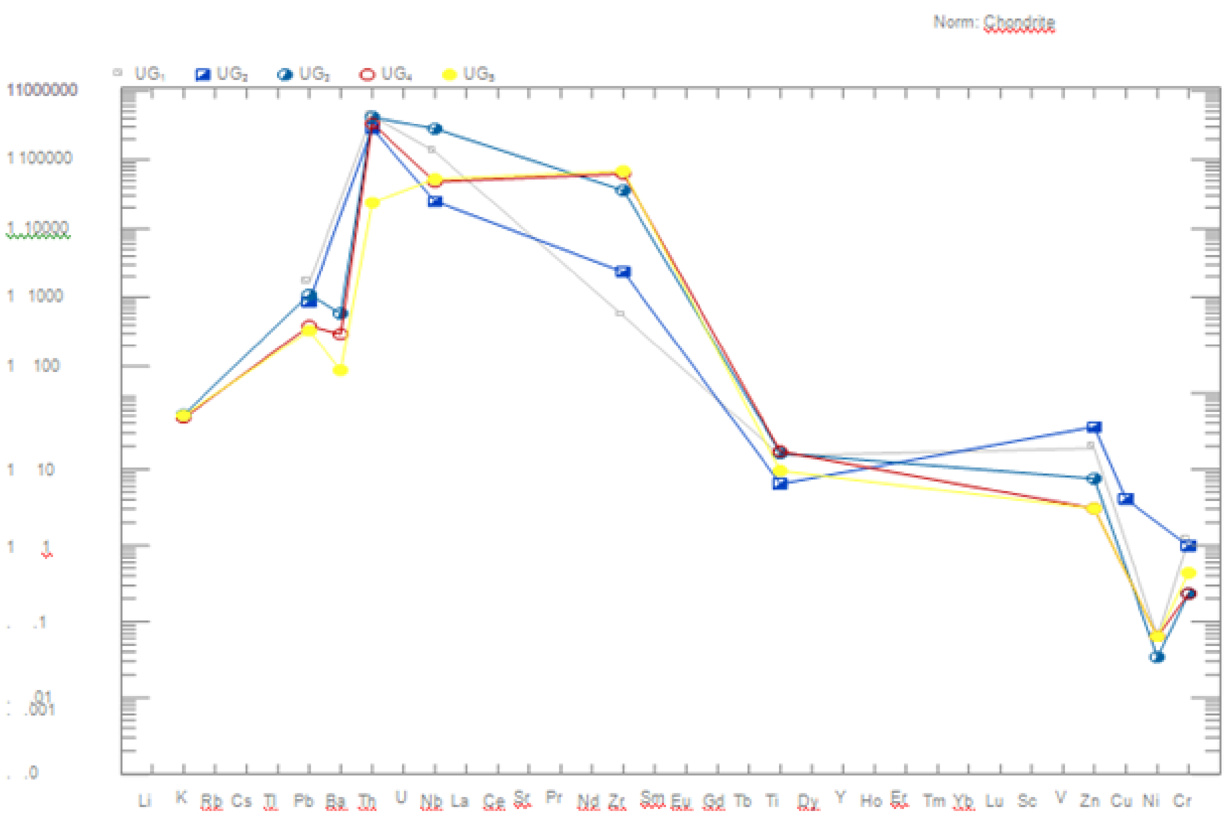


**Figure 10: Chondrite-normalized element abundances correlation diagram (ppm) for cassiterite and niobium ores $UG_1$ –$UG_5$**

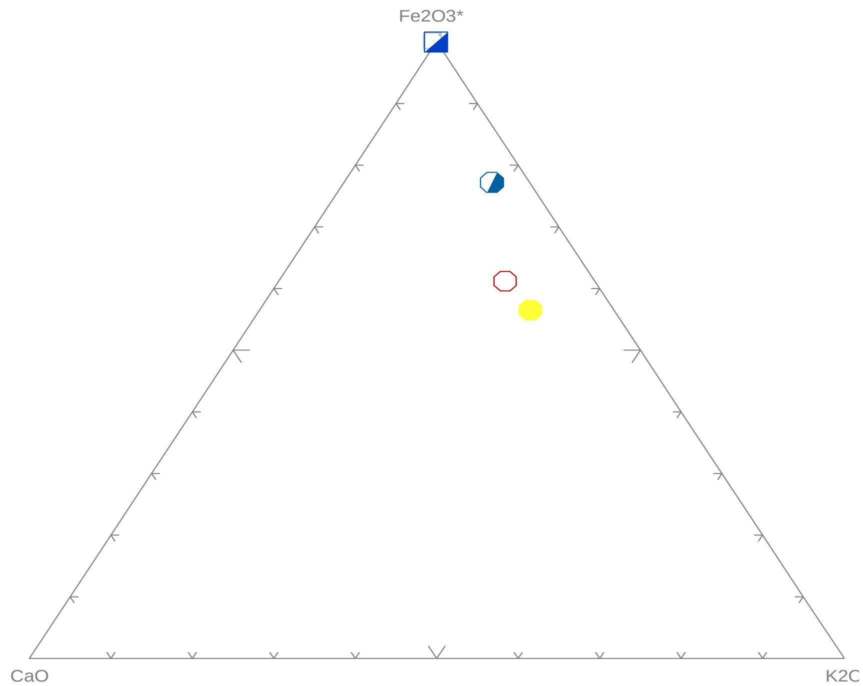


**Figure 11: Bivariate major elements correlation plot for cassiterite and niobium ores. After Bhatia (1983)**

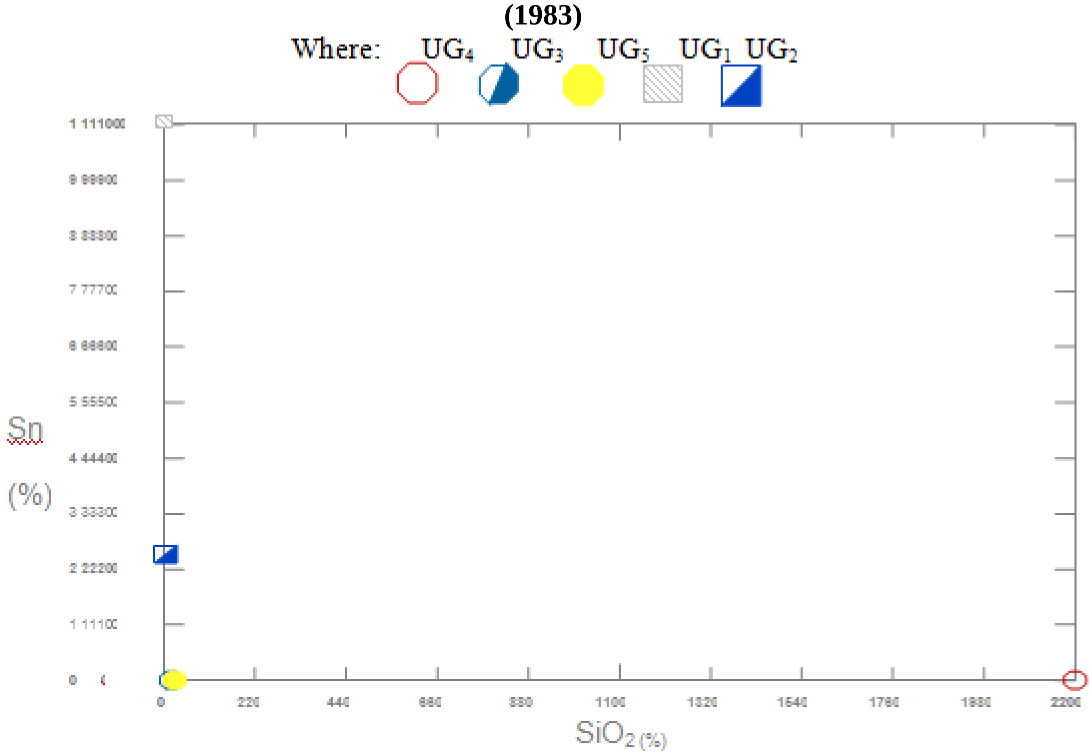


**Figure 12: So vs $SiO_2$bivariate correlation plot for cassiterite and niobium ore deposits ppm. After Bhatia (1983)**

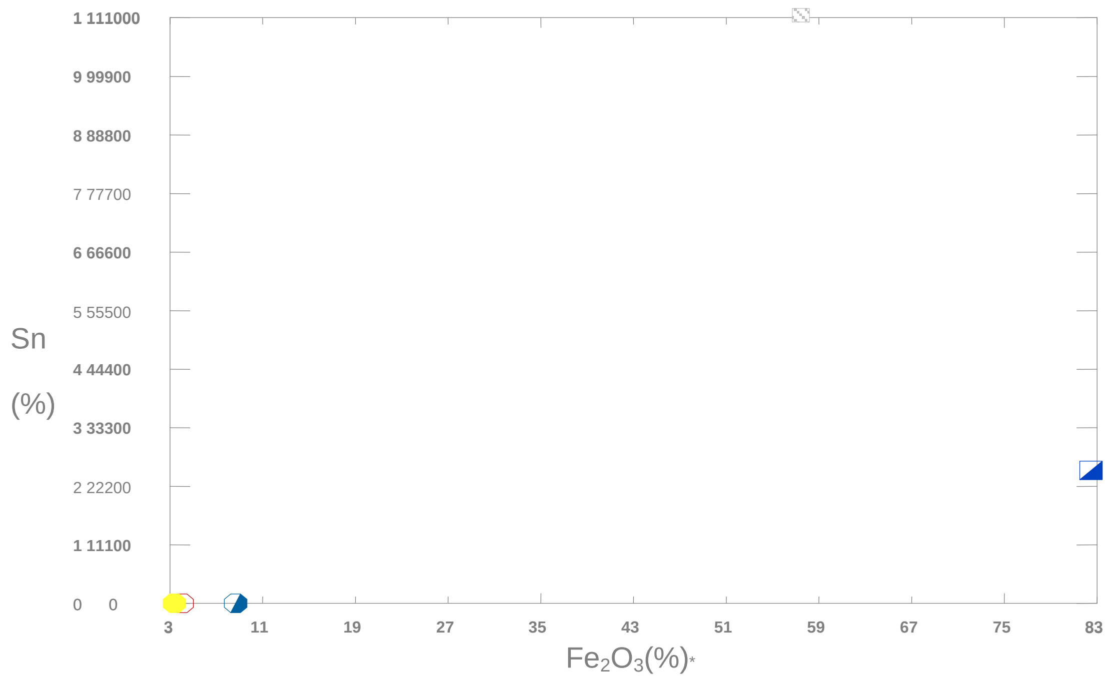


**Figure 13: Sn vs $Fe_2O_3$bivariatecorrelationplotforcassiteriteandniobiumoredeposits ppm** *(After Bhatia, 1983)*

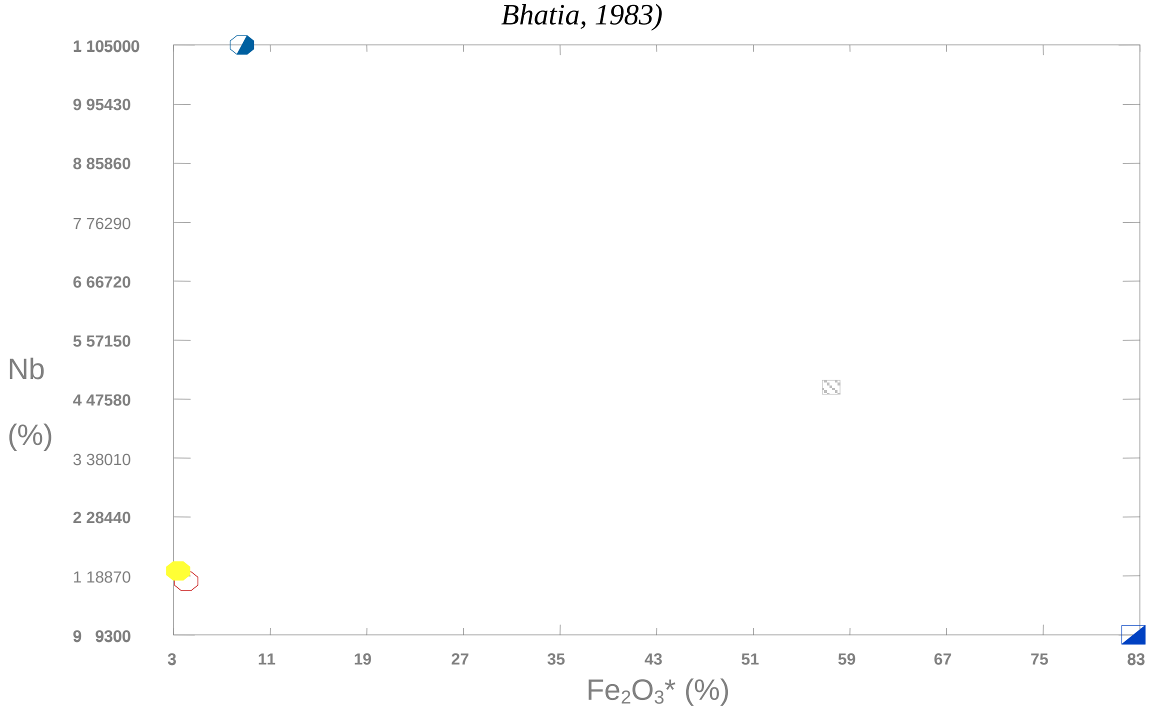


**Figure 14: Nb vs $Fe_2O_3$ bivariate correlation plot for cassiterite and niobium ore deposits ppm (After Bhatia, 1983)**

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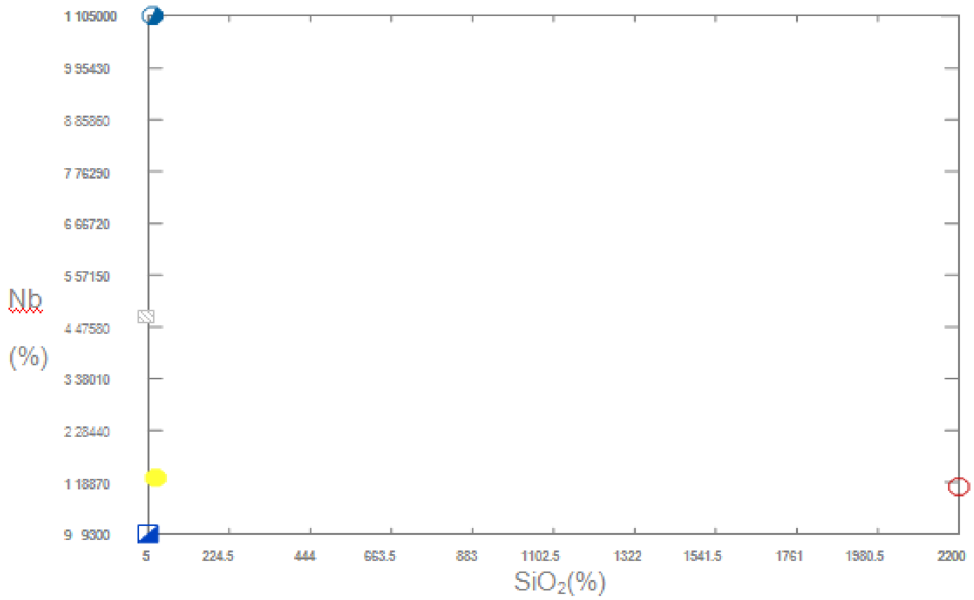


**Figure 15: Nb vs $SiO_2$bivariate correlation plot for cassiterite and niobium ore deposits ppm After Bhatia (1983)**

Where: $UG_4$ $UG_3$ $UG_5$ $UG_1$ $UG_2$

$UG_1$ – $UG_3$ are cassiterite samples while $UG_4$ and $UG_5$ are niobium samples

***Conclusion***

From the results obtained and supported data Nasarawa–Eggon and Udege Beki mining areas contained metal minerals resources which varied both in quantities and concentrations with high prospect owing to the geochemical occurrence of the ore deposits. The ores can therefore be concentrated depending on the method to required industrial requirement and applications. The researched areas could as well serve as potential local raw material base for the State (Pb, Zn, Sn, Nb and Fe) for industrial advancement and socio economic potential in terms of local sourcing of raw materials to the mineral based and allied industries.

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