Geochemical Investigation of Cassiterite At Bisichi (Kara II) And Kuru-Jentar, Plateau State, Nigeria Using X-Ray Fluorescence Analysis (xrf).

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Research Article

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Abstract

Background: *Artisanal Mining of Cassiterite at Bisichi (Kara II) and Kuru-Jentar is a very tedious activity that is carried out by artisanal miners. It involves the use of primitive tools like digger, spade, shovel and to mention a few. Most of the artisanal mining activity in the study area is done with no prior knowledge about the geochemical constituent of the mineral deposit in the area but in order to solve the above stated problem, a geochemical analysis was conducted on the obtained samples of cassiterite from the study area and a geologic map of the mining pit was digitized using Ilwis 3.1 academic and Surfer 12.*

Result: *A random sampling method was used to obtain ten (10) samples of cassiterite from the various visited pit at the study area with each weighing 10g. A laboratory analysis was also conducted using X-ray Fluorescence (XRF) analysis which shows that samples from Pit 1 to Pit 5 in the mine site at Kuru-Jentar has 44.45% - 44.9% of Tin (Sn) and 7.86% - 9.00% of Iron (II) oxide (Fe_2O_3) while samples from Pit 5 to Pit 10 in the mine site at Bisichi (Kara II) has 28.2% - 32.2 % of Tin (Sn) and 15.57% - 16.67% of Iron II oxide (Fe_2O_3).*

Conclusively, *an understanding of the geochemical constituent of a mineral deposit within a given study area would help increase the knowledge of miners and also attract interested investors.*

Background

Minerals are found associated with the parent rocks from which they are derived. The content of the ore mineral is defined according to the composition of the parent rock from which it is derived and when formed in sufficient concentration, it can be mined and transformed into useful product for the comfort of man and other economic purpose. For example, Mallo, (2007) described the general geology of the Jos Plateau and confirmed the presence of Tin ore and Columbite - Tantalite which are of economic importance. They are all from the pegmatite associated with the older Granite but the pegmatite however is believed to be relatively less important compared to the rich alluvial deposition of Tin and Columbite derived from the younger granite but due to the constant unprofitable mining of cassiterite at the study area with very little percentage of Tin Ore found in it, this paper stands to address the problem of mining with no prior geochemical analysis by local miners. This would be addressed by randomly collecting samples from the various pits in the mine site and then an X-ray fluorescence analysis (XRF) was conducted.

Literature Review

Mining industries are viewed as major key drivers of economic growth and in the development process of a nation. Bradshaw (2005), it can also be seen as the lead sector that drive economic expansion which can lead to higher levels of social and economic well being. Bridge (2008)

Many countries of the world like Australia, Canada, Russia, India, Saudi Arabia and Botswana have depended on solid minerals wealth to finance their societies.

The rising demand for primary commodities from fast-growing and emerging countries, like China, has added to the persistent high level of solid mineral in developed countries. UNCTAD (2007). Likewise, high prices and demand of solid mineral have stimulated an investment surge in mineral exploration and production in particularly the developing countries. Okeke (2008)

The Younger Granite rocks of the Jos Plateau and surrounding areas are richly mineralized with cassiterite. Cassiterite is associated with other minerals such as columbite, monazite and accessories like zircon and topaz. As a result, a lot of mining activities such as formal and informal mining have been carried out over the years in the area. Presently, most of the mining activities carried out are still by trial and error means such has lotto mining.

Cassiterite within the study area are obtained from shallow alluvial deposits notably from the river system of the Delimi, Jaura and Asob whose sources are from Jos Plateau. The Tin was smelted at Liruei Delma in Bauchi and the smelted Tin was used for the production of Tin straws. The products which could have been used for the production of arrows and other implements were marketed at Kano, the Southern markets of Ilorin and Lagos as far back as the late 18th Century.

More than 90% of the cassiterite produced in Nigeria was mined from Jos Plateau area. The mining area extends to the South as far as Wamba, the West to Kafanchan, in the North to Bura and in the East up to the Jarawa Hills. The maximum extent of the Tin producing area on the Jos region amount in longitudinal direction to about 240km and latitudinal direction to about 120km. Large scale mining of the mineral started about 1911 and Nigeria was ranked as the world sixth Tin producer and the largest producer of Columbite. Tin production on Jos Plateau increased rapidly from 1.36 tons in 1904 to 5,573 tons ten years later reaching its peak production level of 15,842 tons in 1943. Mallo S.J (2007).

The Geologic map showing the various rock distributions and various mineral deposit in the study area is seen in Fig. 1.

2.1 DEFINITION OF MINERAL PROCESSING

Mineral processing also known as mineral dressing or ore dressing is the process of separating commercially valuable minerals from their ores. (Miettinen et.al., 2010).

Before the advent of heavy machinery, the raw ore was broken up using hammers yielded by hand, a process called “spalling”. Before long, mechanical means were found to achieve this process. Mineral processing thus includes the following:

Comminution- This is the action of liberating valuable mineral from it associated gangue through crushing and grinding.

Separation – This is the action of separating valuable minerals through the application of individual force that differ in magnitude and direction.

2.2 THE MINERALS

The following minerals obtained from cassiterite are: Tin (Sn), Columbite (Fe,Mn $(Nb_2)O_6$, Tantalite (Fe,Mn, Ta_2O_6), Wolframite (Fe, Mg) WO_4 etc.

2.3 COMMINUTION

Comminution involves a process in which solid materials are reduced in sizes by Crushing and Grinding. It occurs naturally during faulting in the upper part of the earth crust and it is an important operation in mineral processing, ceramics, electronics and other fields. Within industrial usage, the purpose of comminution is to reduce the size and to increase the surface area of solid. It is also used to free useful materials from matrix materials in which they are embedded. During this process, mineral processing plant is subjected to two processes of comminution which are **Crushing** and **Grinding**. Balasubramanian (2017)

2.3.1 Crushing

Crushing is the first mechanical stage in comminution process and the sole objective of such operation is the liberation of valuable minerals from the gauge. It is carried out in heavy, slow moving equipment in which the breaker faces are mechanically prevented from making contact with one another. Crushing is classified into Primary and Secondary Crushing. Balasubramanian (2017)

2.3.2 Grinding

This is the last unit operation in the comminution process. It is concerned with the final stage of size reduction into powdered form and it is done by a combination of impact and abrasions (dryer on water suspension). The optimum size of release is determined by both technical and economic considerations. The finer the ore, the higher the cost. Finer grinding usually results in improved value recovery. Grinding is performed on tumbling mills and also, it can be done using a pulverizer. Balasubramanian (2017)

Methods

3.1 DATA COLLECTION TECHNIQUES

A period of three weeks was used for both the inspection of the various mine site and also, the collection of the mineral samples from the various visited mine pit found at the study area.

Ten (10) samples were collected from the pits at random and each weighing 10g. Other methods adopted for the collection of information involved interaction with the artisanal miners at the study area and the use of materials such as: articles, journals and related textbooks.

3.1.1 Reconnaissance Survey

This involved the preliminary study of the area before commencement of the actual field work; such as the acquisition of satellite imagery and review of previous literature of the study area. A map scale of 1:1500 and 1:600 was used to digitize the map of the both study area. Clinton E. (2020)

3.1.2 Field Work / Geological Mapping

The methodology of research used in the study area are taking of coordinates of the study area using various tools which include: Global Positioning System (G.P.S), Tape, Camera and a Field notebook. A total of 10 samples weighing 10g each were obtained from the study area using random sampling method.

The extracted mineral deposit (cassiterite) are in the following forms:

(i) Raw form

The raw form of the mineral are extracted by artisanal miners on site through the use of a local hoisting mechanism for extraction. The depth of the pit is 30 ft while the adit spans to about 25ft. Clinton E. (2020). This is seen in Fig. 2.

(ii) Semi Processed form: The extracted mineral has undergone local processing using panning method. This is seen in Fig. 3.

(iii) Processed form: The extracted mineral has been processed using industrial machines either Magnetic Separators or Air float machine as seen in Fig. 4.

Also, Fig. 5 clearly shows the ways at which artisanal miners extract cassiterite horizontally; this horizontal opening is called an **Adit**. The obtained coordinates from the mine site is shown in Table 1. The co-ordinates from Table 1 was used in the construction of the maps shown in Figs. 6 and 7 which contains the various mine pits seen in the study area. Some of these pits are active pits while others are inactive pits.

Table 1
Coordinates of Bisichi(Kara II) and Kuru-Jentar (Study Area)

BISICHI (KARA II) MINE SITE COORDINATES			
S/N	Latitude(X)	Longitude (Y)	Elevations (Z)
1.	1075377	490195	1239m
2.	1075316	490147	1240m
3.	1075194	490089	1238m
4.	1075194	490031	1239m
5.	1075132	490040	1239m
6.	1075334	490135	1230m
7.	1074745	490055	1224m
8.	1074739	490149	1240m
9.	1074729	490152	1235m
10.	1074724	490155	1245m
KURU-JENTAR MINE SITE COORDINATES			
11.	1071961	487516	1228m
12.	1071948	487486	1227m
13.	1071908	487452	1228m
14.	1071902	487476	1225m
15.	1071883	487495	1226m
16.	1071930	487494	1232m
17.	1071963	487565	1233m
18.	1071965	487550	1225m
19.	1071930	487487	1223m
20.	1071948	487480	1227m
Source: Clinton E. (2020)			

Results

The obtained cassiterite samples from Kuru-Jentar and Bisichi (Kara II) were taken to the laboratory for XRF analysis and the obtained results are shown in Table 2 and Table 3. The obtained elemental percentage from samples in Pits numbered 1 to 5 are shown in Table 2 and samples from Pits numbered 6 to 10 are shown in Table 3 below while Fig. 8 is a bar chart representation used to show an overview of the various percentages in the both study area (Kuru and Bisichi). Each bar represent an element but the different colors help in differentiating the various the different elements of interest. It is a bar chart of percentages of mineral ore against the place of mineral deposit.

Table 2
XRF result of obtained samples from the study area (Kuru- Jenter).

Oxide Composition (%)	Pit 1	Pit 2	Pit 3	Pit 4	Pit 5
SiO_2	12.48	19.47	18.44	16.63	19.96
CaO	ND	0.24	0.22	0.20	0.24
Cl	0.52	ND	ND	0.51	ND
TiO_2	4.49	3.81	3.82	4.35	3.91
Cr_2O_3	ND	ND	ND	0.01	0.025
Fe_2O_3	9.00	7.976	8.311	8.853	7.859
MnO	0.49	0.47	0.501	0.51	0.748
CuO	0.056	0.042	0.055	0.063	ND
ZnO	ND	0.037	0.029	0.12	ND
As_2O_3	0.014	0.028	0.012	0.01	0.006
SeO_2	0.003	ND	ND	0.003	ND
Y_2O_3	0.12	0.12	0.14	0.12	0.12
Nb_2O_5	18.50	18.40	20.80	19.00	18.00
SnO_2	49.45	44.90	42.70	44.50	44.90
CeO_2	ND	0.02	0.04	ND	ND
Eu_2O_3	ND	0.40	0.40	0.41	0.31
HfO_2	0.818	0.743	0.821	0.852	0.781
Ta_2O_5	2.07	1.90	1.98	2.01	2.04
WO_3	0.30	0.20	0.24	0.21	ND
ThO_2	0.991	1.04	1.09	1.04	0.798
L.O.I	0.70	0.20	0.40	0.60	0.30
ND = NOT DETECTED					
Source: Clinton E. (2020)					

Table 3
XRF result of obtained samples from Bisichi (Kara II)

Oxide Composition (%)	Pit 6	Pit 7	Pit 8	Pit 9	Pit 10
SiO_2	ND	6.00	14.00	12.74	8.24
Cl	ND	0.994	ND	ND	ND
K_2O	0.99	0.94	ND	0.76	ND
CaO	0.20	0.20	0.61	0.20	ND
TiO_2	17.00	15.20	13.80	15.90	14.70
MnO	0.75	0.66	0.59	0.65	0.61
Fe_2O_3	16.67	15.81	14.22	17.02	15.57
CuO	0.23	0.17	0.21	0.14	0.22
ZnO	ND	ND	0.087	0.084	0.088
SeO_2	ND	ND	ND	0.004	ND
Ga_2O_3	0.070	ND	0.048	ND	ND
AS_2O_3	0.028	0.008	ND	ND	0.02
Y_2O_3	0.832	0.653	0.696	0.832	0.738
ZrO_2	9.71	9.56	9.15	9.09	10.10
Nb_2O_5	11.20	10.60	10.20	9.42	11.00
SnO_2	32.20	30.00	30.44	24.00	28.20
BaO	1.80	2.20	1.20	2.40	1.10
CeO_2	2.10	2.00	1.90	2.20	2.30
Nd_2O_3	0.26	0.40	0.20	0.51	0.19
Eu_2O_3	0.40	0.37	0.52	0.48	0.50
HfO_2	ND	0.41	0.26	0.40	0.39
Ta_2O_5	1.00	1.33	0.79	1.18	1.11
WO_3	ND	ND	0.22	ND	0.16

Source: Clinton E. (2020)

Oxide Composition (%)	Pit 6	Pit 7	Pit 8	Pit 9	Pit 10
PbO	0.13	0.15	0.26	0.17	0.596
ThO_2	1.53	1.44	ND	1.62	1.47
L.O.I	2.90	0.90	0.60	0.20	2.70
ND = NOT DETECTED					
Source: Clinton E. (2020)					

Discussion

The discussion of result is drawn from Table 2 and Table 3 and summarized in Fig. 8 using a Bar - Chart to clearly represent the percentages of the captured elements of interest as reviewed under the Literature Review. The elements as seen in the bar chart above are obtained from the samples gotten from Pit 1 to Pit 10 of the study area.

5.1 SAMPLES FROM PIT 1 – PIT 5

The percentage of Tin Ore (SnO_2) ranges from 44.45% -44.9%, Niobium Pentoxide (Nb_2O_5) ranges from 18.40%-19.00%, Iron (II) oxide (Fe_2O_3) ranges from 7.86%-9.00%, Rutile (TiO2) ranges from 3.81% – 4.49%, Tantalum Pentoxide (Tn_2O_5) ranges from 1.90%-2.07%, Tungsten Oxide (WO_3) ranges from 0.00%-0.30%. Progressively, its percentages are thus: $SnO_2 > Nb_2O_5 > Fe_2O_3 > TiO_2 > Tn_2O_5 > WO_3$. As seen from the result, the Tin Ore content in Kuru- Jentar is high in percentage. It also has very low percentage of Iron (II) oxide (Fe_2O_3). The reason for the much concentration of Tin- Ore in Kuru-Jentar is because of the lower presence of Iron (II) oxide (Fe_2O_3). Using chemical illustration to further explain; it means that Rutile (TiO_2) displaces Iron (II) oxide (Fe_2O_3) giving out 1 molecule of Oxygen.

Fe_2O_3 (Hematite)+TiO_2 (Rutile) $\longrightarrow$ $4FeTiO_3$ (Ilmenite)+O_2

5.2 SAMPLES FROM PIT 6 - PIT 10

Tin Ore (SnO_2) ranges from 24%-32.2%, Iron (II) oxide (Fe_2O_3) ranges from 14.22% – 16.67%, Rutile (TiO_2) ranges from 13.8% – 17.00%, Niobium Pentoxide (Nb_2O_5) ranges from 9.42% – 11.2%, Tantalum Pentoxide (Ta_2O_5) ranges from 1% – 1.18%, Tungsten Oxide (WO_3) ranges from 0.00 %– 0.22%. The sequential succession of the minerals as seen in the result are thus: $SnO_2 > Fe_2O_3 > TiO_2 > Nb_2O_5 > Ta_2O_5 > WO_3$

Recommendation

The recommendations are as follows:

(i) Locally separated cassiterite at the mine site should be taken to processing mill for proper separation and value addition either through the use of High magnetic separator or an Air float machine.

(ii) The federal government should give financial support through the various geoscience institutions in order to encourage more geologic research around various states of the federation for record purpose.

(iii) The federal government should partner with various institutions where Geology and other related discipline are taught in order to foster the drive for geologic survey thus creating better partnership between the various institutions.

Conclusions

From the obtained result conducted using XRF analysis, the both study area has high percentages of Tin ore deposit though Kuru-Jentar has more percentage compared to that of Bisichi. Also, samples from both study area has low magnetic susceptibility because of the absence of magnetite in the obtained result. As a result, artisanal miners can use High Intensive Magnetic Separator in processing the obtained mineral deposit (cassiterite).

Conclusively, more geologic survey of various mine site around Nigeria would help increase the knowledge of miners with regards to the geochemical constituents of mineral deposit found in the study area. This action can also attract more investors since there is easy assess to the data base that contains the chemical constituent of the mineral deposit at any given area of interest.

Abbreviations

XRF- X-ray Flourescence Analysis

Declarations

Ethics approval and consent to participate: As approved by the Department of Mining Engineering; University of Jos, Nigeria for the purpose of “Academic Research” and “Addition to Knowledge”.

Consent for publication : Not applicable

Availability of data and materials: Please contact the authors for data request

Competing interests : Not applicable

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Author’s contributions: CEE was involved in digitizing the map, field work , writing and typing of the research, SJM helped in supervising the field work while CKA and MB helped in editing and reviewing this research. All authors have read and approved the final manuscript.

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References

1. **Abere et.al (2017):** Comparative Study of Local Mining Methods and Assay of Cassiterite with other Alluvial Mineral Deposits in Kuru-Jantar, Plateau State, Nigeria
2. **A.Balasubramanian (2017)**: Size reduction by Crushing Method; https: www.researchgate.net/publication/31547098
3. **Bradshaw, M. J. (2005):** Population, Resources, Development and the Environment. In: Daniels, P. *et al*, eds. An Introduction to Human Geography: Issues for the 21st Century. 2nd ed. (Section 2)
4. **Bridge, G. (2008):** Economic Geography: Natural Resources. In: International Encyclopaedia of Human Geography. Eds. Kitchin and Thrift. Elsevier.
5. **Clinton E. (2020):** Benefits of cassiterite mining by artisanal miners in Jos Plateau, Nigeria; Bulletin of the National Research Centre, Vol. 44:113
6. **Mallo S.J (2007)**: Minerals and Mining on the Jos Plateau, First Edition.
7. **Miettinen (2010)**: The limits of fine particles Flotation, Minerals Engineering, Pg 23, 420 – 437
8. **Okeke, C. N. (2008):** The Second Scramble for Africa's oil and Mineral Resources: Blessing or Curse? *The International Lawyer*, 42 (1), 193-210.
9. **UNCTAD** (United Nations Conference on Trade and Development), (2007): World Investment Report 2007: Transnational Corporations, Extractive Industries and Development. New York and Geneva: United Nations

Figures

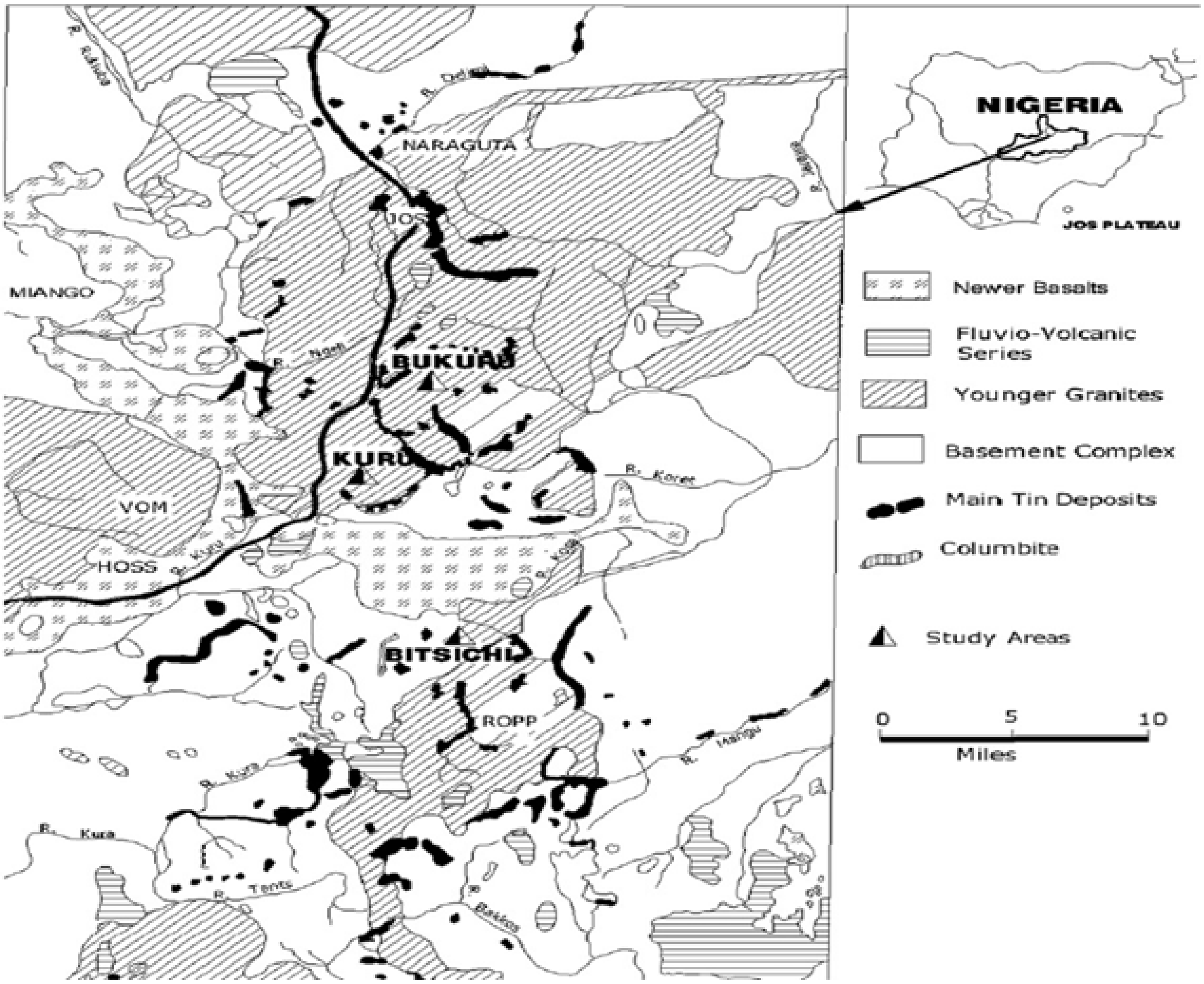

Figure 1

Geologic Map of the study area Source: Abere et. al (2017)

Figure 2

An image of locally extracted cassiterite using local hoisting mechanism at the study area.

Figure 3

An image of semi processed cassiterite at the study area through the use of Panning Method

Figure 4

An image of Industrial Air float machine for processing the cassiterite using the action of vibration for even separation of the various minerals due to their different densities.

Figure 5

An image of a locally made adit for assessing the mineral deposit horizontally at the study area

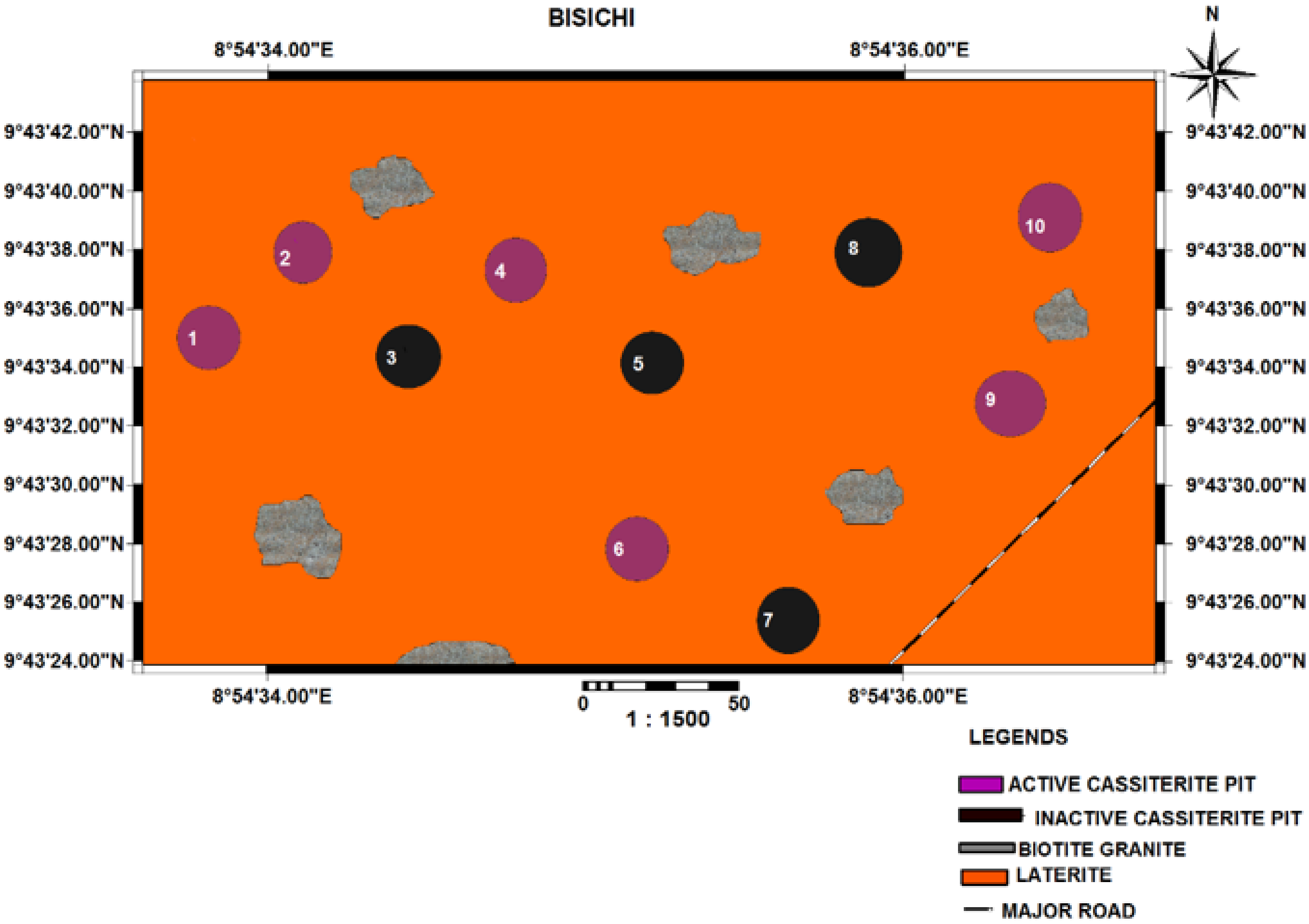

Figure 6

A digitized map of mine site at Bisichi (Kara II). Source: Clinton E. (2020)

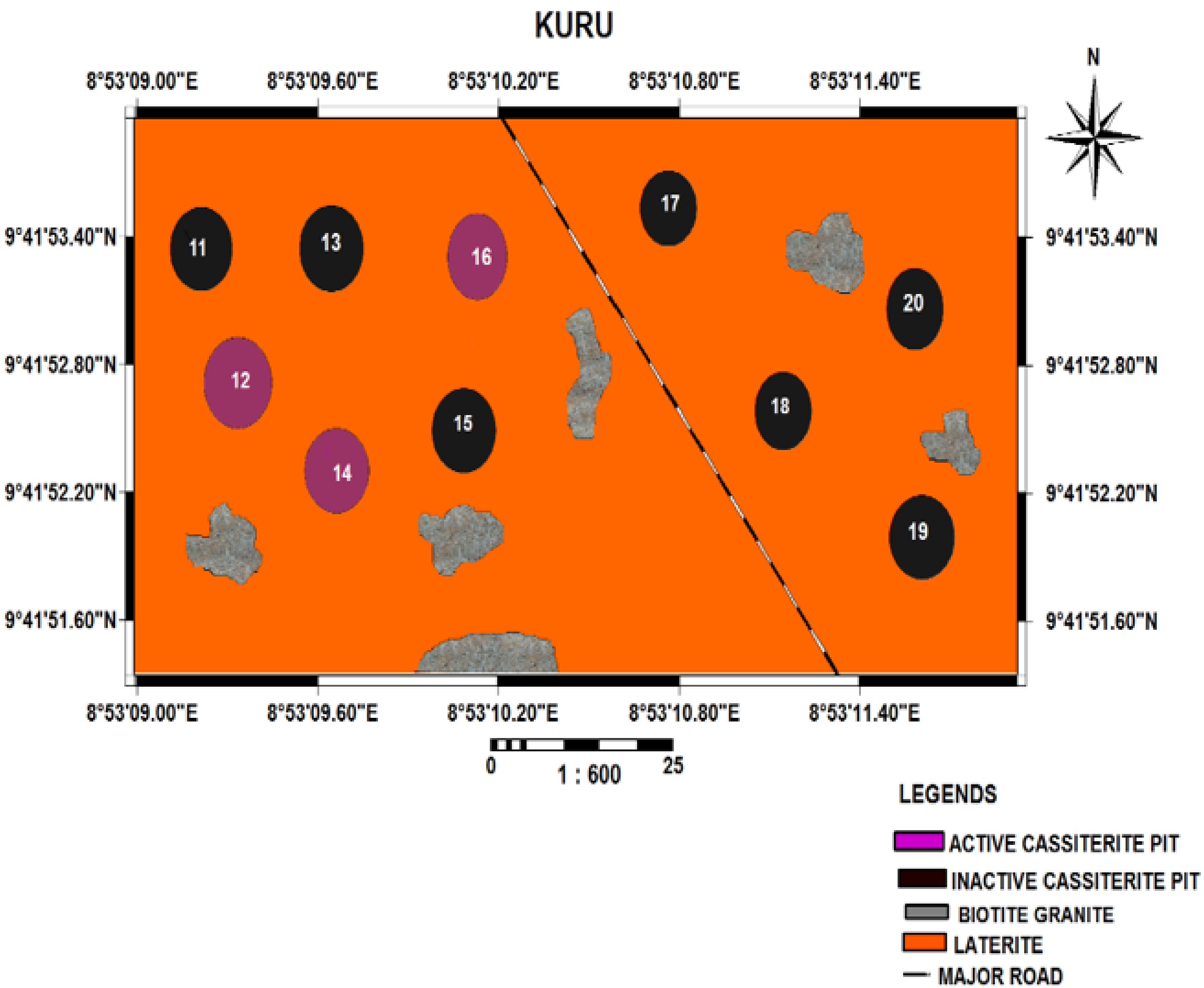

Figure 7

A digitized map of mine site at Kuru- Jentar. Source: Clinton E. (2020)

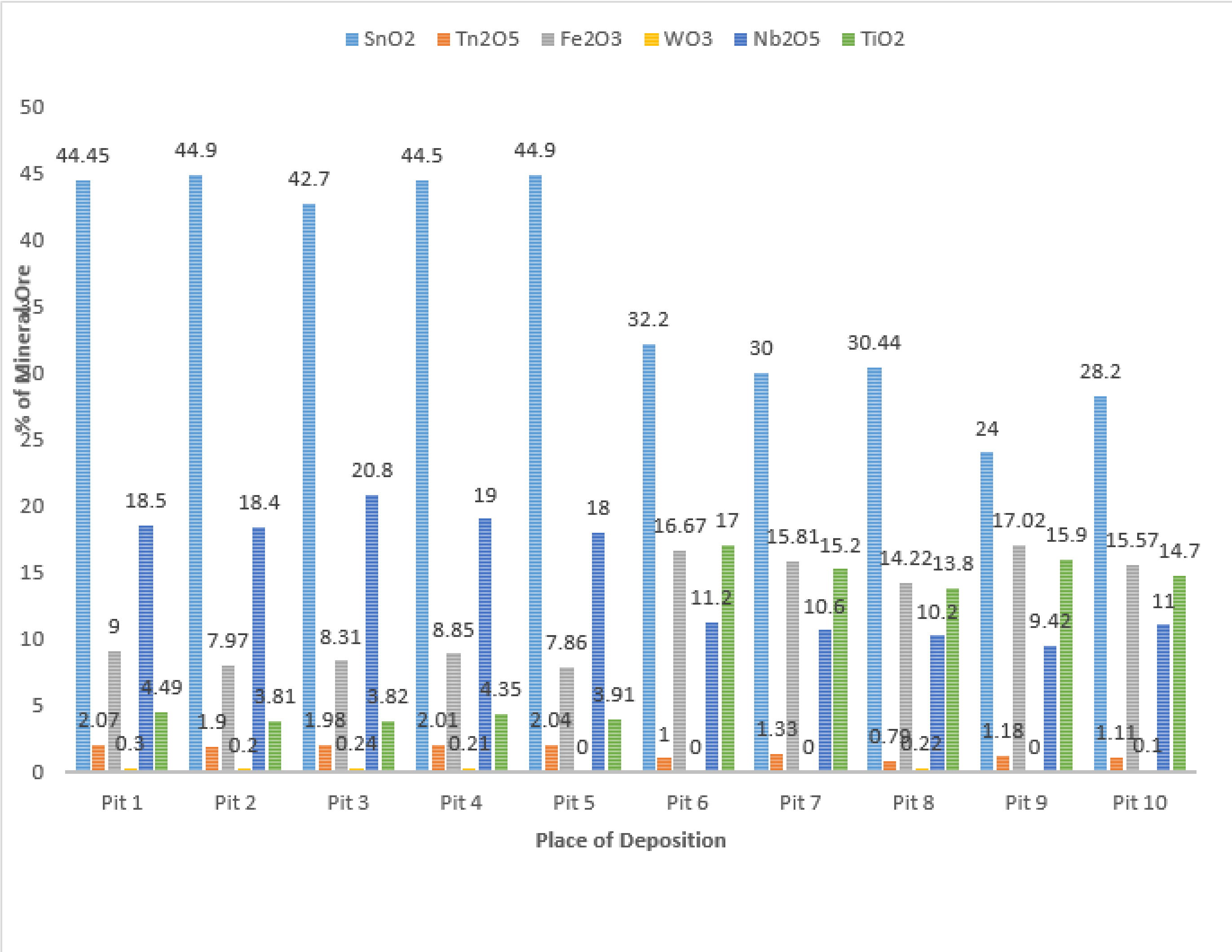

Figure 8

A Bar Chart of Percentage (%) of Mineral Ore against Place of Mineral Deposition