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Benefits of cassiterite mining by artisanal miners in Jos Plateau, Nigeria

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Abstract

Background: Artisanal mining of cassiterite is one tedious activity that is done daily. It involves daily extraction of economic mineral deposits through the use of primitive tools like shovel, digger, and spade. The continuous extractive act by these artisanal miners tends not to bother the Government of Nigeria and as such, there is no detailed record that collates the quantity of cassiterite mined and processed per day. For instance, tin, tantalite, columbite, zircon, ilmenite, and wolframite are buried in the bowels of Plateau, Nasarawa, Kaduna State, etc. This research aims at discussing the importance of cassiterite mining in Plateau and its benefit to Nigeria's economy

Results: The obtained results from an interactive session with artisanal miners at Bisichi (Kara II) and Kuru-Jentar as well as sampling active and inactive mine pits at the visited mine site prove that a maximum number of 4 bags of cassiterite is mined per day from each lotto pit which is equivalent to ₦660,000 (using the 2018 price of ₦165,000 per processed 50 kg of tin). Samples of cassiterite gotten from the study area show a high percentage of tin (Sn) after X-ray fluorescence (XRF) analysis was conducted on it. Also, the visited mine pit is 3 ft in diameter, the shaft is 30 ft and an adit of 25 ft. Conclusively, the Nigerian Government stands the chance of having financial stability if she seizes the opportunity by ensuring that the mining sector is improved and, also, by forming cooperatives that would be involved in collating the various products made. Taxes paid to these cooperatives will serve as another source of Internally Generated Revenue (IGR) for the nation. Financial grant can be disbursed through these cooperatives to encourage the use of mechanized mining, but if nothing is done, the economy of Nigeria will continue to dwindle leading to a financial crisis.

Keywords: Artisanal Miners, Cassiterite, Industrialization, Component production, Metallurgy, Alloys, Metallic minerals

Background

Artisanal mining is one of the basic mining activities that is carried out in Nigeria. It is a primitive way of extracting alluvial deposits from the earth. Nigeria has thrived well in certain sectors of the economy such as in the oil and gas sector, telecommunication, and recently, in the cement manufacturing subsector. Nigeria also produces over 2.6 million barrels of oil per day and has installed extensive oil and gas facilities which include nearly 200 flow stations, three (3) refineries, five (5) coastal terminals, extensive networks of pipelines, flow lines, and bulk lines (Ohimain, 2004), but in all this, the iron and steel industry remains dormant. Iron and steel are very important for both the growth and developing of any modern society because it plays a major role in the industrialization and infrastructural development of any nation. Nigeria has the potentials of becoming a great nation in West Africa sub-region but this can be made possible if the iron and steel industry is working again (Agbu, 2007), hence the need to revisit the mining sector.

The geology of the northern part of Nigeria

There are two distinct groups of granites in Northern Nigeria which differ considerably in age, structure, and mode of origin. These are the Older and Younger Granites which range in composition from granite to granodiorite with subordinate diorite and quartz – syenites. The

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Younger Granite is discordant, high level, magmatic intrusion with strong alkaline affinities. Jacobson (1963) have attributed the age of Older Granite to early Paleozoic whereas the Younger Granite is Jurassic. Falconer (1921) first recognized the essential difference between the Older and Younger Granites when minerals surveyed in the Northern Nigeria was established in 1911. According to Macleod and Turner (1971), they described the general geology of Jos Plateau and confirmed the presence of economic minerals such as cassiterite (tin) and columbite (niobium). Small amount of cassiterite-tin ore and columbite-tantalite are from the pegmatite associated with the Older Granite. Other environments that have the Basement Complex comprising of the pegmatite and migmatite are Nasarawa State, Kaduna State, etc.

The diverse rock types of Nigeria can be sub-divided into three main groups which are the Basement Complex, (ii) the Younger Granite, and (iii) the Sedimentary Series.

A good understanding of the rock type distribution is shown in Fig. 1 below.

Each group has its own associated meta-volcanic or volcanic rocks. Both igneous and metamorphic rocks of the Basement Complex and igneous rocks of the Younger Granite together occupy about 50% of Nigeria's surface area while the sedimentary series occupy the remaining area (Ajibade et al., 1988).

Different states where cassiterite is mined in Nigeria

Artisanal mining of solid minerals like cassiterite started 1905–1972 rating Nigeria as the 6th producer of tin in the world while mining of columbite started from 1933–1945 rating Nigeria as the world exporter of columbite (Mallo, 2017. This activity still has its practice done in many parts of the states in the country and thus are the following: (1) Kaduna State: Artisanal mining of economic solid mineral like cassiterite and others are located in various local government of the state, places

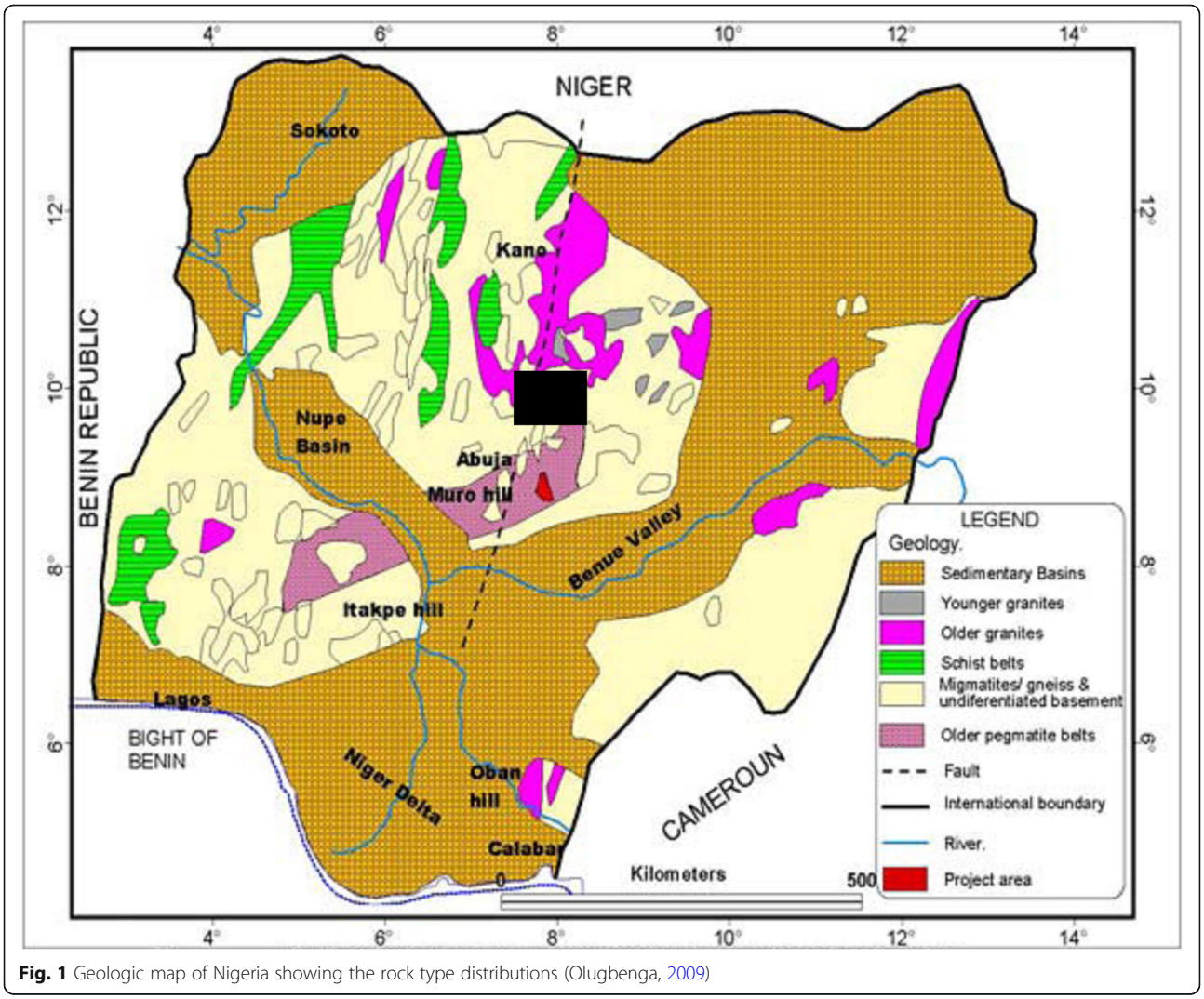

Fig. 1 Geologic map of Nigeria showing the rock type distributions (Olugbenga, 2009)

like Jaba, Jemaba, Kachia, and Ikara (NBRM 2012). (2) Nasarawa State: This state is also blessed with a lot of solid mineral deposits in places like Kama-Otto, Kwotto, and Angwan-Mada. These communities indulge in a lot of small-scale mining of cassiterite and Tantalite. (3) Plateau State: This state is called the home of tin because of its rich deposit of cassiterite both along the street of the state and also along stream sides due to alluvial deposition. Certain local government areas of the state that has the deposition of cassiterite are Jos-North, Jos-South, Barkin-Ladi, etc. States like Bauchi and others also have cassiterite deposits.

Associated minerals in cassiterite

Cassiterite is the chief ore of tin (Sn), but it houses other associated minerals such as columbite, wolframite, ilmenite, monazite, and others. When this mineral deposit (cassiterite) is mined from the earth by artisanal miners, it is further processed (either locally or industrially). The associated economic minerals that can boost the economy of this nation are thus discussed:

Tin (Sn)

Tin (Sn) is a chemical element belonging to the carbon family. It is a soft, silvery-white metal with a bluish tinge. Tin is widely used for plating steel cans used as food containers, in metals used for bearings, and in solder. Tin-plating of iron protects from corrosion.

Wolframite (Fe, Mn) Wo_4

Wolframite is the chief source for tungsten (W), but other sources of tungsten are ferberite $FeWO_4$ (60.5%) and hubnerite $MnW0_4$ (63.9). Wolframite and hubnerite constituent 75% source of world production of tungsten and scheelite has 25%. Impurities include magnesium (Mg), calcium oxide (CaO), tantalum oxide (Ta_2O_5), columbite oxide (NbO_s), and tin oxide (SnO_2).

Columbite (Fe, Mn (Nb_2) O_6 –Tantalite (Fe, Mn, Ta_2O_6)

Columbite is the most widespread niobium mineral and makes for an important ore of the industrially useful metal. Niobium, Nb, is used in alloys for improved strength. It also has shown superconductive properties. Tantalite replaces niobium in all properties up to 100%, and when tantalite exceeds niobium, the mineral is called tantalite, and when niobium exceeds tantalite, it is called columbite.

What is metallurgy?

Metallurgy is a domain of materials and engineering that studies the physical and chemical behavior of metallic elements, their inter-metallic compounds, and their mixtures which are called alloys. This also is the process that is used for the extraction of metals in their pure form from their ores.

Metallurgical operations

Various metallurgical operations that lead to obtaining pure metals from their ore are through the following steps: (i) crushing and grinding of the ore; (ii) concentration of the ore; (iii) roasting, calcination, and smelting; (iv) reduction; and (v) refining of the metals. After the mineral ore has been extracted, beneficiation is done either through the use of a magnetic separator or an air float machine. The following are the importance:

(i) Tantalite: They are used for the production of tantalum capacitor which is used in various electrical panels. They are very good in the electrical industries.
(ii) Wolframite: It is used for making ammunition and as an alloy.
(iii) Zircon sand: It is also used in the ceramics industry for the making of ceramics.
(iv) Columbite: It is used as a source of niobium as an alloy of steel to form weldable high-speed steel for radio transmitting valves, heat-sensitive detective devices called a barometer, for jet engines, and other aircraft components.
(v) Quartz: It is used in glass and silica bricks and paint scouring, soaps and paper. In its powdered form, it is used in porcelain paint, scouring soaps, and wood filter.
(vi) Tin: It is an alloy that is basically used to increase the strength of other materials. With this in view, if the Government of Nigeria take a proper record of the quantity of cassiterite mined from the various state, it would go a long way in reviving the various dead and lifeless milling industries.

Materials and methods

Data collection technique

A period of three (3) weeks was used for the inspection of the mine site in Plateau State (Kuru-Jentar and Bisichi-Kara II). A total of fifteen (15) pits were active while twenty (20) other pits were inactive as shown in Figs. 2 and 3. Other methods adopted for the collection of information involved interaction with the artisanal miners at the mine site and the use of materials such as articles and journals.

Field work/geologic mapping of pit

The field work was done on both Kuru-Jentar and Bisichi-Kara II with the aid of a G.P.S for taking coordinates of the various mining pits as seen in Table 1, camera for taking pictures, and a field note for jotting. Ilwis 3.1 academia and Surfer 12 were used in digitizing the maps.

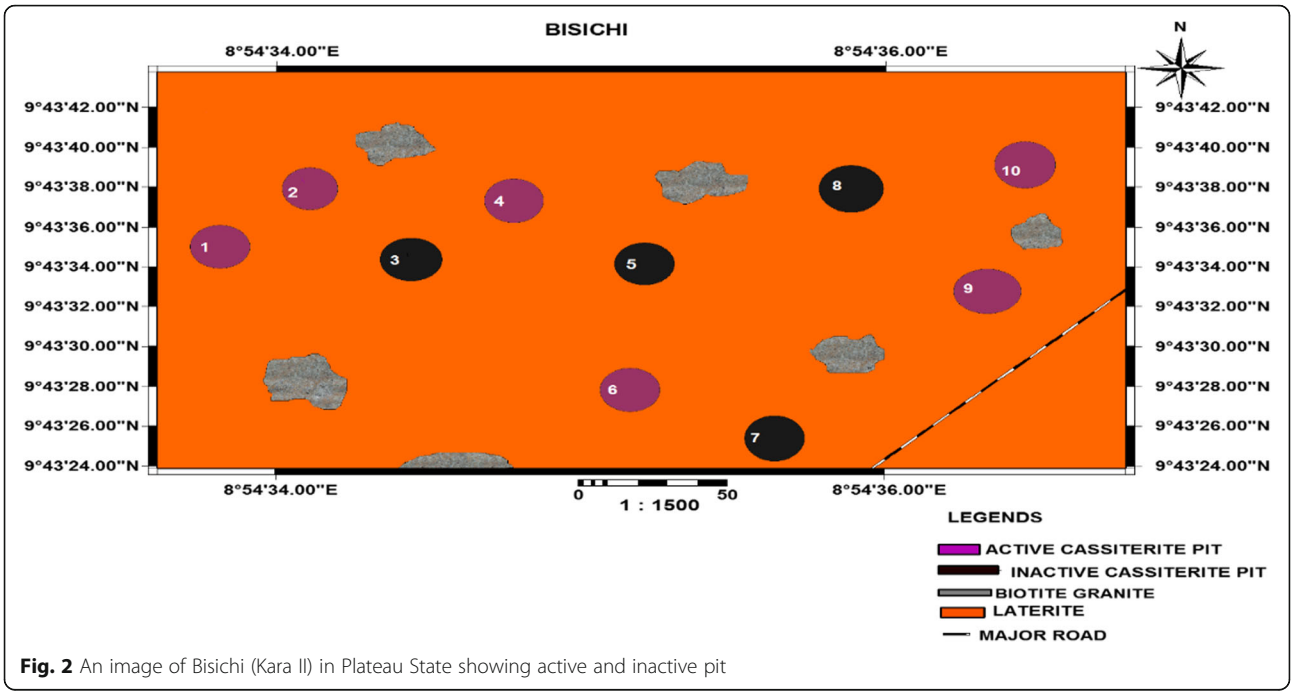

Fig. 2 An image of Bisichi (Kara II) in Plateau State showing active and inactive pit

Well development and extraction of cassiterite (tin ore) in Bisichi-Kara II and Kuru-Jentar, Plateau State

Around the study area (Bisichi-Kara II and Kuru-Jentar), mine development is accomplished through a series of vertical pits (shafts) while the extraction of the mineral (cassiterite) is done using diggers and shovels. A total of fifteen (15) active mining pits, six (6) active sluice boxes, and 20 inactive pits were sighted during the visit. The areas where pits were sighted had a stronger soil formation which made it possible for the pit to be dug. The development and extraction of minerals is accomplished through the mine syndicate system consisting of about ten team members. The various means employed in mining the mineral deposit are fully shown in Table 2 below while a cross-section of the mine pit is shown in Fig. 4 below.

Digging

The digging of the pits extends to a depth of between 30–50 ft but the shallowest pit being about 30 ft with a diameter of about 3.0 ft. The tools used include a digger, shovel, torchlight, wheel, and bucket.

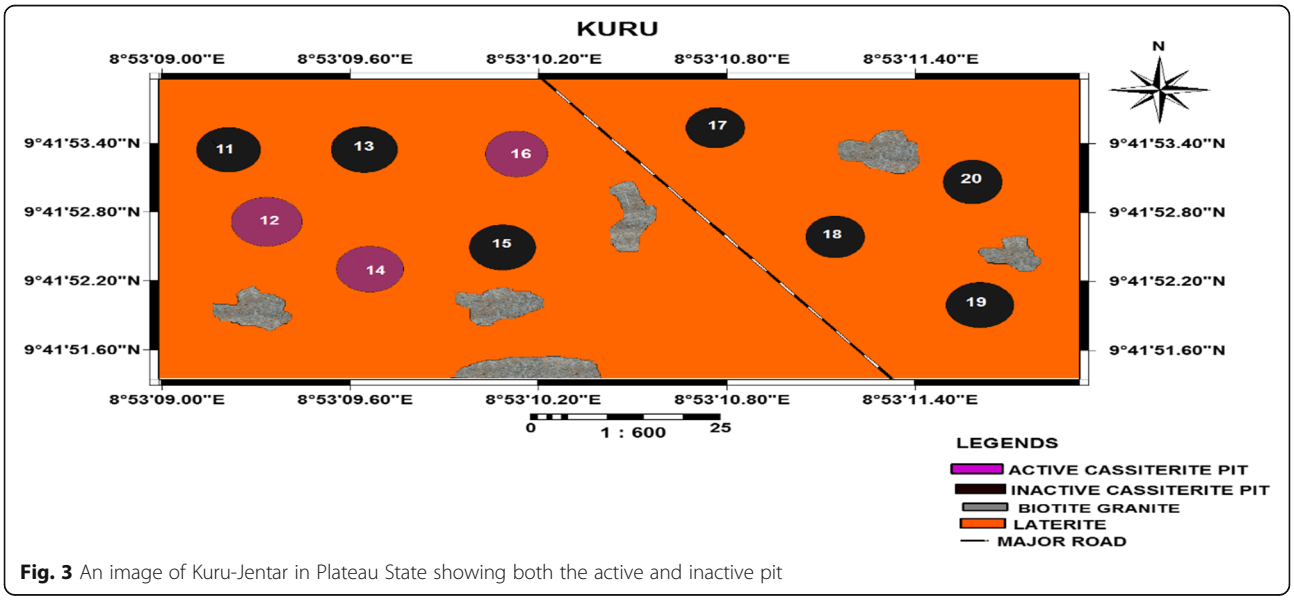

Fig. 3 An image of Kuru-Jentar in Plateau State showing both the active and inactive pit

Table 1 Table of sampling point location

S/N	Latitude	Longitude	Elevation	S/N	Latitude	Longitude	Elevation
1.	1075377	490195	1239 m	6.	1071961	487516	1228 m
2.	1075316	490145	1240 m	7.	1071948	487486	1227 m
3.	1075194	490031	1239 m	8.	1071908	487476	1228 m
4.	1075132	490040	1239 m	9.	1071902	487476	1225 m
5.	1075132	490040	1239 m	10.	1071883	487495	1226 m

Excavation

Excavation of the mineral deposit from the primary deposit is carried out along the trend of mineralization. Horizontal opening can extend to about 25 ft depending on the extent of mineralization or availability of oxygen within the sub-surface.

De-watering

A water pump machine is used to extract water out of the mine pit into a neighboring pit. Two types of water pumps are used which are the 2-inch inlet and outlet pump and 3-inch water inlet and outlet pump. The 2-inch water pump is considered to be more efficient because of its higher water pumping height.

Haulage and hoisting

The use of a wheel and buckets were employed by the miners as a hoisting system for the extraction of the wash layer from the well to the surface while the women further haul the mineral ore in headpans to the ground sluice boxes locations.

Processing

The artisanal miners use the rudimentary method in the absence of a mechanized method. Ground sluicing boxes are designed in a manner that the wash passes through several stages pushed by flowing water delivered by water pumps. The lighter materials float pass while the denser materials (those with higher specific gravity), tin, columbite, and iron tailings, are left behind. Ground sluicing is effective in places where there is a large water body.

Mine illumination

Candles and torchlight are used for illumination within the shaft though torches are more preferable because it reduces competition of air consumption between the

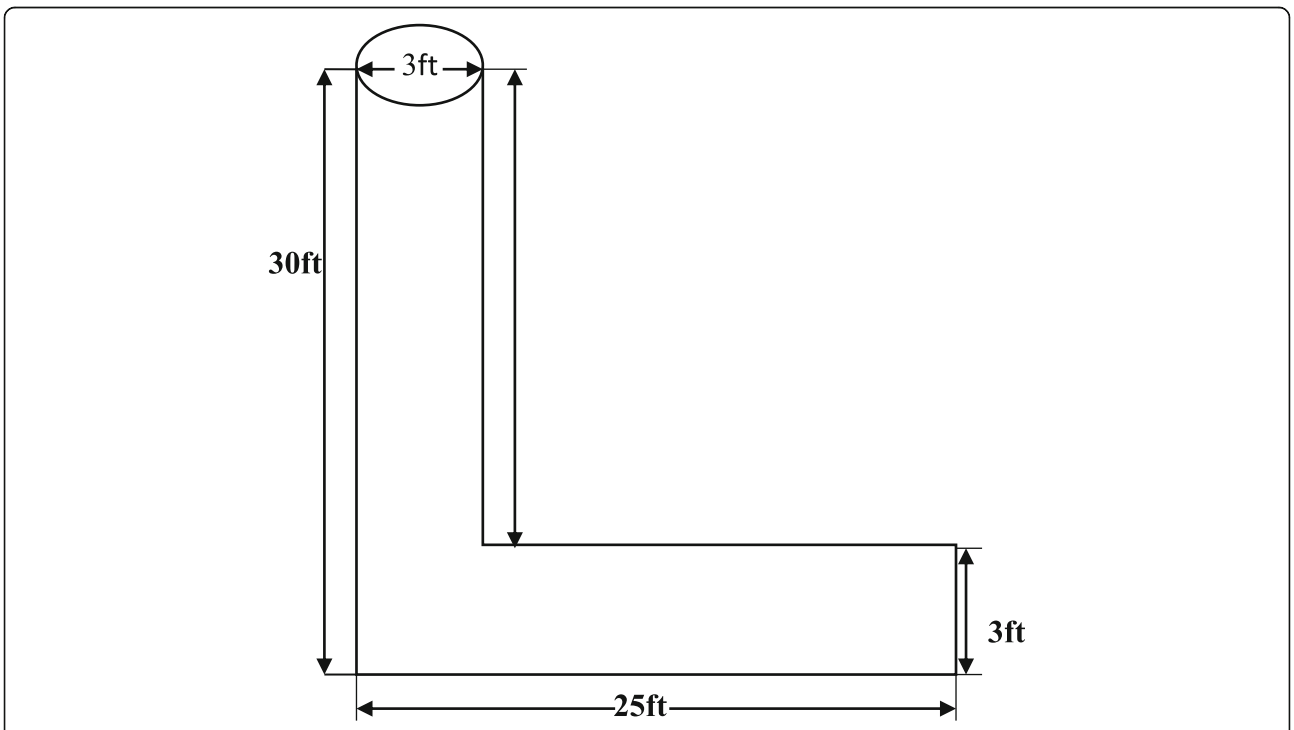

Fig. 4 A Cross-sectional design of a lotto pit

individual and the candle. Also, it reduces heat generation within the hole.

Table 2 Outlined images for the different processes used for mine development

Result

The obtained results are shown in Fig. 5 and Tables 3, 4, and 5 below

ND not detected

Mallo (2017)

Discussion

From Table 3 above, the obtained result from the laboratory proves that the content of tin (Sn) in Kuru-Jentar ranges from 44.45 to 44.9% and hematite (Fe_2O_3) ranges from 7.86 to 9.00% which makes it clear that the grade of tin (Sn) in the study area is high compared to that of hematite (Fe_2O_3). Table 4 contains the cassiterite reserve in Nigeria from 1972 to 1977 while Table 5 contains the cassiterite reserve of the study area where samples were taken for analysis. It shows that Kuru Jentar – Bisichi has a cassiterite reserve of 507. As seen in Fig. 5 above, the bar chart shows the various prices of Tin in its raw form and semi-processed and processed form. Though the practice used at the visited mine site is local and primitive yet, they are able to extract the following daily.

One lotto pit = 3–4 bags (50 kg) full of cassiterite (depending on the lode), 35 lotto pits as seen in the site will produce 104–140 bags of cassiterite. When it is processed industrially using either the magnetic or the air float machine, 1 bag (50 kg) of floated cassiterite = ½ bag of tin and other associated minerals (depending). One hundred forty bags of floated cassiterite can be within the range of 70–80 bags of tin (could be ¼ of columbite and others).

Using the price rate of 2018 for processed tin;

One bag of tin (50 kg) = ₦165,000

Table 3 Analyzed cassiterite samples at Kuru-Jentar

Oxide composition (%)	CEB 6	CEB7	CEB 8	CEB 9	CEB 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
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

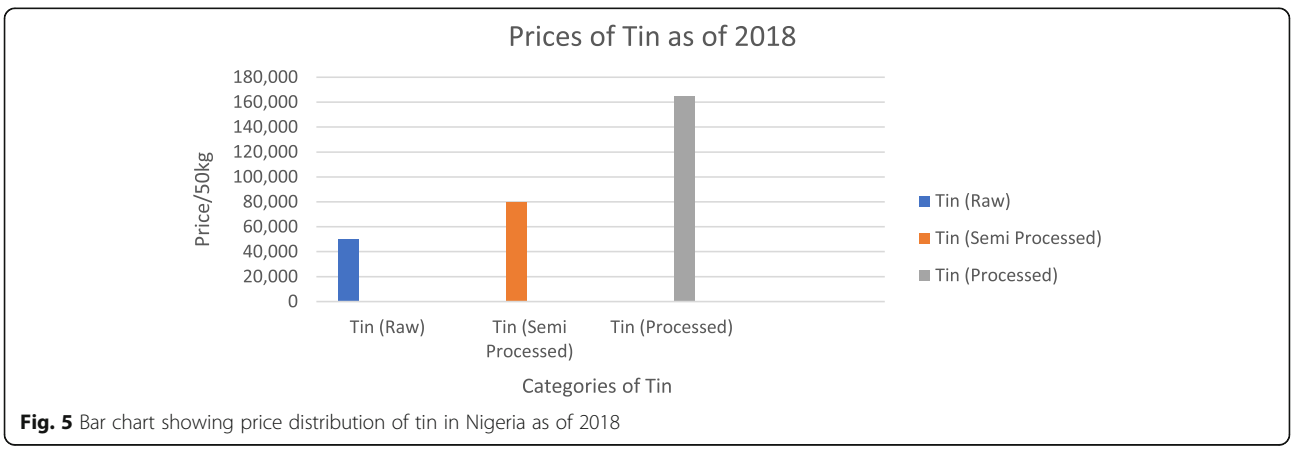

Fig. 5 Bar chart showing price distribution of tin in Nigeria as of 2018

Table 4 Cassiterite reserve in Nigeria from 1972 to 1977 (metric tonnes)

Company	1972	1973	1974	1975	1976	1977	Latest reserve position
ATMNLTD.	–	44,436	45,172	49,165	48,165	48,840	49,313 31 March 1978
Ex-lands Nig.Ltd.	3283	2964	2969	2722	3054	2953	2953, 31 December 1977
Kaduna Prospecting Nig.Ltd.	2300	2330	2820	3083	3087	2596	3004, 31 December 1977
Gold and Base Metal Mines of Nig.Ltd.	2292	2190	2291	2269	2510	2260	2260, 31 December 1977
Bisichi-JentarNig.Ltd.	–	–	–	–	–	11,638	11,638, 31 December 1977

1 lotto pit = 4 bags (₦660,000)/day, #19,800,000/month, and this continues as long as there is no interruption in the production but even though there is, the money realized within the period of production will add up to the GDP of Nigeria thus strengthening the economy.

Note: This price is subject to International Market which depends largely on demand.

The various contributions from a controlled mining scheme

Irrespective of the rudimentary means used by these artisanal miners in mining this mineral deposit yet, they are able to pull out a maximum number of 4 bags of cassiterite per hole which is equivalent to ₦660,000 daily (using 2018 price rate for processed tin of #165,000 per 50 kg). This amount of money is far above the minimum wage saga that has been debated on a daily basis in Nigeria**.** A well-controlled scheme will lead to the following:

(1) Revival of the various dead milling industries in Nigeria thus making Nigeria a producing nation instead of been a consuming nation.
(2) Job creation: This will in turn create jobs for both the educated and the uneducated. This also will make Nigerians become self-employed thus reducing the pursuit for a white-collar job.
(3) Component production: Through this avenue, Nigeria can become a producing nation after proper mineral beneficiation and metallurgical processes applied.
(4) Financial stability: When this mineral is mined in a large quantity, it can be exported to other countries that need it and when exchanged, it will further strengthen the GDP of the nation and, thus, place the nation back on her economic feet again.

Table 5 Estimated cassiterite reserve in the study area (metric tonnes)

Study area	Cassiterite reserve
Kuru Jenter – Bisichi	507

Recommendations

The recommendations are as follows:

(1) Forming of registered cooperatives that would take a record of cassiterite mined per day/yearly.
(2) Payment of taxes to the various cooperatives
(3) The government should bring the market to the artisanal miners instead of the middlemen
(4) Special financial grants through the cooperatives to encourage mechanized mining thus increasing productivity.

Conclusion

Nigeria is blessed with an abundance of solid minerals (such as cassiterite, columbite, and tantalite) which are needed for the production and development of components such as electrical motherboard and jet engines. Also, the exportation of these minerals can also add to a more stable economy in Nigeria when it is exchanged instead of relying on the dwindling monetary supply from the oil and gas sector.

Abbreviations

GDP: Gross Domestic Product; XRF: X-ray fluorescence analysis; IGR: Internally Generated Revenue

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Author's contributions

Field work, digitizing of mine maps, writing, and typing of research. The author read and approved the final manuscript.

Author's information

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