A Reconnaissance Survey Of Artisanal Mining Clusters At Rasa And Rahei-Larwin, Naraguta Sheet 168 SE, North-Central Nigeria

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***Abstract*—Artisanal mining plays a pivotal role in alleviating poverty in the developing world, and contributes significantly to national revenues and foreign exchange earnings. Its contribution has been recognized by the United Nations and is being encouraged to be carried out in a sustainable and environmental friendly manner. This paper examines the characteristics of mining activities of a selected artisanal mining locality in Jos Plateau while underscoring the need for friendly environmental mining practice that will check the furtherance of menace of land degradation within acceptable measures pertinent to the industry. Two mining clusters were reviewed to ascertain the mining methods used and the extent of environmental degradation and exposures to possible radiation by the artisanal Miners. The traditional sub-Surface Loto mining methods were employed with little or no regard to health, safety and environmental considerations. Land subsidence observed in the mining environment resulted from ground pressure exerted on sub-surface excavations made without recourse considerations on geological factors (physical and mechanical properties) of the overlaying ground, the bedding conditions, the presence of water, the dimensions of the excavation and the amount of support provisions in the excavated areas. Alluvial gamma radiation was taken at two dimension, horizontally =0.357(μSv) and vertically=0.470(μSv). Gamma readings taken around Primary deposits around the ground sluice box gave horizontal reading of 0.385(μSv) and vertical reading is 0.401(μSv). This level of radiation is relatively low and not harmful by face value however long time exposures could impair on health of the artisanal Miners. It is recommended that adopting conventional mining methods and appropriate land reclamation will significantly reduce environmental degradation and health risk.**

Keywords—Artisanal mining; Environmental degradation; Radiation; Reconnaissance survey; Subsidence

I. INTRODUCTION

Artisanal mining is of great economic and social significance in Nigeria though often an illegal and high-risk activity. It is usually practiced on a small scale by people who are often poor, uneducated, and lack other employment opportunities Mallo et al. (2011). It is a highly unregulated sector and subject to harsh working and living conditions. Since small-scale miners are not trained, they often do not realize that the methods they use to mine minerals are potentially risky to life, the environment and their health (Mallo, 1999). Artisanal mining methods include open cast which involves the use of primitive tools such as diggers, hoes, shovels etc. and underground tunneling (loto). Apart from stripping off arable farmlands, very deep pits are often left behind after exploitation without being reclaimed and these usually serve as death traps to the inhabitants of the area. In spite of the above mentioned consequences, artisanal mining has become a major occupation of most rural communities (where the soil is highly mineralized) during the dry season when farming activity would have ended, serving as a source of income for such people. It is important to note that in spite of experiencing its share of environmental, health and safety related problems that adversely impact human quality-of-life; artisanal mining plays a pivotal role in alleviating poverty in the developing world, and contributes significantly to national revenues and foreign exchange earnings (Hilson, 2012). Though these important socio-economic contributions make artisanal mining an indispensable economic activity (Hilson, 2012), there is an obvious need for improved sustainability in the Nigerian mining industry, more specifically, for operations to resolve pressing problems, many of which have wide-ranging impacts. Mallo et al., (2012) stated that if the problems associated with artisanal mining are solved through legalization, institutionalization and environmentally sound technology, artisanal mining might have a prospect of developing into sustainable small scale mining sector.

This paper examines the practice of small-scale mining in two localities in Jos Plateau. It furthermore underscores the need for friendly environmental mining practice that will check the furtherance of menace of land degradation and health risk factors. Reworking of the mine dumps is done mostly in the dry season on relics of defunct international mining Companies such as Amalgamated Tin Mining of Nigeria (ATMN), Gold and Base and Bisichi

Jantar. This mining activity has devastated the land, thereby rendering the land difficult for infrastructural development, agriculture purposes and socio economic development. In fact, from the study carried out, 45% out of 25square kilometer of the area under study has been devastated due to pit and dumps created out of it. Furthermore, this pits created due to mining activities have been death traps for both animals and humans. Therefore, the area calls for urgent intervention by the Government to reclaim the devastated land and also orientate the artisanal miners presently mining the minerals on how to mine the minerals safely without destroying the environment.

The area covers part of Jos South and Barkin-Ladi Local Government Areas situated within Jos-Bukuru and Ropp complexes respectively. The Younger Granite in the study area have been washed downstream and therefore making the cassiterite mined as alluvial deposit in the eastern part and as primary deposit in the south western part of the study area (Fig. 1). The mineralization of this area has been obscured by the lateritic layers and is of paramount interest because they are highly mineralized with Cassiterite, Columbite, and Tantalite. Despite the decline in large scale mechanized mining, small scale mining and reworking of old mines has been on the increase. From observation, all these mining activities started from the colonial era (mechanized mining) to post-colonial era (artisanal mining) which has led to environmental degradation or devastation and formation of mine ponds or artificial lakes. Therefore destroying the vegetation and exposing the land to erosion as well as rendering the land difficult for agriculture.

2. Geology and Mineralization

Jos-Plateau is part of the Nigerian Plutonic Younger Granite province which was first defined by Falconer (1911). The Younger Granites occur as hilly massifs sharply differentiated from the smoother topography of the surrounding basement rocks. The biotite-granites are the most abundant and widespread rock types on the Plateau (fig.1). They form some of the largest individual intrusions (MacLeod et al., 1971), and contain a wide variety of interesting accessory minerals which include zircon, fluorite and iron oxides, thorite, monazite and xenotime (Turner, 1989).

The Younger Granites of Jos Plateau are known to be predominantly mineralized with tin (cassiterite) and columbite (Falconer, 1921 & MacLeod et al., 1971) which has prompted extensive mining activities in the area presently and uncontrolled. The biotite granite of the Jos-Bukuru and Ropp complexes where the study area is situated have produced at least 75% of Nigeria's cassiterite, and it is on and around these two complexes that the greater part of the mining industry is concentrated (Mallo, 2007).

Total reserves of cassiterite and columbite in Nigeria Younger Granite province are estimated to be of the order of 140,000 and 70,000 tonnes respectively and exist as rich alluvial deposits (Mallo, 2011). This is sufficient for several years of further production at existing rates, other minerals found as alluvial concentrations include magnetite, ilmenite, zircon, thorite and monazite, basal gravels and sand layers of the fluvio-volcanics are also repositories of alluvial cassiterite derived from early un-roofing of the Younger Granites. Thin basaltic flows of the youngest volcanoes are hindrances; they occupy old river valleys covered with alluvium hard capping. This interferes with geophysical prospecting for concentrations of cassiterite and columbite in underlying alluvium (MacLeod et al., 1971).

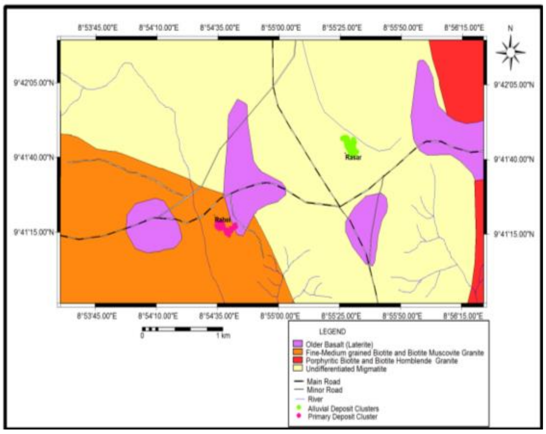

Fig. 1: Geologic map of the study area showing the various clusters (Modified after MacLeod, 1971)

3. Materials and Methods

Satellite image, Topographic map, Gamma Scout, Shuttle Radar Topography Mission (STRM) image and geological map were brought together into a Geographic Information System (GIS) data base. This involved establishing the spatial extent of the study area and assembling the various spatial data used in the study in digital form with the aid of ArcGIS 9.3 software. Ground trotting was done to delineate geological boundaries with the help of a Global Positioning System (GPS). Photographing and satellite image was used to confirm the acquired field data, mining ponds, mining spoils, ground sluice boxes, mining pits and their aerial coverage. The GPS coordinates of the pits were itemized using an XYZ data file format to post in ARCGIS environment as clusters (Mining Clusters).

4. Findings and Discussions

4.1 Reconnaissance Survey of Mining clusters

The field visits were concentrated on present and past areas of tin mining with easy accessibility. It was focused in two localities, Rasa of Foron District which is an alluvial deposit and Rahei Larwin of Heipang District being a primary deposit. The primary deposit site was an abandoned site mined by the Bisichi-Jantar since the 1960s. The area under study falls within Latitude 9^{0}40' 51.23"N – 9^{0} 42' 15.14"N and Longitude 8^{0} 53' 30.87"E – 8^{0} 56' 23.30"E (fig.2).

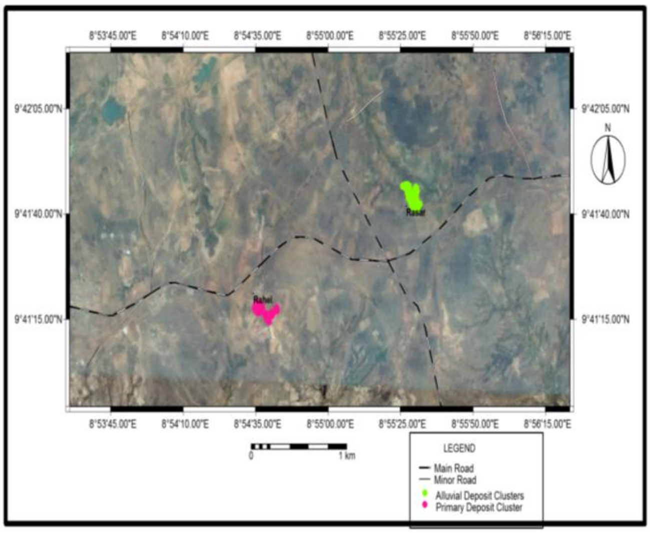

Fig. 2: Satellite image of the Rahei and Rasar mining clusters and environs

4.1.1 The Rasa Alluvial Mining Cluster

This Mining Cluster is located in Rasa, Foron along an old river channel N $09^0$41’38.9” and E$008^0$55’26.3” and Elevation 1249 m above sea level.

The mineral is mainly won from near surface to sub-surface by a group of individuals. Vertical shafts are sunk to the wash level or mineralized area before horizontal excavations for several meters till the wash is exploited. As the horizontal distances increase, another shaft is sunk to intercept the horizontal adit in order to increase ventilation in the mine and also to guide against roof collapse. The miners employed crude method to exploit the minerals without any form of mechanization and recourse to safety. The work is divided between the workers, some dig while others hoist the ore from the pit to be washed or processed. Women are normally found at the site waiting to be employed for the purpose of hauling the mineral from the mine to the closest source of water for ground sluicing. After the Tin must have been washed and separated from the gangue, the women are then paid in kind with a portion of the cassiterite ore. On a daily basis up to 500- 1000 people converge at the mining clusters, consisting of the miners, women haulers, food sellers, alcohol dealers, middle men and other hungers-on. There were several number of pits dug, which can be estimated to cover an area of 500m by 250m. For each of the pit, an estimated number of four or more people are involved in the digging, hoisting and dressing of the mineral.

The owner of the piece of land being mined is compensated for every wash exploited, hence has the sole responsibility of reclamation. However, this is not usually the case. In situations where there is reclamation, only the vertical shafts are filled while the underground horizontal opening left opened; thereby subjecting the land to subsidence. A reclaimed land is expected to be cultivated to allow for stabilization before any development can be carried it on it.

There have been cases of deaths recorded at the site due to mine collapse which can be attributed to the poor structuring of the mine. Various mining activities at the Rasa alluvial Cluster are shown in Plates 1-3.

Plate 1: Mine pits within the alluvial tin field (Rasa Foron)

Plate 2: A sluicing box for the washing of the ore (Wash)

Plate 3: Reclaimed site being cultivated. (Rasa Foron)

4.1. 2 The Rahei-Larwin Primary Deposit Mining Cluster.

This Mining Cluster is located at Rahei-Larwin in Barkin Ladi LGA - N09^0 41’16” and E008^0 54’34.3”, Elevation of 1269m above sea level.

Historically, the area was first mined by Bisichi Mining Company and later joined by Jantar Mining Company to become Bisichi-Jantar. Mechanized method of mining using draglines, dredges and electric pumps were employed during the 1950’s and 1960’s. A pit dug in the 1950s by this company was discovered on the site. A void created underground during the operation caused sinking of the dragline into the ground making the Bisichi-Jantar company to resort back to the pitting method of mining just like the artisanal miners do, but here the room and pillar mining method is employed, i.e. a pillar is created on the wall of the underground to protect the wall from collapsing.
Due to the sinking of the ground the site was abandoned until recently when the locals resume work on the site using the crude method of mining (plate 4). The vertical shafts range from 7 to 13m depending on the level of the wash and the horizontal movement can run for several meters long. As excavation of the mineral deposit takes place through the process of digging, other people take it to a source of water to be washed.

Sluice boxes are used for washing of the ore to separate the mineral from the gangue (plate2). Generally, the sluice boxes are arranged parallel to each other all connecting to collection centre (the tailing dam). The mineral is placed at the top end of the sluice boxes and water is directed with pressure at its face which runs down the sluice boxes as slur under gravity. The Cassiterite settles at a collection chamber just before the tailing dam, tailings are then emptied into the tailing dam. Direct and indirect methods of exploration by prospecting pits were used by Bisichi-Jantar to search for the Wash and the level of mineralization. The direct method has to do with evidence of mineral on surface and the indirect method involves understanding structural geology and mode of occurrence or deposition of the mineral. The trend of the wash underground determines the pattern of horizontal movement. Below is the field sketch of active and abandoned pit defining the trend of wash, mining is carried out based on the mineral trend. Depending on the trend of the mineral, the pits are interconnected to each other as shown in fig. 3

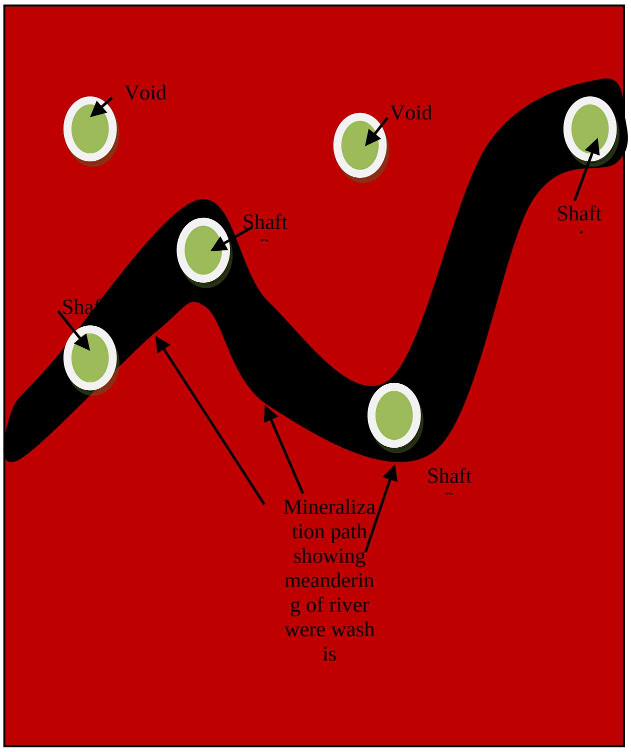

Fig.3: Plan view of schematic illustration of shaft/mining pit mineralization pattern

4.2 Ground Subsidence

Geologically, alluvial tin wash, which is mined by artisanal miners, is often bedded or flat in structure (Mallo, 2007). Whenever a bedded mineral deposit is extracted the overlying strata sinks to fill the void (plate 6). Such subsidence may not occur when the extracted areas are small, but it inevitably follows extraction over a large area. According to Mallo (2007), the overlying clay/sand strata do not dip more than about 15or 20^0 (about 1 in 3). The subsidence results from rock pressure which depends on the geological factor (physical and mechanical properties) of the overlying ground, the bedding conditions, the presence of water, the dimensions of the excavation and the amount of support provided in the excavated area (goaf). The basis of rock pressure is weight, because the upper layers of ground mass press on those below them and these in turn react to this pressure. At the Rahei-Larwin site where ground subsidence was reported, after the ground mass have been penetrated by subsurface loto excavation, the loss of balance resulted in the change in stresses around the excavation resulting in failure of the earth material. A line of subsidence with relative displacement of 15cm to 20cm with a distinct angle of inclination between 20-25^0close to one of the pits on site was abandoned because of ground subsidence, but no life was loss because of early detection (plate 5). Similarly, death site resulting from carbon monoxide suffocation emitted from an electricity generating plant led to the death of some of the miners in the same pit (plate 7).

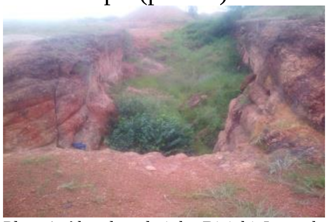

Plate 4: Abandoned pit by Bisichi-Jenta showing relative displacement in Rahei-Larwin

Plate 5: Showing evidence of subsidence (black line showing line of fault while the orange line shows extend of displacement)

Plate 6: Evidence of collapse in a nearby open pit close to the line of subsidence

Plate 7: Death site of miners from carbon monoxide suffocation

4.3 Radioactive Hazard

The study shows several heaps of mineral tailings which are by-products of cassiterite processing which could be sources of radioactive materials such as monoxide, zircon found in association with cassiterite and columbite (plate 1). A gamma count was used to measure the gamma radiation of the heaps and tailings around the sluice boxes using the Standard unit of Sievert (Sv). Maximum permissible dose recommendations for occupational exposure are usually greater than for general public (Solomon, 2002). The rationale is that “radiation workers” presumably accept theincreased risk by informed consent as a trade-off in exchange for the benefits of employment. Radiation doses from gamma sources in the study area indicate alluvial material to be 0.357µSv-0.470µSv. Primary deposit gamma reading around the ground sluice box has a range of 0.385µSv- 0.401µSv (Plate 7 and tables 1& 2). In line with radiation study by Solomon (2005), the doses of the radiation from the study area do not pose much occupational health risk. But long term exposure could lead to long-term impact on the environment as radionuclides may gradually enter the food chain and cause radiological hazards.

Table 1. Radiation reading within and around the mine pits

S/NO	CORDINATES	DEPTH (m)	RADIATION (µSv)
1	09º41’33”; 08º55’31.2”	2	0.306
2	09º44’32.9”; 08º55’31.8”	6	0.290
3	09º41’33.5”; 08º55’30.7”	2.1	0.280
4	09º41’33.5”; 08º55’30.8”	3	0.226
5	09º41’34.2; 08º55’30.8”	5.7	0.242
6	09º41’34.2”, 08º55’30.6”	1.6	0.226
7	09º41’34.3” 08º55’30.5”	5.9	0.242
8	09º41’35.0”, 08º55’31.0”	6.2	0.188
9	09º41’34.9”, 08º55’30.7”	4.2	0.180
10	09º41’35.6”; 08º55’31.1”	1.7	0.174
11	09º41’35.6”, 08º55’30.1”	2.4	0.188
12	0941’36.6”; 08º55’31.8”	4.5	0.290
13	09º41’36.0”; 08º55’30.4”	2.7	0.173
14	09º41’36.0”; 08º55’30.0”	5.6	0.203
15	09º41’35.8”; 08º55’29.8”	3.3	0.226
16	09º41’37.3”; 08º55’31.3”	4.3	0.188
17	09º41’37.4”; 08º55’29.1”	3.5	0.188
18	09º41’37.4”; 08º55’29.4”	1.3	0.219
19	09º41’37.8”; 08º55’29.9”	3.3	0.203
20	09º41’38.0”; 08º55’31.6”	3.3	0.234
21	09º41’39.9”; 08º55’28.3”	3.9	0.250
22	09º41’42.7”; 08º55’28.3”	5	0.266
23	09º41’4203”; 08º55’23.5”	40.8	0.306

Table 2. Radiation reading within the active pits

S/NO	CORDINATES	DEPTH (m)	RADIATION(µSv)
1	09º44’32.9”; 08º55’31.8”	10.7	0.290
2	09º41’31.9”; 08º55’30.9”	13.4	0.226
3	09º41’33.2”; 08º55’30.6”	10.1	0.178
4	09º41’35.5”; 08º55’3101”	13.4	0.258
5	09º41’34.1”; 08º55’30.9”	12.2	0.173
6	09º41’34.0”; 08º55’30.7”	8.8	0.173
7	09º41’34.4”; 08º55’30.8”	11.89	258
8	09º41’35.5”; 08º55’31.2”	8.4	0.332
9	09º41’34.7”; 08º55’31.5”	7.89	0.226
10	09º41’34.6”; 08º55’30.3”	11.8	0.234
11	09º41’35.2”; 08º55’31.5”	7.3	0.196
12	09º41’35.1”; 08º55’31.2”	8.14	0.250
13	09º41’34.8”; 08º55’30.8”	13.6	0.196
14	09º41’34.6”; 08º55’30.4”	7.8	0.226
15	09º41’35.1”; 08º55’31.1”	7.4	0.219
16	09º41’35.7”; 08º55’31.2”	8.19	0.234
17	09º41’35.5”; 08º55’30.7”	11.2	No tailing
18	09º41’35.4”; 08º55’30.3”	14.2	0.211
19	09º41’35.6”; 08º55’30.4”	9.2	0.179
20	09º41’35.9”; 08º55’30.7”	9.5	0.188
21	09º41’36.0”; 08º55’31.0”	13.7	0.203
22	09º41’36.6”; 08º55’31.6”	10.6	0.226
23	09º41’36.5”; 08º55’31.3”	12.4	0.203
24	09º41’36.7”; 08º55’31.5”	12.1	0.250
25	09º41’36.5”; 08º55’31.1”	14.2	0.234
26	09º41’36.3”; 08º55’31.0”	13.4	0.234
27	09º41’36.4”; 08º55’30.8”	12.8	0.306
28	09º41’36.2”; 08º55’30.8”	14.8	0.226
29	09º41’36.5”; 08º55’25.6”	8.7	0.258
30	09º41’36.6”; 08º55’29.5”	13.5	0.185
31	09º41’36.9”; 08º55’30.2”	9	0.203
32	09º41’37.0”; 08º55’30.6”	12.6	0.173
33	09º41’37.2”; 08º55’30.4”	13.3	0.258
34	09º41’37.0”; 08º55’31.0”	12.3	0.196
35	09º41’37.3”; 08º55’30.2”	13.2	0.250
36	09º41’37.3”; 08º55’30.1”	13.2	0.299
37	09º41’37.5”; 08º55’30.3”	12.7	0.242
38	09º41’37.7”; 08º55’30.4”	13.5	0.196
39	09º41’39.7”; 08º58’30.5”	13.6	0.336
40	09º41’40.2”; 08º55’29.5”	12	0.306

5. RECOMMENDATIONS

1. Geophysical survey should be encouraged in mineral exploration to avoid digging of void pits.
2. The face of digging should be aligned (the surface of digging should be smooth)
3. The geo-mechanical properties of the soil should be tested to know if it’s likely to collapse when tempered with
4. Mining activity should be carried out in line with best practices. Mine sites should be reclaimed after exploitation, so as to reduce the danger of radioactive material and the land can be used for other purposes. This can be achieved through the provision of educational and technical support by government if the miners are organized into Cooperatives.

5. CONCLUSION

Mining of cassiterite and other economic minerals in some localities of Jos south and parts of Barkin Ladi of the Naraguta sheet168NE is basically a source of livelihood, as the minerals are exchanged in the market for money which can be used to purchase some house hold needs and as well to sponsor wards in schools.

Mining activities has affected the land use of the study area by creating voids within the overburden leading to subsidence and also causing untimely death among individuals involved; this is as a result of lack of proper skill to extract the mineral from the subsurface geology. Evidently, random digging of pits to access mineralized zone is more of a competition amongst the artisanal miners in order to make quick cash.

With geophysical exploration, more mineralized zones can be detected. By adopting conventional mining methods and appropriate land reclamation, there will significant reduction of environmental degradation. It is evident that the level of radiation is relatively low, but continues exposures could impair on health over time.

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