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Radiation and other environmental hazards of mining: focus on Jos Plateau mining region

F.X.O. Ugodulunwa, R.O. Ukpong, A. Ongbatabo, B.N. Onazi

Department of Geology and Mining, University of Jos, P.M.B. 2084,Jos, Nigeria

Abstract

Geological mapping and gamma radiation measurements were carried out in the northern part of the Jos Plateau Mining Region. The superficial deposits were also mapped. Photographic record of the minefields in the area was also made. The area is underlain by biotite granite, hornblende biotite granite and riebeckite granite of the Younger Granite suite, as well as porphyritic biotite granite, gneisses and migmatites of the Basement Complex. The superficial deposits include laterite, clay, alluvial sand, mine tailings and mine dumps. The minesfields are littered with hundreds of hectares of mine spoils, ponds and gullies of various sizes. The ecosystem in the area has been disturbed because of the destruction of the natural vegetation (and the dependent animal life), and distortion of the physical part of the ecosystem. Gamma radiation measurements in Barkin Ladi and Sabon Gidan Kanar revealed that the radiation levels of both the bedrock and the superficial deposits (2.0mSv/yr – 62.0mSv/yr) are above the 1mSv/yr maximum permissible exposure limit for the general public which was established by international bodies like the International Commission on Radiological Protection (ICRP). Recommendations were made for close collaboration between the three tiers of government and the local people so as to ensure that all miners obey the Nigerian mining laws and regulations. Public awareness campaigns should be mounted to address the problem of exposure to high radiation levels. People should be evacuated from areas that cannot be cleaned up.

1. Introduction

The Jos Plateau Mining Region is located between longitudes $8^0$33E and $9^0$30’E, and latitudes $8^0$56’N and $10^0$12’N (Figure 1). Many types of ore (minerals) and rock aggregates are mined in this region on various scales. They include cassiterite (tin ore), columbite, tantalite, monazite, zircon, xenotime, wolframite, topaz, tourmaline, fluorite, molybdenite, lead, zinc, feldspar (orthoclase), kaolin, rutile, magnetite, ilmenite, quartz varieties and rock aggregates. The mining sites are located in virtually all parts of the Jos Plateau and immediate low lands. Some of the ores occur in lodes in hard granitic rock (e.g molybdenite), some (eg. cassiterite) occur as placer deposits in old river channels that are covered by thick overburdern, while others (e.g tourmaline and quartz varieties) occur in pegmatites. Figure 2 shows a section of a mine indicating mineralized zone. Extraction of these ores from their host rocks and subsequent processing to prepare the desired ore for sale, have resulted in great devastation of the Jos Plateau Mining Region. The region is therefore littered with hundreds of abandoned mines, mine dumps, tailings, mine lakes and polluted water (Figure 3). An effort is made in this work to highlight some of the problems mentioned above, including the high gamma radiation levels at some locations. Hopefully, the government and other stakeholders will collaborate and address these problems.

1.1. Geology

The Jos Plateau is underlain by Pre-Cambrian crystalline Basement Complex which is intruded in places by Jurassic Younger Granite Ring Complexes (Figure 4). The Basement rocks on the Jos Plateau consist of a wide variety of rocks, including granites (Older Granites), granite gneisses, granulitic gneisses, migmatties, diorites, basic dykes, etc. (Macleod et al., 1971). The Younger Granites consist of high level intrusions of granites emplaced by ring faulting and cauldron subsidence. They are petrographically, chemically and mineralogically distinct from the Older Granites. The Older Granites have clear or subdued foliation while the Younger Granites are not foliated. Some of the Younger Granites have sodium-rich amphiboles. Such amphiboles are absent in Older Granites. The Younger Granites can be classified into two based on their chemistry, namely, peraluminous or peralkaline granite. They can also be classified according to their mineralogical composition, namely, hornblende-pyroxene-fayalite granite, biotite or riebeckite granite. The Basement Complex is overlain in most locations by basalts, the Older Basalts and Newer Basalts. These basalts were released during two episodes of volcanism in the area of Jos Plateau, during Plio-Pleistocene (22-0.7 Ma?) and Cenozoic (70-60 Ma?) periods. In order to overcome the difficulty of differentiating fresh basalts from decomposed basalts, Macleod et al. (1971) classified all the basalts into three, Lateritised Older Basalts, Unlateritised Older Basalts, and Newer Basalts. Older Basalts include weathered and/or lateritised basalts, while Newer Basalts include fresh basalts. The cassiterite and columbite mineralization of the Younger Granites is associated with the peraluminous granites. The alluvial deposits are derived from weathered biotite granites and they occur in old river channels. In most places, the mineralized alluvium overlies the basement under very thick overburden. The overburden is more than 15m thick in many locations (Figure 2), while the thickness of the mineralized alluvium varies from 20cm to as much as 1 m (Ugodulunwa et. al, 1994). Local miners employ lotto mining technique to extract the mineralized alluvium (Figures 5 & 6) while big mining companies use draglines to remove the overburden to get to the mineralized alluvium (Figure 7).

2. Materials and methods

2.1. Fieldwork

Mapping of the bedrock and superficial deposits was carried out at Naraguta, Rukuba, Kigom, Sabon Gidan Kanar, Bukuru and Barakin Ladi areas of sheet 168 (Naraguta). This was supplemented by reconnaissance mapping of the geology and superficial deposits of Garun Kurama, Karambana, Jengre and Saminaka areas of adjacent sheet 147 (Lere). The main rock types mapped include biotite granite, hornblende biotite granite and riebeckite granite of the Younger Granite suite, porphyritic biotite granite, gneisses and migmatites of the Basement Complex, as well as fresh basalts of the Newer Basalt series. The superficial deposits mapped include laterite, clay, alluvial sand, mine tailings and mine dumps. Each of the mined-out area visited was littered with many hectares of mine spoils, ponds of various sizes and gullies (e.g Figures 3 & 9).The peraluminous granites of the Younger Granite suite are associated with the cassiterite (SnO_2) and columbite [$(Fe,Mn)(Ta,Nb)_2O_6$] mineralization on the Jos Plateau. These minerals occur in old river channels as alluvial deposits derived from weathered biotite granites. They occur in association with other minerals like zircon ($ZrSiO_4$), thorite ($ThSiO_4$) and monazite [$(Ce,La,Yt)PO_4$], which are radioactive and may be emitting ionizing radiation.

Radiation measurements were then carried out on the bedrock, alluvial sand, mine tailings and mine dumps in Barakin Ladi and Sabon Gidan Kanar areas, to compare the radiation levels of these environments. The bedrock in both areas consists of biotite granite and hornblende biotite granite. The Gamma Scout equipment was used for the measurements while Garmin 12 Global Positioning System (GPS) was used to determine the coordinates of the location of each measurement. The Gamma Scout measures gross gamma radiation using a radiation detecting device at its tip. Measurements were made at 31 locations. At each station the Gamma Scout is held 5-10 cm above the ground level for 30 – 40 seconds before a reading is made. An average of 10 readings were recorded for each station.

2.2. Presentation of radiation data

The gross gamma counts were converted to exposure rate in Roentgen/hour. Thereafter the exposure rates were converted to absorbed dose rate in rad/hour using the relation between the absorbed dose rate (Da) and exposure (E) as given by Grasty et. al (1984), i.e.

$$D(rad/h) = a(rad/R).E(R/h)$$

where a has the value of 0.869rad/R.

Since the effects of radiation on biological tissues differ with the types of radiation (Noz and Maguire, 1979), the roentgen equivalent man (rem) unit is normally used to compare the effects of radiation on living systems. Values obtained in rad were then converted to their rems equivalent and the Sievert (Sv), as described in Ike et. al (2002). The results obtained (in milliSievert/year) were then plotted for each environment (Figure 8).

3. Discussion

Almost all the economic mineral deposits in the Jos Plateau Mining Region occur as alluvial deposits in old river channels. The mineralized alluvium overlies the Basement Complex under several meters of overburden (Figure 2). Consequently the opencast mining method was applied by the multinational mining companies to remove the overburden and have access to the mineralized alluvium. They used draglines, power shovels and bulldozers. Unfortunately the overburden was never returned to the mining pits. They left a scarred topography with gaping holes in the ground and ugly mounds of mine spoils that extend to the horizon. Following the destruction of the natural vegetation and the laterite cap, the soil and loose rocks are readily carried away by flood to create gullies, and cause erosion and mass movements like landslides, slumping, soil creep and mudflow (Figure 9). Water has accumulated in many of the abandoned mines to form hundreds of ponds and lakes. When the multinational mining companies withdrew because of their declining economic fortunes, they were replaced by local miners who engage in random digging and informal adit mining plus tunneling (locally called lotto mining). See figures 5 and 6. Thus the devastation of the environment continued, with the addition of many unmarked deep vertical pits that litter the environment.

The mine tailings that result from the initial processing of the ores to separate them from the gangue also cause environmental hazards like contamination of surface and underground water. They also cause siltation of streams, flooding, as well as water- logging by reduction of the porosity and permeability of soils because of admixture with mine tailings. It is obvious, from the foregoing, that mining has greatly disturbed the ecosystem in most parts of the Jos Plateau Mining Region by causing the destruction or departure of some elements of the ecosystem.

Figure 8 shows that the radiation levels for the biotite granite, hornblende biotite granite, the mine dumps and sands in stream channels are in the range of 2.0mSv/yr to 7.2mSv/yr, while the radiation level of the mine tailings ranges from 3.0mSv/yr to 62.0mS/yr. One plausible explanation for this difference is that the radioactive minerals in the granites are dispersed so the radiation from them may be much less harmful than radiation from the mine tailings. The processes of extracting the ore have led to greater concentration of these radioactive minerals in the mine tailings. Nonetheless, none of these radiation levels is below the 1mSv/yr maximum permissible exposure limit for the general public which was established by international bodies like the International Commission on Radiological Protection (ICRP, 1977) and the National Council on Radiation Protection and Measurement (NCRP, 1971).

4. Conclusion

The Jos Plateau Mining Region has experienced extensive degradation of its environment as a result of many decades of mining activities. The area is littered with mine spoils and is characterized by scarred topography and mine ponds. The ecosystem has been disturbed by the destruction of the natural vegetation (and the dependent animal life), and distortion of the physical part of the ecosystem. Some parts of the area are also exposed to levels of radiation that are much higher than the maximum internationally permissible exposure limit. There is an urgent need for close collaboration between the three tiers of government and the local people to ensure that all miners obey the Nigerian mining laws and regulations. Current efforts by the government to reclaim some of the devastated land is highly commendable. The problem of dangerously high radiation levels should be vigorously addressed by mounting public awareness campaigns and evacuating areas that cannot be cleaned up.

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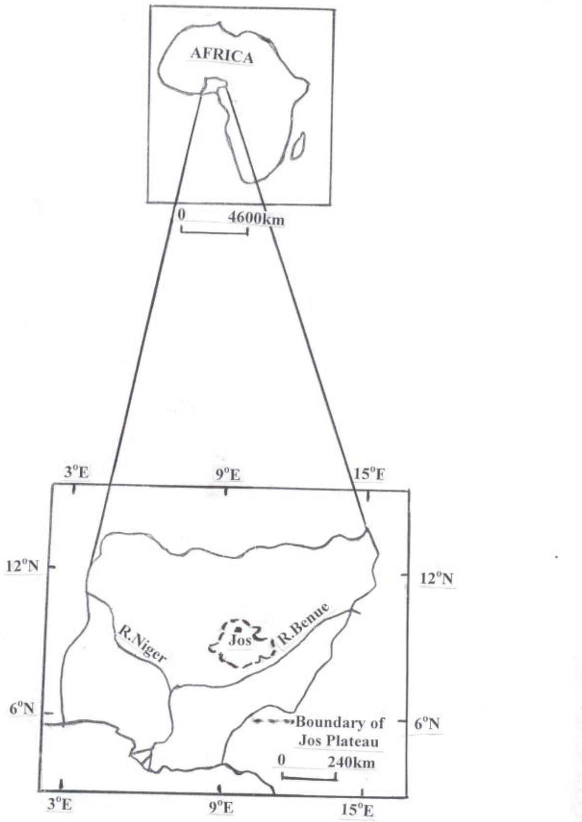

Fig. 1. Maps of Africa and Nigeria showing the location of Jos Plateau.

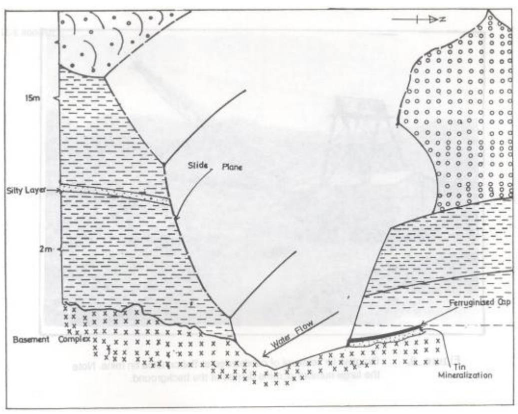

Fig. 2. Vertical section of a paddock in Sabon Gidan Kanar tin mine. Notice the mineralized zone.

Fig. 3. Amina pond in Barkin Ladi.

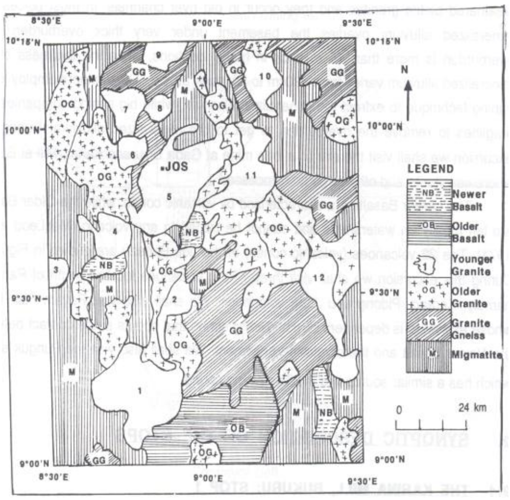

Fig. 4. Simplified geological map of the Jos Plateau. (After Macleod et al., 1971).

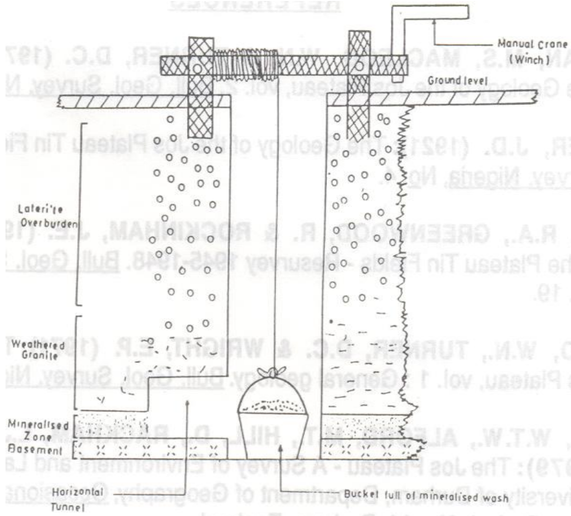

Fig. 5. Vertical section of a lotto mine.

Fig. 6. Lotto miners operating the winch. Notice the bucket of mineralized alluvium brought to the surface.

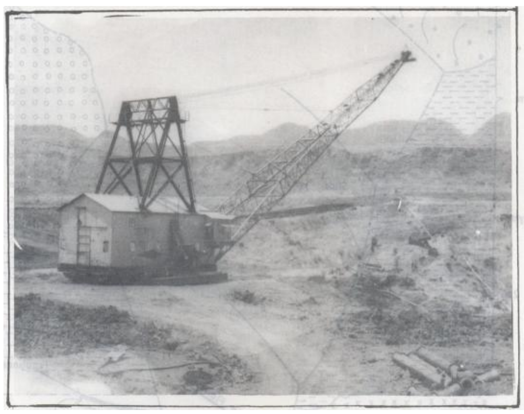

Fig. 7. A dragline for removal of overburden.

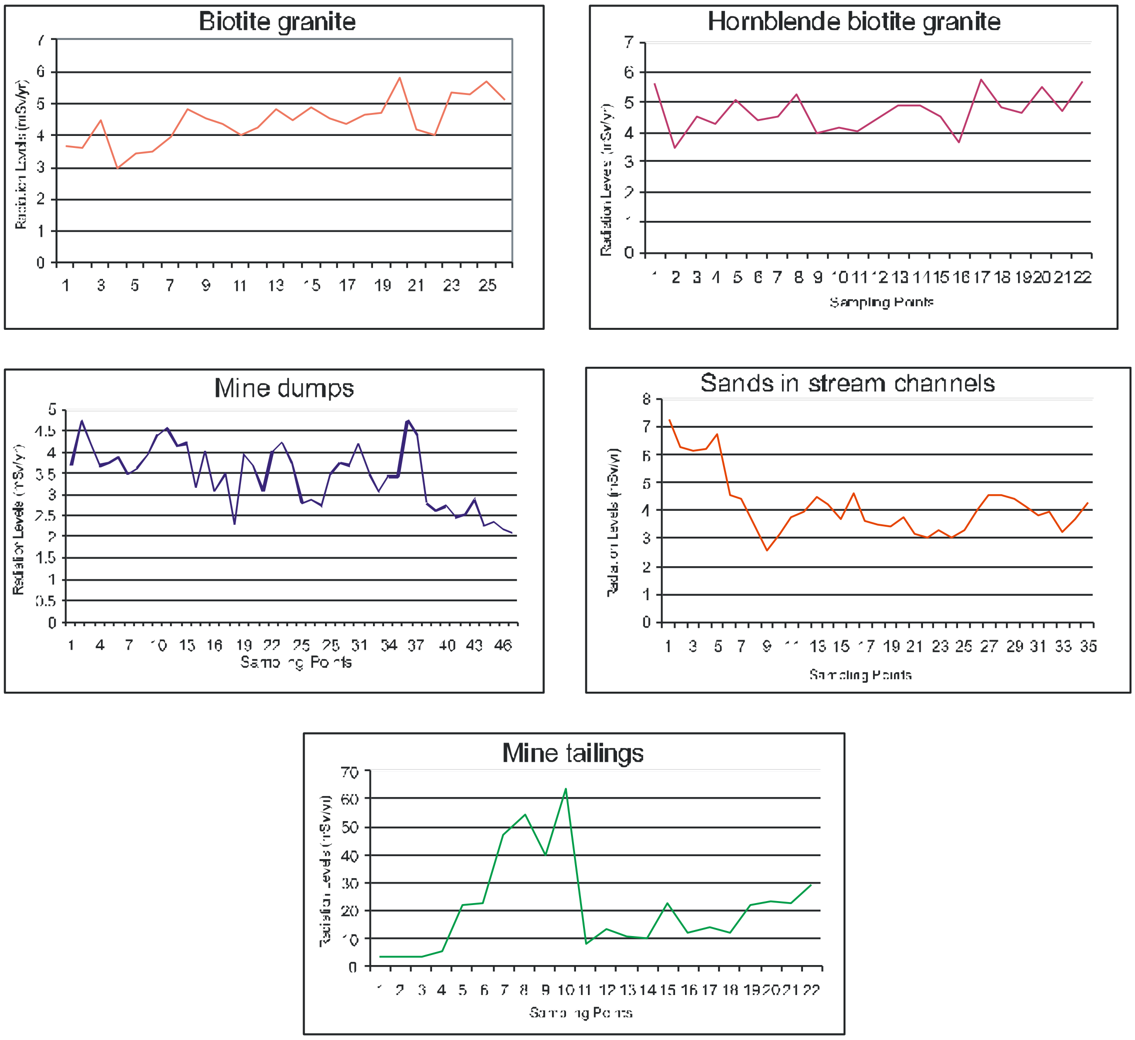

Fig. 8. Radiation levels in Barkin Ladi.

Fig. 9. Gully in a mined – out area near Barkin Ladi.