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Full Length Research Paper

Geological analysis of ground radiometric survey data of Hong hills, Hawal basement complex, N. E. Nigeria

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A ground radioactivity survey report and it geological analyses are presented in this work. The survey was aimed at delineating possible zones of concentration of pegmatite intrusions, a rock whose components are useful in the in the electrical and ceramic industries among others. The survey covers longitude 12°54'-13°00'E and latitude 10°7'-10°15'N, with a total surface area of 155.52 km2. Dominant plutonic rocks in the area are coarse grained/pegmatitic granites which occur as intrusion in the metamorphic rocks (gneiss and migmatite). The survey was undertaken with a Geiger counter at station spacing of 1 min (1') following mostly a system of grid lines. A total of 48 stations were occupied and measurements of the radiometric field variations were made. Thirteen radio-lineaments have been mapped, majority (7) align with pan African deformational direction (N-S, NE-SW). Others align in the NW and E-W directions. Some radio-lineaments correlate or align with geomorphologic features of hills and straight channel streams. Based on high radiometry and ground truthing results the northern sector of the study area is designated as a pegmatite zone. Other high radiometric zones are suggested as targets for investigation for possible pegmatite occurrences because of the economic importance of this rock.

Key words: Radiometric anomalies, basement complex rocks, pegmatites, lineaments and geomorphic features.

INTRODUCTION

Radiometric mapping came to limelight with the demand for uranium with the advancement of nuclear technology. The method can also be used in searching for non radioactive deposits associated with elements such as Titanium and zirconium. Radioactive survey is useful in geological mapping as different rocks can be recognize from their distinctive radio-signatures (Moxham, 1963; Pires and Hartil, 1989; Bassey et al., 2013). The method is also applied in structural mapping (Parasnis, 1986; Bassey et al., 2013). In geological and structural mapping radiometric survey is essentially a survey for gamma ray emissions. As such emissions are more penetrative than alpha and beta emissions.

The study area lies in the south central part of Hawal

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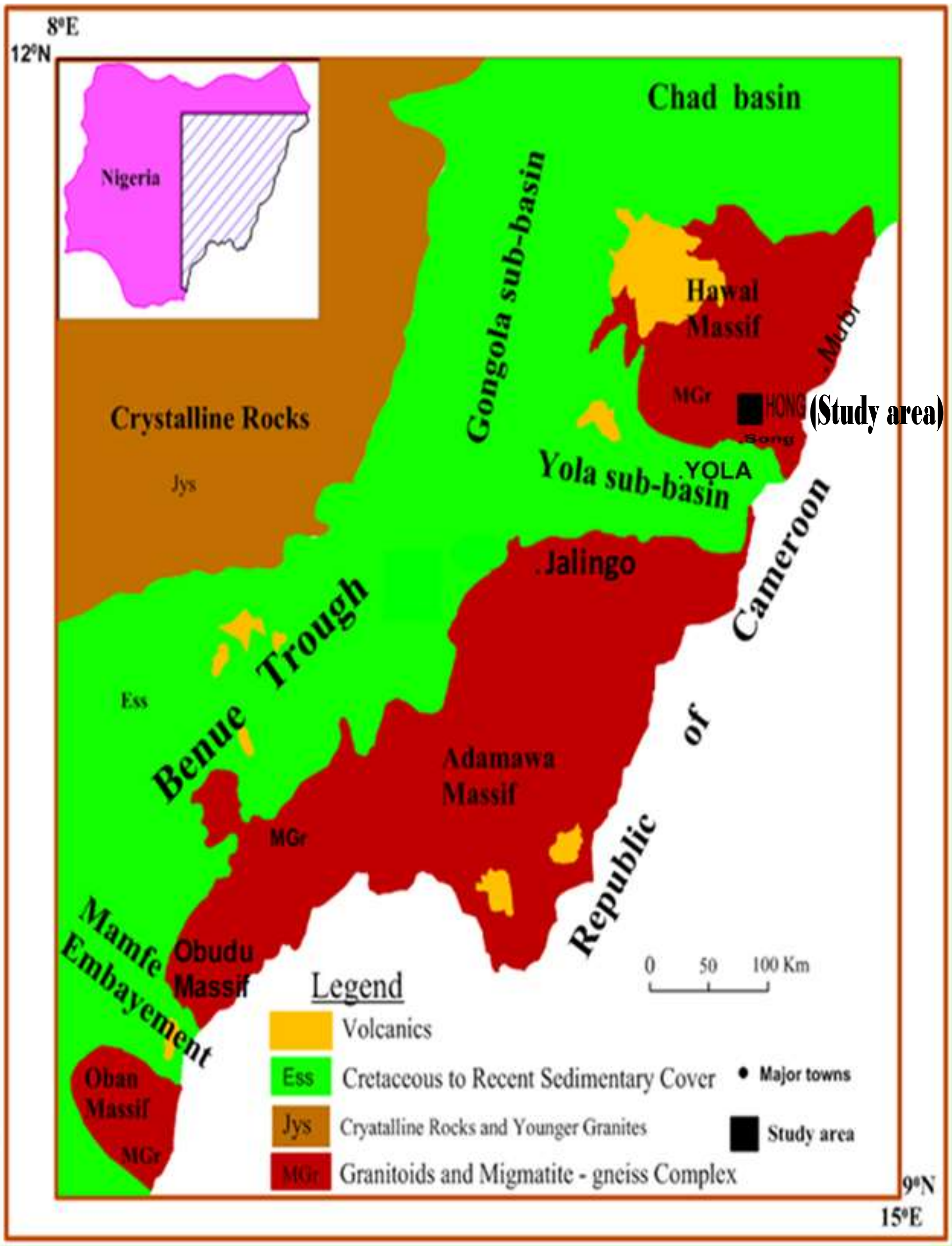

Figure 1. Regional geological map of Nigeria’s eastern Basement Complex massifs showing location of study area. Source: Adapted from Haruna et al. (2011).

Precambrian Basement Complex in North East Nigeria (Figure 1). It is bounded by longitudes 12°54' and 13°00'E; latitudes 10° 07’ and 10°15’N. Very few research works have been conducted or published in the area. Available records show some academic theses/publications. Bassey (2006) wrote a doctoral thesis which covered the Hawal massif and part of the Yola trough. Bassey et al. (2013) did radiometric mapping of Song area and delineated different rock types based on radiometric anomalies. Unachukwu (2014) wrote a radiometric based MSc thesis which covered Hong and adjacent areas. This was followed by Bassey and Barka (2015) who did litho-structural mapping using aeromagnetic and radiometric data over Song. Okunlola et al. (2016) did a research on ground water quality from shallow aquifers of Hong area and discovered high fluoride content in the ground water which they said is geogenic, attributing it to the porphyritic granite which occurs in the area. Bassey (2018, submitted) did a work on the structure of Hong Hills. He concluded that the plutons of the area are concordant with respect to country rock and that their emplacements are structurally

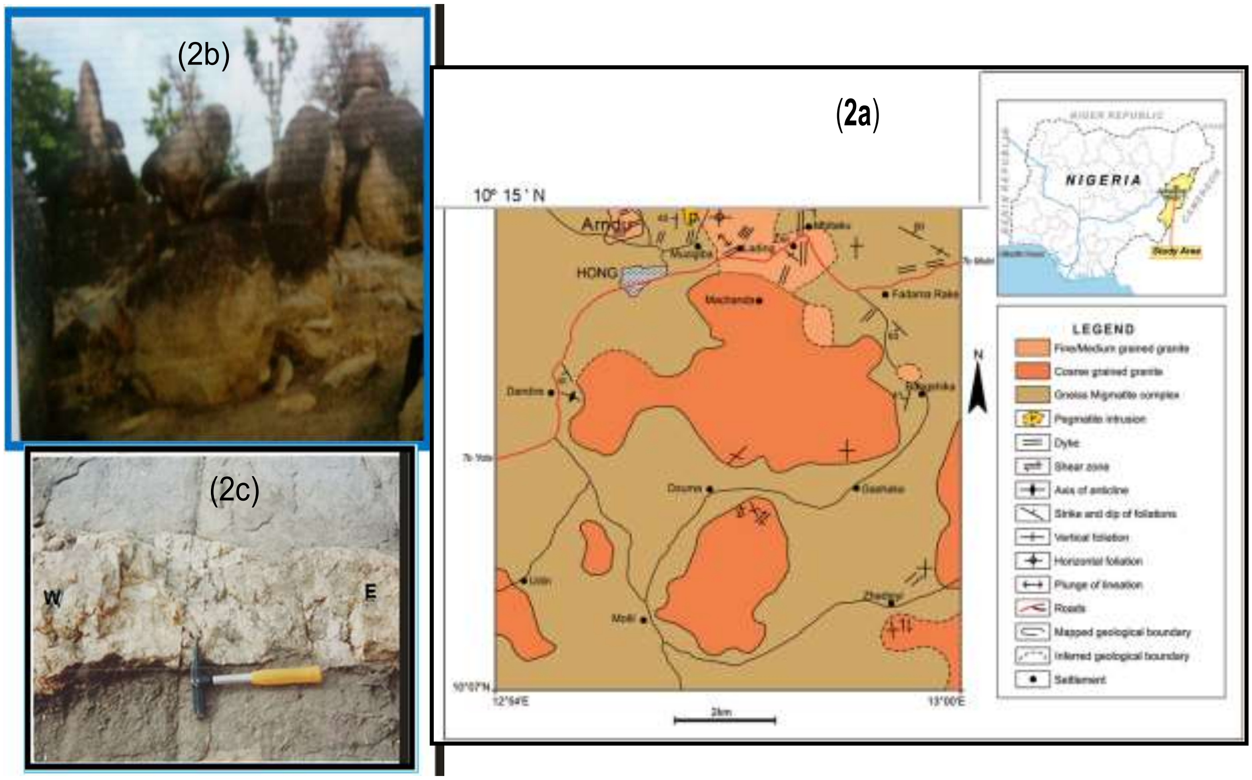

Figure 2a. Geological map of study area, 2b: close view of Hong granite boulders, 2c: part of a pegmatite intrusion in granite, locality Muzigiba hill.

controlled. Ashano and Olasehinde (2010) using an integrated approach (landsat, total count radioactive and total magnetic field data) to study Ropp Younger granite Complex of Jos Plateau observed high radioactivity over some highly altered Younger granites compared to their unaltered counterparts which have much lower values. The authors explained that the alteration process involved the release of potassium from feldspar (as kaolinite is formed) into the environment as free positive ions in soil and ground water thus possibly producing high radioactivity in the altered rocks. Haruna et al. (2011) reported high radiometric counts in fine grained granite and pegmatite of Zing-Monking area of Adamawa Basement region. The authors attributted this to possible uranium occurrences in this rocks. Ademila et al. (2018) investigated radioactive properties of rocks in parts of SW Nigeria and concluded that high radioactivity implies that the rocks are crystalline, undeformed and feldspar rich and also rich in U-Th bearing minerals. While they attributed radioactive low to weathered materials and fluids formed due to intense metamorphism. The authors also delineated different rock types from their radioactive studies.

The present work was undertaken to delineate areas of concentration of pegmatite bodies. Some of them were observed by the first author during an earlier ground geological mapping exercise. The work was done using a *Geiger counter* to detect gamma radiations which emanate from granitoids in the area, with exceptional levels observed over pegmatite intrusions. It presents total count radiometric anomalies of the area and interprets them in the light of lithogical characteristics. It is an in-depth study beyond the work of Unachukwu (2014). It also present structural trends based on linearity of anomalies. Areas of very low anomalies are identified and explanations are given. An attempt is made also to relate radio-lineaments with lineaments mapped from satellite (remote sensing) data. Comparison of radio-lineaments with structurally controlled stream channels is also made. These perspectives of study make the present work contradistinctive from the structural work of Bassey (2018) which was based mainly on mapping of small scale geological structures and lithologies.

GEOLOGY

The rocks of the area are part of the Precambrian Basement Complex of Nigeria comprising of high grade metamorphic rocks (banded gneiss, migmatite and granite gneiss), which are intruded by coarse grained granite/pegmatitic granite and fine-medium grained granite (Figure 2a). The banded gneiss and migmatite are the most widespread in occurrence and their field

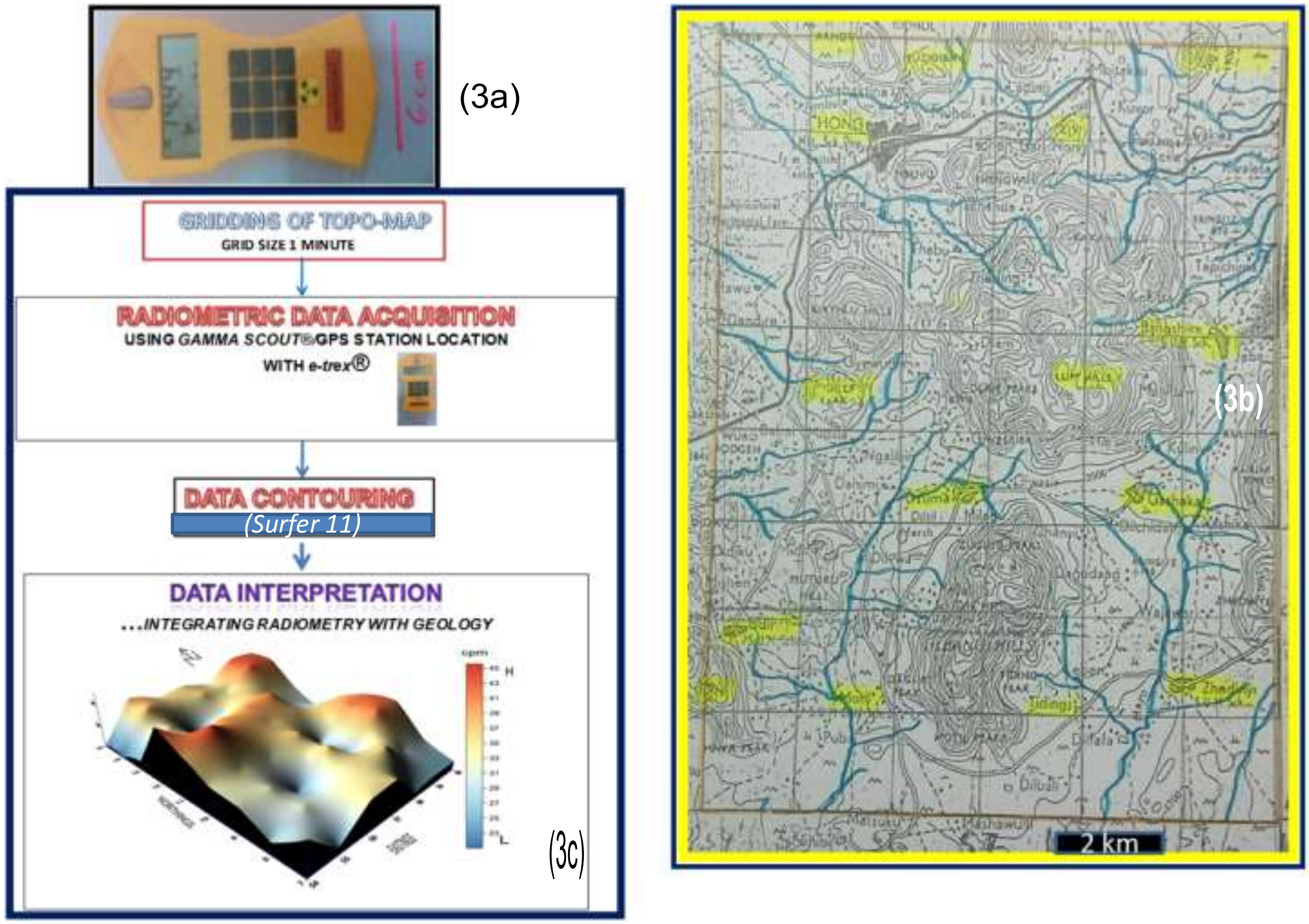

Figure 3a. Survey instrument *Geiger counter*, 3b: gridded topographic map used as base map, 3c: work flow chart.

relationship is very intimate such that boundary between the two is often difficult to establish. The gneiss is however distinguished by their alternating light and dark coloured bands which contain mostly feldspar, quartz, biotite and hornblende. The bands are commonly contorted and folded presenting a convoluted look. The granites outcrop as boulders on the various hills (Figure 2b). Acidic/basic dykes and veins occur as minor intrusions in all rock types. An example of a pegmatite intrusion is shown in Figure 2c. The coarse grained/pegmatitic granites are emplaced as N-S elongate bodies within gneiss/migmatite country rocks, which are commonly folded in the N-S direction also. The emplacement took place during the pan-African orogeny (750±150 ma). Rock foliation, boundins, pinch and swell structures are other structures observed on the metamorphic rocks). Many small scale structures such as dykes, veins and joints found in the area are oriented N-S, or NE-SW. The geology of the area is reported to a greater detail by Bassey (2006, 2018).

METHODOLGY

The radioactive survey instrument used in the work was the *Gamma scout*® (Figure 3a). It is a *Geiger muller* counter tube which can measure all radioactive emissions, depending on the setting. It simply detects the radiation and presents the amount digitally on a screen as number of pulses (counts). The instrument can be set to present the counts per second, per minute or per hour according to the surveyor's choice. In the present work count per minute (cpm) was chosen.

Radiation intensity may strongly fluctuate on a short terms basis, hence instrument manufacturer recommends measuring of average pulse rate, this take care of atmospheric and cosmic ray backgrounds on the results obtained. In this work pulse rate was measured over three minutes interval for each station and the average rate computed per station. The three minutes interval was considered satisfactory as the average pulse rate over similar lithologies showed a good level of consistency. Several readings were taken over different but major rock types in the area so as to determine the radiometric background value of the area. This was found to be about 32 cpm. Radiometric reading above or below this background were considered significant and attributed to geogenic causes. Measurement were made by raising the instrument about 1m (about 3 ft) above the ground or rock surface (Parasins, 1986).

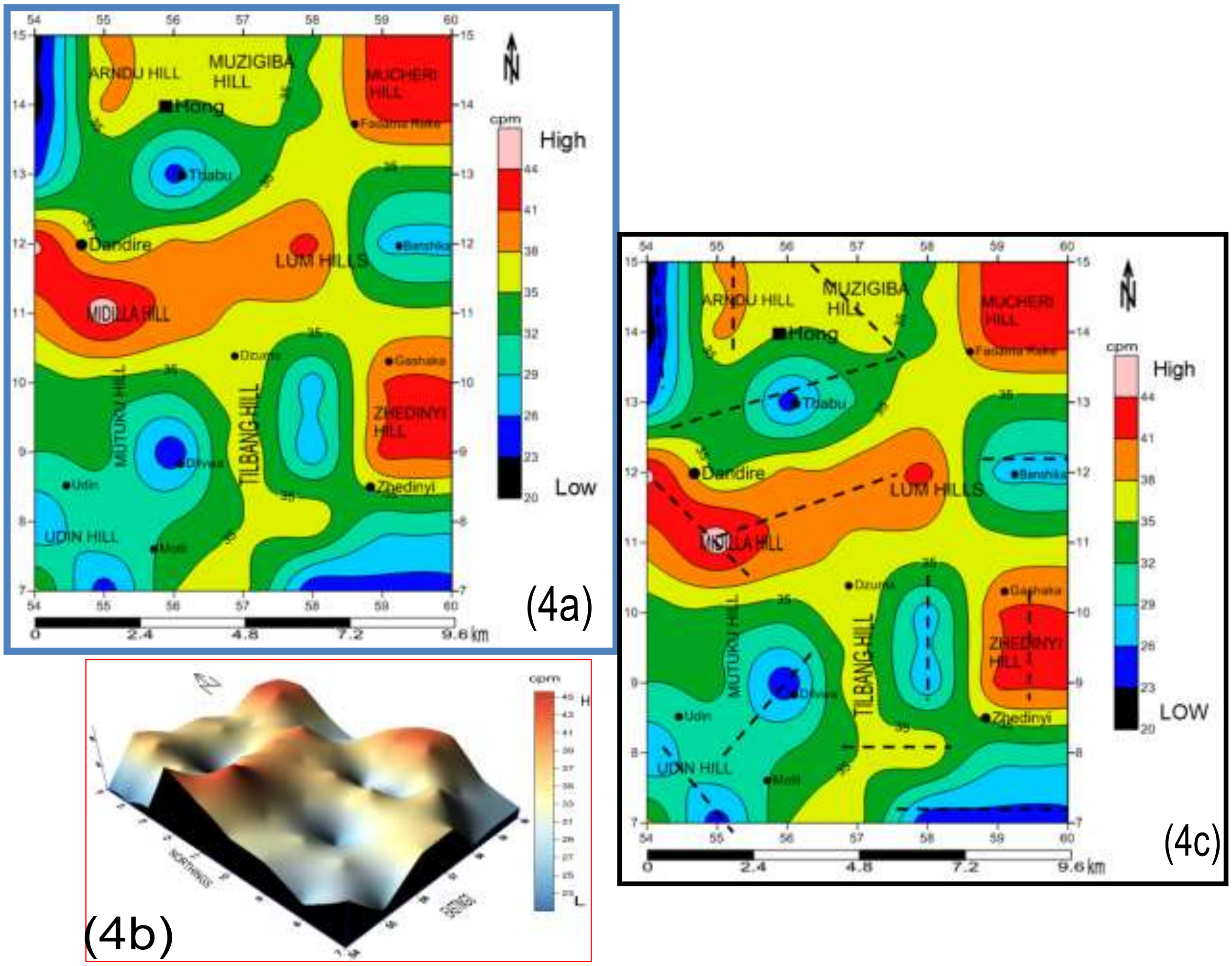

Figure 4a. Radiometric map of study area, 4b: its 3-D version, 4c: radio-lineament map of study area.

The survey was done in the dry season where outcrops/rocks exposures are excellent due to loss of much vegetation by effect of drought. The measurements were taken at 48 stations using gridded topographic map (Figure 3b). The stations had a spacing of 1 min (about 1.8 km). The station spacing of 1 min was considered adequate considering the large sizes of lithological bodies present in the area. Bassey (2018) has reported that the granite plutons have an axial ratio range of 1.3 to 3.0 km). A global positioning system (GPS) *e-trex*™ was used to locate the stations on the ground. The averaged radiometric field readings were contoured using a surface mapping software (*Surfer 11*). The study area has only one major macadamized road (Yola to Hong, and Hong to Mubi, Figure 2a). Others are dirt roads. Station readings were made away from the macadamized road to avoid recording of radiations from unnatural sources. A field vehicle was used to enhance movements by the field crew. A work flow chart of this research is shown on Figure 3c.

RESULTS

The radiometric map of Hong is presented as a 2-D contour map in Figure 4a, the 3-D version follows in Figure 4b. The radiometric readings vary from 20 to 43 cpm. Radiometric lineaments are inferred from some of the anomalies and are inserted as shown in Figure 4c. A *google earth* satellite imagery of the study area is presented in Figure 5a. The satellite imagery of Muzigiba and Arndu hills is shown in Figure 5b. This imagery is reproduced separately from Figure 5a because of poor resolution of the northern part of the latter. Muzigiba and Arndu hills are NW and N-S trending respectively. In Figure 4c there are 13 radio-lineaments mapped. Those that trend to the NE are 3, N-S are 4, NW are 3 and E-W are 3. Based on topographic trends lineaments are also inferred on the satellite imagery where the image quality is high.

DISCUSSION

The radiometric anomalies (Figure 4a) can be categorized into three based on intensity levels. These

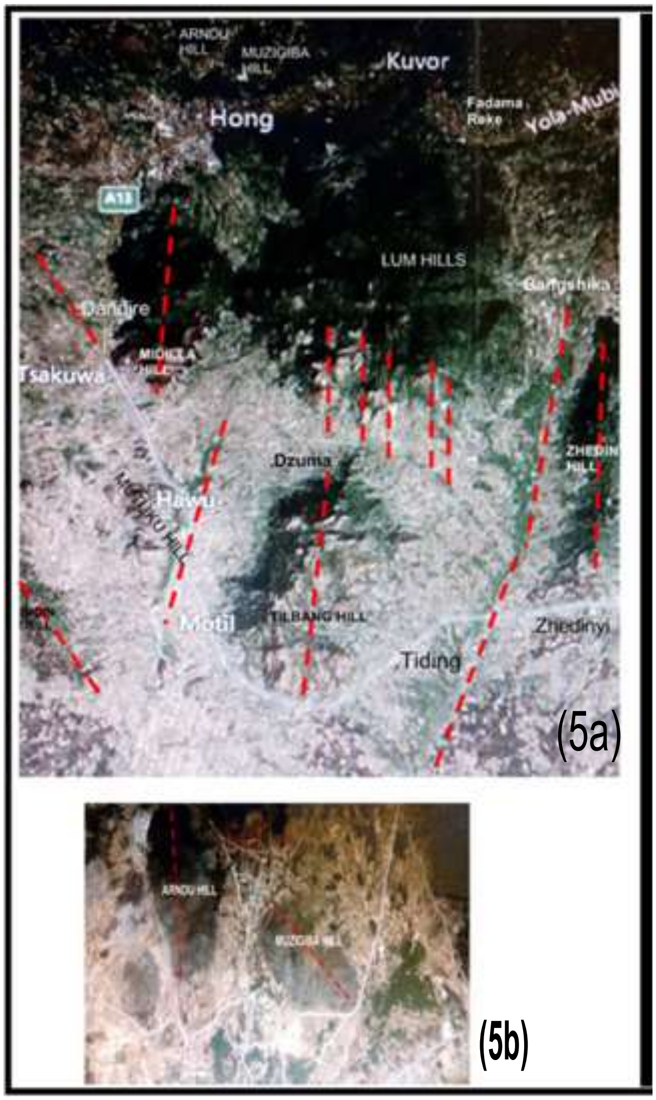

Figure 5a. *Google* satellite imagery of Hong area, 5b:*Google* imagery of Arndu and Muzigiba hill, Hong.

are: high (>35 cpm), intermediate (29-35 cpm) and low (<29 cpm). The areas of high radiometry are in the central part (with peak at Midilla hill), northern part (over Arndu, Muzigiba and Mucheri hills) and southern part (over Tilbang and Zhedinyi hills). These are areas of occurrence of fine grained and coarse grained/pegmatitic granites (Figure 2). Granite and pegmatite contain feldspars (Orthoclase and microcline varieties) which contain potassium a radioactive element. Hence the high radioactivities over these areas are due to the granites/pegmatite.The areas of intermediate radiometry are in the SW, SE and NW. These are areas of mainly gneiss and migmatite. The intermediate range of radioactivity of the metamorphic rocks is due to the presence of orthoclase feldspar to a lesser amount (Telford et al., 1990) Monazite a radioactive mineral is founded in gneiss and this can contribute to the radioactivity of these rocks.

Areas of low radioactivity are mainly over human settlements where we have thick accumulation of soil/elluvium or regolith. These areas are found at Thabu, Bangshika, south of Zhedinyi, Dilvwa, Motil, and west of Zhedinyi hill. This regolith is formed by mechanical and chemical weathering of the bedrock. The regolith is thick enough to support farming activities. Due to this bedrock radioactivity are largely masked. Transported regolith is found along streams courses such as in the NW, (west of Arndu hill) and at the SE margin. These areas have very low radiation of <26 cpm. Radio-lineaments as mapped align with trends of some hills (compare Fig.4c with 5a/5b).The hills are Arndu, Muzigiba, Undin, Zhedinyi, and Tilbang. Others seem to follow flow direction of second order streams (suggesting subsurface structural control). Examples: the NW lineament west of Dandire (cf. with Figure 3b) and the NW lineament between Dilvwa and Mutuku hill. Another lineament which correlates with stream flow (E-W) direction is at Bangshika. Two parallel NE lineaments (at Thabu, and between Lum hill and Midilla hill) apparently cannot be explained from surface features. Their parallelism and spatial closeness may indicate their common geological origin and are probably basement fault related. Three radiometric sections or profiles are presented in Figure 6. The profiles over the granite hills have high radiometry while those over regoliths show low radiometry.

Comparison of structural data (Figure 7) of the area based on satellite, stream flow and radiolineament patterns show the following. In the southern part N-S satellite lineaments are in agreement with stream flow pattern. NW-SE radiolineament at Udin hill is also observed in satellite map. Also N-S radiolineament at Zhedinyi hill is has its satellite equivalent. South of Dandire on the radiolineament map is a NW-SE lineament. This is reflected both in the satellite map and the stream flow pattern. A major stream flow direction in the northwest is NW-SE (on topographic map). The radiolineament at Muzigiba hill is similar in trend and reflects the orientation of the hill (Figure 5b). Arndu hill radiolineament (N-S) also reflects the hill's orientation. Other lineament trends (especially E-W) on the radiolineament map have no equivalents on the other maps.

The study has shed more light on the geology of Hong area. It has revealed some structural trends not presented in earlier works on the area. The relationship between radiometric anomalies and lithologies has been further highlighted. High radiometry coincide with granites and pegmatite bodies. Radio-lineaments align with major (second order) stream channels. Radiometric intermediate zones coincide with metamorphic rocks while the radiometric lows are areas of regolith.

Pegmatite bodies (Veins, dykes and irregular occurrences) have been mapped between 12°56'-

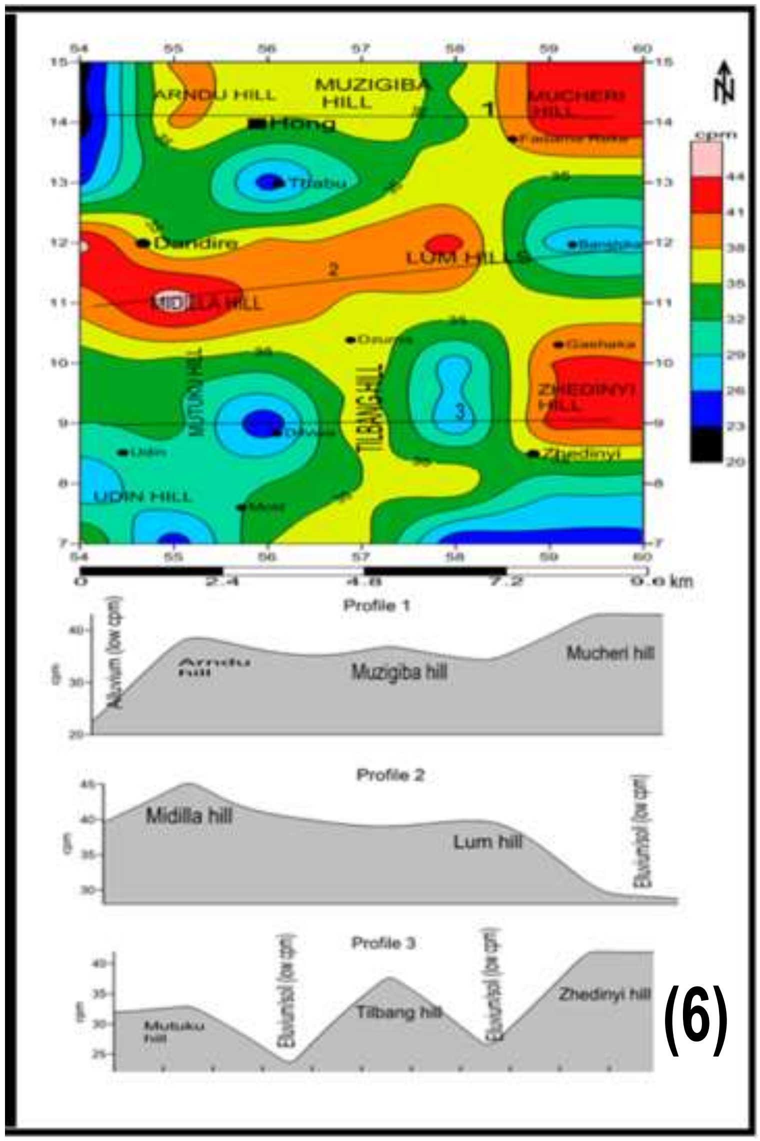

Figure 6. Radiometric map with cross sections.

12°58'E (Muzigiba hill, Ladin and Zivi) and 10°14'-10º15'N. Others have been observing beyond the north limit of the present study area by the first author. Based on the above it could be inferred that the radiometric anomalous zone between Arndu hill and Mucheri hill is generated by pegmatite intrusions and can be called pegmatite zone. The granites serve as host rocks to the pegmatites. The anomalies at Midilla and Lum hills may be in investigated for possible pegmatite occurrences, At Ladin (Figure 2a) a NE-SW (40°) pegmatite ridge is found; north of this area Bassey (2006) observed pegmatite bodies which occur as dykes/ veins or as irregular bodies around the margins of the coarse grained granites. The study area lies within the NE-SW pegmatite belt of Nigeria which extends into Obudu and Oban massifs, in SE Nigeria (Ekwueme, 1993). Other prominent pegmatite occurrences within the Hawa massif observed and reported by the first author in his unpublished doctoral thesis are at Madagali, Song and Mubi. The pegmatites are intrusions of pan-African orogenic event. Pegmatites in their commercial form are sources of muscovite (used as electrical insulators), feldspars (used in glazing of ceramics), quartz (used in electrical industry and optical industry) and gemstones. Cassiterite (tin oxide) is often found in association with pegmatites.

Conclusion

The study has shed more light on the geology of Hong area based on radiometric field variations. The anomalous radioactive zones between 10°14' to 10°15'N

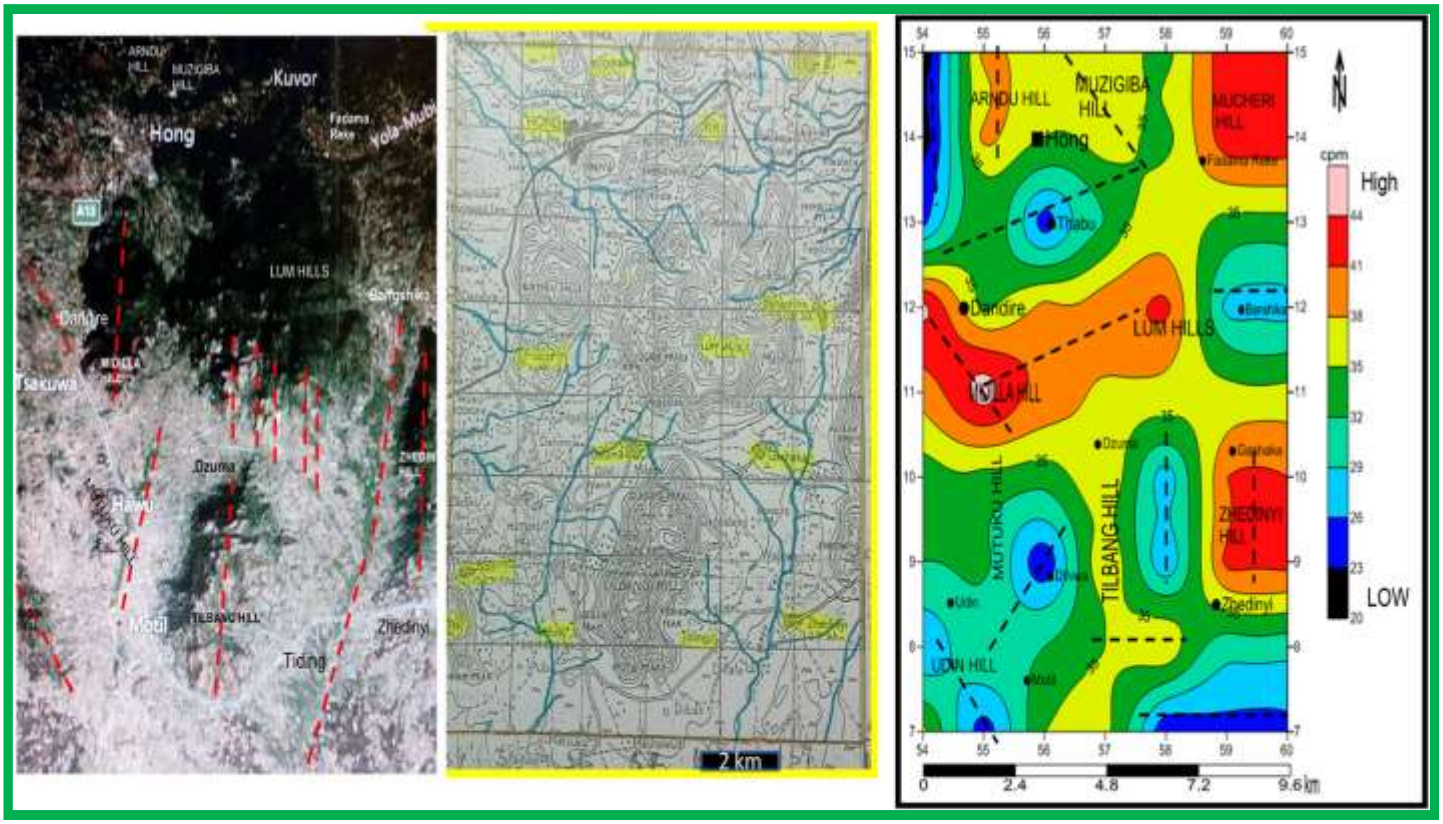

Figure 7. Comparison of satellite lineament data (left) with stream flow patterns (centre) and radiolineament data (right).There is good correlation especially in the southern part.

is designated a pegmatite zone due to the abundance of pegmatite intrusions. Other anomalous zones in the central and south east of the area need to be investigated for possible pegmatite occurrences owing to the economic importance of this rock. The study has revealed the relationship between radiometry and basement structure, also some structural trends not presented in earlier works are shown. Radio-lineaments align with structurally controlled (second order) stream channels and some hills. The relationship between radiometry and lithologies has been demonstrated in the study area. High radiometry coincide with granites and pegmatite bodies. Radiometric intermediate zones coincide with metamorphic rocks while the radiometric lows are areas of regolith (elluvial and alluvial deposits) which masks bedrock radioactivity. The objective of the work has been achieved with the delineation of the pegmatite zone in the north of the study area. Hence chemical analysis of rocks was not considered necessary but could be undertaken in future.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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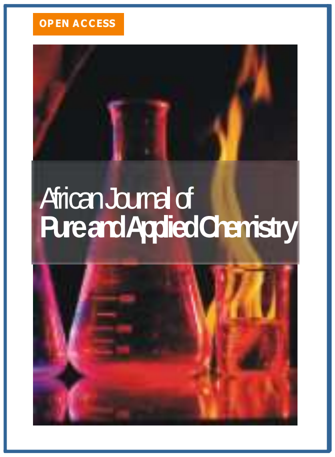

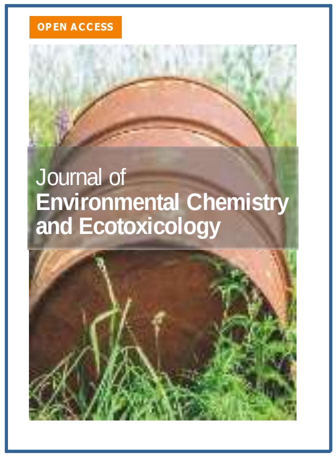

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