

Geological Interpretation of Radiometric Survey Maps of Pasam - Bali Hills and Environs, Upper Benue Trough, Northeastern Nigeria.

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ABSTRACT

Structural and radiometric surveys of Bali, Pasam areas and environs of the Upper Benue Trough of northeastern Nigeria were aimed at providing detailed information on the structures and detection of radioactive anomalies of the area. To achieve these, a detailed structural/geological and radiometric mapping were conducted. Different structures were found including tectonic (faults and joints) and non-tectonic (beds and rain marks). The area is composed of the calcareous Bima sandstone (which is the oldest in the area) and Quaternary to Recent alluvium. Petrographic analysis was done on Bima sandstone representative samples from the study area. The major minerals observed under both plane polars and cross-nicols include quartz, orthoclase and iron. A total of 120 Gamma Scout readings (in count per minute) were taken from the survey area using the Gamma Scout, an instrument that detects radioactive anomaly. GPS coordinates of each gamma count were also recorded. Gamma scout readings were contoured using Surfer 11 software to produce Iso-rad map of the study area both in 2D and 3D view. The Iso-rad maps show areas of high, medium and low radioactive anomaly. Areas of high radioactivity are generally coincident with outcrops of Bima (feldspathic) sandstone, whereas the low radioactive anomaly is due to thick soil accumulation in the area.

Keywords: Bali and Pasam, Radioactive Anomalies, Bima Sandstone, Gamma count.

INTRODUCTION

The intracratonic Benue Trough located in Nigeria is part of the chain of basins in the West and Central African Rift System, falling in between the Chad and Niger/Delta Basins (Shettima et al., 2019). It stretches for over 1000 km in length and varies in width between 50 – 150 km (Figure 1), and hosts more than 6000 m of Cretaceous – Tertiary sediments associated with volcanics. Geographically, the basin is subdivided into Northern, Central and Southern portion with Northern Benue Trough constituting of the Gongola, Yola and Muri – Lau Sub – basins (Dike, 2002). The trough evolved as a consequence of the break-up of the African and South American plates during the Late Jurassic – Early Cretaceous times (Genik, 1992). Though, its origin remained controversial owing to contrary theories of rifts model (Fairhead et al., 2013) and sinistral wrench faulting model (Benkheilil, 1989). Nonetheless, its evolution and basin architecture are quite defined with horst and graben system, typical of rift basin (Abubakar, 2006). The opening of this trough is accompanied with Aptian – Albian marine transgression that terminated in the Central Benue Trough, leaving continental depositional processes to dominate the Northern Benue Trough, thereby depositing the syn and post – rift sequences of the continental Bima Formation (Guiraud, 1990).

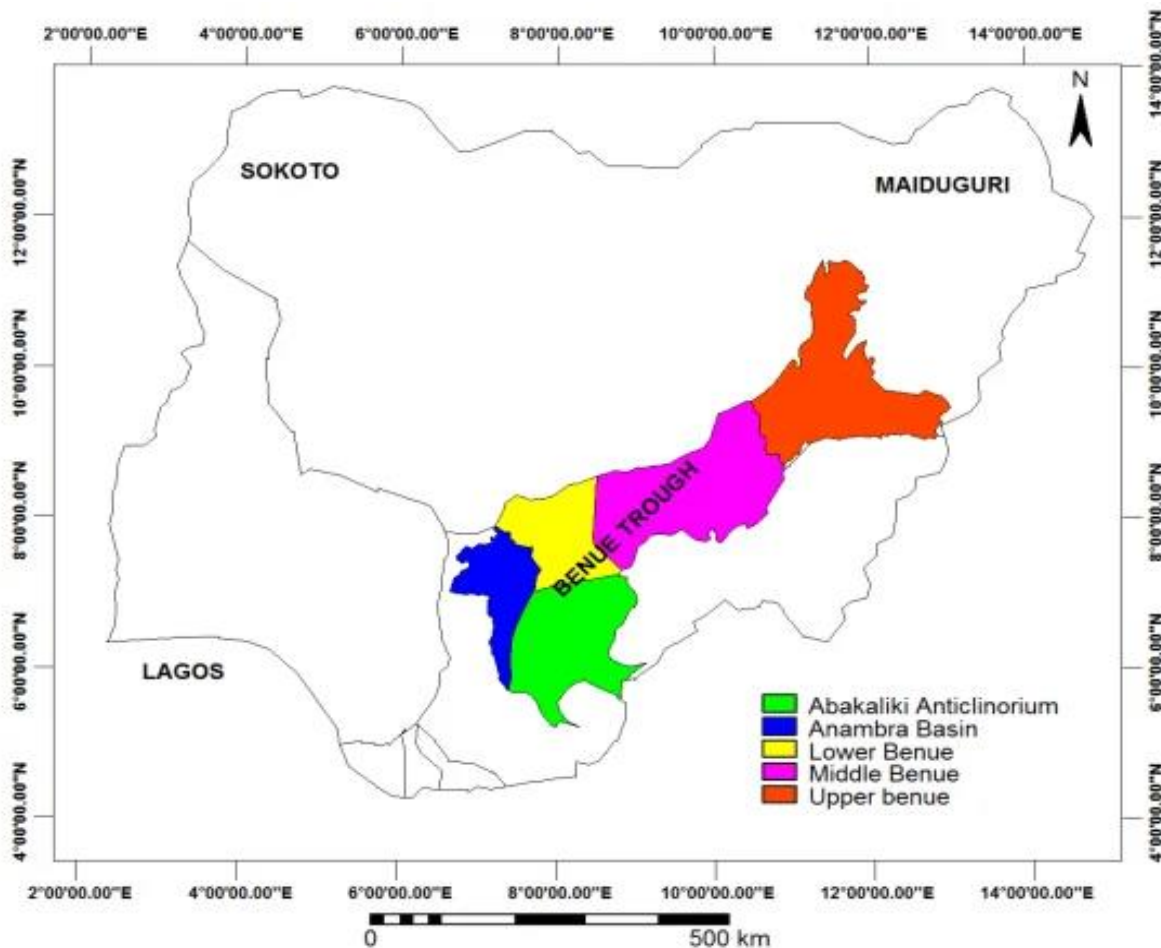


Figure 1 : Map of Nigeria showing the major divisions of the Benue Trough . (after Ologun et al 2008)

The Benue Trough is so dominant in the Cretaceous tectonic and sedimentary geology of Nigeria that almost all the sedimentary basins of Nigeria (excepting the Iullemmeden Basin) are directly or indirectly related to it (Nwajide, 2013). The stretch of the Benue Trough within Nigeria is subdivided into three segments – northern, central and southern segments – on the bases of structural and stratigraphic contiguity, as well as geographical convenience.

Practically all terrestrial materials contain measurable quantities of the radioactive elements. In the case of sedimentary deposits, these elements are laid down as components of some mineral in the beds or are precipitated with the sediment subject to the existing physical, colloidal, and chemical conditions (Bassey and Udoh, 2022). Not only are the atoms of these elements susceptible to subsequent changes of chemical affiliation, but they spontaneously disintegrate according to the laws of radioactivity. The natural decay of these elements produces a variety of types of radiation (alpha, beta, and gamma) at specific energy levels. Only gamma-ray radiation has sufficient energy to be useful for geological mapping or exploration.

The three most common naturally occurring radioactive elements are potassium, uranium and thorium, which are found at some concentrations in most rock-forming minerals. Potassium occurs mainly in the mineral feldspar, which is abundant and widespread in the earth's crust and a component of granitic rock. Uranium and thorium are generally present in low concentrations in wide range of minerals and their high concentrations may represent a target of economic interest to mining companies (Tom, 2000). Radiometric surveys detect and map natural radioactive emanations called gamma rays, from rocks and soils. All detectable gamma radiation from earth materials come from the natural decay products of only three elements, namely, uranium, thorium, and potassium. Radioactive surveying for radioactive minerals has become important over the last few decades because of the demand for nuclear fuels. It is employed in the search for radioactive mineral deposits and also for those associated with radioactive elements.

LOCATION AND GEOLOGY OF STUDY AREAS

Bali area is located within the Nigerian 1:50,000 topographical sheet (Dong) and is situated between latitudes $9^{\circ} 15' 00''$ N and $9^{\circ} 18' 00''$ N and longitudes $11^{\circ} 48' 00''$ E and $11^{\circ} 52' 00''$ E, and has an area of 44.8km (Figure 2).

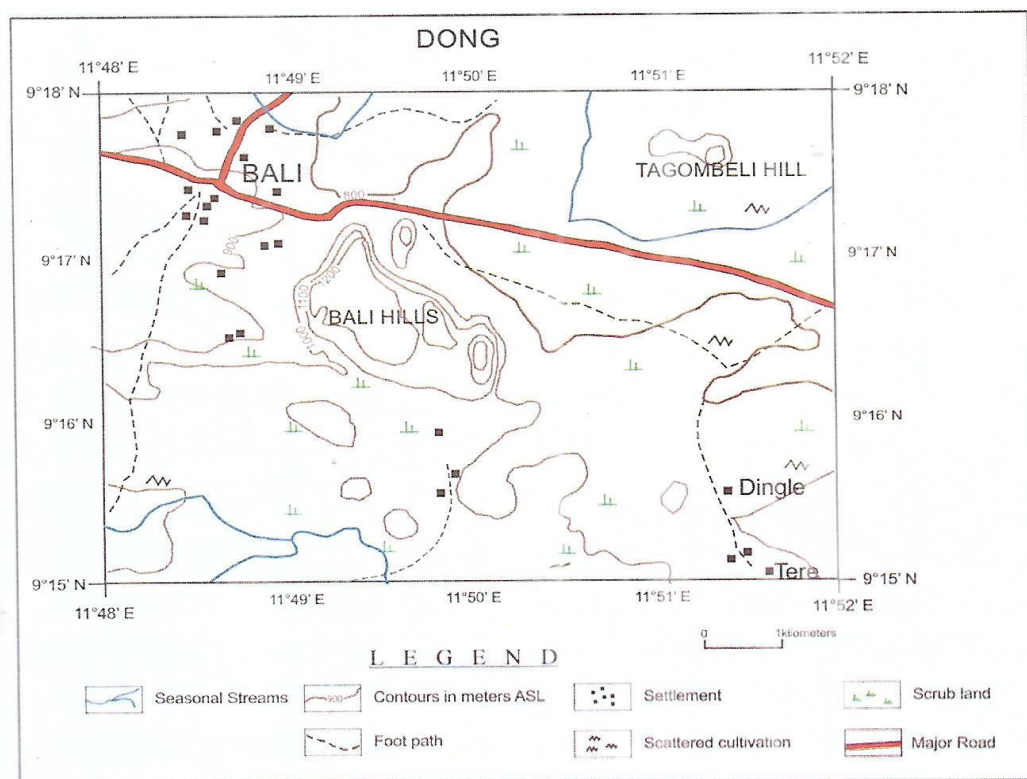


Figure 2 : Topographical Map of the Study Area and Environs (Modified from Federal Surveys, 1969).

Pasam area lies within latitudes $9^{\circ} 15' 00''$ – $9^{\circ} 18' 00''$ north of the equator and longitudes $11^{\circ} 43' 00''$ – $11^{\circ} 48' 00''$ east of the Greenwich Meridian (Figure 3).

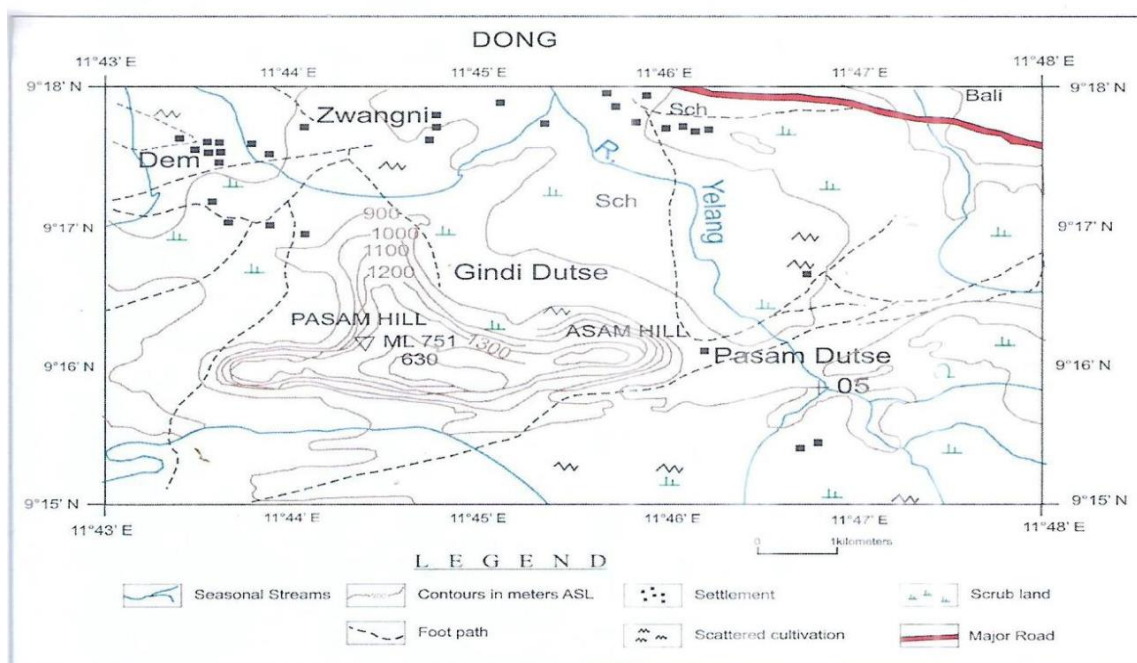


Figure 3: Map of Pasam and Environs

Bima area falls within the Yola arm of the Benue trough. The Benue Trough is a Cretaceous folded linear-shaped rift sedimentary basin, extending from the Niger Delta northward to the Chad Basin, through the N-S trending Gongola rift and branched into Northern Cameroun through E-W trending Yola rift. The area is composed of the Bima sandstone which is the oldest, thickest, and most extensive formation in the Upper Benue Trough. It is also composed of shale, sandy clay, and calcareous sandstone which belongs to the Yola – Bima Yoldé Formation (Figure 4).

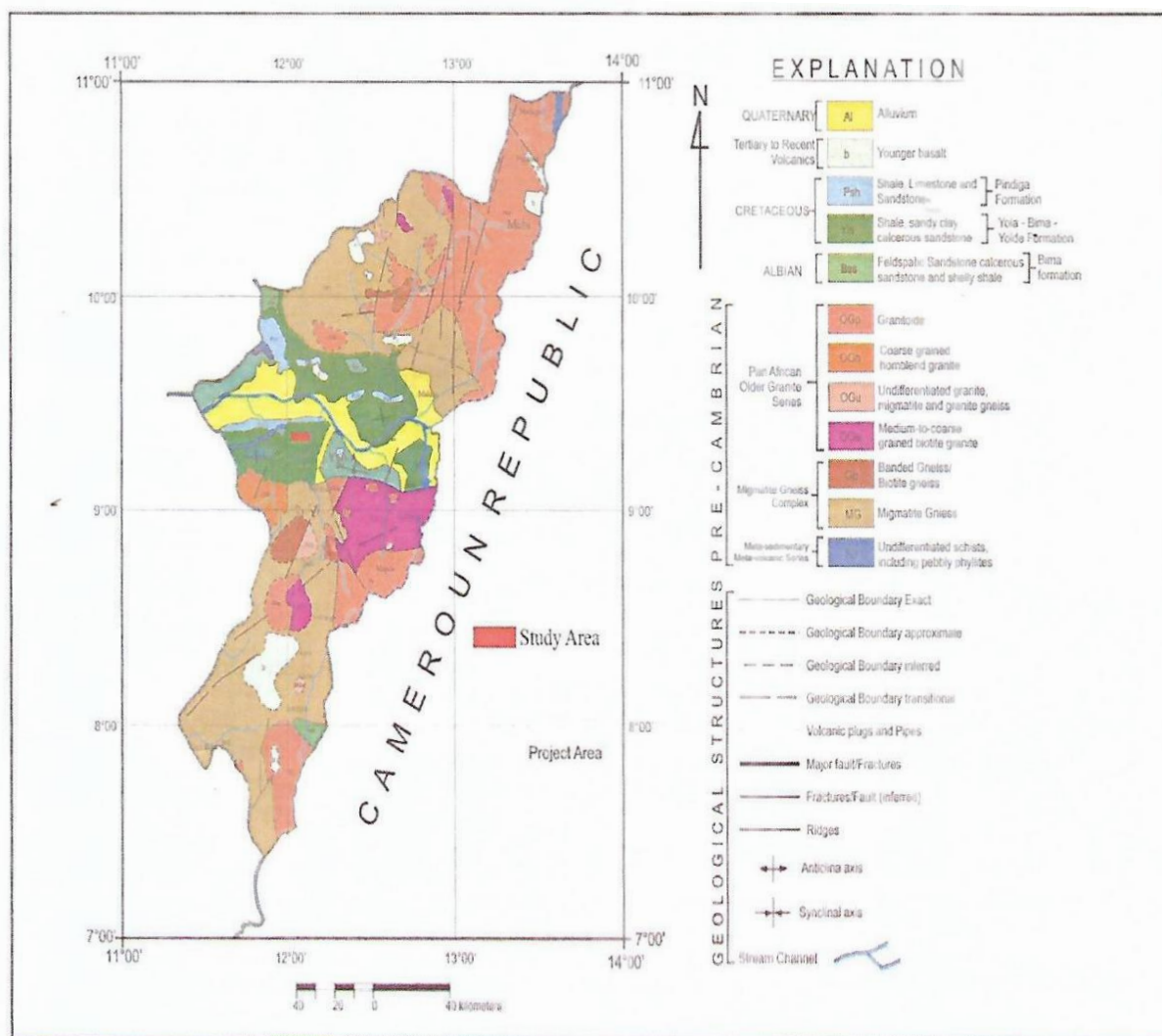


Figure 4: Geological Map of Adamawa State showing the Study Area (Modified from Geological Survey of Nigeria, 2011).

Similarly, Pasam area also belongs to the Upper Benue Trough and has Bima sandstone which is the oldest, thickest, and most extensive formation followed by the recent alluvium which was subsequently deposited on the Bima sandstone. The sandstone in the area is feldspathic in nature. Clay and shale are also common in the study areas (Figure 4).

Geological and Structural Setting of the Upper Benue Trough

The Benue Trough is divided into three segments, viz; the lower, middle and upper Benue regions. The Upper Benue Trough (Figure 5) is a Y-shaped basin bounded to the Northeast by the basement rocks of the Hawal Massif, to the South by the Adamawa Massif, and to the west by the North Central Basement complex (Figure 5). The Upper Benue Trough is subdivided into three sub-basins: the Southern Muri-Lamurde branch trending northeast, the E-W trending Yola Arm to the east and N-S Gongola Arm to the North.

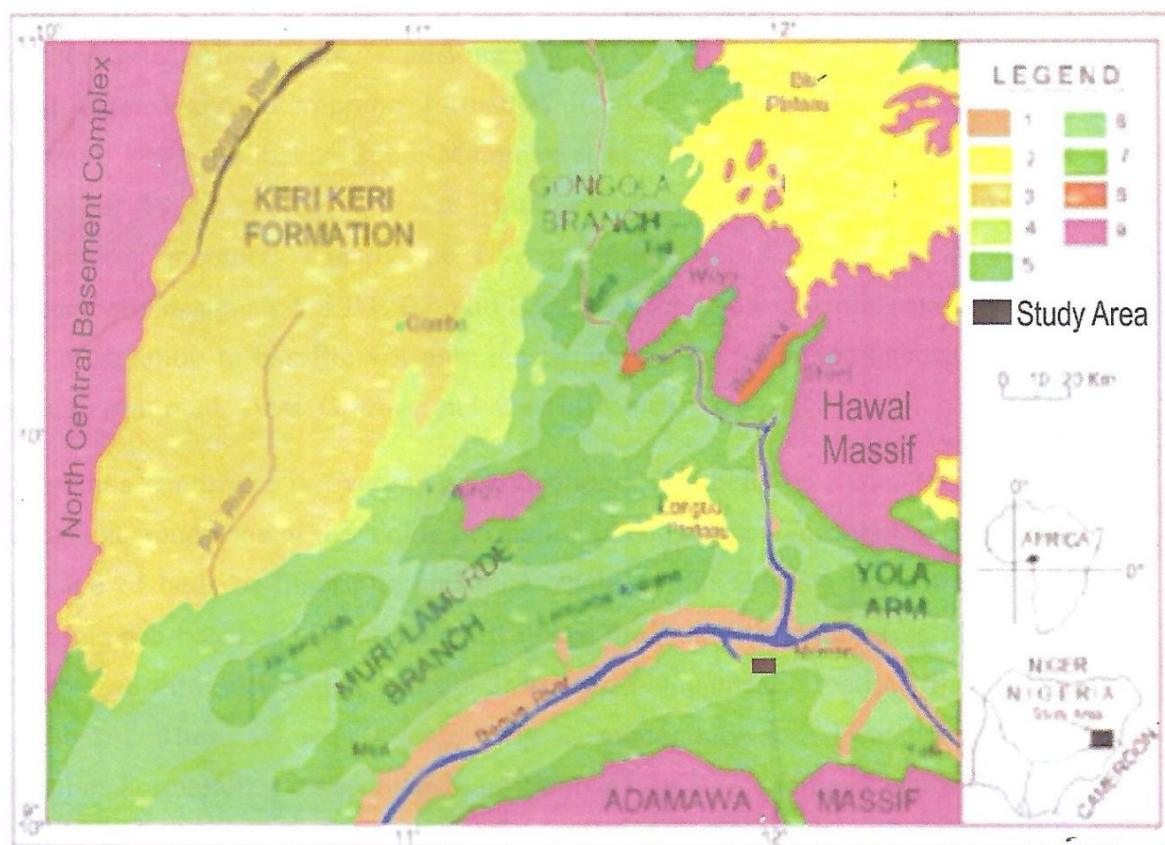


Fig. 5: Geological map of the Upper Benue Trough. 1, Alluvium: 2, Tertiary to Recent Volcanism: 3, Kerrikerri formation: 4, Gombe Sandstone: 5, Pindiga formation: 6, Yolde formation: 7, Bima sandstone: 8, Burashika group (Mesozoic Volcanism): 9, Granitoids Precambrian (modified after Maurin et al., 1985).

In the Upper Benue Trough, the Precambrian basement is unconformably overlain by the Aptian-Albian Bima sandstone (Figure 5) which is the oldest, thickest, and most extensively outcropping Formation in the Trough (Carter et al., 1963; Guiraud, 1990; Abubakar, 2006; Mamman et al., 2010).

Sedimentological studies (Guiraud, 1990) showed that the Bima sandstone can be divided into three siliciclastic members namely the Lower, Middle and Upper Bima Members, respectively designated as B1, B2, and B3. B1 is rich in basaltic and rhyolitic clasts and in rhyolitic to basaltic volcanic lenses, indicating contemporaneous volcanic activity (Guiraud, 1990; Guiraud and Maurin, 1992).

The Bima sandstone is overlain by transitional interbeds of shale, siltstone and calcareous mudstone of the Yolde Formation (Cenomanian-Turonian), grading into massive beds of limestone and thick shale of the Gongola Formation, in the Gongola sub-basin and its lateral equivalents: the Dukul Formation (mainly of grey shales and thin silty beds), and the Jessu and Numanha Formations in the Yola Sub-basin.

These sequences are poorly to moderately sorted sandstone of the Gombe Formation (Campanian-Maastrichtian) in the Gongola sub-basin and Lamja sandstone in the Yola Arm. The succession is capped by sandstone of the Kerri -Kerri Formation (west of Gombe town) in the Gongola Arm.

A subdivision of the Benue Trough into the northern, central and southern segments was based on tectonic, geographical, and stratigraphic features (Figure 6, Benkhelil, 1987).

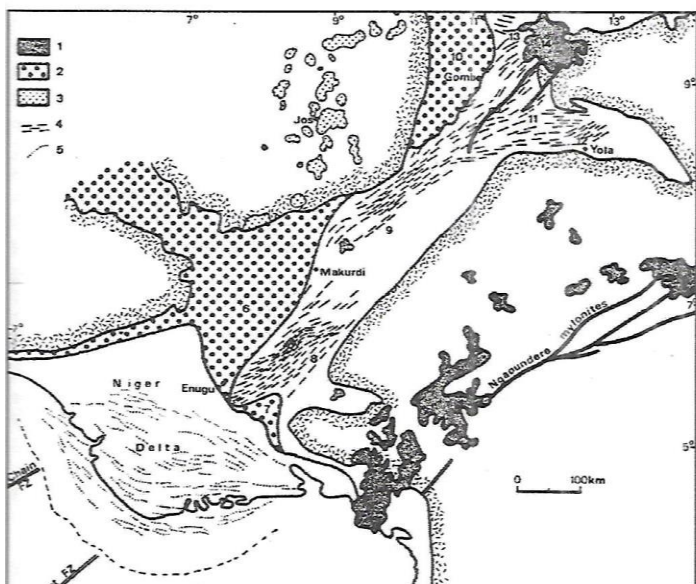


Figure 6. Sketch map of the Benue Trough showing the main structural units: 1= Tertiary volcanics, 2= Post-tectonic basins, 3= Jurassic Younger Granites, 4= Structural trends, 5= Growth fault traces in the Niger Delta, 6=Anambra Basin, 7= Afikpo Syncline, 8= Southern Benue Trough, 9=Central Benue Trough,10= Kerri-Kerri Sub-basin, 11= Northern Benue Trough, 12= Yola Arm,13= Gongola Arm, 14= Biu Plateau (after Benkhelil, 1987).

The Upper Benue Trough is structurally marked by numerous NE-SW trending mylonitic shear zones generated during the late Pan-African Orogenic phase, and reactivated as sinistral strike-slip faults during the Cretaceous (Figure 7) (Benkhelil and Robineau, 1983; Benkhelil, 1986; Maurin et al.,1985). Generally, three major fracture zones trending northeast have been recognized: the Gombe fault, the Kwol-Kaltungo lineament which extends for about 150 km, and the Burashika fault. These major fractures, cross-cut the Cretaceous deposits and originates from the basement according to Akintoye et al (2023). The tectonic deformation along these major fractures is represented by cataclastic and brecciated bands that are about 300 m to 1 km wide in the basement, and by 100 m wide crushed zones in the sedimentary cover. This deformation superimposes the Pan-African mylonitic shear zones, and provides post-depositional fracture/fault zones which are favourable sites for uranium concentration in the sedimentary units (Benkhelil, 1986).

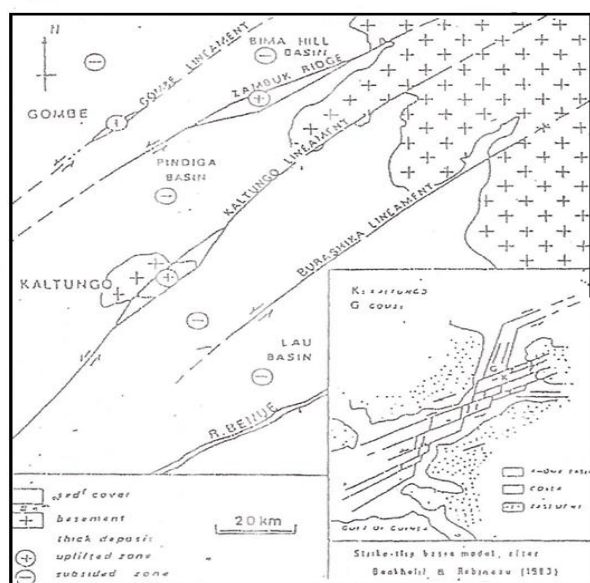


Figure 7. Structural Geology of Benue Trough (Maurin et al, 1986)

METHODOLOGY

Field study involved extensive mapping of the study areas in order to produce geological, structural and iso-rad maps of the study areas. The field mapping exercise was conducted simultaneously with sample collection and radiometric measurements along traverses. On the field, mapping was done following a regular grid with size of 1 minute representing 1.83km. The geological map is shown in Figure 8.

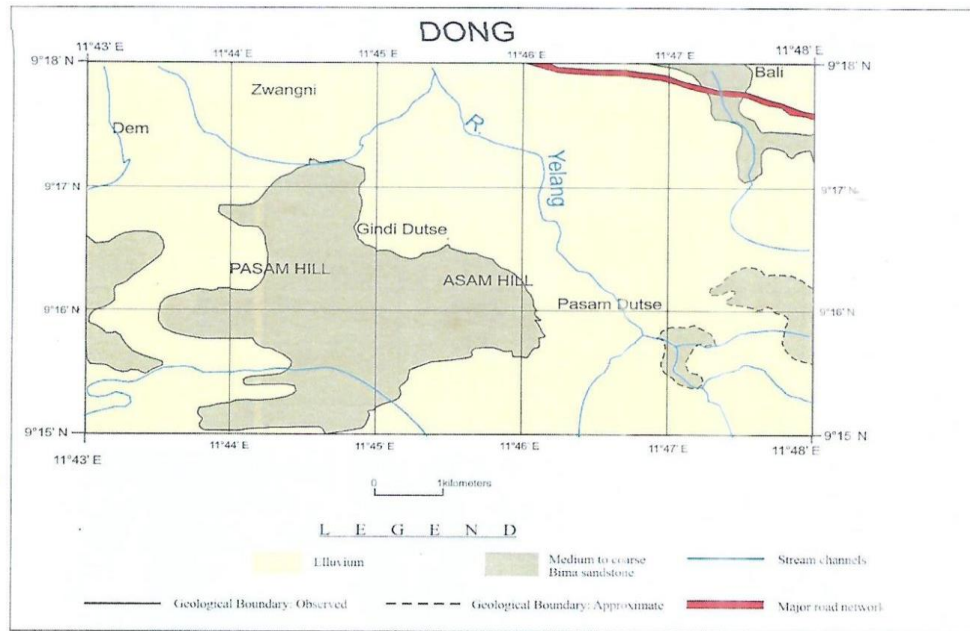


Figure 8 : Geological Map of the Study Area and Environs

The study area was gridded into 15 equal squares in which 1' on paper represents 1.83 km on ground. In each grid square, a total of 10 gamma scout readings was taken and their GPS coordinates recorded. Traversing across the gridded map was in a regular pattern (Figure 9).

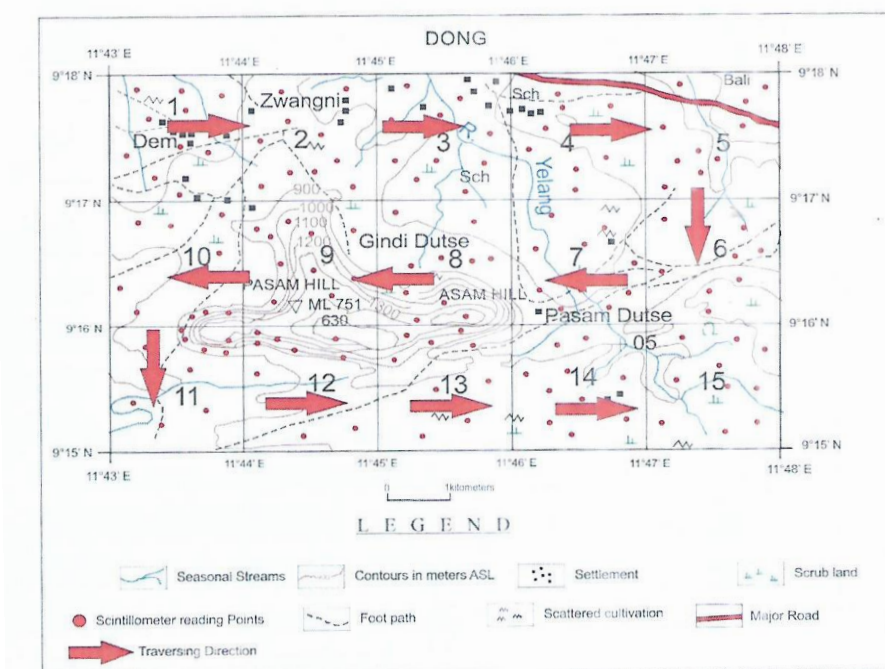


Figure 9: Topographical Map of the Study Area showing the traversing pattern during radiometric Mapping.

RESULTS AND DISCUSSION

Rose Plot

During the geological field mapping, strike and dips of joints and faults were measured using compass clinometer. Table 1 shows the statistical representation of joint and fault readings in the study area while Figure 10 shows rose diagram showing trending direction of structures from the study area.

The major trending direction of the faults are NW – SE direction as suggested by Effiong et al., (2017) and Ikumbur et al., (2019); this is not one of the major trending directions of the Benue trough, but it aligns with one of the trending directions of the radioactive anomaly in this study area (Figure 12). But the trending direction may have occurred due to tectonism, which has influenced the radiometric anomaly as it aligns with the structures.

TABLE 1: Statistical Presentation of Joint and Fault readings in the study area.

Joint readings taken in degrees	Class Interval	Frequency of Occurrences
63, 70(3), 65(2), 90(3), 15(2), 30 (3), 25, 29, 20 (2), 28,	0 -30	35
33, 35(7), 45(5), 60(6), 55, 53, 54 (2), 43, 120(2), 95, 115,	31 – 60	40
110, 125(3), 122, 145(10), 150(2), 135(3), 130, 132, 147,	61 – 90	21
138, 180(4), 155(2), 175, 170, 165, 160, 177, 15(9),	91 – 120	18
25(5), 30(5),12, 14, 19, 17(3), 32(3), 35(4), 60(3), 55, 45,	121 – 150	30
50, 40(2), 65(3), 90(2), 75, 77, 70, 85(2), 88, 72, 95(2),	150 – 180	19
120(5), 110, 115(2), 108, 120(2), 145, 140, 150, 135, 125,		
155, 180(2), 165, 160(2), 175, 179		
	TOTAL	163

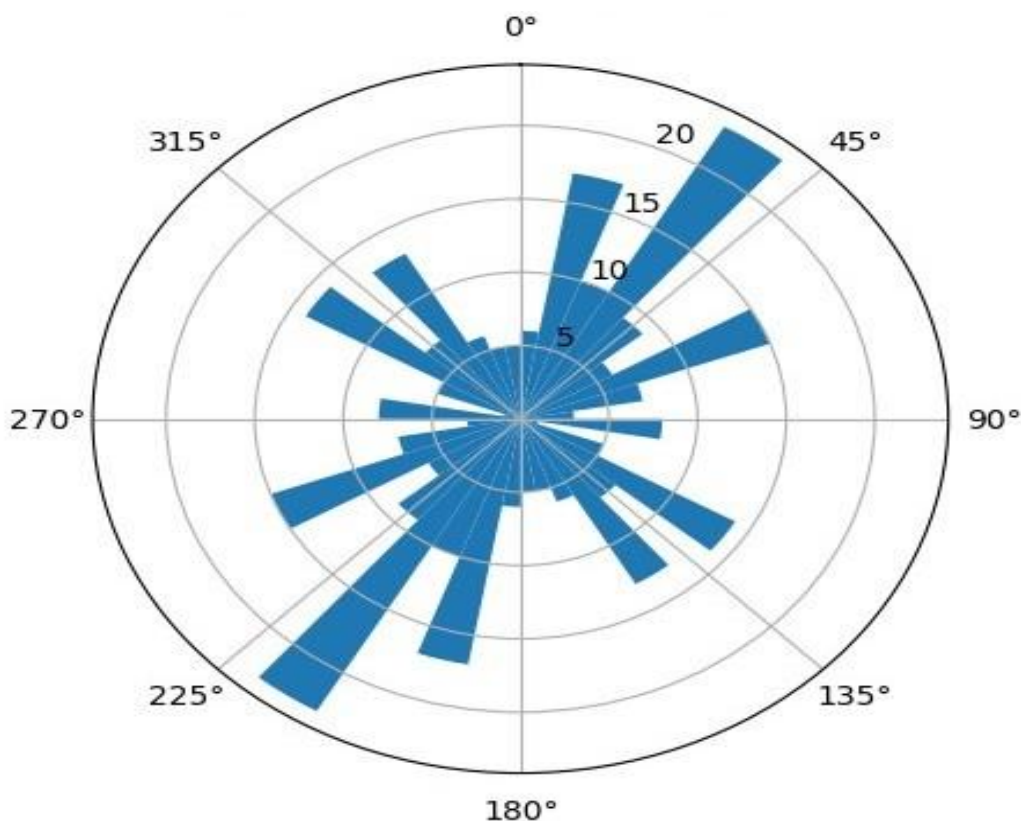


Figure 10 : Rose diagram of joints and faults readings in the study area (n=163).

Radiometric Data Interpretation

About 120 gamma scout data (in counts per minute) were obtained from the study area, the data were averaged to achieve accuracy and precision. This is because radioactive readings are affected by the sun. The data was later subjected to surfer 11 software. In this regard, iso-rad map of the study area showing areas of high and low radioactive anomaly was plotted both in 2D and 3D (Figures 11 and 12).

The areas of high radioactivity anomaly are located around Dingle and Tere areas, southeast of the study area. The radioactive anomaly extends to the southern part of the Tagombeli hill but the northern part of the hill has low radioactive anomaly. The northern part of the area around Bali area has high radioactive anomaly. The reason for the high radioactive anomaly in the area can be attributed to the presence of potassium feldspars in the Bima sandstone according to Effiong et al (2017). The variation in the radioactive anomaly is structurally controlled (Figure 11).

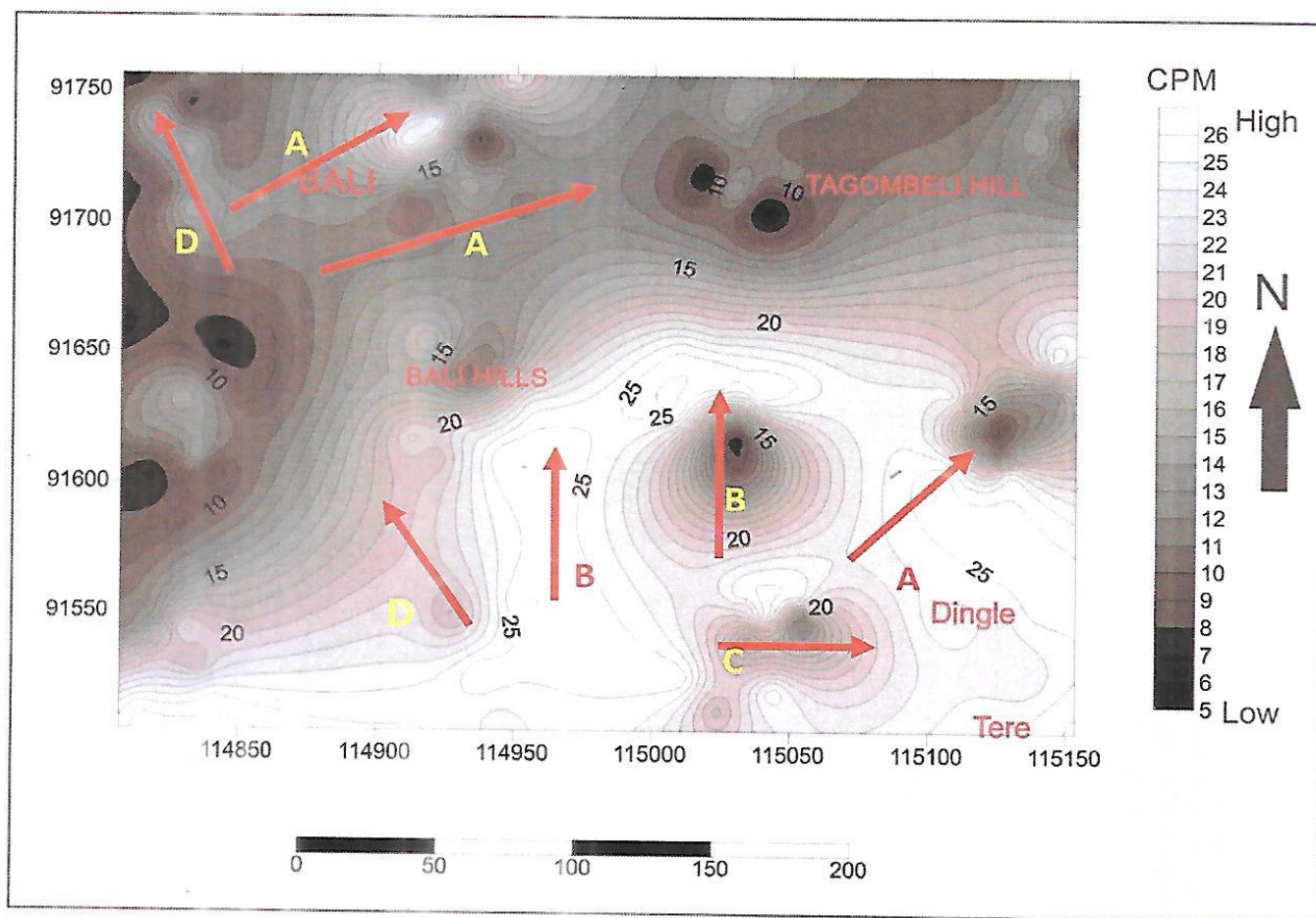


Figure 11: 2D view of the Iso-rad map of the study area showing areas of high and low radioactive anomaly.

The arrows above show the various directions the anomaly is trending.

A : is trending to NE-SW direction of the Benue trend.

B : is trending towards N – S direction of the Gongola trend.

C : is trending towards E -W direction of the Yola arm of the Benue Trough.

D: is trending towards NW – SE in alignment to the rose plot (Figure 11).

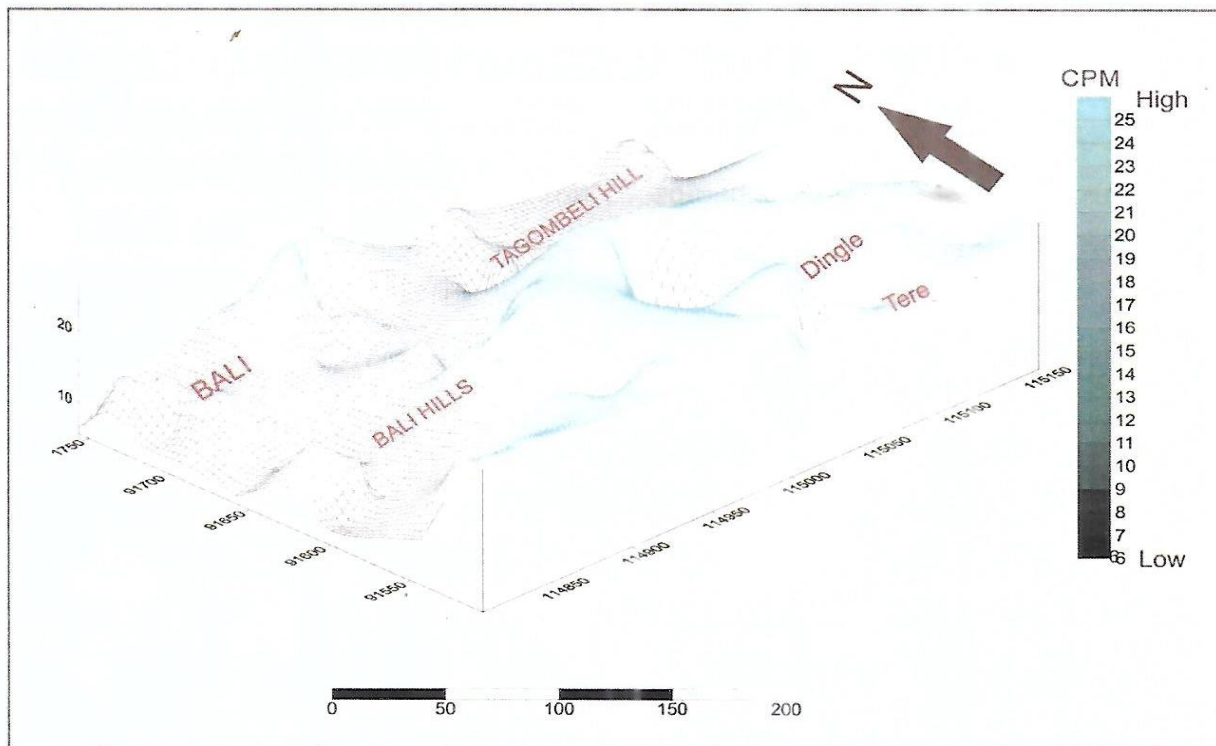


Figure 12 : 3D view of the Iso-rad map of the Study Area showing areas of high and low radioactive anomaly.

The anomaly is structurally controlled in the directions of the Benue Trough NE-SW, N-S, E-W. The anomaly also aligns to the structural trend displayed by the rose plot (Figure 10) while the areas of low radioactive anomaly is as a result of anthropogenic activities in that specific area, which creates a thick soil cover. The thick soil cover makes it difficult for the gamma scout device to detect radioactive emission from the rocks which gave low radioactive readings in the area. From the study, the areas of high radioactive anomaly are devoid of settlement. The areas of high radioactive anomaly on the 3D iso-rad map are represented by elongation in form of a hill while the lowlands signify low radioactive anomaly (Figure 12).

SUMMARY AND CONCLUSION

Structures encountered include faults, veins and joints which are trending NE-SW direction. Major lithologies in the area include calcareous Bima sandstone and Quaternary to Recent alluvium. The major mineral constituents of the Bima sandstone are quartz, orthoclase feldspar and iron which were all visible under plane polars and cross polars. The radiometric survey indicate that the southeastern part of the study area has high radiometric anomaly. Pasam hill and extending towards the southern part of the area also has high radioactive anomaly. Gindi Dutse and Asam experienced high radioactive anomaly. Zwangni area at the northern part of the area has high radioactive anomaly. Bali area at the northeast and Dem area at the northwest has very low radioactive anomaly. While the presence of orthoclase feldspar in the sandstone is attributed to its high radioactivity, thick soil cover within the study area causes low radioactive anomaly in some places.

Conclusion

Conclusively, the geology of the area is sedimentary which is part of the Upper Benue Trough and is characterized by calcareous Bima sandstone and shales. Structures encountered in course of the field mapping include faults, veins and joints with majority trending NE-SW. Minerals identified under plane - polarized light and cross-polarized light include quartz, orthoclase feldspar and iron. The areas of high radioactive anomaly in the study area are as a result of the presence of orthoclase feldspar in the Bima sandstone while areas of low radioactive anomaly are attributed to thick soil accumulations.

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