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Radiometric Mapping of Song Area and Environs, Hawal Basement Complex, Northeast Nigeria

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ABSTRACT

A ground radiometric mapping of Song area and environs in Nigeria's northeast basement complex was done as part of on-going geo-exploration work of the area. The area lies between longitude $12^0$35'- $12^0$40', and latitude $9^0$45'-$9^0$52'. It covers about 113.4 km^2. Mapping was done following a regular grid with a size of 1minute (1.8 km), and a total of 35 stations were occupied. Station identification was done with aid of a GPS. Lithological data where exposed were recorded alongside radiometric data. The latter were recorded using the *Gamma scout®* tuned to Geiger counter mode. Gamma radiations were recorded over interval of three minutes and averaged out to give the counts per minute (cpm). The averaged data were contoured using computer software *Surfer 8*. Three rock groups were observed in the area namely: granitoids (granites, pegmatites and aplites), metamorphic rocks (gneisses and migmatite) and basalts. Isoradiometric anomalies reflect the general distribution of these rock groups. Significantly the anomalies align in three major directions namely N-S, NE-SW, and NW-SE.E-W anomalies are few. These are consistent with published structural data, alignment of geomorphic bodies and fluvial channels over the area. By implication the emplacement of lithologic bodies follows the structural grain in the Precambrian basement complex. The survey has enabled mapping of lithologies where outcrops are absent.

Keywords: *Radiometric mapping, Precambrian basement and Song*

I. INTRODUCTION

Song area has been variously mapped by Adekeye and Ntekim (2004 and Bassey (2007). These authors identified gneisses, migmatites, granites and basalt flow as the major rock types, with basic intrusions as minor. The aerial coverage of these earlier surveys was limited to latitude $9^0$47'30"-$9^0$52'00"N, and longitudes $12^0$35'-$12^0$40'E. The present work covers latitudes $9^0$45'- $9^0$52'N and longitudes 12^0 35'- 12^0 40'E, an area of 113.4 km^2 (Fig.1.). Thus it covers approximately 25% more than previous works. The present work identifies areas of low, medium and high radioactivity, and interprets the results in terms of lithological variations based on the radioactivities. Hence it sheds more light on the geology of the area especially the southern part hitherto unsurveyed in detail due largely to paucity of outcrops. Structural and tectonic interpretations are also attempted.

Radiometric surveying came into lime light with the demand for uranium in nuclear technology. But the technique is not limited to search for uranium ores or associated minerals. It can be used in geological and structural mapping also (Parasnis, 1986). It is in this regard that effort was made to explore Song and environs using radiometry.

Certain nuclei of atoms disintegrate spontaneously emitting α-particles. This is the phenomenon of radioactivity. The nucleus is generally in an excited energy state after a β-emission and returns to its ground state with the emission of a further particle the γ-ray. In some rare instances emission of α-particles is followed by γ-ray. The γ-ray is purely an electromagnetic radiation which does not alter the nuclear charge. The α- and β-particles lose their energy in passing through matter by collision or ionization and are easily stopped by matter. Hence they are of very limited use in exploration since they will be undetectable as soon as radioactive deposits or rocks have even the thinnest cover of soil. Thus radiometric surveying is ultimately the search for places with abnormally high γ-radiation.

II. METHODOLOGY

The field instrument used in this survey is German made *Gamma-scout®* acquired by the Geology department, Modibbo Adama University of Technology, Yola. The instrument is a Geiger-Muller counter tube which can be used to detect not only gamma rays but alpha and beta particle also depending on the setting. In this case it simply measures the radiation and present the reading electronically (digitally) as number of pulses received. See its photograph in Fig.7. For the present work, the instrument was switched to the Geiger counter mode for gamma ray detection. The number of pulses is proportional to the level of radioactivity in the environment, the measurement is taken.

The instrument is also equipped with an electronic timer. Thus pulse rate can be determined in second, minute, or hour. Radiation intensity may strongly fluctuate on a short term basis, hence instrument manufacturer recommends measuring of average pulse rate. This takes care of atmospheric and cosmic ray backgrounds on obtained results. For this work, pulse rate was measured over an interval of 3 minutes for each station and the average pulse was computed per station. The three minutes timing was considered satisfactory for this work as the average pulse per minute or counts per minute (cpm) over similar rock types showed a good level of consistency. Several readings were taken over the different but major rock types in the area so as to determine a background value. This value was found to be about 26 cpm. Radiometric readings above or below this were considered significant and attributed to lithological changes.

The work began by gridding of the topographic map of the study area which was obtained from the Federal Surveys in Kaduna (Fig.1). The map is on a scale of 1 cm: 0.5 km, and published in 1968. Not much physical development has taken place in the area since the production of the map, hence natural features represented are still well preserved. Therefore the map's reliability was considered adequate. The grid size chosen was 1 minute interval equivalent to approximately 1.8 km. This interval was chosen as it made station density to be moderate and field work completed within available time. In this respect a total of 35 stations were covered, station co-ordinate identification and positioning was achieved using an *e-trex*™ global position system (GPS). A field motor vehicle was used to enhance movement.

Measurement were done by raising the gamma scout about 1 metre (about 3 ft.) above the ground (Parasnis, 1984). The survey was done in November 12-15 2010. November is a dry season month in Nigeria, when vegetation are virtually dried up so outcrops were within easy reach. Measurements of radiation were done directly over the outcrops except where exposures or outcrops were absents.

Outcrops of rocks were mapped simultaneously as the readings were taken. A lithological (geological) map of the area was prepared to enable interpretation of the radiometric data. The radiometric data were imputed into a computer software namely *Surfer 8* and contoured. A work flow chart of this project is presented in Fig.2. Fig.3 shows the radiometric map of the area while Fig.4 is the geological map as generated by Bassey, (2007) by direct outcrop mapping. Fig.5. is the geological map of the area generated from present study. Fig.6. shows the structural patterns based on radiometric anomalies. Fig. 7 shows a photograph of Gamma scout® used in this work.

III. RESULTS /DISCUSSION

Fig.3 shows that radiometric anomaly amplitudes range from 19-34.5 cpm. The radiometric anomalies are generally coincident with mapped (gross) lithologies namely granitoids, basalt and the metamorphic rocks (gneiss, migmatite and granite gneiss). Highest radiometric anomalies occur over granitoids as found northeast of Song town (>34 cpm). While the lowest radioactivity occur over basaltic areas such as northwest and west of Song, southwest of study area, south and southeast of Song. The radiometric values over the basalt range from 19-24 cpm. Some low anomalies are probably caused by sub-cropping basic (near surface or soil covered) rocks occurring as intrusion in the metamorphic basement. Intermediate radiometric anomalies with amplitude range from about 25-29 cpm are attributed to the metamorphic rocks. Radiometric anomalies can be used to infer lithologies in the absence of outcrops based on the results obtained over outcrops.

The high radioactivity of granites is due to the presences of feldspar minerals namely orthoclase and microcline which contain potassium (^{40}K) a radioactive element; orthoclase feldspar has the chemical formula $KAlSiO_8$. Microcline and orthoclase differ only in crystal system; the former is triclinic while the latter is monoclinic. The intermediate radioactivity of the metamorphic rocks is due to presence of orthoclase feldspar also but lesser amount (Telford et al., 1984). Part of the radioactivity of the rocks may however be due to presence of minute quantities of uranium and thorium (Telford et.al.,op.cit.). Thorium another radioactive element is found in monazite and thonalite. These minerals are found in granite and pegmatites. Monazite is also found in gneiss. Pegmatites occur in the granites of the area but at unmappable dimensions based on the scale of mapping in this study.

Based on lithological observation and radiometric anomalies a new geological map of Song was prepared and presented in Fig.5. Lineaments are mapped following structural closures or nosings of radiometric anomalies (Fig.6). Some of these lineaments correlate/or are coincident with mapped structures such as faults, shear zones, dykes and foliation.They are also parallel or sub-parallel to fluvial channels of Fig.5.

Emplacements of basalt in the area seam to follow basement fractures and/or faults (lineaments), this indicates fissure type volcanic eruption. These lineaments also define the river channels in the area such as River Song (Mayo Song), River Dalachi (Mayo Dalachi) among others (Fig.5). The flow direction of rivers commonly is NW-SE in the north of the area, and N-S in the south. The NW-SE emplacement direction of the basalt was also observed and reported by Benkhelil, (1986), who said that the N135^{0}direction is dominant in emplacements of Tertiary (65-1 Ma) magmatic (basalt) rocks.

The reliability of the radiometric data analysed here is consistent with published data for basalt and granite by Telford et al. (1984), and Parasnis (1986), respectively. This is shown in Table 1. The authors gave no values for metamorphic rocks.

IV. CONCLUSION

The radiometric survey data of Song and environs shows close relationship with gross lithologies. Areas of high amplitudes correlate with granites, those with low amplitude correlate with basalts. Intermediate amplitudes correlate with metamorphic rocks. There is field and radiometric evidence to show that emplacement of basalts in the area is lineament controlled indicative of fissure type volcanic eruption in the area during the Tertiary (65-1 Ma). The work has shown that sub-cropping or un- exposed near surface rock could be mapped based on radiometric anomalies; this is of much importance to mineral exploration and other geo-exploration disciplines. This study has produced a more detailed lithological map of Song area covering over 113 km^2 which can be of vital importance to our solid mineral sector in national economic drive. The reliability of this study is calibrated with existing published radio-lithological data. It is recommended that a study of this nature be extended to other areas to assist in geological mapping effort of the Nigeria Geological Survey Agency.

Table 1: Radiometric Data for Basalt and Granite

Rock type	Telford et al.(1984)	Parasnis (1986)	Present work
Basalt	$0.5x10^{-12}$ curies/gm	0.9 gram/ton	19-24 cpm
Granite	$0.7\text{-}4.8x10^{-12}$ curies/gm	3-5 gram/ton	29-35 cpm

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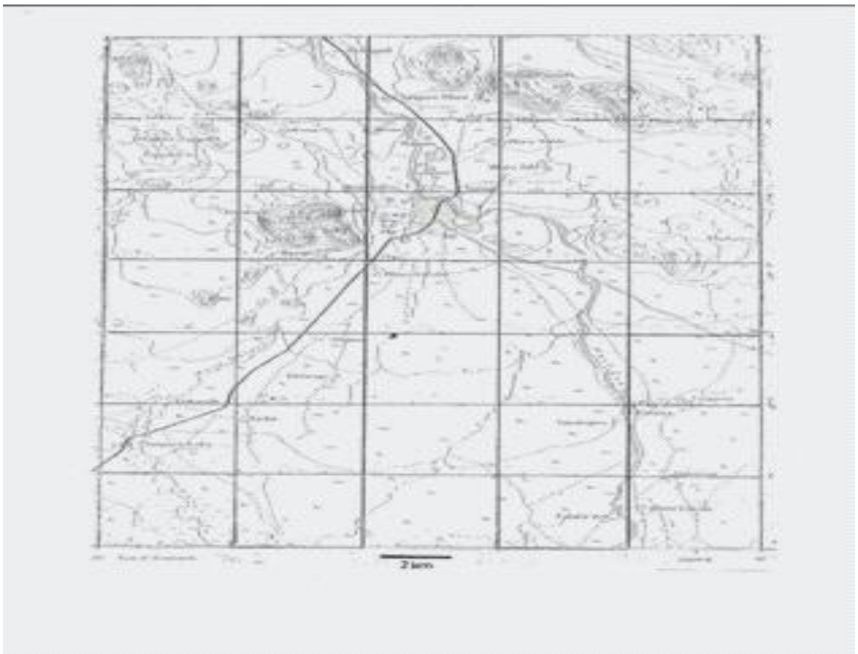

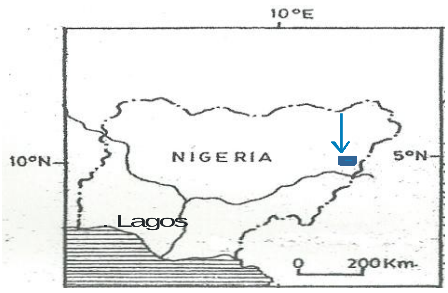

Fig. 1. Gridded topographic map of study area (left), map of Nigeria showing location of study area (right).

WORK FLOW

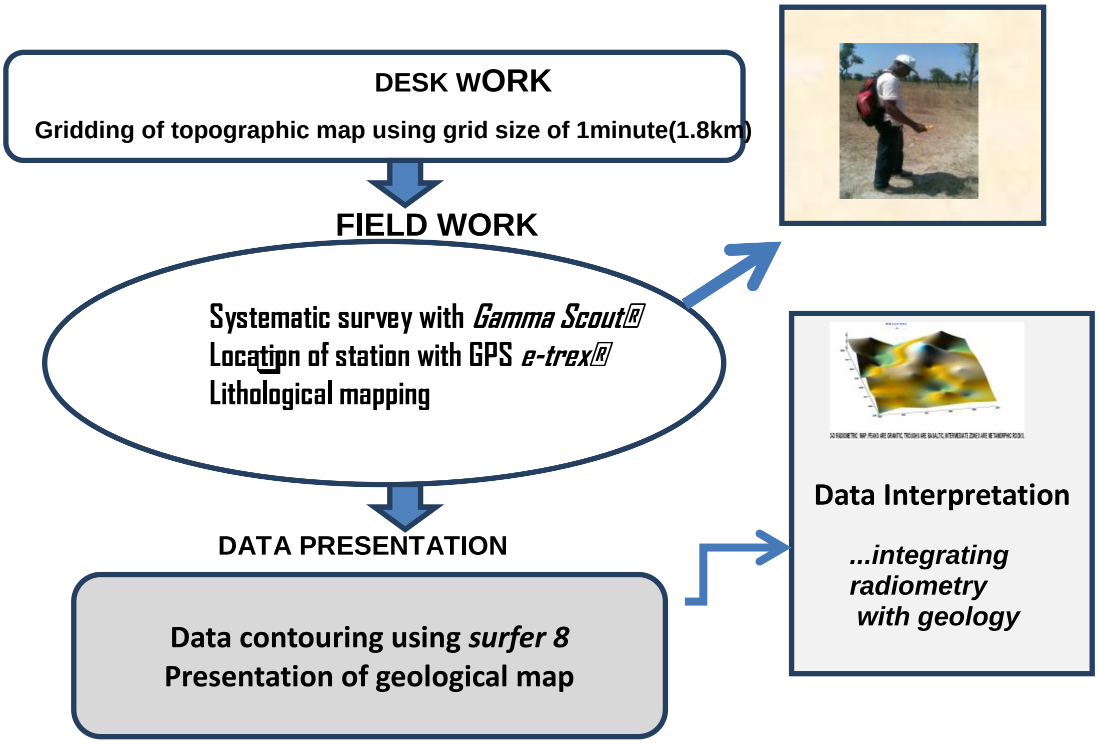

Fig.2. Work flow chart

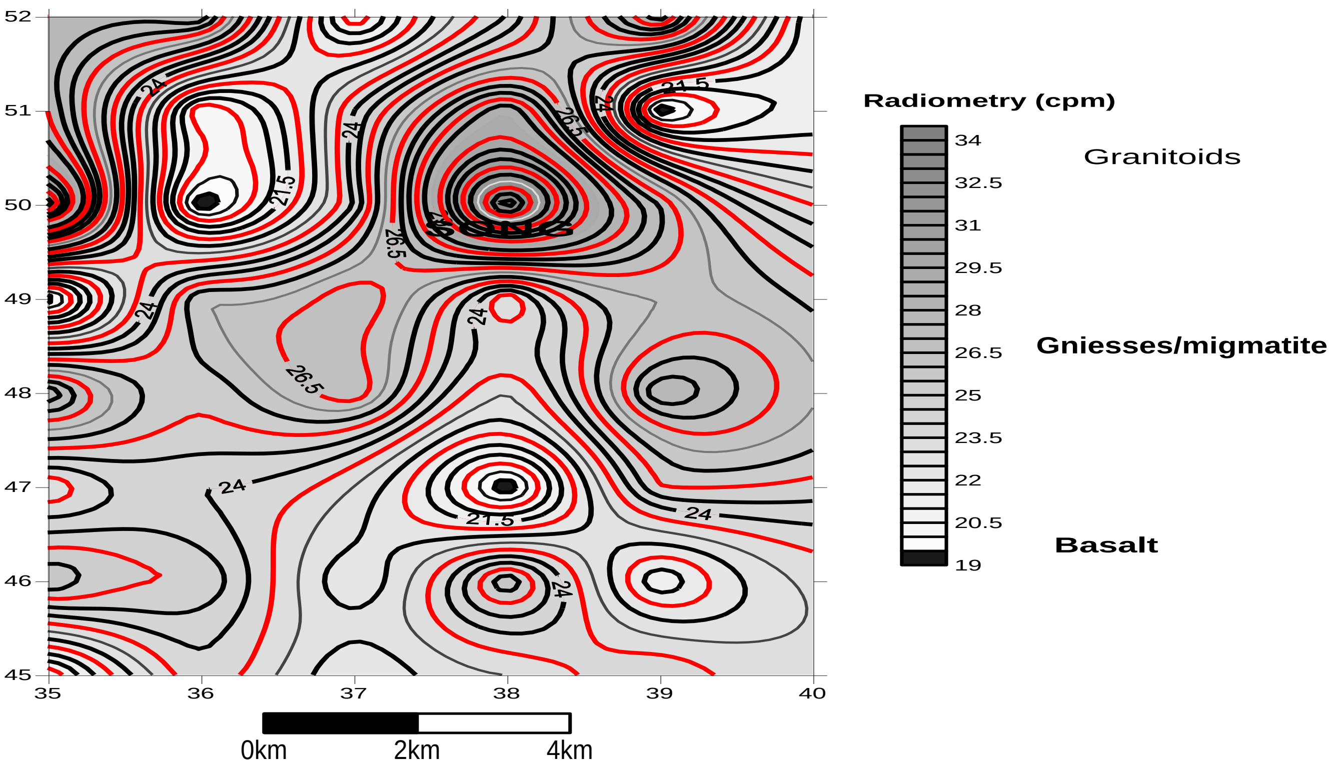

Fig.3. Radiometric map of Song and environs.

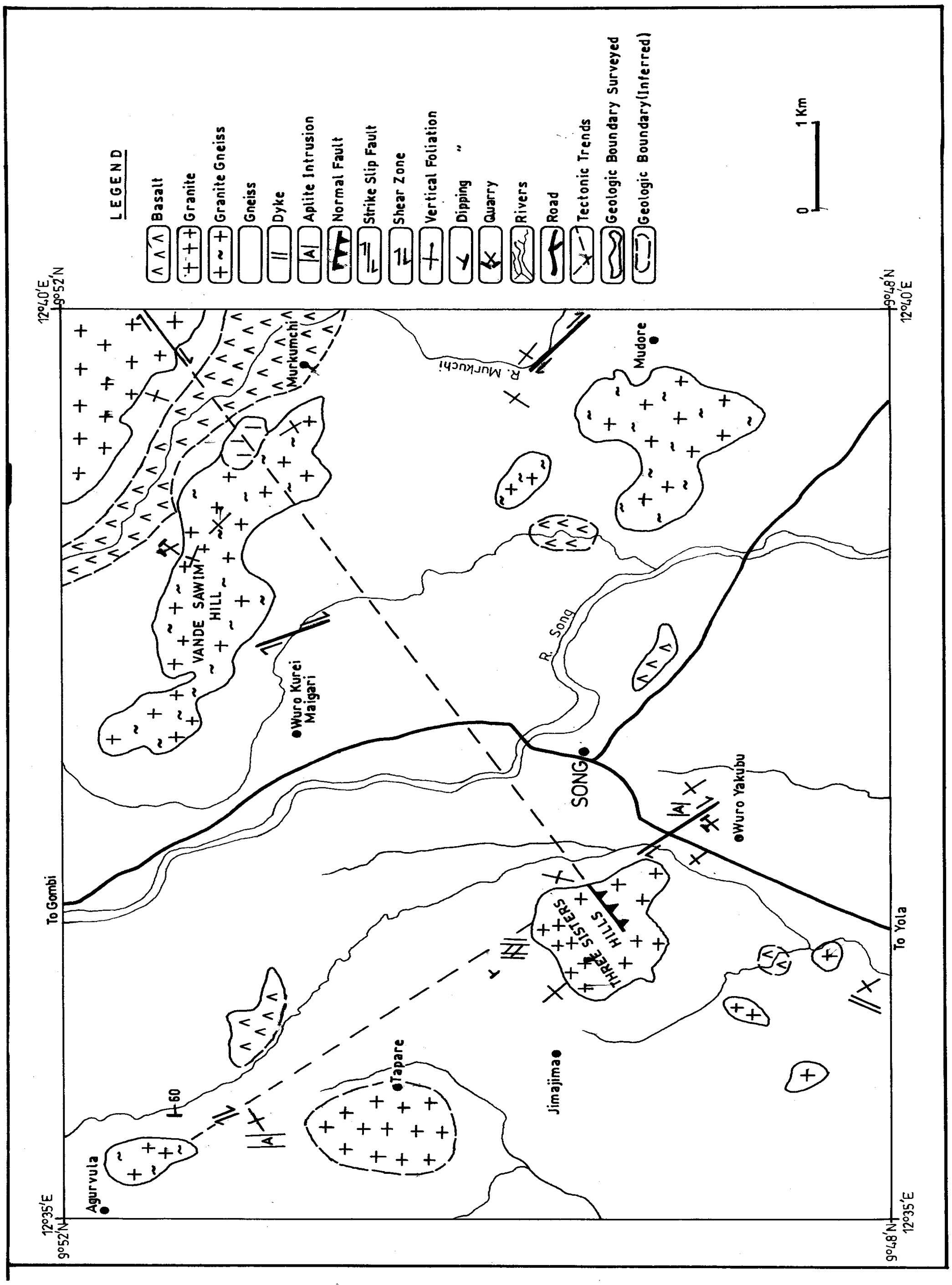

Fig.4. Earlier geologic map of Song area (Bassey,2007))

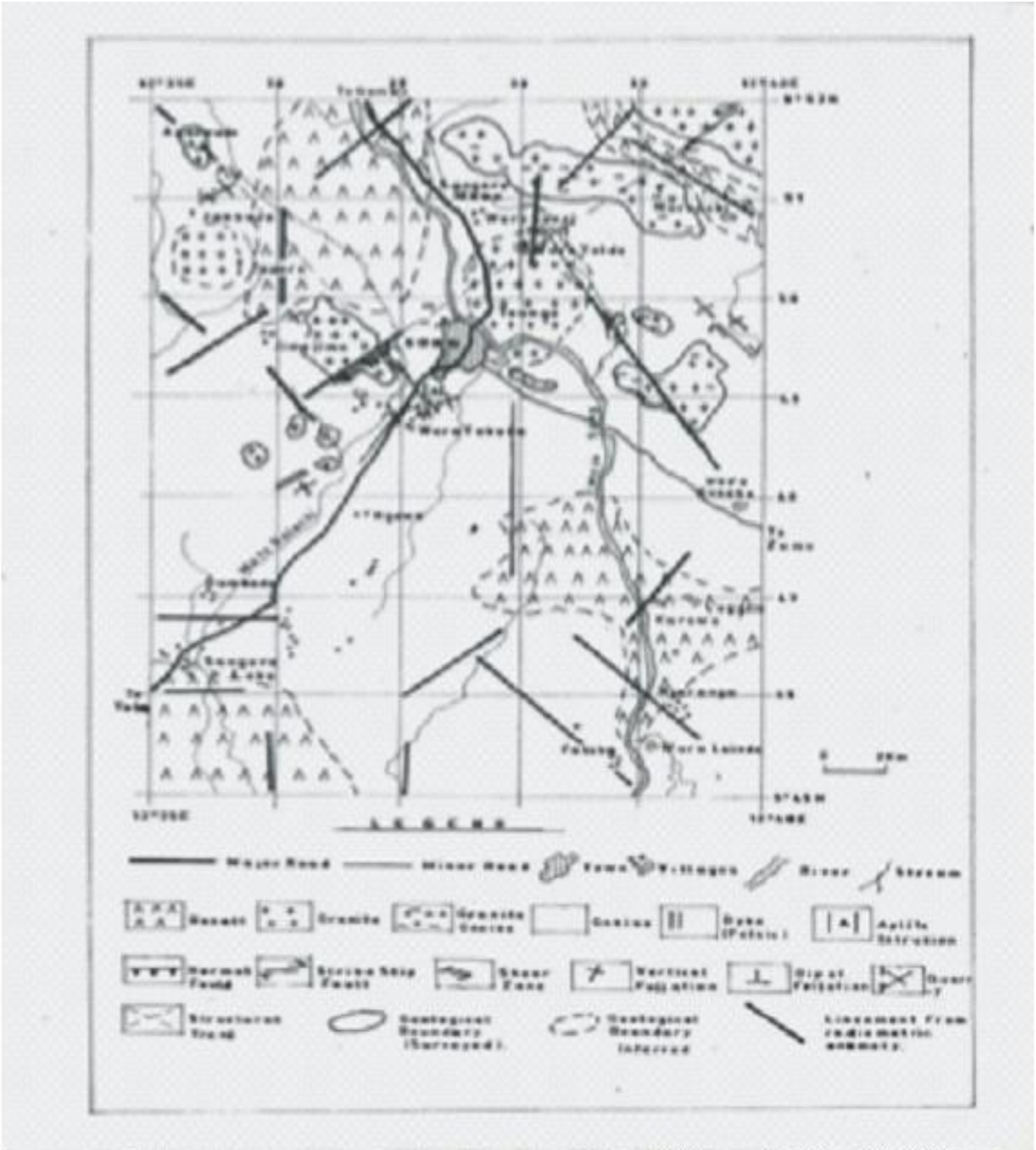

Fig.5. Geological map of Song area produced from present study.

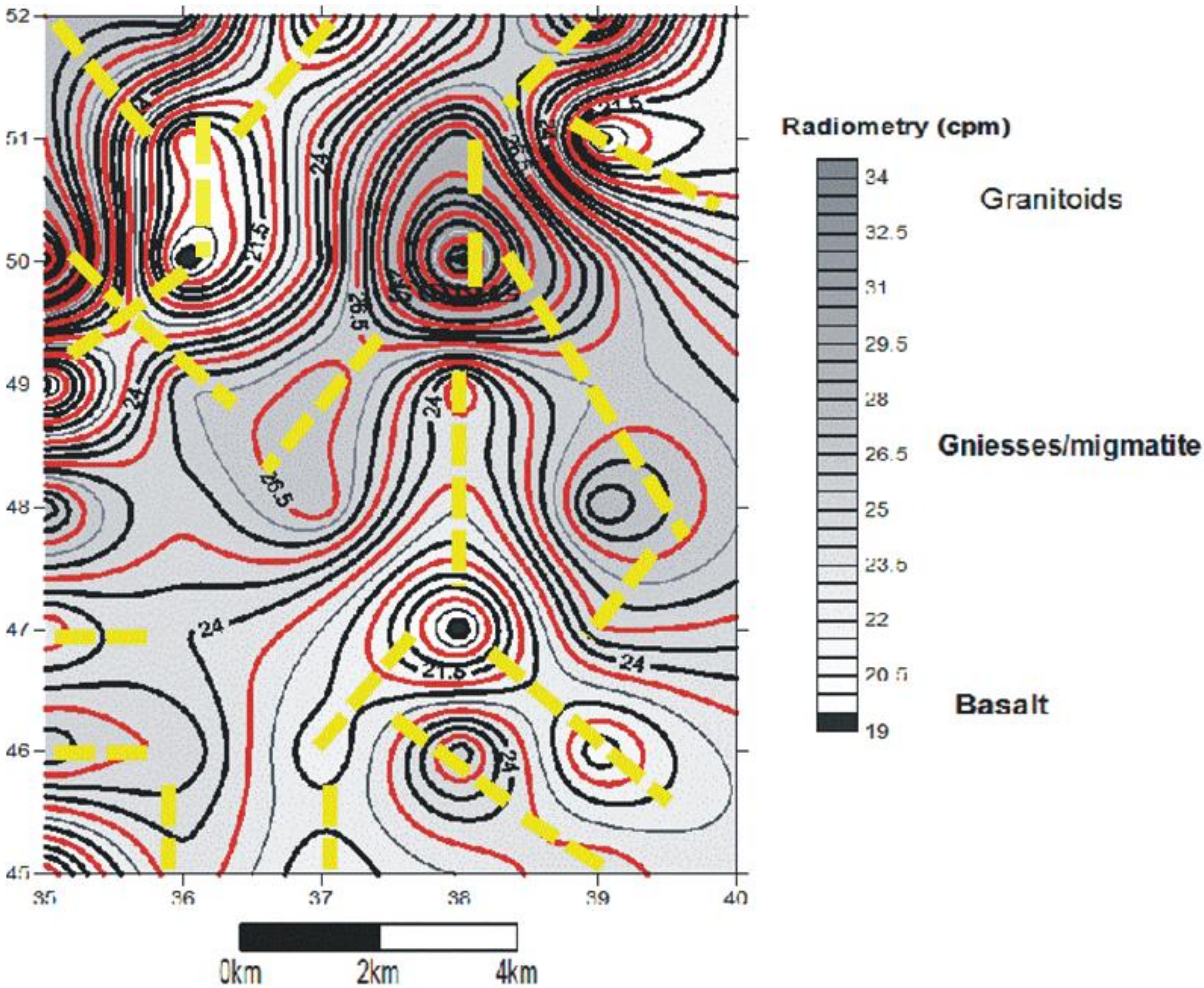

Fig.6. Structural patterns based on radiometric anomalies

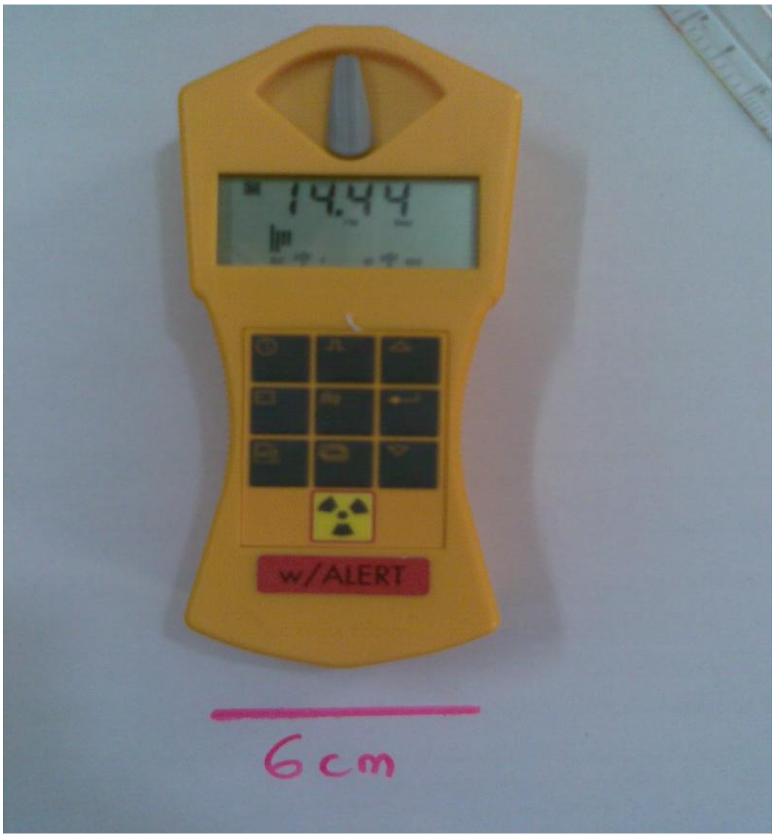

Fig.7. Gamma Scout Instrument

