Gamma-Ray Measurements of Naturally Occurring Radioactivity at Dumbeir Area, East Nuba Mountains, Central Sudan

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***Abstract*— A total number of 185 Gamma-ray readings were collected from Jebel Dumbeir area using the BGS – ISL Gamma –Ray Scintillometer. The survey was applied to investigate the occurrence of radioactive elements (U, Th and K) and to delineate their relation with the different lithological units in the area.**

Dumbeir area is underlain by crystalline metamorphic complexes sequences, which are cut by post-tectonic Nephaline-Syenite and Granitic intrusions. These intrusions are characterized by the presence of sharp contact, chilled margin and small xenolith near their boarder with the country rocks associated with sulphides mineralization along the chilled margin of the Nephaline Syenite, and a fluorite mineralization is also found along the shear zone. A series of earthquakes were recorded in the area, the last one was in April 1967, which was associated with reactivated strike slip fault.

The Gamma-ray survey was carried out over different lithological units in the area. These lithological units show large variation in their Gamma-ray readings. The highest reading was recorded over the skarn deposits (up to 3900 cps), the Fluorite ridge gives readings are ranging from 750 to 800 cps, the Nephaline- Syenite (350-450 cps) and the post- tectonic granite (250 – 300 cps), while the local background reading range from 100 to 150 cps.

These results are used as criteria for the geological mapping of the rock units in the area. The monitoring of these readings are used to investigate the sites of high radioactive elements concentrations. Moreover these readings give positive results that confirm the relationship between the uraniferrous- fluorite mineralization and the shear zone. Geochemical analysis of rock samples are recommended to differentiate between the different radioactive elements (U, Th and K) as well as confirmation of their concentration in each rock unit.

***Index Terms*— Gamma ray, Radioactivity, Nuba mountains, and Dumbeir**

I. INTRODUCTION

The Nuba Mountains lie between longitudes 28° 15' – 32° 35' E and latitudes 09° 35' – 13° 30' N, and represent a crystalline basement uplift in south-central Sudan. They are formed of basement migmatite gneisses, schists and metavolcanics underlying the plains, and are usually obscured by Quaternary clayey deposits. The rocks are intruded by post-orogenic, mainly granitic and syenitic intrusions forming rugged topography reaching in places 1460 m a.s.l. Examples are Jebel Ed Dair, Jebel Dumbeir and Jebel El Higierat. The whole region is surrounded by Mesozoic to Cainozoic sedimentary basins.

The study area (Fig. 1) is situated in the northern part of the region between longitudes 30° 40' – 30° 53' E, and latitudes 12° 30' – 12° 48' N, covering an area of about 150 km^2. It is accessed from Es-Semeih, on Khartoum – El Obeid Motorway, by a 20 Km seasonal track which is motorable from October to June (Fig. 1). Jebel Dumbeir is the most prominent topographic feature and rises to a height of 260m above the surrounding plains. It is made up of nepheline syenite and carbonatite intruding biotite gneisses about 550 My ago. Jebel Ed Dair, 8 km to the southwest of Jebel Dumbeir, is formed of sodic granites and rises to 1413m a.s.l. Together with other nearby small granitic or syenitic intrusions like Jebel El Higierat, Jebel Ahmar, Azrag , Abu Reish and Nimir, they lie in a linear belt trending NE/SW (Fig.2). They all belong to the alkaline post- orogenic "younger granite" province of the Sudan which spans the period 650 – 137 Ma [1], [2]. The fluorite ridge is located 100m east Jebel Azrag and it has the same trend of the shear zone (NE/SW). The area was hit by an earthquake in 1966 with the epicenter located at Jebel Dumbeir (Fig. 5).

The usual objective of gamma-ray survey is to locate anomalous zones of gamma radiation in the study area and to determine their nature and concentration.

The main objectives of this study were to carry out Gamma-ray surveys to investigate the occurrence of the naturally radioactive elements (U, Th and K), as well as delineating their aerial distributions through the whole of the Dumbeir area; and to confirm the control the radioactive anomaly by the structural pattern. Moreover is to correlate between radioactivity and the different lithological units, as results, using the correlation results (if possible) for geological mapping purpose.

The main basement subdivisions of the Nuba mountains into older metamorphic rocks and relatively younger plutonites with ophiolitic fragments are given in the accounts of eg. [3] - [14]. Groundwater investigations were carried out by e.g. [15]. Mineralization studies were provided by [16]-[20]. [7], [21] carried out radiometric dating of some of the plutonic rocks of the region. [22] carry out gravity surveys to investigate the presence of a recent subsurface fracture zone related to Jebel Dumbeir earthquake

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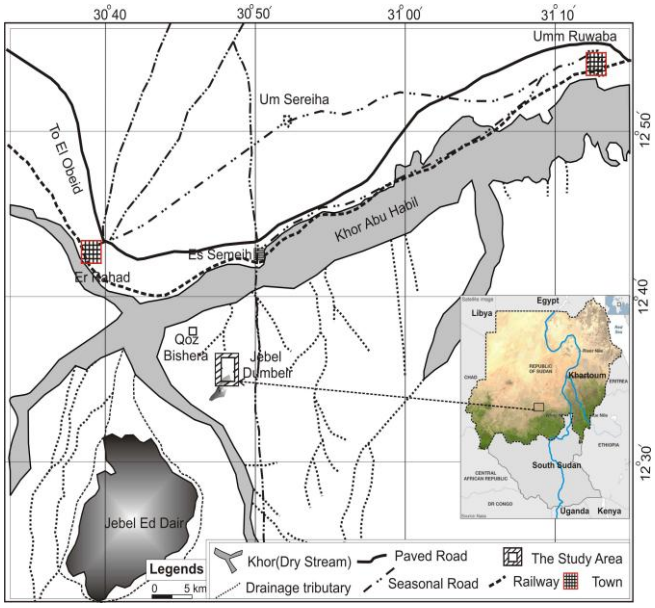

Figure 1. Location map of the study area, accessibility and drainage system.

II. General Geology and Tectonic Setting of the Nuba Mountains

The main rock groups in the Nuba Mountains include from bottom to top:-

6. Superficial deposits.
5. Tertiary- Quaternary deposits.
4. Mesozoic sedimentary sequences.
3. Post- orogenic granites.
2. Syn-orogenic granites.
1. The crystalline metamorphosed rocks.

The Nuba Mountains form an uplifted massif, made up of crystalline metamorphic sequences as well as late – to post-orogenic igneous intrusions of Precambrian to probably early Palaeozoic age [3],[5], [1], [2], entirely surrounded by a Mesozoic to Caenozoic cover, filling probably graben structures, (Fig.3). The layered basement rocks include high grade (amphipolite facies) granitic gneisses (older rocks) with local migmatites and lenses of amphipolite schists, structurally overlain by low-grade metavolcano-metasedimentary sequences in the greenschist facies of metamorphism. The regional trend of foliation of the rocks is NNE to NW [3].

In eastern Nuba Mountains an ophiolitic mélange, known as Kabus ophiolitic mélange, structurally separates the Pre-Pan African, high-grade gneisses to the west from the Pan-African, low-grade metavolcano-metasedimentary sequence to the east. It is believed that the mélange marks the site of collision of the gneissic and oceanic terrains, as argued by [14].

These layered sequences are cut by syn- and post-orogenic granitic and syenitic intrusions forming high rugged topography. They are, in turn, cut by basic and acid dykes [5]. The layered basement rocks are partially covered by various continental sedimentary rocks of Mesozoic to Cainozoic age cropping out to the northwest, west and southwest of the region. Unconsolidated clays, sands and gravel of the Tertiary to the Quaternary Umm Ruwaba Formation flank the eastern part of the region, while recent alluvial deposits and wind-blown sands constitute the superficial cover over much of the flat ground.

III. Geological, Structural and Tectonic Setting of Dumbeir Area

The oldest rock in the study area (Fig. 4) belongs mostly to the Pre-Cambrian basement complex, which is differentiated into gneisses, volcano-sedimentary sequence of relatively younger age, basic, ultrabasic, acid intrusions and dykes. The basement is unconformably overlain by unconsolidated sediments of the Tertiary to quaternary Umm Rawaba Formation. Recent deposits of alluvial and windblown sand constitute the superficial cover over the extensive flat ground. Migmatized quartzo feldspathic gneisses occur (one km) north of Sidra village [20]. The volcano- sedimentary sequence constitutes interbanded system of micaschist, quartzite and marble.

Different an orogenic igneous masses were injected into the older basement such as the granitic intrusive of Jebel Eldair in southern part of the area, the nephaline syenite carbonatite complex of Jebel Dumbeir in the central part of the study area, and Elhigirate finger-like granites in the eastern part of the area. These post tectonic intrusions occurs as batholith stocks, irregular masses or ring and arcuate dykes, they form roughly NNE belts of intrusions (Fig.4)

The mineral occurrence related to this complex is represented by carbonate dykes, fluorite veins, skarn deposits and the radioactive elements.

General Field relations and petrographic studies support the following stratigraphic succession in the area, from older to younger rocks.

1- Carbonatite
2- Pyroxenite
3- Skarn deposit
4- Younger Granite
5- Orthoclasite
6- Nephaline Syenite
7- Metasediments(Schist, Marble and quartzite)
8- High grade gnisses

Tectonically the Dumbeir area witnessed a complex structural history, related to the Nuba Mountains. There are three period of deformation affected the area described as F1, F2 and F3 successively. The oldest rock (gneisses and metasediment) have been affected by the three deformation phases. Where as the post-tectonic intrusion (Syenite & Granite) was only affected by the last events (F3). The deformation phases were characterized as two folding events and a third brittle deformation resulted in Faulting and jointing , that continued throughout the geological history of the region up to recent [5]. The intrusive complex of Dumbeir is believed to be controlled by these faults. These are Jebel Dumeir, El Dair, El Ahmar, Nemir, Abu Reish, El Higirat, El Semeih and Jebel Tibna, shows a linear belt of general trend (NNE), as shown in Fig.4. The " isoseismals" (lines separating zones of equal intensity) for the Jebel Dumbeir Earthquake were plotted in Fig.5 on the basis of the 1956 version of the Modified Mercalli Scale.

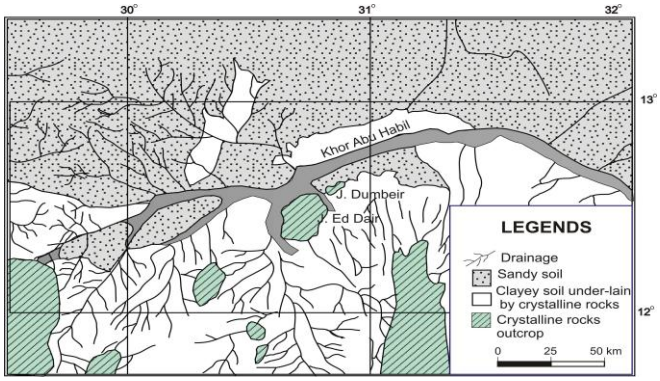

Figure 2. The major physiographic and rock unit map of Northern Nuba Mountains

The following succession of the tectonic history of the mapped area was described after [20].

IX Erosion and Earthquake (Present day)
VIII Quaternary to Recent Sediments
Unconformity
VII U- Th bearing fluorite and associated Mineralization (L-Proterzoic)
VI Major faulting (Strike slip faults)
V Post-tectonic intrusions (syenite & younger granite)
Major unconformity
IV Deformation (F1, F2 and F3) (late proterozoic- early Paleozoic)
III Metasediment Major unconformity
II Folding and Metamorphism
I High grade gneisses

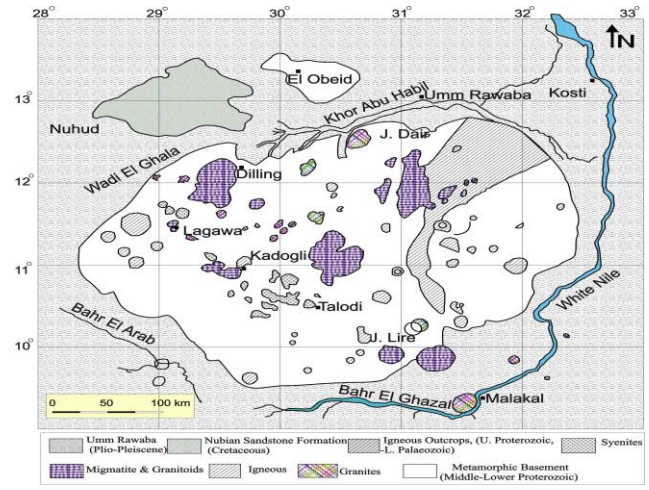

Figure 3. The geological map of the Nuba mountains (modified after Ahmed, 1982).

IV. Gamma – Ray Measurements

The Gamma-ray technique is simply to move appropriate spectrometric system across the area of interest. The BGS – ISL gamma-ray scientillometer is a portable, light-weight, transistorized instrument useful in prospecting for Uranium or indeed for locating any Gamma-ray emitting material. The Scientillometer is sensitive to gamma ray energies from approximately 100 Kev to greater than 3 Mev. It is therefore useful for the geologists searching for (K40), Uranium (U238 and daughter products) and Thorium (Th232 and daughter products). The energy response all gamma energies above 0.1 Mev, the refractor ranges are 30, 100, 300, 1000, 3000 and 1000 CPS and the accuracy is +5% full scale.

Gamma-ray measurements were carried out in Dumbeir area during the period of one week (1\6 -8\6\1995). Abroad band gamma-ray scientillometer Mod. 801013 was used for the field data acquisition. A total number of 185 readings were collected from the whole of the area (about 12 km^2) the measurements conducted through nine profiles (Fig.4). The distance between each two profiles is about 400m and the interval between the stations is varies from 25, 50 to 100m.

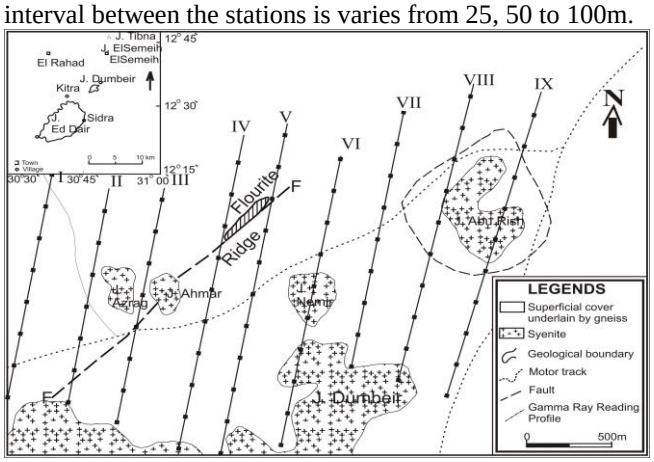

Figure 4. The sketch geological map of Jebel Dumbeir showing locations of the gamma-ray points.

V. Results and Discussions of Gamma-ray Readings

The gamma-ray readings were displayed in a form of radioactive contour map to show the sites of high concentrations of radioactive elements (Fig.6), as well as to correlate this reading with the different rock units in Dumbeir area. The relationship of the contoured pattern and the distribution of the major anomalous lithologies have formed the basis of this interpretation. It could be seen that the contours show a general relationship to the principal rock units and structural trends; and they provide information about the highest radioactivity levels. These levels are associated with the skarn deposits, carbonatite and the fluorite ridges that related to the shear zone (NNE trend). A summary of the correlation between gamma-ray readings and the rock units are shown in table.1.

Table 1. Show the variations in gamma-ray readings in correlation with different rock units and mineral deposits in Dumbeir area.

Rock Unit and Mineral deposits	Gamm-ray in CPS
Skarn deposit	500 – 3900
Fluorite Mineralization	750 – 800
Orthocalcite	450 – 800
Nephaline –syenite	350- 450
Carbonatite	300 – 350
Post-tectonic granite	250 – 300
Local back-ground	100 – 150

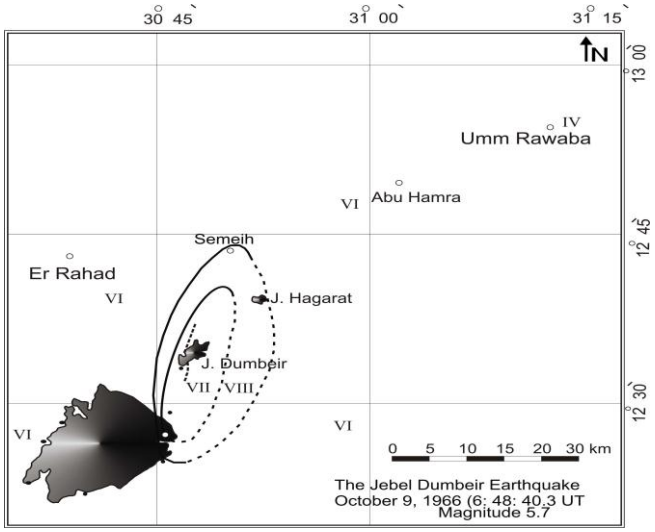

Figure 5. Intensity and isoseismals (on modified Mercalli Scale- 1956 version), and the fault trace associated with Jebel Dumbeir earthquake of October 9, 1966. [23].

From the foregoing of these results, the followings are considered significant:-

A) The regional background gamma-ray counts were rarely above 40 cps. This tends to rise to 100 – 150 cps for local background in area of radioactive mineralization.

B) The nephaline-syenite displays an average readings of 350 -450 cps. While in the orthoclasite, the reading reach up to 450cps.The latter has a grater tendency to display counts as much as 800cps when it enriched in fluorite, as an example Jebel Nemir, El Ahmar and Jebel Abu Reish.

C) The skarn deposits shows the highest gamma-ray reading in the area (up to 3900cps) this in association with pyrite, barite and fluorite mineralization (NNE part of Jebel Dumbeir).

D) The most distinctive high readings are related to the fluorite veins (750- 800cps) at Jebel El Gedian.

E) The post-tectonic granites shows the lowest reading (250-350cps) eg. Jebel Eldair and Jebel El Higirat.

F) The reading is reduced to a range of 40 to 45cps in areas far from Jebel Dumbeir such as El Semeih and El Rahad towns (more than 10 km far).

G) The scientillation over the carbonatite has showed maximum readings of 350cps.

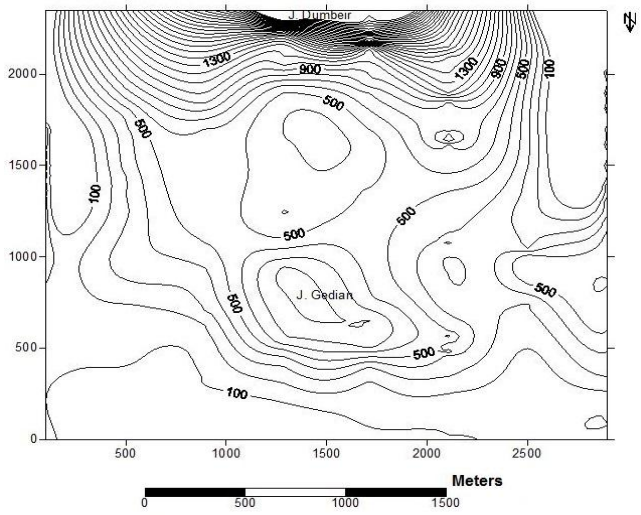

Figure 6. Radioactive contour map of Jebel Dumbeir area.

VI. Conclusions and Recommendations:

- Radioactive contour map delineates the regional and the localized patterns of radioactive element distribution. The most important features revealed by this measurements is the confinement of radioactive mineralization to nephaline-syenite carbonatite complex, in a NNE regional zone, including Jebel Dumbeir in the south and Jebel Elsemeih in the north. No sign of any radioactive mineralization was recorded in the far north (Jebel Tibna) or in the far south at Jebel Ed Dair.
- It could be seen that the radioactive contours show a general relationship to the principle rock units and structural trends; however they provide information about the highest radioactivity levels. This level is associated with the skarn deposits, carbonatite and the fluorite ridges that related to the shear zone (NNE trend).
- From this work we can conclude that the radioactive mineralizations are lithologically and structurally controlled, where it is mainly related to the younger igneous intrusion rocks (granite and syenite) and it is restricted also to fractures and faults specially the strikeslip shear zone. The occurrence of radioactive mineralization in the area can be considered as of hydrothermal origin.
- The use of gamma-ray measurements as a tool in geological mapping and in localization of the subsurface contacts of post-tectonic intrusions gave extremely positive results; this is due to the anomalous readings of different lithological units.
- Geochemical analysis of rock samples are recommended to differentiate between the different radioactive elements (U, Th and K) as well as confirmation of their concentration in each rock unit.

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