Radioactive Gamma Ray Response of Some Mesozoic Lithological units Exposed in Gharyan Area NEW Libya

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Abstract:

Mesozoic sedimentary rocks are exposed in Gharyan area NW Libya. The age of these rocks ranges from Ladinian/Carnian beds exposed in some hillocks in the foot plain of Jabal Nefusa around the city of Al Azizia up to Cenomanian Nalut (previously Gharyan) formation over which the city of Gharyan is settled. The formations are composed of different lithological units, and are interbeded locally in some areas with igneous intrusions and extrusions along with some tectonic elements such as faults. Gamma rays are small bursts of very high frequency electromagnetic waves that are spontaneously emitted by the nuclei of some isotopes of some elements. Only a limited number of isotopes of the natural elements emit gamma rays; and among these, there are only three which are: Potassium (K), Uranium (U) and Thorium (Th). K is a major constituent of most rocks and is the predominant alteration element in most mineral deposits. Uranium and thorium are present in trace amounts, as mobile and immobile elements, respectively .As the concentration of these different radioelements varies between different rock types, we can use the information provided by a gamma-ray spectrometer to map the rocks. SPP2 Gamma Ray Scintillometer and RS320 Gamma Ray Spectrometr were used in this study to measure the gamma ray radioactivity of the different units of the geological formations in the area. The measured radioactivity range of the different units in the measured channels was: total radioactive channel (222 ppm –

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2920 ppm); potassium (0.3% - 7.3%), Uranium (0.7ppm – 14.3ppm), Thorium (0.6ppm – 23.7ppm), and total gamma ray scintilometry (15 c/s to 180 c/s). The measured geophysical radioactive data showed a very well accordance with the different geological units. This work is an attempt to denote the natural radioactivity of the lithological units exposed in jabal Nefusa in Gharyan area and it is the first is kind of such study and will serve as a guide line to any radioactivity survey or study that will be carried in the future in this area or the surrounding areas.

Introduction:

Nefusa Uplift:

The Nafusa Uplift is a major east-west ridge which extends for 400km from Misrata to the Tunisian border. It is bounded to the north by the Jifarah Fault and the Jifarah Basin and to the south by the Ghadamis Basin (Figure-1).

The Nafusa Arch was reactivated during the mid-Tertiary in response to the closing of Tethys. It was subjected to uplift accompanied by wrench faulting on the Jifarah Fault Dextral strike-slip faulting can be seen at several locations along the line of the fault. Eocene tectonism also led to the production of basaltic sills and flows near Gharyan, and the volcanic activity has continued until recent times (Conant and Goudarzi, 1967).

Figure-1 Location map of the study area(Gharyan area)

Basic principles of gamma ray spectrometry:

Surface gamma-ray logs or scintillometer profiles are not widely used but are a potentially valuable approach to stratigraphic correlation in regional field surveys, given suitable continuous outcrop (Chamberlain, 1984)

Gamma rays are tiny bursts of very high frequency, hence high energy, electromagnetic waves that are spontaneously emitted by the nuclei of some isotopes of some elements (Duval, 1980). Numerous authors describe the basic principles of gamma ray spectrometry and the use of these techniques in geological mapping and exploration (Darnley and Grasty, 1971, Galbraith and Saunders, 1983, Graham and Bonham-Carter, 1993, Wilford, 1995, and others) .

Some isotopes of the natural elements emit gamma rays; and among these, there are only three which are common enough within earth materials to make them geologically useful.

These three are Bi^{214}, Tl^{208}, and K^{40}. Bi^{214} comes from the decay of U^{238} and is, therefore, an indication of the concentration of uranium in the earth materials that lie within the range of the detector. Tl^{208} comes from the decay of Th^{232} and is an indicator of thorium content; and K^{40} is one of the minor natural isotopes of potassium and the only isotope of K that is radioactive. It makes up only .012% of the total potassium in rocks and soils, but because this fraction remains quite constant, even during weathering and metamorphism, the gamma radiation from it is a good indicator of changes in the amount of potassium in rocks.

Gamma rays are defined by their energies, measured in electron volts, or eV. One eV is the amount of kinetic energy that a single electron would acquire in falling through an electrical potential difference of 1 volt. The gamma rays from Tl^{208}, the Th indicator, have an energy of 2.62 million electron volts or 2.62 MeV. We can understand the physical meaning of 2.62 MeV by noting that this amount of energy is sufficient to lift a speck of dust having a mass of one microgram a distance of 1/25 millimeter. The

gamma rays from Bi^{214} have an energy of 1.76 MeV; while those from K^{40} have an energy of 1.46 MeV. All three of these energies are constant; they never change, they therefore constitute well defined peaks in the energy spectrum emanating from rocks. Figure-1 shows an example of the natural gamma ray spectrum.

Geology of the study area:

The formations that are exposed in the Gharyan area may briefly be summarized in the following starting from the oldest (Fatmi et. al., 1971):

Al Aziziyah Formation:

The base was taken at the first appearance of carbonates overlying the Kurrush Formation. The upper boundary was defined at the unconformity with the overlying continental sandstones of the Abu Shaybah Formation. As redefined at the type locality the Al Aziziyah Formation comprises 160m of dark grey, hard, dolomitic limestones with occasional marls, claystones and chert bands. The top is marked by a thin unit with phosphate bands. The formation contains an abundant pelecypod fauna which indicates a Ladinian/Carnian age. The formation also contains characteristic algal laminae.

Abu Shaybah Formation:

At outcrop in the Gharyan area, the Al Aziziyah Formation is unconformably overlain by 125m of red fluvial sandstones and conglomerates. The formation comprises varicoloured fine to coarse-grained cross-bedded sandstones with a few thin dolomite and calcareous horizons towards the top. The lower contact with the Abu Shaybah Formation is distinctly unconformable, but the upper contact with the Jurassic Abu Ghaylan Formation is conformable. The formation outcrops at the foot of the escarpment north of Gharyan, and in three small inliers south of Ra's Ajdir. The formation is poorly fossiliferous with only a few undiagnostic pelecypods and fish fragments being found in the carbonates near the top.

Abu Ghaylan Formation:

It outcrops at Abu Ghaylan, north of Gharyan, and for about 20km along the escarpment. At the type locality, 60m of dolomitic limestone are exposed, interbedded with marls, thin sandstones and breccias. The contact with the underlying Triassic Abu Shaybah Formation is abrupt, but the upper contact is variable.

Kiklah Formation:

In the Gharyan area the Kiklah Formation is composed of impersistent beds of mudstone, sandstone and conglomerate which were probably deposited in a braided-river system carrying high sediment loads, with frequent migration of the principal channels.

Sidi as Sid Formation:

The Sidi as Sid Formation in the Gharyan area overlying the Kiklah Formation in the west and the Abu Shaybah Formation in the east. The formation comprises two members, a lower carbonate unit named the 'Ayn Tobi Member, and an upper marlstone unit, the Yifran Member.

The Ayn Tobi Member:

Comprises 100m of grey and yellow crystalline limestones and dolomites with thin marlstone interbeds. The base is marked by a thin sandstone horizon which contains quartz pebbles derived from the underlying Kiklah Formation. At the type locality the middle of the limestone is marked by a distictive horizon full of rudistids and other pelecypods. The lower contact is unconformable, the upper contact with the Yifran Member is gradational.

Yifran Member:

Is composed of 70m of soft, thinly bedded alternations of marly limestone, claystones, marlstones and bedded gypsum. The gypsum horizon develops westwards, but is not present in the outcrops to the east. The fauna is generally poor, but some fragmentary pelecypods have been found along with fish teeth,

echinoid debris, foraminifera and ostracods. The environment of deposition ranges from lagoonal in the west through littoral to low-energy neritic in the east.

Nalut Formation:

Is composed of 53m of hard, crystalline, dolomitic limestone that overlie the Yifran Member of the Sidi as Sid Formation. The formation contains bands of chert and concretions. It contains rare, badly preserved pelecypods.

Volcanology:

The Gharyan volcanic province comprises three distinct units. An early (50–55 m.y.) phase of extensive plateau lava (basaltic hawaiite) eruption was followed by the emplacement of small phonolite domes (about 40 m.y.). After a long period of inactivity, a rejuvenation phase (less than 12 m.y. ago) led to the formation of scattered minor volcanic centres, generally of basanitic composition, and carrying Iherzolite fragments. 39 new analyses illustrate the distinctive chemical characteristics of each episode. Differences in volume and composition between early and late basic volcanicity can be related to regional episodes of strong mantle convection in the early Tertiary and weak convection in the late Tertiary (Picooli, 1971). The phonolites may be fractionates of an intervening injection of basic magma trapped at moderate depth. Continuing structural control was exerted on a regional scale by the zone of uplift and fracturing connecting the Ghariyn area with Tibesti.

Geophysical Radioactive Methods:

Field measurements:

Gamma ray spectrometry:

Measurements of surface gamma ray spectra were made using Radiation Solution Model RS-230 Spectrometer equipped with (103 cm3) higher density Bismuth Germanate (BGO) crystal detector. It gives very significant increase in performance over the

normal NaI detector (typically 3x). Each surface station included measurements of equivalent uranium concentration (eU= U measured as 214 Bi , the equivalent thorium concentration (eTh = Th measured as 208 TL) and the potassium concentration (K measured as 40K). the total count and the number of counts in each of the windows. The primary acquisition data set is measured in the field in a multichannel gamma-ray energy spectrum. Figure-2 shows this spectrum. This diagram shows a typical natural radiation energy spectrum, depicting the relative count rates at each energy level, from 0 to 3 MeV. The area from 0 to 0.4 MeV is not used and consists of counts created by Compton scattering. For geological mapping, the K40 (potassium), Bi214 (uranium) & Tl208 (thorium) peaks are of interest.

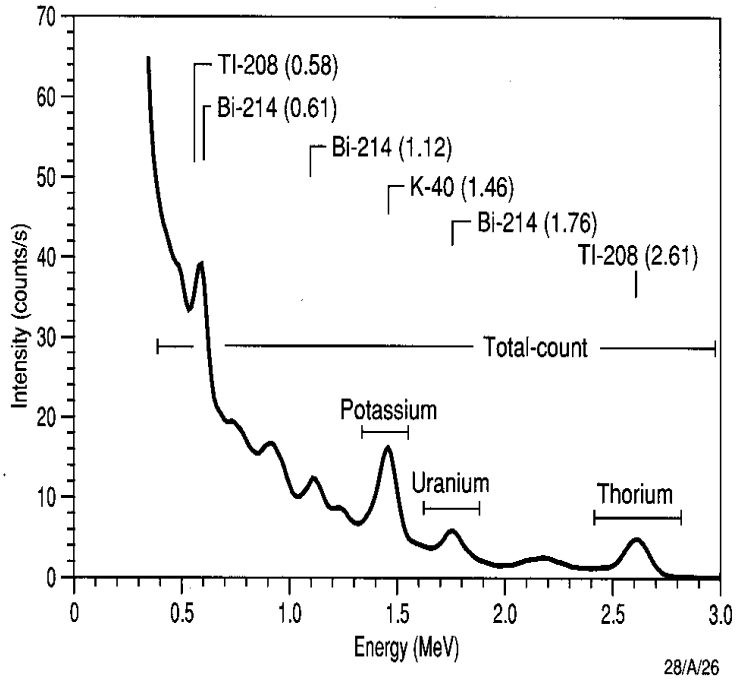


Figure-(2) Gamma-Ray Energy Spectrum showing the three radioactive chanells of Uranium, Thorium, Potasium and the Total Count channel (Wilford et.al 1997)

Gamma ray scintillometry:

The Saphymo-SRAT S.P.P.2 NF scintillometer is manufactured by Saphymo-PHY (Massy,France). It is designed for uranium exploration in rugged conditions. The detector is a 1 x 1.5 inch (15.2 cm3) NaI(Tl) (sodium iodide activated with thallium) scintillation crystal. The operation range for gamma radiation is 0.02 to 30 microsieverts per hour (μSv/h). The instrument has a built-in audible alarm that gives a high signal. The threshold and the frequency of the sound alarm can be varied according to the strength of the radiation. The time constant for the sound alarm is 0.25 seconds. The s unit of measurement is cps (counts per second).

Correction of the SPP2 NF scintillometer data:

Isotopic source of radioactive Cesium (137Cs), with an approximate activity of 250 c/s was used in this work to automatically control the system gain and protect from gain shift caused by temperature effect or component of ageing. A calibration factor of 2.5 was determined accordingly after reading of the isotope source which gave only 100 c/s .

This high calibration factor is logical since the instrument was an old one (I used to work with the same instrument in the late 70's in uranium exploration program in SW Libya). That not means by any means that the instrument is out of use, In other words it can be used at any time as far as one is fully aware of such calibrations and corrections.

Radioactivity of the different lithologies exposed in Gharyan area:

After the mentioned corrections the field gamma ray of the different lithologies exposed in Gharyan area may be summarized in the following table (Table-1):

No.	LITHOLOGY	Spectrometry				Scintillmetry
		Total count (ppm)	K %	U ppm	Th ppm	Counts per second (cps)
1	Background Reading ras Lefha intersection	285	0.6	0.7	1.2	25
2	Aziz Fm (dolomitic Ls unit)	653.3	1.1	3.2	3.0	35
3	Aziz Fm (shale unit)	383.3	2.8	5	12.1	85
4	Aziz Fm (phosphatic brecia)	2804	2.1	13.2	1.8	180
5	Kurush Fm (red-vilot clay)	2044	2.1	2.2	0.9	115
6	Bu Shyba Fm (Ss quarry)	369.5	0.4	1.1	3.2	25
7	Bu Ghaylan Fm	459.8	0.6	2.5	1.1	26
8	Kikla Fm sandstone	694.6	1.3	1.4	8.1	30
9	Ain Tobi	662.2	0.3	5.1	0.6	45
10	Kaf Tekut phonolite	2919.5	7.3	8.3	23.7	130
11	Yefren marl	489.4	1	2.4	2.5	20
12	Nalut Fm	222.4	0.3	1.3	1.3	15
13	Bu shyba quary dyke	1199	0.4	4.1	14.3	---

Table-1 The measured field data of K, U and Th and total count gamma ray radioactivity for the different geological units exposed in Gharyan area

Bausch, 1980 showed that the radioactivity of the Kaf Tekut phonolites is high and X ray diffraction analyses give the following mineral composition of a phonolite sample from Kaf Tekut (table-2)

Table-2 Mineralogical composition of Kaf Tekut ring structure

Mineral	Percentage
Sanadine	49
Nepheline	14
Albite	3
Analcime	27
Sum of felsic component	93

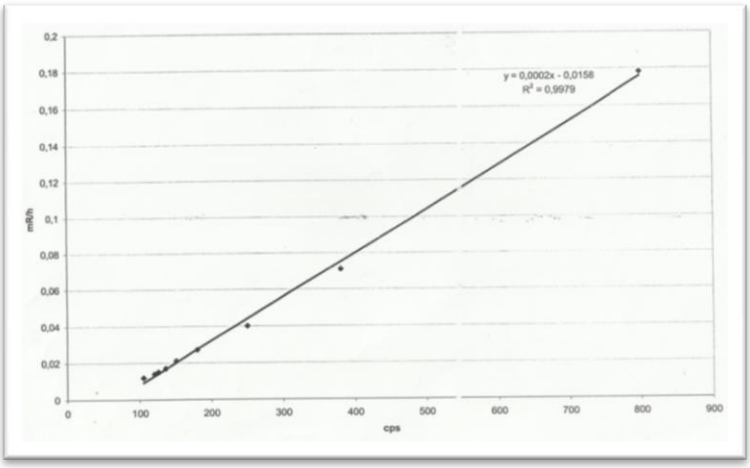
BAUSCH and MEDUNA,(1991) showed that Analcime in the phonolite is higher than the ordinary figures given in literature so these phonolites may be described as Analcime phonolites. Meanwhile Jabal Nefusa phonolites are characterized by enrichment in Na, K, Al, Fe, Cl, Zr, Th,and F. Chemical analysis of the same sample is shown in Table-3.

Table- 3 Analytical result of trace elements of Kaf Tekut phonolite

element	F	S	Cl	Zr	Nb	U	Th
(ppm)	916	202	625	724	102	6	17

Absolute and relative radioactive data used:

The obtained measurements were then subjected to transformation from a relative radioactivity units of counts per second (c/s) to absolute radioactivity units of mill-Roentgen per hour (mR/hr). The transformation was done by using the transformation formula and curve given in figure-3:



Figure(3) Correlation chart between the absolute and the relative total count gamma ray scintillometry as measured by the SPP2 NF

$$Y = 0.0002\ X - 0.0158$$

Combining the two corrections, the transformation formula and the calibration factor mentioned are merged in the formula:

$$Y = 2.5\ (\ 0.0002\ X - 0.0158)$$

Where X is the measured relative radioactivity in counts per second
Y is the measured absolute radioactivity in mili-Roentgen per hour

The use of the absolute radioactivity units is more important in environmental geophysical work, accordingly the relative radioactivity data will be sufficient to the geological mapping and

exploration purposes mentioned in this paper. The highest recorded radioactivity by the SPP@ is 180 c/s. Using the above formula one can get the absolute radioactivity of 0.0505 mill-Roentgen per hour which has not any environmental significance and that anomaly is located in a thin phosphatic bed exposed only in one location in Wadi Bu Shayba.

Discussion:

The conducted gamma ray survey showed the advantage and the use of geophysical technique in geological mapping and exploration. Radioactivity is changed in the area according to the geological units exposed in a manner that one can determine these units even when they are simply covered (less than one meter). A clear cut example is the radioactivity of the different Al Azizia Formation which show tremendous radioactivity of its different units. The total count radioactivity of the argillaceous unit of the formation is 383 c/s and its dolomitic unit with a total radioactivity of 653 c/s and its phosphatic breccia unit is as high as 2804 c/s. Al Azizia Formation is known of its holding of a locally exposed thin unit of breccias that is highly phosphatic. The unit is highly radioactive as mentioned. This anomalous radioactive unit may be used as an exploration tool for phosphate exploration in the area may be with airborne geophysical survey.

In conclusion this work is an example of the application of nuclear (radiation) geophysics to geological mapping and exploration in the area of Jabal Nefusa.

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I would like to deeply thank Mr Ibrahim Abed the General Director of the Industrial Research Centre for his encouragement by borrowing the Gamma Ray Scintillometer used in this work. Mean while I would like to thank the students of the Geophysics Department of the Faculty of Sciences (Universty of Tripoli) who took part in the field measurements during the field season 2012 in Jabal Nefusa area.

استجابة أشعة جاما الإشعاعية في بعض الوحدات الليثولوجية لصخور الدهر الوسيط المنكشفة في منطقة غريان شمال غرب ليبيا

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المستخلص:

تتكشف في منطقة غريان شمال غرب ليبيا صخور الدهر الوسيط الرسوبية. الطبقات الرسوبية يتراوح عمرها من العصر اللاديني و الكارني والتي تتكشف حاليا في بعض الجبال الصغيرة المتواجدة في قدم الجبل حول مدينة العزيزية إلى الصخور المتكشفة في عصر السينوميني والمتمثلة في تكوين نالوت (والمعروف سابقا باسم تكوين غريان) حيث تقبع مدينة غريان على صخور هذا التكوين. تشمل التكوينات الجيولوجية المتكشفة وحدات صخرية مختلفة تتخللها صخور نارية داخلية و خارجية، كما تعرضت المنطقة إلى بعض الحركات التركيبية متمثلة في بعض الفوالق التي يمكن رصدها في بعض المناطق. أشعة جاما هي عبارة عن ومضات صغيرة من الموجات الكهرومغناطيسية عالية التردد تنبعث تلقائيا من أنوية النظائر الذرية لبعض العناصر. تنبعث اشعة جاما من بعض ذرات نظائر العناصر الموجودة في الطبيعة ثلاثة منهما ذات أهمية في الاستكشاف الجيوفيزيائي الإشعاعي وهي: البوتاسيوم و اليورانيوم و الثوريوم. يعتبر البوتاسيوم المكون الرئيسي للعديد من الصخور وهو العنصر السائد في العديد من المعادن المتحولة الموجودة في الرواسب المعدنية. يوجد اليورانيوم و الثوريوم بكميات قليلة كعنصر متنقل و ثابت الحركة. وحيث إن درجة تركيز هذه العناصر تختلف باختلاف نوع الصخر فبإمكاننا التعرف وتخريط الصخور المختلفة وذلك باستعمال المعلومات التي نتحصل عليها من قياس النشاط الإشعاعي لأشعة جاما

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المنبعثة من تلك الصخور. استعملت هذه الدراسة جهاز قياس أشعة جاما (SPP2) و جهاز قياس طيف أشعة جاما (RS320) لقياس النشاط الإشعاعي لمختلف التكوينات الجيولوجية المتكشفة في منطقة الدراسة. تباينت قيم النشاط الإشعاعي المقاس في الحقل حيث تراوحت من 222 إلى 2920 جزءًا من المليون في النشاط الإشعاعي الإجمالي ومن 0.3% إلى 7.3% بالنسبة للبوتاسيوم ومن 0.7 الى 14.3 جزءًا من المليون بالنسبة لليورانيوم ومن 0.6 إلى 23.7 جزءًا من المليون بالنسبة للثوريوم وذلك بحسب جهاز قياس طيف أشعة جاما. تراوحت قيم النشاط الإشعاعي المقاس بجهاز أشعة جاما (SPP2) من 15 عدة في الثانية إلى 180 عدة في الثانية. بين النشاط الإشعاعي المقاس بالطرق الجيوفيزيائية توافقا جيدا مع الوحدات الصخرية المختلفة و المتكشفة في منطقة الدراسة. يعتبر هذا العمل دراسة تمهيدية استهدفت التعرف على النشاط الإشعاعي الطبيعي المنبعث من الوحدات الصخرية المتكشفة في منطقة غريان من جبل نفوسة. نأمل أن تكون هذه الدراسة دليلا يهتدي به عند القيام بأي دراسة تفصيلية لاحقة للنشاط الإشعاعي في المنطقة مستقبلا.

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