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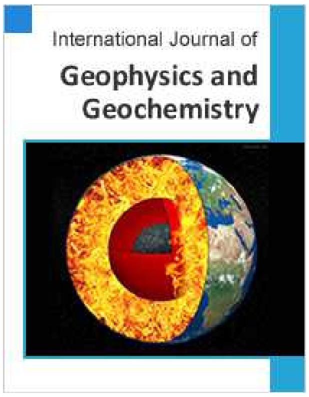

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Studying of Some Physical Properties for Rock Samples Collected from Several Quarries in Palestine

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Abstract
In this study, some physical information of many rock samples, such as, radioactive heat production (*RHP*), radiogenic heat (Q), density (ρ), thermal conductivity (λ), and magnetic susceptibility (χ) were determined by using different methods and instruments. Sixty four fresh rock samples were collected from 32 quarries at different depths in Hebron region to determine the activity concentration of ^{238}U, ^{232}Th and ^{40}K, by using gamma-ray spectrometry. The high values of *RHP* and Q in some rocks are mainly related to the relative increase of uranium contents in these samples. It was noted that there is a clear relationship between the difference in the values of those properties, the depth of collected samples and the color of the rock samples in the area under investigations.

1. Introduction

The contents of radioactive elements and geophysical methods play a key role in some physical information of rocks kind. The physical properties of rocks include radioactive heat production, radiogenic heat; thermal conductivity and magnetic susceptibility are required to conduct analysis and modeling associated with numerous agricultural, hydrological and industrial applications. In addition to characterize the rocks physical properties, knowledge of the rocks thermal properties are necessary for proper rocks and soils management in many processes, determining the energy balance at the rock / soil surface, and rock / soil water retention and unsaturated hydraulic conductivity [1].

Terrestrial radiation exposure originates from the primordial radionuclides, whose half-lives are comparable to the age of the earth, and the secondary radionuclides produced by their radioactive decay. Gamma radiation from these radionuclides represents the main external source of irradiation of the human body. Natural radioactivity in geological materials, mainly rocks and soil, comes from ^{238}U and ^{232}Th series and natural ^{40}K [2].

The abundances of natural radioactive elements in the earth's crust constitute a large heat source to the surface heat flow, which comes from the density of outflow of heat from the earth interior. Heat flow measurements are very important for the knowledge of the thermal structure of the lithosphere, for understanding the extent, intensity of thermal anomalies, and for the determination of potential areas of geothermal resources [3]. The annual production of radiogenic heat in the Earth, 6.3×10^{20} J [4], corresponds twice more than the global production of primary energy in the year 2000. This huge energy source by itself clearly exceeds the world's energy annual demands predicted through the year 2030 [5]. If it were used at great scale, it might satisfy a large proportion of the primary energy demand of the entire 21st century. Apart from the heat content of the infant Earth immediately after formation, the radiogenic decay of the unstable isotopes of uranium (^{238}U; ^{235}U), thorium (^{232}Th), and potassium (^{40}K) provides the largest internal source of heat. Most of these isotopes are enriched in the Earth's crust and mantle. The energy emitted by all of these decay processes comprises the kinetic energy of the emitted particles and the γ-radiation associated with the different decay processes. It is absorbed by the rocks and finally transformed into heat [6].

In other hand, typical rock magnetic parameters are now widely used to analyze temporal and geographical variations in the origin of the magnetic particles in the earth's crust [7]. Magnetic susceptibility is widely used property that, in its most basic of magnetic inferences, gives some indications of the amount of ferromagnetic minerals, mainly the mineral magnetite. Magnetic susceptibility is a common measurement employed in pale climate reconstruction of terrestrial environments [8, 9].

Rocks that have been collected in this study are of the type of limestone rocks which is a sedimentary rock consisting of more than 50% carbonate minerals, generally the mineral calcite (pure $CaCO_3$) or dolomite (calcium-magnesium carbonate, $CaMg[CO_3]_2$) or both. However, it can also contain clay, iron carbonate, feldspar, pyrite and quartz in minor quantities. Most types of limestone have a granular texture. Limestone makes up about 10% of the total volume of all sedimentary rocks. The solubility of limestone in water and weak acid solution leads to karst landscapes, in which water erodes the limestone over thousands to millions of years. Limestone has numerous uses: such as building material, base for cement, aggregate for the base of roads, white pigment or filler in products such as paints, and as a chemical feedstock [10].

In this study, the activity concentrations of ^{238}U, ^{232}Th and ^{40}K and other measurement data were calculated for different rock samples collected from many quarries in Hebron region-Palestine, in order to determine some physical properties of the rocks namely, radioactive heat production, and radiogenic heat. I carried out laboratory measurements of thermal conductivity and magnetic susceptibility of rock samples.

The Study Area

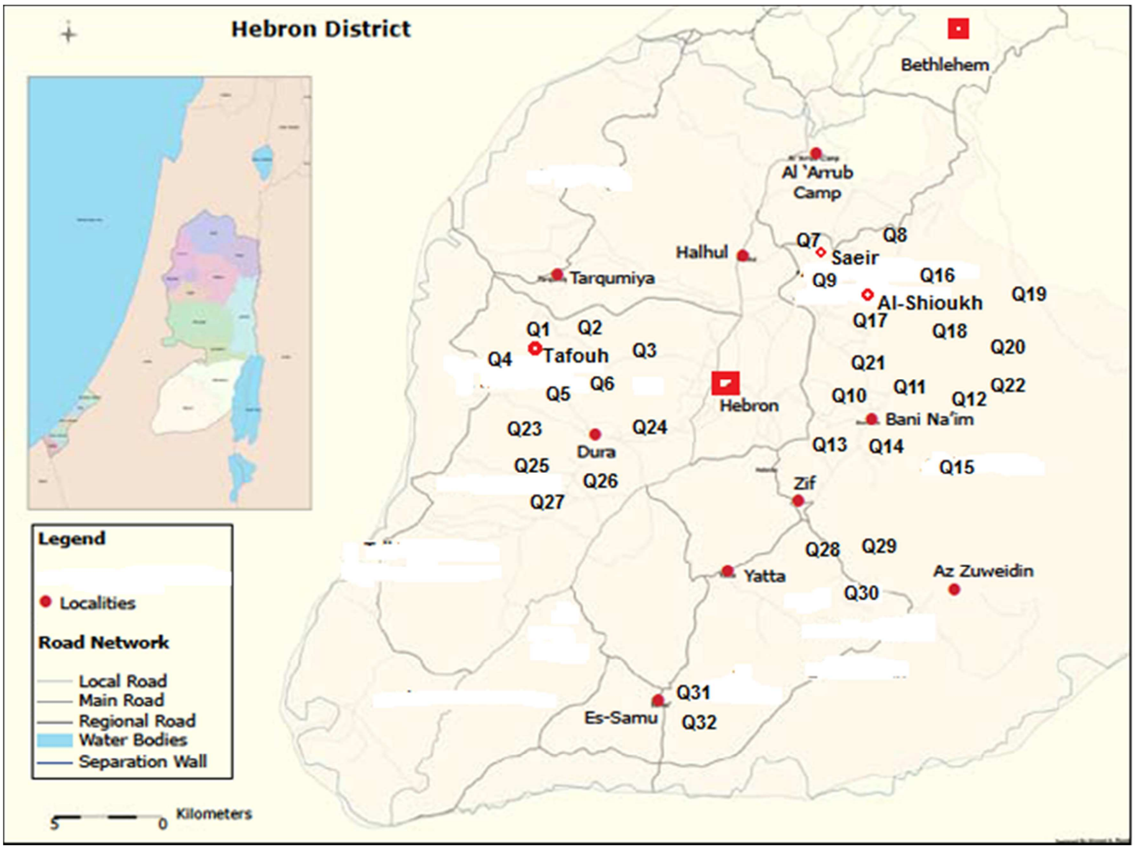

Fig. 1. Sketch map of West Bank- Palestine showing the location of Hebron region (left), and map of Hebron region showing the quarries locations (right) [12].

Hebron Governorate (Al-Khalil) (Latitude: 31° 32' 0" N, Longitude: 35° 5' 42") is located in the south of West Bank, 30 km south of Jerusalem (Fig. 1). It is the largest Governorate in the West Bank in terms of size and population. Its area is about 1068 km^2, which is represents about 19% of the West Bank total area. The population of Hebron Governorate is 650,000 according to the estimates of the Palestinian Central Bureau of Statistics [11]. The number of Palestinian communities in the Governorate is 158, the largest of which is Hebron city, located in the Hebron Mountains. It lies between 400 to 1013 meters above sea level. Hebron is a busy hub of West Bank trade, responsible for roughly a third of the areas gross domestic product, largely due to the sale of rocks from quarries. In addition to sale of rocks, local economy relies on handicraft, different industry and construction [12]. The area mainly consists of Cenomanian, Eocene, Turonian and Senonian limestone. Whilst the Cenomanian and Turonian limestone are mostly very hard and resemble marble, the Senonian and Eocene limestone are generally of soft and chalky nature [13]. The main soil type is "terra rossa". This is the most typical soil of the mountains in the governorate and soil formation on hard limestone. Its soil reaction is generally neutral to moderately alkaline; and it has a high content of soluble salts. Both the high iron content and the low organic matter are responsible for the red color. They are mainly of loamy texture. In addition to the "terra rossa" soils, mountain marl soils and alluvial soils are also present in considerable areas. Mountain marl soils are formed from the chalky marls of Senonian and Eocene age [13]. Agricultural areas surround the region where the farmers in the region usually cultivate fruits such as grapes, figs and plums [12]. The climate is of Mediterranean type with a long hot and dry summer, and short cool and rainy winter. Accordingly, the climate of Palestine is classified as an eastern Mediterranean one. The temperature increases to the south and towards the Jordan Valley (east) [13].

2. Materials and Methods

2.1. Sample Preparation

Fig. 2. *Photos of some quarries of samples collected in the study area.*

A total of 64 rock samples were collected from 32 main quarries at area under investigation (Fig. 1 and Fig. 2). The samples were collected from different layers and at depths of (5, 10, 15 and 20) m, respectively. After collection, the rock samples were crushed and milled to a fine grain powder (200 mesh). Then they were dried in an oven at 110°C for 12 h, completely removing water from the samples. Weighted samples were placed in polyethylene 1 ℓ Marenilli beaker and the beakers were completely sealed for four weeks to allow radioactive equilibrium to be reached.

2.2. Methods

After sealed period, all the decay products in the ^{232}Th series and ^{226}Ra sub-series were in radioactive equilibrium with their daughters.

To measure the thermal conductivity and magnetic susceptibility of the rocks, 32 samples were collected from the quarries in the area under investigation. All samples were drilled and cut into standard specimens (10 cm length and 4 cm diameter) and then measure these properties using the appropriate measurement devices.

3. Results and discussions

3.1. Activity Concentrations of ^{238}U, ^{232}Th and ^{40}K

After the isolation period, the concentrations of radionuclides (^{226}Ra, ^{232}Th and ^{40}K) in each sample were determined using a high purity germanium (HPGe) gamma ray spectrometer consisting of a n-type intrinsic germanium coaxial detector (Ortec) mounted vertically. Each sample was run for 70000 second.

The concentration unit, m, in part per million (ppm) of *U*, *Th* and *K* percentages in the samples were calculated from the measured activity values using the equation [14]:

$$m(\text{ppm}) = \left[\left(A \ \ M_w / N_{AV} \ln 2 \right) \ \ t_{\frac{1}{2}} \right] \times 10^6 \qquad (1)$$

Here *A* is measured in Becquerel per kilogram (Bqkg^{-1}) of the radionuclides, M_w the molecular weight (g/mol), N_{Av} the Avogadro's number and $t_{1/2}$ the half-life in seconds.

The state of radioactive equilibrium makes it possible to employ the obtained uranium concentration instead of radium concentration to estimate the radiation hazard indices for this study [15]. The values of A_U and A_{Th} in ppm as well as A_K in % were converted to activity concentration, (Bqkg^{-1}), using the conversion factors given by the International Atomic Energy Agency, [16]. The activity concentration of a sample containing 1 ppm by weight of ^{238}U is 12.4 Bqkg^{-1}, 1 ppm of ^{232}Th is 4.1 Bqkg^{-1}, 1 ppm of ^{40}K is 30.5 Bqkg^{-1} and 1 % ^{40}K is 313 Bqkg^{-1}.

The average activity concentrations of Uranium (in Bqkg^{-1} and ppm), Thorium (in ppm) and Potassium (in ppm and %) in rock samples collected from different quarries are given in Table 1. From all samples, the ^{238}U activity ranges from 1.71

ppm (21.3 $Bqkg^{-1}$) (in Q_{20} at depth 5 m, pink color) to 8.11ppm (100.5$Bqkg^{-1}$) (in Q_{25} at depth 20 m, yellow color) with an average value of 3.84 ppm (47.6 $Bqkg^{-1}$). The activity concentration of ^{232}Th ranges from 0.32 ppm (in Q_{18} at depth 5 m, pink color) to 2.83 (in Q_5 at depth 10 m, black color) with an average value of 1.02 ppm. Finally, the activity concentration of ^{40}K ranges from 0.43 ppm (0.04 %) (in Q_3 at depth 10 m , white color) to 19.1ppm (1.86%) (in Q_{26} at depth 15m, yellow color) with an average value of 3.25 ppm (0.32%). The total average activity concentration of ^{238}U in the study area is higher than the world average value, while that of ^{232}Th and ^{40}K are lower than the world average value (35 $Bqkg^{-1}$ for ^{238}U, 30 $Bqkg^{-1}$ for ^{232}Th and 400 $Bqkg^{-1}$ for ^{40}K) [17]. In addition, 70% of all samples appear to present concentration of ^{238}U that surpass the world average. The recorded high values of the radionuclides ^{238}U in these samples may be the result of the presence of radioactive-rich granite, phosphate, sandstone, and quartzite.

Table 1. *The color, the depth of the collections and the radioactivity concentration in some rock samples collected from many different quarries in Hebron region –Palestine.*

Quarry code	Color	No. of Samples	Depth (m)	The activity concentrations ^{238}U $Bqkg^{-1}$	^{238}U ppm	^{232}Th ppm	^{40}K ppm	^{40}K %
Q_1	Yellow	2	20	77.2	6.23	0.61	1.28	0.12
Q_2	Yellow	1	20	79.6	6.42	0.90	1.00	0.10
Q_3	White	3	15	59.1	4.77	2.12	0.43	0.04
Q_4	Yellow	1	20	87.7	7.07	1.29	2.26	0.22
Q_5	Black	2	10	33.0	2.66	2.83	8.92	0.87
Q_6	Black	2	5	35.6	2.87	1.02	2.07	0.20
Q_7	White	2	10	38.9	3.14	0.73	1.57	0.15
Q_8	Pink	3	5	22.5	1.81	10.3	0.54	0.05
Q_9	Pink	2	10	37.8	3.05	0.68	1.31	0.13
Q_{10}	Pink	3	10	39.6	3.19	0.66	1.48	0.14
Q_{11}	White	3	15	47.3	3.80	1.00	3.28	0.32
Q_{12}	Black	3	10	44.0	3.55	0.80	1.69	0.16
Q_{13}	Pink	3	5	30.0	2.42	0.83	1.05	0.10
Q_{14}	White	2	5	35.0	2.82	0.73	1.33	0.13
Q_{15}	Black	1	20	42.4	3.42	0.51	0.64	0.06
Q_{16}	Black	2	10	35.6	2.87	0.68	1.29	0.13
Q_{17}	White	2	15	46.6	3.76	0.66	1.10	0.11
Q_{18}	Pink	2	5	25.6	2.06	0.32	0.53	0.05
Q_{19}	White	1	15	44.0	3.55	0.71	1.05	0.10
Q_{20}	Pink	1	5	21.3	1.71	0.73	1.08	0.11
Q_{21}	Yellow	2	20	51.8	4.18	1.88	18.0	1.76
Q_{22}	Yellow	1	15	59.3	4.78	2.41	15.1	1.48
Q_{23}	White	2	15	58.7	4.73	1.83	7.97	0.77
Q_{24}	White	3	15	57.5	4.64	1.05	2.43	0.24
Q_{25}	Yellow	1	20	100.5	8.11	1.15	0.80	0.08
Q_{26}	Yellow	3	15	44.9	3.62	1.78	19.1	1.86
Q_{27}	Black	2	5	44.2	3.56	1.10	1.69	0.16
Q_{28}	White	1	10	38.7	3.12	0.63	1.21	0.12
Q_{29}	Pink	2	5	31.8	2.56	0.49	0.82	0.08
Q_{30}	White	3	20	43.0	3.47	0.71	1.03	0.10
Q_{31}	Yellow	2	20	72.2	5.82	1.00	1.50	0.15
Q_{32}	White	1	10	37.3	3.01	0.49	0.51	0.05
Total average	-------	64	------	47.6	3.84	1.02	3.25	0.32

The results of gamma-ray measurements presented in this study give current information about natural radioactivity variation in varying quarries, colors and depths, respectively (Table 2). This database shows that the average activity concentrations of ^{238}U increase, with increasing depth for most samples, but no relation to the average activity concentrations of ^{232}Th and ^{40}K, respectively. In general, the average activity concentrations of ^{238}U and ^{40}K in yellow samples are greater than for other samples with other colors, while the pink color samples have lower activity concentrations (Table 2).

Table 2. *The variation of the activity concentrations and the radioactive heat production (RHP) with depth and colors in rock sample.*

		The activity concentrations ^{238}U ($Bqkg^{-1}$)			^{238}U (ppm)			^{232}Th (ppm)			^{40}K (%)			*RHP* Av. (μWm^{-3})
		Min	Max	Av.	Min	Max	Av.	Min	Max	Av.	Min	Max	Av.	
Depth (m)	05	21.3	44.2	30.8	1.71	3.56	2.48	0.32	10.3	1.94	0.05	0.20	0.11	0.53
	10	33.0	44.0	38.1	2.66	3.55	3.07	0.49	2.83	0.94	0.05	0.87	0.22	0.60
	15	44.0	59.3	52.2	3.55	4.78	4.21	0.66	2.41	1.45	0.04	1.86	0.62	0.81
	20	42.4	100.5	69.3	3.42	8.11	5.22	0.51	1.88	1.01	0.06	1.76	0.32	1.00

		The activity concentrations												RHP Av. (μWm^{-3})
		^{238}U						^{232}Th			^{40}K			
		($Bqkg^{-1}$)			(ppm)			(ppm)			(%)			
		Min	Max	Av.	Min	Max	Av.	Min	Max	Av.	Min	Max	Av.	
Color	Pink	31.3	39.6	29.8	1.71	3.19	2.40	0.32	10.3	2.00	0.05	0.14	0.09	0.58
	Black	33.0	44.2	39.1	2.66	3.56	3.16	0.51	2.83	1.16	0.06	0.87	0.26	0.61
	White	35.0	59.1	46.0	2.82	4.77	3.71	0.49	2.12	0.97	0.04	0.77	0.20	0.73
	Yellow	44.9	100.5	71.7	3.62	8.11	5.78	0.61	2.41	1.38	0.10	1.86	0.72	0.93

3.2. Radioactive Heat Production (RHP)

Radioactive heat production is a scalar petro physical property independent of *in situ* temperature and pressure. It is usually expressed in terms of heat generated per unit volume and time. Rocks exhibit a natural radioactivity caused by the decay of natural radionuclides. The radioactive heat production of a rock (RHP in $\mu W.m^{-3}$ and in $pWkg^{-1}$) can be calculated by taking into account the heat generation constant (amount of heat released per gram U, Th and K per unit time) and from the uranium, thorium and potassium concentrations A_U, A_{Th} and A_k present in rock [18]:

$$\mathrm{RHP}(\mu \mathrm{Wm}^{-3}) = \rho\ (9.52A_U + 2.56A_{Th} + 3.48A_K)\times 10^{-5} \qquad (2)$$

Or

$$\mathrm{RHP}(\mathrm{pWkg}^{-1}) = 95.2\ A_U + 25.\dot{6}\ A_{Th} + 0.00348\ A_K \qquad (3)$$

Were ρ is the density of the rock (in kgm^{-3}); A_U and A_{Th} are in weight ppm; A_k are in weight % and ppm. In Rybach's formula, it is first necessary to know the density and the concentration of radioelement's U, Th and K in the rock samples. Radioactive heat production has been calculated from concentrations of radio elements measured in the laboratory and directly from gamma-ray logs. Also, radioactive heat production has been estimated from airborne gamma-ray data [19].

From the results shown in Table 3, the radioactive heat production was estimated to range from 0.40 μWm^{-3} in the sample Q_{18} to 1.29 μWm^{-3}in the sample Q_4, with an average value of 0.68 μWm^{-3}. The differences in the results of this study may be attributed to variations in local geology of the different study areas, and lithological variations of the different areas of study. On the other hand, the low of average radiogenic heat generation obtained in this study agrees with the lower mean heat generation values for limestone rocks.

Table 3. *The average density (ρ), the radioactive heat production (RHP) and the radiogenic heat (Q) in rock samples.*

Quarry code	P (Kgm^{-3})	RHP		Q (μCal/gyr)			
		μWm^{-3}	$pWkg^{-1}$	^{238}U	^{232}Th	^{40}K	Total
Q_1	1880	1.15	608.7	4.55	0.12	0.08	4.75
Q_2	1810	1.15	634.2	4.69	0.18	0.07	4.94
Q_3	1940	1.00	508.4	3.49	0.42	0.03	3.94
Q_4	1810	1.29	706.1	5.17	0.26	0.15	5.58
Q_5	1490	0.53	325.7	1.95	0.57	0.61	3.13
Q_6	1950	0.60	299.3	2.10	0.20	0.14	2.44
Q_7	1880	1.26	317.7	2.29	0.15	7.11	9.55
Q_8	1620	0.71	436.0	1.32	2.10	0.04	3.46
Q_9	1360	0.43	307.6	2.23	0.14	0.09	2.46
Q_{10}	1350	0.44	320.6	2.33	0.13	0.10	2.56
Q_{11}	1660	0.66	387.4	2.77	0.21	0.22	3.20
Q_{12}	1700	0.62	358.4	2.59	0.16	0.11	2.86
Q_{13}	1710	0.44	251.6	1.77	0.17	0.07	2.01
Q_{14}	1510	0.44	287.2	2.10	0.15	0.09	2.34
Q_{15}	1560	0.53	338.6	2.50	0.10	0.04	2.64
Q_{16}	1620	0.48	290.6	2.10	0.14	0.09	2.33
Q_{17}	1460	0.43	290.1	2.10	0.13	0.08	2.31
Q_{18}	1920	0.40	204.3	1.50	0.06	0.04	1.60
Q_{19}	1925	0.69	356.1	2.59	0.14	0.07	2.80
Q_{20}	1360	0.73	181.5	1.25	0.15	7.08	8.48
Q_{21}	1890	0.96	446.2	3.05	0.38	1.23	4.66
Q_{22}	1610	0.92	516.8	3.49	0.48	1.04	5.01
Q_{23}	1940	1.02	497.2	3.45	0.37	0.54	4.36
Q_{24}	1810	0.86	468.6	3.39	0.21	0.17	3.77
Q_{25}	1530	1.23	801.5	5.92	0.23	0.06	6.21
Q_{26}	1960	0.89	390.2	2.64	0.36	1.30	4.30
Q_{27}	1250	0.47	367.2	2.60	0.22	0.11	2.93
Q_{28}	1450	0.46	313.2	2.28	0.13	0.08	2.49

Quarry code	*P* (Kgm^{-3})	*RHP*		*Q* (µCal/gyr)			
		μWm^{-3}	$pWkg^{-1}$	^{238}U	^{232}Th	^{40}K	Total
Q_{29}	1750	0.45	256.3	1.87	0.10	0.06	2.03
Q_{30}	1740	0.61	348.5	2.53	0.14	0.07	2.74
Q_{31}	1790	1.05	579.7	4.25	0.20	0.11	4.56
Q_{32}	1840	0.55	299.1	2.20	0.10	0.04	2.34
Average	1690	0.68	391.7	2.80	0.20	0.22	3.22

However, radioactive heat production may exhibit some irregularity due to the dissimilarity in the geochemical behavior of U, Th, and K during the metamorphism process, which determines the distribution of the natural radio-elements. Higher-resolution survey data are highly recommended assisting in understanding the spatial distribution of U, Th and K within each rock unit.

The measured radiogenic heat production values show a clear relationship with the SiO^{+2}content. Therefore, the higher values (up to 4.7 μWm^{-3} correspond to acidic rocks (granitoids) and the lower ones (nearly zero) to basic and ultra-basic rocks. These values are in the range obtained by Wollenberg and Smith [20] for a very large set of crustal rock samples. Radiogenic heat production values reported by Correia et al. [21] from porphyry and gabbros-diorite complexes in the central part of Portugal show similar values (from 0.11 μWm^{-3} for gabbros, to 2.88 $\mu Wm^{-3}$for micro granite).

Radiogenic heat production due to radioactivity in rock samples with concentrations C_u, C_{Th} and C_k (in ppm) are listed and given in table 2 (in $pWkg^{-1}$ unit). Measurements of radiogenic heat in rocks of many quarries in Hebron Region, show relatively higher values, in the range of 181.5 to 801.5 $pWkg^{-1}$ as the contribution of radiogenic heat production to surface heat flow noted that rock samples from this area are associated with high average total heat production 391.7 $pWkg^{-1}$, which varies significantly with geological location.

The results showed that the heat production varies with rock type over several orders of magnitude. The high values of *RHP* in some rocks are mainly related to

(a) The relative increase of uranium and thorium contents in these samples, and

(b) The presence of increased amount of accessory minerals.

Finally, the average radioactive heat production within the area under investigation increased as the depth of the sample collected increased (Table 2). We also found that, the average radioactive heat production in yellow samples is greater than for other samples with other colors, while the pink color samples have lower activity concentrations (Table 2).

3.3. Radiogenic Heat (Q)

The heat generated from rocks does not only come from the original heat in the rock, but is also due to the radioactivity in the rock. For that, the knowledge of the abundant distribution of natural radioactivity in rock is used to evaluate the heat generated in the rocks. The evidence that evaluations of distribution of isotopes are responsible for the rock radioactivity: ^{238}U, ^{232}Th and ^{40}K are of fundamental importance in establishing the radiogenic basis for rock heat [22].

To convert the concentration in ppm to heat, it requires some factors given by Birch [23]: The activity concentration of a sample containing 1 ppm by weight of ^{238}U is generated 0.73 μCal/gyr, 1 ppm of ^{232}Th is generated 0.20 μCal/gyr and 1% ^{40}K is generated 0.70 μCal/gyr**.**

For the radiogenic heat, it was apparent that the heat produced by ^{238}U was highest (2.80μCal/gyr) while ^{232}Th produced the least heat (0.20μCal/gyr), (Table 3). From the results shown in table 2, the total radiogenic heat was estimated to range from 1.6μCal/gyr in the sample Q_{18} to 9.55μCal/gyr in the sample Q_7, with an average value of 3.22μCal/gyr. The high values of *Q* in some rocks are mainly related to the relative increase of uranium contents in these samples.

3.4. Thermal Conductivity (λ)

Thermal conductivity (λ) is physical property governing heat diffusion in the steady state. It defines how much heat flows across a unit cross-section of rock along with a unit distance per unit temperature decrease per unit time; dimension: $Wm^{-1}K^{-1}$ [6]. Thermal conductivity depends on several factors: (1) chemical composition of the rock (i.e., mineral content), (2) fluid content; the presence of water increases the thermal conductivity (i.e., enhances the flow of heat), (3) pressure (a high pressure increases the thermal conductivity by closing cracks which inhibit heat flow), (4) temperature, and (5) isotropy and homogeneity of the rock [24]. For understanding the thermal structure of rocks, it is important to determine thermal properties of the sediments, which constitute the basin. Thermal conductivity is perhaps the most important factor, which controls the configuration of the isotherms and the flow of heat within the basin [25].

The thermal conductivity of rock samples in this study was measured using a TLS 300 Pro Thermal Conductivity Meter. The TLS 300, designed with ease of use and convenience in mind, is capable of testing materials with an excellent accuracy of 5% and reproducibility of 2%. With the available on board memory, several measurements can be saved and stored. The TLS-300 uses two different probe types: needle probe (100 and 300 mm), which is fully inserted into the sample and single-sided probes which are placed on a surface of the sample. TLS 300 is designed for testing rocks and soils, and for in-situ tests in the measuring range of 0.02 to 10 $Wm^{-1}K^{-1}$. The main object of this part is to estimate the thermal conductivity of consolidated specimens of limestone rocks. Thermal conductivity is the essential ones to describe and understand the thermal regime of the ground. The corrected result of this formation is shown in Table 4.

Table 4. *The thermal conductivity (λ) and the magnetic susceptibility (χ) in rock samples.*

Quarry code	λ_{dry} (Wm^{-1}c^{-1})	λ_{wet} (Wm^{-1}c^{-1})	χ(×10^{-6}) SI units	Quarry code	λ_{dry} (Wm^{-1}c^{-1})	λ_{wet} (Wm^{-1}c^{-1})	χ(×10^{-6}) SI units
Q_1	3.55	3.84	57	Q_{17}	3.28	3.53	38
Q_2	3.28	3.57	44	Q_{18}	2.56	2.90	64
Q_3	3.12	3.42	31	Q_{19}	3.47	3.77	32
Q_4	3.44	3.76	55	Q_{20}	2.71	2.94	51
Q_5	2.98	3.22	78	Q_{21}	3.56	3.95	46
Q_6	2.68	2.95	74	Q_{22}	3.33	3.67	56
Q_7	2.82	3.11	33	Q_{23}	3.07	3.48	36
Q_8	2.62	2.87	48	Q_{24}	3.31	3.67	38
Q_9	2.77	2.98	56	Q_{25}	3.46	3.71	46
Q_{10}	2.74	2.96	44	Q_{26}	2.98	3.28	33
Q_{11}	3.06	3.48	35	Q_{27}	2.71	2.97	80
Q_{12}	2.91	3.18	68	Q_{28}	2.85	3.26	47
Q_{13}	2.55	2.86	55	Q_{29}	2.71	2.95	65
Q_{14}	2.80	3.04	33	Q_{30}	3.43	3.87	28
Q_{15}	3.45	3.82	69	Q_{31}	3.54	3.91	50
Q_{16}	2.95	3.25	65	Q_{32}	2.91	3.15	38
Average	2.98	3.27	53	Average	3.12	3.44	47
Total	Average	--------	---------	--------	3.05	3.36	50

It is clear that, the thermal conductivity (λ_{dry}) in investigating dry samples, is ranged between 2.55 and 3.56 Wm^{-1}c^{-1}, with an average value of 3.05 Wm^{-1}c^{-1}, and for wet samples (λ_{wet}) is ranged between 2.86 and 3.95 Wm^{-1}c^{-1}, with an average value of 3.36 Wm^{-1}c^{-1}. Thermal conductivity, on average, show a slight increase with depth, and we also found that wet samples increase its thermal conductivity for dry samples (Table 5). We also found that, the average thermal conductivity in yellow samples is greater than for other samples with other colors, while the pink color samples have lower activity concentrations (Table 5).

Generally, the thermal conductivity in the limestone rock units is highly affected by lithologic composition, which is mainly based on the depositional environment. This means that, at the transgressive stage, which is characterized by the increase of shale content and reduction of sand (quartz) content, the result is the decrease of thermal conductivity. This causes the measured bottom hole temperature to be lower than the case of a high stand system tract or regressive stage, which is characterized by the increase of sands of higher thermal conductivity and higher heat flow. We also found in the study samples, the thermal conductivity increases with a high concentration of uranium in these samples.

Table 5. *The variation of the thermal conductivity and the magnetic susceptibility with depth and colors in rock samples.*

		Thermal conductivity						**magnetic susceptibility**		
		λ_{dry} (Wm^{-1}c^{-1})			λ_{wet} (Wm^{-1}c^{-1})			χ (m^3 kg^{-1})		
		Min	**Max**	**Av.**	**Min**	**Max**	**Av.**	**Min**	**Max**	**Av.**
Depth (m)	05	2.55	2.80	2.67	2.86	3.04	2.94	33	80	59
	10	2.74	2.98	2.87	2.96	3.26	3.14	33	78	54
	15	2.98	3.45	3.20	3.28	3.77	3.54	31	56	37
	20	3.28	3.56	3.46	3.57	3.95	3.80	28	69	49
Color	Pink	2.55	2.77	2.67	2.86	2.98	2.92	44	65	55
	Black	2.68	3.45	2.95	2.95	3.82	3.19	65	80	72
	White	2.80	3.47	3.10	3.04	3.87	3.43	31	47	35
	Yellow	2.98	3.56	3.41	3.28	3.95	3.63	33	57	48

3.5. Magnetic Susceptibility (χ)

Magnetic susceptibility is probably the most easily measurable petrophysical parameter. It can be measured not only in the laboratory on rock specimens, but also in the field on rock outcrops. Various instruments for measurement of magnetic susceptibility in the field on rock outcrops have been developed recently [26].

Magnetic susceptibility of rocks is in principle controlled by the type and amount of magnetic minerals contained in a rock. Sometimes, it is dominantly controlled by paramagnetic minerals, often by ferromagnetic minerals and much less frequently by diamagnetic minerals. As the ferromagnetic minerals, mostly belong to accessory minerals that are often sensitive indicators of geological processes, the magnetic susceptibility is a useful parameter in solving some petrologic problems [27].

The magnetic susceptibility of rock samples in this study was measured using a KT-10 Kappameter. The KT-10 is a handheld instrument used for fast and a high sensitivity magnetic susceptibility meter measuring down to 10^{-6} SI units. It is designed for measurement of rocks with very low susceptibility, yet is still auto ranging through the full- scale up to 2000×10^{-6} SI units. The KT-10 Kappameter is simply operated using two buttons: the first one for measurement and the second one for data storage. More comfortable operation, including point labels, comments and data storage for next processing is available using PC handling. The Li cells supply and the automatic power off function provide a long working time without battery change [26].

Magnetic susceptibility of sedimentary rocks is in general low. The new model (KT-10) has potential to measure with sufficient precision even those weakly magnetic rocks. The magnetic susceptibility of the rocks varies from 28×10^{-6} (in Q_{30} at depth 10 m, white color) to 80×10^{-6}SI units (in Q_{27} at depth 5 m, black color) with an average value of 50×10^{-6} SI units (Table 4). The magnetic susceptibility record across the black color rocks are greater than for other samples with other colors, while the white color samples have a lower magnetic susceptibility (Table 5).

Higher susceptibilities in some samples are possessed by were the sediments containing tuffitial components.

Some sedimentary rocks may contain siderite or ankerite whose susceptibilities are an order of magnitude higher. Then, the susceptibility of such rocks can be also relatively high, according to the amount of the heavy carbonates contained in the rock. All the above effects on the increased susceptibility values in sedimentary rocks may be indicated by the sensitive KT-10 Meter [26]. We did not find a relationship between the magnetic susceptibility and the depth at which the samples were collected, but the average value is higher at a depth of 5m (Table 5).

4. Conclusion

The main conclusions that are derived from the present work can be summarized as follows:

- The average activity concentrations of ^{232}U, were found to be above the world's average, while the average activity concentrations of ^{232}Th and ^{40}K were lower than the world's average values.
- There is a clear relationship between the activity concentrations and color, where activity concentrations changes as the color changes.
- There is an uneven contribution of these radionuclides (U, Th, and K) to radiogenic heat production in rock as a result of their geological location. The high values of heat production in the rocks are mainly related to the relative increase of uranium content.
- There is a clear relationship between most physical parameters and color where the physical parameters changes as the color changes.
- The thermal conductivity increases with a high concentration of uranium in the samples that have been studied and we also found that wet samples increase its thermal conductivity compared with dry samples.

References

[1] Hopmans, J.W., Dane, J.H. (1986). "Thermal conductivity of two porous-media as a function of water content, temperature and density". *Soil Sci.*, 142: 187-195.

[2] Kinyua, R., Atambo, V., Ongeri, R. (2011). "Activity concentrations of ^{40}K, ^{232}Th, ^{226}Ra and radiation exposure levels in the Tabaka soapstone quarries of the Kisii Region, Kenya". *African J of Environmental Science and Technology*, 5(9): 682-688.

[3] Fernandez, M., Cabal, J. (1992). "Heat-flow data and shallow thermal regime on Mallorca and Menorca (western Mediterranean)". *Tec-physics*, 203:133-143.

[4] Jaupart, C., Labrosse, S., Mareschal, J.C. (2007). "Temperatures, heat and energy in the mantle of the earth". In D. Bercovici (ed.), *Mantle Dynamics - Treatise on Geophysics, Elsevier, Amsterdam*, 7: pp253-303.

[5] IAEA, International Energy Agency (2008). *World Energy Outlook 2008, (IEA), Paris*; See also: http://www.iea.org/textbase/nppdf/free/2008/weo2008.

[6] Clauser, C. (2011). "Thermal storage and transport properties of rocks, II: thermal conductivity and diffusivity". In: Harsh Gupta (Ed.), Encyclopedia of Solid Earth Geophysics, 2nd ed., *Springer, Dordrecht, preprint*.

[7] Evans, M.E., Heller, F. (2003). "Environmental magnetism: principles and applications of environmental magnetic". *Academic Press, London* p. 299.

[8] Murdock, K.J., Wilkie, K., Brown, L. (2013). Rock magnetic properties, magnetic susceptibility, and organic geochemistry comparison in core LZ1029-7 Lake El'gygytgyn, Russia Far East". *Clim Past*, 9: 467–479.

[9] Salome, A., Meynadier, L., Allegre, C. (2004). "Volcanic influence on the susceptibility signal; a case study in Indian Ocean". *American Geophysical Union, Washington, DC, United States, In: Anonymous, AGU 2004 fall meeting*, 85 (47, Suppl.), georefid:2008-081521.

[10] *en.wikipedia.org/wiki/Limestone*,www.britannica.com/rock/80 193/*Thermal-conductivity*.

[11] Palestinian Central Bureau of Statistics (PCBS) (2012). "Population, Housing and Establishment Census 2011, and it's update until 31/12/2011". *Ramallah – Palestine*

[12] Applied Research Institute – Jerusalem (ARIJ), (2009). "GIS Database, 2006-2009". *Spanish Cooperation and Azahar program, Palestinian Localities Study Hebron Governorate*.

[13] Dudeen, B. (2001). "The soils of Palestine (The West Bank and Gaza Strip) current status and future perspectives". *Bari : CIHEAM* , 34: 203-225.

[14] Dabayneh, K.M., Mashal, L.A., Hasan, F.I. (2008). "Radioactivity concentration in soil samples in the southern part of the West Bank, Palestine". Rad Prot Dos, 131(2): 265–271.

[15] Alharbi, W.R., Al- Zahrani, J.H., Adel Abbady, A.G. (2011). "Assessment of radiation hazard indices from granite rocks of the Southeastern Arabian Shield, Kingdom of Saudi Arabia". *Australian Journal of Basic and Applied Sciences*, 5(6): 672-682.

[16] IAEA, International Atomic Energy Agency, (1989). "Construction and use of calibration facilities for radiometric field equipment". *Technical Reports Series 309: IAEA, Vienna*.

[17] UNSCEAR, United Nations scientific committee on the effects of atomic radiation, (2000). "Sources, effects and risks of ionizing radiation". *Report to the general assembly. United Nations Publication, New York*.

[18] Rybach, L. (1976). "Radioactive heat production in rocks and its relation to other petro physical parameters". *Pure and Appl. Geophysics*, 114: 309-318.

[19] Salem, A., Elsirafy, A., Aref, A., Ismail, A., Ehara, S., Ushijima, K. (2005). "Mapping radioactive heat production from airborne spectral gamma-ray data of Gebel Duwiarea, Egypt". *Proceedings World Geothermal Congress. Antalya, Turkey*: 24-29.

[20] Wollenberg, H.A., Smith, A.R. (1987). "Radiogenic heat production of crustal rocks: An assessment based on geochemical data". *Geoph Res Lett*, 14: 295-298.

[21] Correia, A., Jones, F.W., Dawes, G.K., Hutton, V.R. (1993). "A magneto-telluric deep crustal study in South-Central Portugal". *Studiageoph etgeod*, 37: 331- 344.

[22] Okeyode, I.C., Akanni, A.O. (2009). "Determination of some physical parameters of Olumo rock, Abeokuta Ogun-State, Nigeria". *Indian Journal of Science and Technology*, 2 (7): 6- 10.

[23] Birch, F. (1954). "Heat from radioactivity". *In: Nuclear Geology*. H. Faul (ed.). John Wiley and Sons, New York, NY, p. 148-174.

[24] www.britannica.com/rock/80193/Thermal/-conductivity.

[25] Abubakr, F. Maky, Mohamad, A. Ramadan. (2010). "Thermal conductivity, radiogenic heat production and heat flow of some upper cretaceous rock units, north western desert, Egypt". *Journal of Applied Sciences Research*, 6(5): 483-510.

[26] Hrouda, F., Chluacova, M., Chadima, M. (2009). "The used of magnetic susceptibility of rocks in Geological Exploration (case histories study)". *Terraplus: Geophysical Equipment Supplier*, Brno: 1- 2.

[27] Nawrocki, J., Wojcik, A., Bogucki, A. (1996). "The magnetic susceptibility record in Polish and Ukrainian loess- palaeosol sequences conditioned by palaeoclimate". *Boreas,* 25: 161-169.