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Measurement of natural radioactivity in granites and its quartz-bearing gold at El-Fawakhir area (Central Eastern Desert), Egypt

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ABSTRACT

The distribution of natural radionuclides (^{226}Ra, ^{232}Th and ^{40}K) in Granites and its quartz-bearing gold at El-Fawakhir area (Central Eastern Desert, Egypt) were measured by using γ-ray spectroscopy [NaI (Tl) 3″ × 3″]. X-Ray Fluorescence technique was used for chemical analyses of the studied samples. The specific activity of ^{226}Ra, ^{232}Th and ^{40}K values are in range (3 ± 0.5 to 43 ± 2 $Bqkg^{-1}$), (5 ± 0.7 to 41 ± 2 $Bqkg^{-1}$) and (128 ± 6 to 682 ± 35 $Bqkg^{-1}$) respectively. The absorbed dose rates ranged from 13.8 to 58.4 nGy h^{-1}, where the total effective dose rates were determined to be between 16.7 and 70.9 μSvy^{-1}. The maximum external hazard index (H_{ex}) is 0.3 $nGyh^{-1}$. The calculated values of the excess lifetime cancer risks (ELCR) and annual effective dose rate values are in between (8.48×10^{-5} and 2.63×10^{-4}) and (24.2 and 72.9 μSvy^{-1}) respectively. Geochemically, the studied granites consist of major oxides, they are characterized by SiO_2, K_2O, Na_2O, Al_2O_3, and depleted in CaO, MgO, TiO_2, and P_2O_5. The average absorbed dose rate (D_o) in air is 37.8 $nGyh^{-1}$ for the whole studied samples, this value is about 3.78% of the 1.0 $mSvy^{-1}$ recommended by (ICRP-60,1991) to the public, so there is no radiological risk for the workers in that area.

1. Introduction

When the earth was formed four billion years ago, it contained many radioactive isotopes. Since then, all the shorter lived isotopes have decayed. Only those isotopes with very long half-lives (100 million years or more) remain, along with the isotopes formed from the decay of the long lived isotopes. Background radiation is the ubiquitous ionizing radiation that people on the planet Earth are exposed to, including natural and artificial sources. Both natural and artificial background radiation varies depending on location and altitude. Every day, we ingest/inhale nuclides in the air we breathe, in the food we eat and in the water we drink. Radioactivity is common in the rocks and soil that make up our planet, in the water and oceans, and even in our building materials and homes. It is just everywhere (Uosif & Abdel-Salam, 2011).

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Granite's durability and decorative appearance make it a popular building material in homes and buildings. Any type of rock could contain naturally occurring radioactive elements like radium, uranium and thorium. Some pieces of granite contain more of these elements than others, depending on the composition of the molten rock from which they formed. Geologists provide an explanation of this behavior in the course of partial melting and fractional crystallization of magma, which enables U and Th to be concentrated in the liquid phase and become incorporated into the more silica-rich products. For that reason, igneous rocks of granitic composition are strongly enriched in U and Th (on an average 5 ppm of U and 15 ppm of Th), compared to the Earth's crust (average 1.8 ppm for U and 7.2 ppm for Th) (Mason & Moore, 1982), the upper continental crust (average 2.7 ppm for U and 10.5 ppm for Th) (Rudnick & Gao, 2003) and rocks of basaltic or ultramafic composition (0.1 ppm of U and 0.2 ppm of Th) (Faure, 1986) and (Me'nager et al. 1993).

The Fawakhir granite is a stock intruded into the older Precambrian rocks. As no agriculture has ever succeeded in this hyperarid desert, the only resources are mineral, namely, gold, granite, and water. The granite was quarried to no great extent in the Roman period, but it also acts as an aquifer, carrying water in tiny cracks until it is stopped by the dense ultramafic rocks to the west. Most importantly, however, the quartz veins injected into the granite are auriferous, particularly towards the edge of the stock. The present work deals with the radioactivity and radiological hazard of El Fawakhir mining area.

2. Geological setting

El-Fawakhir granite platoon hosts and El-Fawakhir gold mines, which are two of several gold mines in the Eastern Desert of Egypt that have been extensively worked since Pharaonic and Roman times (Amer, Kusky, & Ghulam, 2008). The rock varieties encountered from the oldest to the youngest are meta-sediments, gabbroic sheet, younger granites and Quaternary Wadi deposits. The Carbonic sheet is grayish brown in color on the weathered surface and intruded by younger granites to the central part of the studied area. The volcanic rocks (40%) are located around El-Fawakhir granites and running east to west, Fig. 1.

The Gold pockets in the El-Fawakhir quarry in the Eastern side of the studied area. There are two points of view regarding the genesis of the known gold mineralization in the Eastern Desert of Egypt. Some authors discussed the gold mineralization genesis based on the geosynclinals theory (El-Shazly, 1956; Sabet, Tosgeov, Bordonosov, Baburin, & Zalta, 1976). Recently, some authors linked the gold mineralization to the plate tectonic theory (Hassan, 2006; Hassan, Azzaz, Soliman, El-Badway, 1991) under ophiolite, island arc and cordilleran-extensional, group. Each possesses characteristic ore mineral assemblage and geochemical association. Several Gold deposit and plugs are recorded in the studied area. The Gold pockets in the El-Fawakhir quarry in the Eastern side of the studied area. There are two points of view regarding the genesis of the known gold mineralization in the Eastern Desert of Egypt. Some authors discussed the gold mineralization genesis based on the geosynclinals theory (El-Shazly, 1956). Some authors linked the gold mineralization to the plate tectonic theory (Hassan, 2006; Sabet et al., 1976) under ophiolite, island arc and cordilleran-extensional, group. Each possesses characteristic ore mineral assemblage and geochemical association.

Veins: The study area is traversed by gold-bearing quartz veinlets. The main occurrences are those at El Fawakhir main quartz veins are exploited for gold. These quartz veinlets represent the second stage of the heat engine process affecting the area and lead to the accumulation of gold along two stages of formation. The first stage accompanied the granitic intrusion where the mafic ultramafic rocks were heated and gold was mobilized to the heat source. The second stage is the intrusion of these quartz veinlets. The ore bodies of the vein type represent fissure fillings with some wall rock alterations in their vicinity.

2.1. *Geochemistry*

The chemical analysis for the granite samples under investigation has been done in order to identify their geochemical behavior. The chemical analysis for the major oxides (wt %) were done, using wet chemical analysis technique. The trace elements (ppm) were measured by XRF technique. All these chemical analyses were done in the Nuclear Materials Authority of Egypt. Table 1 shows the chemical analysis for major oxides and trace elements as well as some geochemical ratios for the studied monzogranites and syenogranites. The studied granites are, generally, characterized by their relatively high silica and Ba contents. Generally, the monzogranites are characterized by their relatively higher contents of FeO, Fe_2O_3, MgO, MnO, CaO, Sr and Ba as well as lower SiO_2, K2O, Rb, Zr, Y, Nb and F- contents than those of the syenogranite.

The potassic feldspars are responsible for the increase in Ba and Rb, while zircon is responsible for high concentration of Hf content. The gold mineralization hosted in these granodiorites is responsible for the higher contents of ore elements, Cr, Co, Ni, Cu, Zn, As, Sn, Sb, confirming that these are evidence for elements form the geochemical association of the gold mineralization.

3. Experimental procedure and methods

3.1. *Sampling preparation*

Twenty samples (12 quartz-bearing gold and 8 granite samples) were collected from investigated area. The samples were crushed, homogenized and sieved through a 200-mm mesh, which is the optimum size enriched in heavy minerals. Each sample was dried in an oven a 110 °C to ensure that moisture was completely removed. Weighed samples were placed in a polyethylene beaker, of 350 cm^3 volume each. The beakers were completely sealed for 4 weeks to reach secular equilibrium where the rate of decay of the progeny becomes equal to that of the parent (radium and thorium) within the volume and the progeny will also remain in the sample (ASTM, 1983; 1986).