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Integration of geophysical and geological data for delimitation of mineralized zones in Um Naggat area, Central Eastern Desert, Egypt

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Abstract An integrated approach for geophysical, geological and mineralogical data was followed for Um Naggat area, Central Eastern Desert, Egypt, in order to delineate its mineralized zones. The albitized granites are well-defined on the Th- and U-channel images, by their anomalous shapes, reaching 150 ppm and 90 ppm respectively, beside low K content.

Interpretations of the aeromagnetic maps delineated four regional structural trends oriented due NNW, NW, ENE and E–W directions. They are identified as strike-slip faults, which coincide well with field observations, where NW-trending faults cut and displace right laterally ENE-trending older ones. The interaction between these two strike-slip fault systems confining the albite granite is easily identified on the regional data presenting longer wavelength anomalies, implying deep-seated structures. They could represent potential pathways for migration of enriched mineralized fluids. Geochemically, albite granites of peraluminous characteristics that had suffered extensive post-magmatic metasomatic reworking, resulted into development of (Zr, Hf, Nb, Ta, U, Th, Sn) and albite-enriched and greisenized granite body of about 600 m thick, and more than 3 km in strike length. The albite granite is characterized by sharp increase in average rare metal content: Zr (830 ppm), Hf (51 ppm), Nb (340 ppm), Ta (44 ppm), and U (90 ppm). Thorite, uranothorite, uraninite and zircon are the main uranium-bearing minerals of magmatic origin within the enclosing granite. However, with respect to Zr, Nb, and Ta, the albitized granite can be categorized as rare metal granite. The integration of airborne geophysical (magnetic and γ-ray spectrometric), geological, geochemical and mineralogical data succeeded in assigning the albite granite of Um Naggat pluton as a mineralized zone. This zone is characterized by its high thorium and uranium of

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hydrothermal origin as indicated by its low Th/U ratio, with rare metals mineralization controlled by two main structural trends in the NW- and ENE-directions.

1. Introduction

Several studies have shown the advantages, disadvantages, benefits and limitations of uses of geophysical methods in detailing and analysing the morphology of mineral deposits (Irvine and Smith, 1990; White et al., 2001; Moreira and Ilha, 2011; Moreira et al., 2012). The most commonly used first step in a geophysical exploration process is aeromagnetic survey, permitting detection of ambient magnetic fields caused by magnetic minerals that are present in the ground. Magnetic maps are often used in conjunction with other geophysical survey methods such as radiometrics, and VLF-EM to create more comprehensive geophysical and geological picture of the survey area (Gaafar, 2012). Airborne magnetic and radiometric surveys were used extensively in mineral exploration industry, predominantly for the delineation of metalliferous deposits (Airo and Loukola-Ruskeeniemi, 2004). Its application ranges from mineral exploration (Murphy, 2007), structure mapping and rock characterization (Telford et al., 1990). Recent advances in technology have substantially increased the accuracy and resolution of these techniques so that they can be used to provide useful enhanced information on lithology and structure. The increasing use of gamma-ray spectrometry over the past decades indicates that it will play a more important role in geological mapping and mineral exploration in the future.

Effective integration leads directly to increased success potential and reduced exploration risk. Analysis of geophysical features provides new insights into structural framework and can help geologists to target new areas for mineral exploration. The interpretation of high-resolution magnetics has provided an overview of the regional structure as well as further insight into structural controls of the albite-hosted-rare metal mineralization.

Integrated geophysical exploration programmes proved to be successful in identifying the sub-surface evidences of mineralization or associated structures/alteration zones (e.g., Mohanty et al., 2011; Chaturvedi et al., 2013; Patra et al., 2013; Gaafar, 2014). However, detailed geophysical studies have never been carried out for delineation of alteration zones and rock types associated with uranium and rare-metal mineralization of the region. Therefore, in the present study, an integrated geophysical investigation using magnetic, spectrometric and geochemical data was carried out in and around the mineralization zones of Um Naggat area. Various anomalous zones were compared with each other and geologic maps to evaluate their effectiveness for displaying uranium and rare-metal mineralization and know their geophysical signatures.

2. Geologic outlines

Um Naggat area is situated in the Central Eastern Desert of Egypt at the watershed of Wadi Um Gheig draining to the Red Sea and Wadi E1-Miyah draining to the Nile basin, between Latitudes 25°28 and 25°31′N and Longitudes 34°09 and 34°18E (Fig. 1).

The lithostratigraphic rock units cropping out in Um Naggat area comprise metavolcanics, meta-gabbros, granodiorites, biotite granites and albite granites (Fig. 1). Metavolcanics are characterized by moderate to high relief, with deep brown colour. They are found in several localities in the northern parts of the studied area (Fig. 1, modified after Greiling et al., 1988). The grain size is fine. There is a sharp contact between metavolcanics and both biotite and albite granites. The metavolcanic rocks were interpreted as old metavolcanics of low-K tholeiitic basalts, which were an integral part of an ophiolite association and young metavolcanics which belong to the island arc association of andesite and volcanic lastics (Stern, 1981; El-Gaby et al., 1988). Metavolcanics of the study area belong to island arc metavolcanics. Metagabbros have different grain sizes that range from coarse-grained to pegmatitic ones, with dark green to grey colour. They are found in the south western part of the studied area with clear contacts with younger granites. The interaction of these metagabbros with the invading granite material changed them towards diorites, giving metagabbro-diorite complex. Older granites are the oldest intrusive granitic rocks in the studied area and characterized by moderate to low relief hills of medium to coarse-grain size. They are found at the south-eastern part of the studied area, and have xenoliths from the previous rock types. They have grey to pale grey colour, according to the amount of mafic minerals. The composition of older granites ranges from tonalite to granodiorite.

Um Naggat granitic body comprises two granitic types, the biotite granite and alkali feldspar granite. The biotite granite is mainly composed of quartz, K-feldspar, plagioclase and biotite. Zircon, apatite, allanite, sphene and iron oxides are the main accessories. The alkali feldspar granite is mainly composed of alkali feldspar, plagioclase, quartz, biotite and muscovite. Zircon, allanite and opaque minerals are the main accessories. The episyenites are recorded as a result of quartz leaching out with red colour of the whole rock due to the presence of K-feldspars or hematization in some places, along the NW–SE and N–S fault planes. It must be noticed that the wide area in the eastern part of the Um Naggat granitic pluton is covered by Wadi sediments and represented by some small episyenitized parts at its boundary, which can be taken as evidence for the possible presence of larger episyenitization at deeper parts. Trachyte plugs are found in the studied area in its southern part and have a sharp contact with biotite granite. These plugs are massive or blocks and may be found as cone-shaped one. Trachyte has a grain size that ranges from fine to medium. Besides, it has a porphyritic texture with alkali feldspar phenocrysts, and fragments of biotite granite.

The contacts of the granite dip steeply towards the country rocks. On the northern side, the form of the granite is complicated by several dome shaped projections up to 1 km in diameter which created favourable structures for intensive