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Interstratified vermiculite–mica in the gneiss–metapelite–serpentinite rocks at Hafafit area, Southern Eastern Desert, Egypt: From metasomatism to weathering

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ABSTRACT

The Hafafit vermiculite in the Southern Eastern Desert of Egypt at the contact of the metapelite and serpentinite rocks with the pegmatites and gneisses of the Hafafit uplift is the only known deposit in the Arabian–Nubian Shield (ANS) rocks of the Eastern Desert (ED). It is distinctively interstratified with mica. The mineralogy and mineral chemistry of this vermiculite at four sites (HV1, HV2, HV3 and HV4) were studied to better understand its origin, which might refers to a specific geologic setting retained to Hafafit area. The vermiculite at Hafafit forms with phlogopite, actinolite–tremolite, asbestos–anthophyllite–talc and talc zones that are arranged from pegmatite and gneisses to the metapelite and serpentinite rocks. These zones were probably formed by metasomatism that related to the intrusion of the granitoid rocks and the connected pegmatites in the upper Pan-African. The XRD and EMPA studies of the interstratified vermiculite-mica concluded that vermiculitization took place through a layer-by-layer transformation of original micas. This formed, in decreasing abundance, mixed-layer phases of biotite/vermiculite (hydrobiotite), phlogopite/vermiculite (hydrophlogopite) and chlorite/vermiculite (corrensite) and discrete phases of vermiculite, chlorite and smectite. A model is suggested, in which chemical weathering by the moving downward meteoric water led to replacement of the interlayer K, in biotite from gneiss and in phlogopite from metasomatic zones, by H_2O molecules, Fe^{2+} was oxidized and $(OH)^-$ replaced O^{2-} forming hydrobiotite and hydrophlogopite. By more K remove, Fe was replaced by Mg with the introduction of more layers of H_2O molecules leading to formation of the vermiculite. Weathering formed corrensite mixed-layer and chlorite expandable minerals on the expense of chlorite. Formation of the incomplete smectite-like layers and Al-hydroxy interlayers (13.97 Å) took place at the expense of vermiculite, replacing the Mg interlayer cations (12.63 Å). Weathering took place mostly by low-pH solutions and in warm environment and the most extensive degree of weathering was at the HV4 site, in which the lode of vermiculite is the biggest. We propose that vermiculitization at Hafafit occurred due to a specific integration between the geologic setting (including rock type and tectonics) of the area and weathering processes producing the only vermiculite deposit in the ANS rocks of the ED of Egypt.

1. Introduction

Vermiculite is a group of clay minerals with exchangeable cations. They are similar to micas, but have lower layer charge and their interlayer K^+ is replaced to a varying degree by exchangeable and hydrated, often divalent cations. Vermiculite is most commonly a soil-formed clay, while coarsely crystalline vermiculite deposits are formed from alteration of igneous rocks (Huggett, 2005). It is often formed from alteration of micas and sometimes is formed by alteration of chlorite, pyroxenes and amphiboles and this is usually accompanied by formation of transitional phases and secondary layer silicates which develop due to the interlayer gradual changes in the parent mineral (Srodon, 1999). Consequently, vermiculites are sometimes pseudo-phases of the mica or a mixture of vermiculite, interstratified vermiculite–mica and interstratified vermiculite–chlorite (Ross and Kodama, 1974; Ross et al., 1982). Moreover, such vermiculites on saturation with K^+ ions, readily revert to the polytype of the parent mica (de la Calle et al., 1975). Alteration of mica to vermiculite occurs by weathering, percolation of groundwater or hydrothermal fluids or by the influence of all these agents (Basset, 1963). Supergene vermiculitization of trioctahedral micas through intermediate stages of interstratified mica/vermiculite and hydroxy-interlayered vermiculite has been identified as one of the main reported mineral weathering sequences (Wilson, 1986; Buurman et al., 1988; Bain et al., 1990; Moon et al., 1994).

The Hafafit area in the south Eastern Desert of Egypt (Fig. 1), represents a complex Precambrian terrain of economic interest that host vermiculite, asbestos, emerald, chromite, Nb–Ta, and

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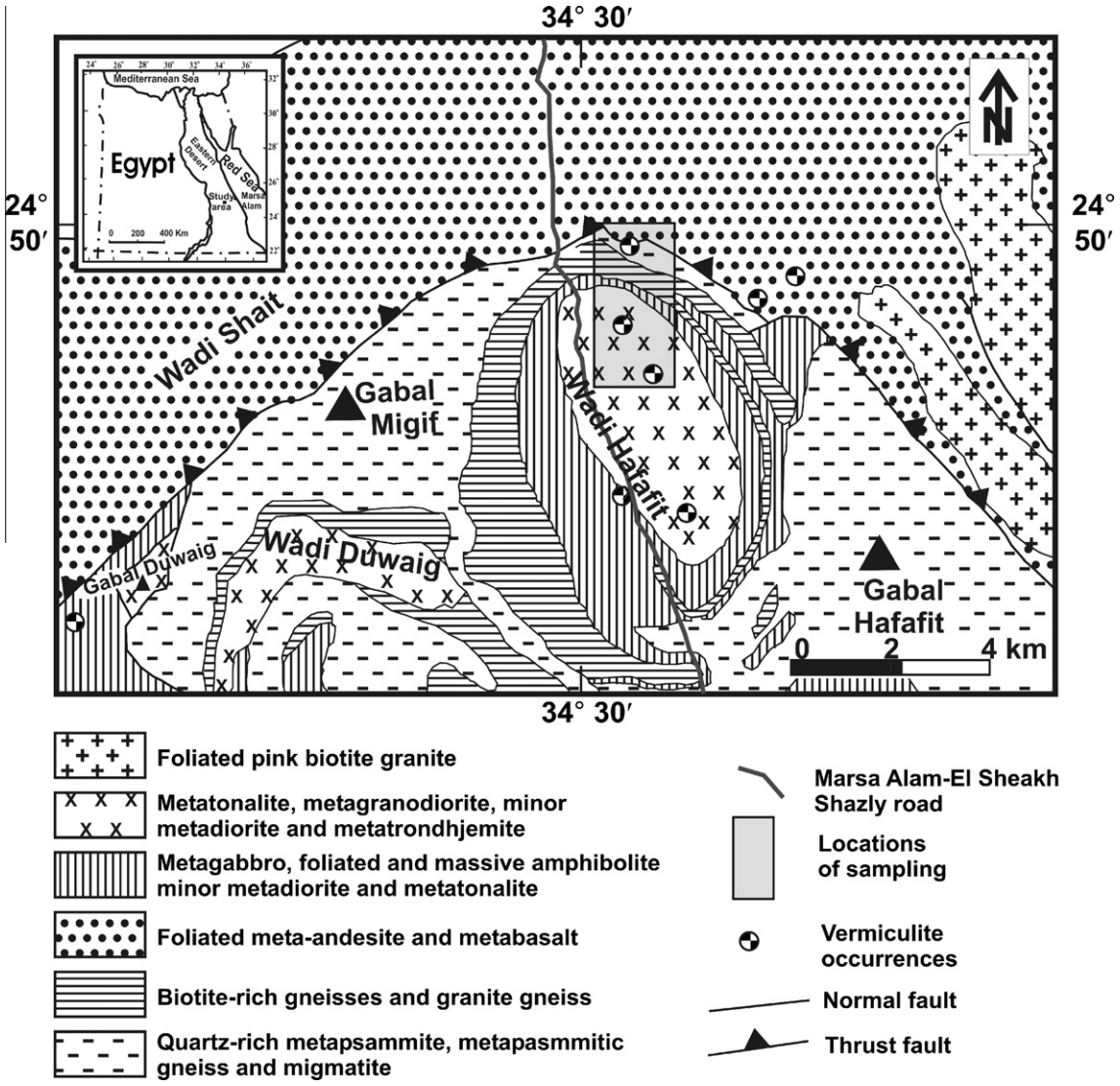

Fig. 1. Simplified geologic map of Gabal Hafafit area, Eastern Desert, Egypt (from El-Ramly and Greiling (1988)).

corundum mineralisation. The area formed during magmatism and metamorphism associating the Neoproterozoic Pan-African subduction and collision (580–640 Ma) (Abd El-Naby et al., 2008). Vermiculite deposit of the Hafafit area is the only recorded one in the Arabian–Nubian Shield (ANS) rocks (950–550 Ma; Vail, 1985; Stern, 1994) in the Eastern Desert of Egypt, where it was mined since Pharaonic times to last-mentioned mining in 1944 (Hussein, 1990). Vermiculite is also exploited from Zabara, Sikait, and Umm Kabo in the vicinity of Hafafit vermiculite deposits as a by-product with emerald, where the gem-quality emerald is confined to the pockets and lenses of vermiculite and phlogopite–actinolite–schist within the ophiolite sequence. Vermiculite in hand specimen is distinctively mixed with mica minerals which are mainly phlogopite and/or biotite. Vermiculite deposits of Hafafit area are found in number of occurrences spreading over an area of ~15 km^2 between 24°40′ to 24°50′N and 34°27′ to 34°47′E. The main occurrences are at Wadi Shidani, El-Dumaig, Um Groof, Um Kuhl, Um Fahm, Um Kisbash, Wadi El-Hisa and north of Bir Hafafit (Amin and Afia, 1954). The north of Bir Hafafit occurrence is the biggest one. Vermiculite deposit is restricted to an ophiolitic mélange serpentinite masses that are embedded in gneiss rocks.

In spite of the presence of such hosting rocks of the Hafafit vermiculite in other places in the Eastern Desert of Egypt, as mentioned before, no vermiculite deposits occur in the Eastern Desert rather than that at Hafafit. Thus, in this paper, we present new XRD mineralogy and mineral chemistry data on the Hafafit vermiculite and compile these data with the geology, including rock type and tectonics, of the area to deeply understand the origin of the deposit, proposing the geologic integration that produced the only vermiculite deposit in the ANS of the Eastern Desert.

2. Geological setting

2.1. Geological framework of vermiculite host rocks

The Hafafit area is a part of the Migif-Hafafit Schist Belt (MHSB) in the Southern Eastern Desert of Egypt. The MHSB rocks at Hafafit consist mainly of metapelitic schist and gneiss forming the core of the Hafafit uplift and are intruded by granitoid masses and cut by a number of dykes of different compositions together with various types of aplitic and pegmatitic veins. It is open to debate whether the schist and gneiss rocks of the Hafafit uplift are part of the African plate (840–720 Ma, El-Ramly et al., 1984; El Gaby et al., 1988; Fowler and El Kalioubi, 2002) or whether those rocks belong to the Nubian shield and were metamorphosed at about 710–680 Ma