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Late Neoproterozoic banded iron formation (BIF) in the central Eastern Desert of Egypt: Mineralogical and geochemical implications for the origin of the Gebel El Hadid iron ore deposit

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ABSTRACT

The banded iron formation (BIF) in the Gebel El Hadid area is part of the Late Neoproterozoic island-arc/ophiolitic assemblage of the central Eastern Desert of Egypt, where it alternates concordantly with low-grade metavolcaniclastics. The BIF units are mainly of oxide facies consisting of iron oxide mesobands with intercalations of quartz–carbonate ± chlorite ± magnetite mesobands in the form of layers and pods. Geochemically, the Gebel El Hadid BIF is characterized by heavy REE-enriched NASC-normalized patterns, rarely with a weak positive Eu anomaly. The Neoproterozoic age of the Egyptian BIF suggests that they are of Rapitan type, but their size, petrological and geochemical characteristics suggest that they are of Algoma type having formed before the final collision between major fragments of East and West Gondwana. The nature and composition of the BIF and associated metavolcaniclastics indicate their formation as a result of submarine hydrothermal activity concomitant with arc volcanism. The Gebel El Hadid BIF units were deposited in pulses during periods of quiescent arc activity at ca. 717 ± 8 Ma (U–Pb age on volcaniclastic zircon). Submarine diagenesis under suboxic conditions produced an early generation of magnetite, hematite and quartz, whereas regional metamorphism led to the formation of coarse-grained and porphyroblastic magnetite and quartz. Post-metamorphic oxidation led to martitization of magnetite, and formation of hematite and specularite.

1. Introduction

Banded iron formation (BIF) globally ranges in age from 3.8 Ga (Late Archean) to 1.8 Ga (Early Proterozoic) with a peak of formation at 2.4 Ga (Beukes, 1973; Klein and Beukes, 1993; Huston and Logan, 2004). Two types of Archean–Paleoproterozoic BIFs were distinguished by Gross (1980): Algoma type of exhalative volcano-sedimentary origin that abounds during the Late Archean (Pufahl, 2010) and Superior type of continent-derived origin mostly of Paleoproterozoic age (Trendall and Blockley, 2004). Younger BIF deposits of Neoproterozoic age (850–700 Ma, Ilyin, 2009) and primarily of glaciogenic association are of restricted distribution (James, 1992). Many occurrences of Neoproterozoic BIF have been discussed in the literature (Ilyin, 2009) including: Rapitan from Canada (e. g., Klein and Beukes, 1993), Damara from Namibia (Breitkopf, 1988), Urucum from Brazil (Klein and Ladeira, 2004), Adelaide Geosyncline from South Australia (Lottermoser and Ashley, 2000), Menhouhou from Morocco BIF (Pelleter et al., 2006) and BIF from the Arabian–Nubian Shield of Egypt and Saudi Arabia (Stern et al., 2013; El-Shazly and Khalil, 2014). BIF occurs in four mineral assemblages defined by James (1992), namely: oxide facies including magnetite and hematite subfacies, silicate facies, carbonate facies and sulfide facies.

Banded iron formations (BIFs) are widely accepted as products of diagenetic and metamorphic alteration of Fe-rich, chemically precipitated marine sediments with a minimum of 15% Fe (James, 1992; Klein and Beukes, 1993; Mücke et al., 1996). However, the sources of Fe and Si, the paleoenvironment of deposition, the paragenetic sequence of the iron oxide minerals and the evolution of the precursor sediments are still debated (e. g., Hamade et al., 2003; Pickard et al., 2004). Various models were proposed for the source of Fe and Si which include surface weathering of continents (e.g. Garrels, 1987), hydrothermal leaching of submarine basalt (e. g., Holland, 1973), or volcanogenic supplies (e. g., Trendall and Blockley, 1970; Isley and Abbott, 1999; Krapez et al., 2003). Iron and silica were precipitated in environments ranging from shelf to deep marine (e.g., Beukes and Klein, 1990; Pickard et al., 2004). The currently most accepted model indicates that Fe and Si were mainly leached by seawater circulation at mid-ocean ridges, and transported in a largely anoxic ocean on the continental shelf where upwelling and/or photosynthesis caused the oxidation of Fe^{2+} and its precipitation as oxide bands. Lascelles (2013) has suggested that the mixing of high temperature fluids and cold seawater leads to immediate

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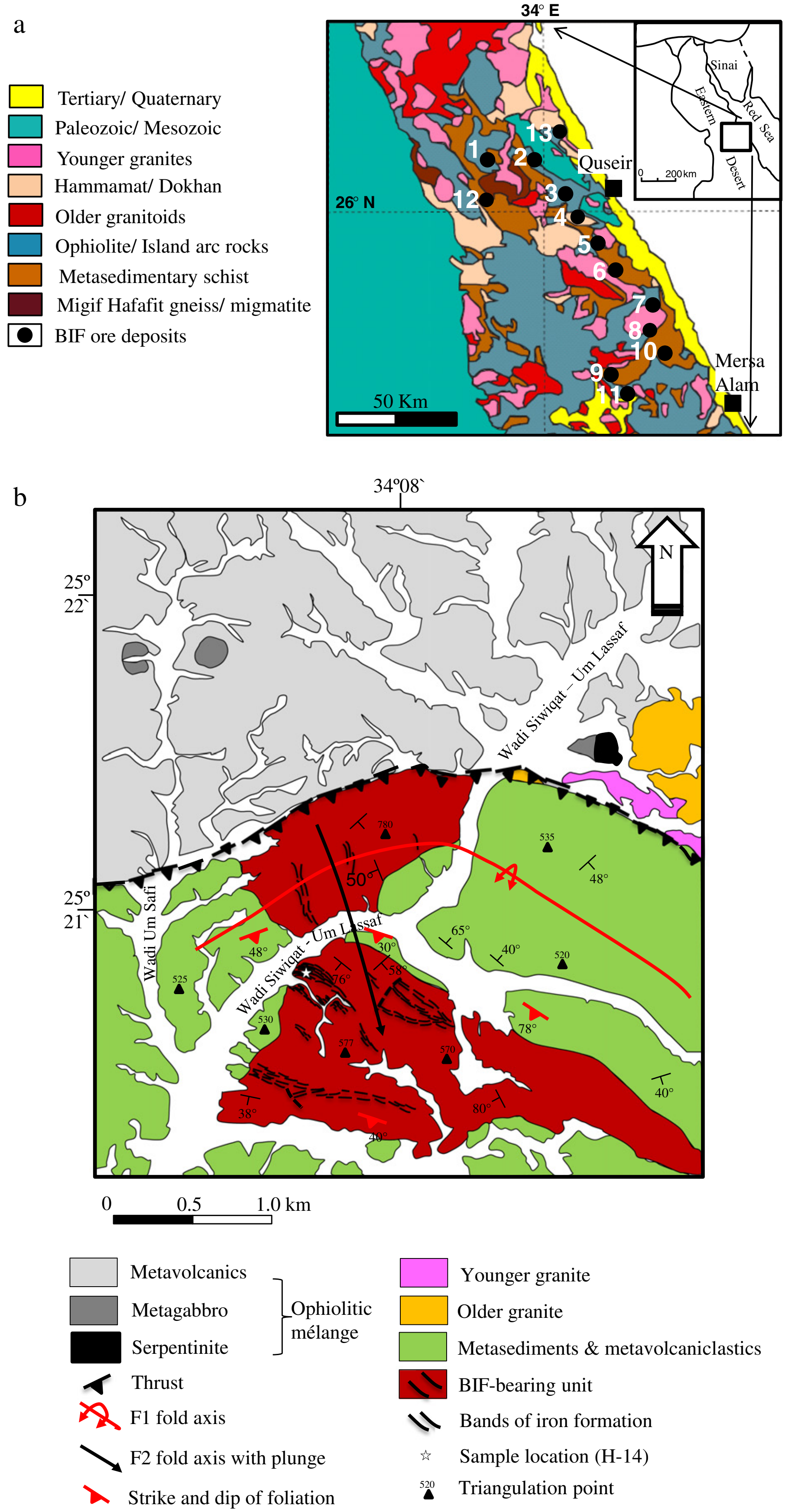

Fig. 1. (a) Simplified geologic map of the central Eastern Desert of Egypt showing the location of some BIF occurrences; 1 — Hadrabia, 2 — Abu Merwat, 3 — Gebel Semna, 4 — Diwan, 5 — Wadi Kareim, 6 — Wadi El Dabbah, 7 — Umm Shaddad, 8 — Umm Ghamis, 9 — Gebel El Hadid (Study area), 10 — El Emra, 11 — Umm Nar, 12 — Wadi Hammama, 13 — Umm Anab. (b) Geological map of the Gebel El Hadid area, central Eastern Desert, Egypt (modified from El Habaak and Mahmoud, 1994), showing the location of sample H-14 analyzed for age dating.