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Mineralogical and geochemical investigations of the Middle Eocene ironstones, El Bahariya Depression, Western Desert, Egypt

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ABSTRACT

The Middle Eocene ironstone succession is located in the northeastern part of El Bahariya Depression, Western Desert, Egypt. This succession is subdivided into lower and upper sequences and consists of two main shallow marine ironstone facies associations. The first is a lagoonal manganiferous mud and fossiliferous ironstone facies association and consists mainly of goethite and hematite, detrital minerals (quartz, rutile, and feldspars), manganese minerals (todorokite, psilomelane, pyrolusite, birnessite, aurorite and manjiroite), and authigenic clay minerals (kaolinite and illite). The second is a peritidal microbially mediated stromatolitic and nummulitic-ooidal-oncoidal ironstone facies association consists of goethite, apatite, and secondary minerals that include quartz, jarosite, psilomelane, and pyrolusite. Organic materials such as proteinaceous compounds, lipids, cellulose, and carotenoids were detected in the cortices of the ferruginous ooids and oncoids. The marine ironstone facies were exposed to subaerial weathering and subsurface alteration processes. The weathering resulted in the formation of lateritic iron ores and paleosols during humid climatic periods. The lateritic iron ores consist mainly of colloform goethite, hematite and psilomelane. The identification of cavity-filling sulfate, nitrate, carbonate and silicate minerals in the marine ironstones and the lateritic iron ore may indicate more recent alteration under arid climatic conditions. The subsurface alteration is attributed to the oxidation of sulfides, primarily pyrite, and weathering of glauconitic clastic rocks in the underlying Cenomanian Bahariya Formation during the interaction with acidic heated groundwater. The formation of ferrous and ferric sulfate, and silicate minerals, and mobilization of trace metals are the products of the alteration process. Enrichments in Ba, Co, K, Pb and Sr are correlated with manganese oxides, whereas anomalous P, V, Cr, Ni, Zn, As, Mo, and U are correlated with iron oxyhydroxides.

1. Introduction

Ironstones are non-cherty, sandy fine-grained siliciclastic or siliciclastic–carbonate sedimentary rocks with >15 wt.% iron, corresponding to 21.4 wt.% Fe_2O_3 (Petránek and Van Houten, 1997). The ironstones may or may not contain >50% ooids, pisoids, peloids and oncoids. Ooids are spherical or ellipsoidal coated-grains <2 mm in diameter, which display regular concentric laminae surrounding a central core. Grains similar to ooids, but >2 mm are known as pisoids. Oncoids and pisoids also differ in that the former have a biogenic origin and irregular concentric laminae (Flügel, 2010). Peloids are fine-grained material with diameters similar to ooids and pisoids, but without recognizable internal structure. These coated-grains, particularly ooids, were formed in either continental or marine depositional environments by biotic or abiotic pathways (Young and Taylor, 1989). The abiotic mechanisms for the formation of the coated-grains were reviewed by Van Houten (1992), Petránek and Van Houten (1997), and Collin et al. (2005). The microbial activity played a significant role in the formation of the ferruginous ooids, oncoids, and ferruginous stromatolite of the Lower Jurassic Minette oolitic ironstones, Lorraine, France (Dahanayake and Krumbein, 1986); the ferruginous oncoids, ooids, and ferruginous stromatolitic microbialites of the Aalenian and Bajocian of the Swiss Jura Mountains (Burkhalter, 1995); Middle Jurassic ferruginous ooids, Normandy, France (Préat et al., 2000); and the ferruginous oncoids, ooids, and ferruginous stromatolitic microbialites of northwestern Egypt (El Aref et al., 2006b). Detailed investigations of the origin and mineralogy of oolitic ironstones are restricted to a relatively small number of the worldwide Phanerozoic ooidal ironstone deposits (Young and Taylor, 1989; Mücke and Farshad, 2005).

The Middle Eocene ironstone deposits of El Bahariya Depression represent the only economic ooidal ironstone along the Tertiary paleo-Tethyan shorelines in northern Africa and southern Europe. These economic deposits represent the main exploitable iron ore deposits of Egypt from 1973 till now. They are located in the northeastern part of El Bahariya Depression, Western Desert, Egypt. The iron ore deposits are developed at the Ghorabi, El Harra, and El Gedida

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mines (Fig. 1). In contrast to the Middle Eocene ironstones of El Bahariya Depression, all other Cenozoic ooidal ironstone of the world are uneconomic to marginally economic and only few of these have been studied in detail (Van Houten, 1992; Petránek and Van Houten, 1997). The ooidal ironstones have a peak in abundance in the Early and Middle Eocene times that reflects major changes in the paleogeographic position of the shoreline during that time. Most of the Cenozoic ooidal ironstones, including El Bahariya ironstones, accumulated in shallow marine environments (Van Houten, 1992; Helba et al., 2001; El Aref et al., 2006a). They were developed during relatively long periods of open circulation, low sedimentation rate, abundant burrowers, and normal amounts of marine fauna and micro-organisms. The ironstone deposits are commonly associated with phosphates and iron laterites. Although most deposits have no direct relation to volcanism (Van Houten, 1992), a few workers suggested a volcanic origin for the Phanerozoic ooidal ironstones (Heikoop et al., 1996; Sturesson et al., 1999, 2000; Sturesson, 2003). In northern Africa, Cenozoic ooidal ironstones occur in mixed siliciclastic–carbonate sequences associated with manganiferous and phosphatic mineralization (Petránek and Van Houten, 1997).

The present contribution aims at studying the mineralogical composition and geochemical characteristics of the different Middle Eocene marine ironstone facies of El Bahariya Depression, Western Desert, Egypt. It also sheds light on the syn- and post-Middle Eocene subaerial weathering and subsurface alteration events that affected the original marine ironstones.

2. Geologic setting

El Bahariya Depression is a large, oval-shaped, NE-oriented depression in the center of the Western Desert (Fig. 1). Its maximum length is about 94 km, whereas its greatest width is about 42 km. It has a surface area of about 1800 km^2 and it is surrounded on all sides by a karst plateau of Cretaceous and Eocene carbonates. The plateau surface rises about 250 m above the present-day sea level. The floor and the basal part of the surrounding escarpment of El Bahariya Depression consist of Early Cenomanian clastic rocks of the Bahariya Formation. The study area includes the Gabal Ghorabi-Nasser (3.5 km^2), El Harra (2.9 km^2), and El Gedida (6.5 km^2) mine areas.

El Bahariya Depression is deformed by a NE-trending right-lateral wrench fault system (Fig. 1), which is associated with several doubly plunging folds and extensional faults (Sehim, 1993; Moustafa et al., 2003). Mapping of El Bahariya Depression also revealed the presence of three ENE-trending fault zones (Fig. 1). The maximum deformation is recorded in the two northern fault zones; Gabal Ghorabi–El Ghaziya and El Gedida–El Harra. The areas surrounding the master faults show small-scale doubly plunging anticlines represented by Early Cenomanian swells in the northeastern plateau of El Bahariya Depression. These

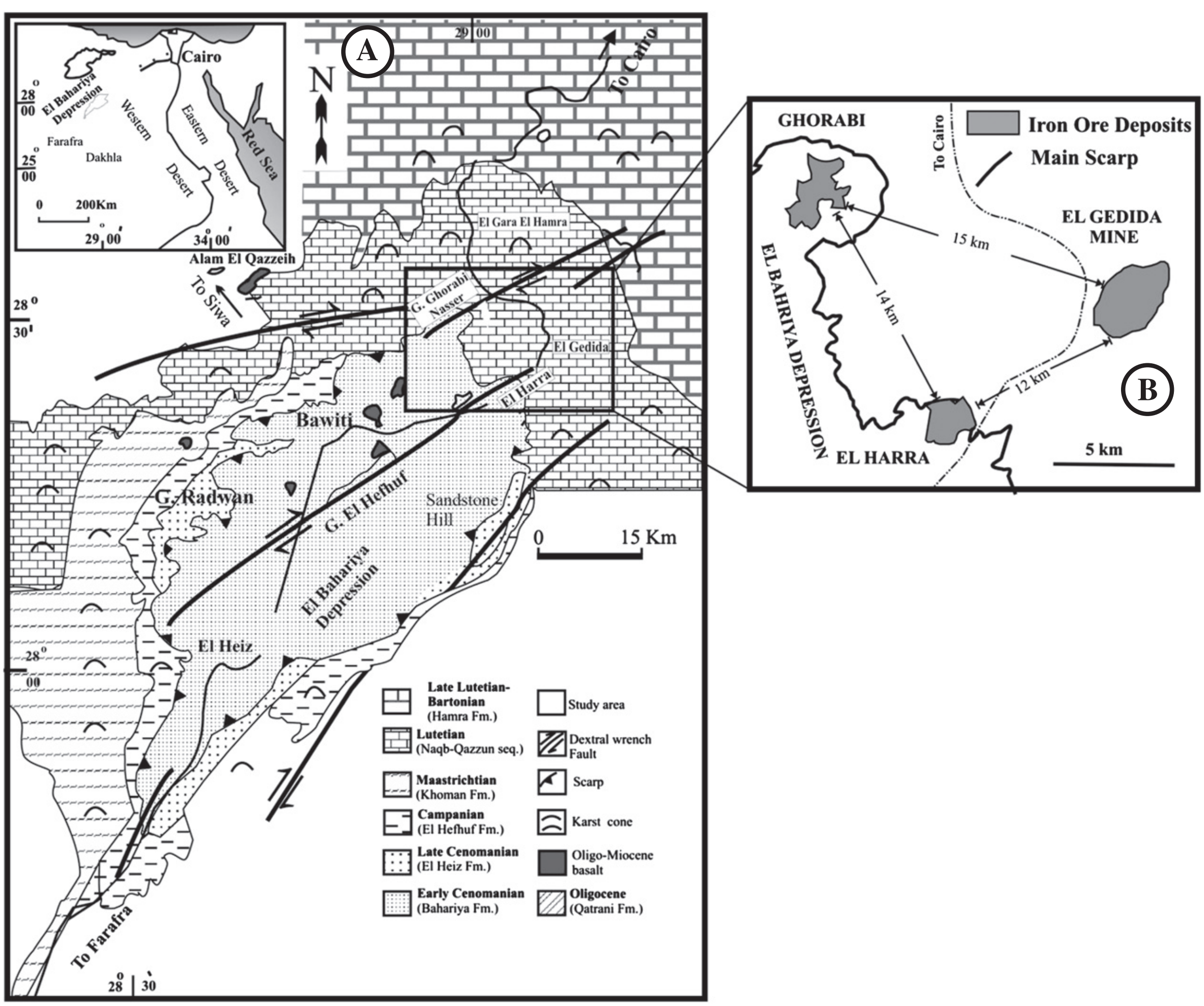

Fig. 1. A. Geological map of El Bahariya Depression showing the distribution of the main geological units (modified after Hermina et al., 1989, detailed structural elements are shown in Sehim, 1993). B. Location map of the iron ore mine areas.