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Research paper

Origin of the gypsum-rich silica nodules, Moghra Formation, Northwest Qattara depression, Western Desert, Egypt

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Abstract

Gypsum rich-silica nodules appear in two shale horizons of the Moghra Formation (early Miocene) northwestern Qattara Depression, Western Desert, Egypt. These nodules are gray to milky white in colour, mostly botroidal and rose-like in shape and range in diameter from 2 to 7.5 cm. The silica nodule-bearing shale is composed mainly of smectite with a little minor kaolinite.

The silica nodules consist mainly of quartz and are composed of gypsum-free matrix and gypsum-rich megacrystalline quartz. The matrix consists of microflamboyant quartz (less than 36 μm in diameter) and chalcedony. The megacrystalline quartz occurs as lenticular and prismatic forms (length: 90–250 μm; width: 30–90 μm). The microprobe, petrographic and SEM examinations confirmed the occurrence of gypsum relics (diameter; 2–16 μm) within the megacrystalline quartz. The chalcedony and mosaic microcrystalline quartz occurs as pore-lining and pore-filling cements. The structure of the silica nodules begins with quartzine in its outer rim, then gypsum-free microcrystalline quartz in the middle part and ends with gypsum-rich lenticular to prismatic megaquartz in the center.

Field study, petrographic examination and microprobe analysis reveal that the silica nodules were formed by silicification of precursor gypsum nodules deposited in a marginal sabkha environment under an arid climate. The silicification selectively affected the gypsum nodules rather than the surrounding shale and occurred both through gypsum replacement and void filling. Transformation of isopachous chalcedony into mosaic microcrystalline quartz also occurred. The texture of the silica minerals reflects the different physico-chemical conditions under which they crystallized. Spherical nodules grew chiefly by the diffusive supply of the silica, and elongated ones grew by pore water advection.

The integrated effect of climate, pH, salinity, crack systems within the sediment and oscillation in the groundwater level and its chemical composition contributed to the formation of the nodules.

Keywords: Nodules; Paragenesis; Silicification; Miocene; Qattara Depression

1. Introduction

Nodules are defined as concretionary bodies in which the authigenic mineral does not incorporate

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clastic materials during growth (Selles-Martinez, 1996). Nodules are sometimes monomineralic and homogeneous, but polymineralic nodules displaying concentric zonation, may also develop. Different mineralogical compositions have been reported for nodule bodies, chert (James et al., 2000; Bustillo, 2001), barite (Pepper et al., 1985), evaporite (Milliken, 1979; Orti et al., 1997), phosphate (Morad and Al-Aasm, 1994) and manganiferous nodules (Mc Kelevy, 1986).

There are fewer studies of silica occurrences for continental than marine environments. Silicification is a common diagenetic phenomenon in marine sediments. The source of silica required for development of chert nodules in marine sediments is generally thought to be intraformational redistribution of biogenic silica during diagenesis. Silicification of host sediments may happen even under shallow burial diagenesis (Thiry and Ribet, 1999).

Silicification associated with evaporites is complex and the time needed for silicification can be difficult to determine (Krainer and Spotl, 1998). In the sulfate facies of ancient marine evaporites chert nodules are scarce. These nodules are frequently pseudomorphs of precursor anhydrite nodules and may appear as replacement products of stromatolitic carbonates as well as laminated facies developed in pre-evaporitic stages (Orti et al., 1997).

The occurrence of modern and ancient Magadi-type silica (abiogenic silica) is generally rare in the geologic record. Its recognition, however, has important palaeoenvironmental implications. This is because formation of Magadi type chert requires a delicate balance of silica source (s), hydrologic setting and semiarid climate (Eugster, 1986; Krainer and Spotl, 1998). Intervals of chert nodules can form condensed sections that can be correlated regionally using sequence stratigraphic concepts, and more precisely, a maximum flooding surface of a third-order sequence (Haq et al., 1987; James et al., 2000).

Although silicification of clastic deposits in the continental environments was described (Eugster, 1969, 1986; Murata and Larson, 1975; Bustillo et al., 1991; Bustillo and Bustillo, 2000; Bustillo, 2001; Simon-Coincon et al., 1996; Krainer and Spotl, 1998), its genesis and mode of formation are not clear. Up till now there are several disputable unanswered questions concerning silica nodules in continental deposits. These questions include (1) What is the silica source? (2) What factors affect the growth of the nodules? (3) What is their mechanism of formation? This paper is an attempt to find the answers for the above-mentioned questions via sedimentological study of silica nodules developed within the lower Miocene Moghra Formation cropping out in Talkh El-Fawakheir area, northwestern Qattara Depression, Western Desert, Egypt (Fig. 1).

2. Geological setting

The Qattara Depression forms one of the most significant features in the north Western Desert of Egypt. It is closed and lies at −134 m below sea level. The Depression is bounded from the north and west by steep escarpments, with an average elevation of about 200 m above sea level.

The exposed stratigraphic section around the study area is composed of a sedimentary sequence ranging in age from the middle Eocene to the Quaternary (Fig. 1). The middle Eocene calcareous sediments of the Mokattam Formation form the southern scarp of the depression. The upper Eocene Qasr El Sagha Formation is composed of black shales with coquina and oyster intercalations (Said, 1990). The Miocene rocks in the study area are represented by two formations: a lower Miocene fluvio-marine Moghra Formation and a middle Miocene shallow marine Marmarica Formation (Said, 1962). Sandy and clayey beds of the lower Miocene Moghra Formation form the bottom and the surroundings of the Qattara Depression, where the ground level reaches 50 to 80 m below sea level. In parts of the study area, the Moghra sediments occur as small plateaux and residual hills within the Quaternary sabkhas.

The Quaternary deposits are represented by unconsolidated eolian sands, sabkhas and wadi filling unconformably overlying the Miocene rocks (Ball, 1933; El Bassyony, 1995; Aref et al., 2002). The eolian sands occur as seif dunes that are composed of very fine sands with few detrital carbonates. The sabkha sediments cover large areas of the floor and lower slopes of the Qattara Depression, occurring at or below the elevation of 50 m below sea level (Ball, 1933).

In the Qattara Depression Aref et al. (2002) distinguished three types of evaporites: 1, 2 and 3