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Cretaceous Research 26 (2005) 261–275

CRETACEOUS RESEARCH

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Origin of Late Cretaceous phosphorites in Egypt

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Received 15 April 2004; accepted in revised form 7 December 2004
Available online 7 April 2005

Abstract

The Duwi phosphorite deposits in Egypt are a part of the Middle East to North African phosphogenic province of Late Cretaceous–Palaeogene age. Their origin is controversial. Most previous authors have considered them to be in situ, authigenic deposits. Phosphatic grains in the Egyptian phosphorites are well-rounded phosphatic mudclasts (45–65%) and phosphatic bioclasts (35–55%). Phosphatic mudclasts are internally structureless but sometimes contain silt-sized detrital grains such as quartz and bone fragments, suggesting a reworked origin from pre-existing phosphatic mudstone. Analysis by Electron Probe Microanalyzer (EPMA) confirmed that the phosphatic mudclasts are chemically homogeneous, without any concentric structure suggestive of authigenic origin. The presence of bone fragments within some of the phosphatic mudclasts, the occurrence of phosphatic mud filling bone cavities, and the similar appearance of the matrix of phosphatic mudclasts and the phosphatic mud in the bone cavities suggest that the bioclasts are also of reworked origin and washed out from the phosphatic mudstone. Scanning electron microscope observations of the fractured surface of the mudclasts have revealed the capsule-like texture that is characteristic of bacterially mediated authigenic phosphorites formed under upwelling conditions. Campanian authigenic phosphorites with similar texture have been reported from Israel, suggesting that the phosphatic grains were reworked from pre-existing authigenic phosphorites equivalent to those in Israel. Sedimentary facies analysis of the Egyptian phosphatic sequence suggests that the major phosphorite beds represent transgressive lag deposits that accumulated in an oxic, bioturbated, wave-dominated shelf environment. It is likely that offshore authigenic phosphorites, formed in an upwelling-dominated environment during an early Campanian highstand, were reworked during a mid Campanian lowstand, transported landward, and concentrated in a near-shore, oxic environment during subsequent late Campanian transgressions. Another transgressive-regressive cycle is recognized to have occurred during the late Campanian–early Maastrichtian, suggesting that formation, reworking and redeposition of the Duwi phosphorites resulted from sea-level changes during the Campanian and Maastrichtian.

Keywords: Egypt; Phosphorites; Bacterially mediated phosphatic sedimentation; Phosphatic bioclasts; Phosphatic mudclasts; Redeposition; Transgressive lag deposits

1. Introduction

The Campanian–Maastrichtian phosphatic deposits in Egypt, called the Duwi Formation, comprise a part of the extensive Middle East to North African phosphogenic province of Late Cretaceous–Palaeogene age. The province holds the greatest accumulation of phosphorites in geological history, possibly in excess of 70 billion metric tons (Cook and McElhinny, 1979). The phosphate resources in Egypt alone exceed 3 billion metric tons (Notholt, 1985). The discovery of phosphatic rocks in Egypt dates back to the end of the nineteenth century (Hermina, 1972). Since then, Egyptian phosphorites have been the subject of intensive studies due to their economic and geological significance (Abdel-Rahman, 1992). However, both the origin of the phosphorites and their depositional mechanism are still the subject of controversy.

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0195-6671/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.cretres.2004.12.004

Many previous studies considered that the phosphorites are composed of authigenic peloids. For example, Rittman and Machu (1955) attributed the formation of apatite in the Egyptian phosphorites to a chemical reaction between calcium carbonate particles and ammonium phosphate ions. The carbonate particles were considered to have been produced through erosion by strong agitating currents on the limestone sea floor, and the ammonium phosphate to have been produced by the decay of marine organic matter. Youssef (1965) considered the phosphorites to have formed in situ in association with synclines that provided a sheltered environment. El-Tarabili (1969) attributed their formation to upwelling currents that brought nutrients from deep water into the photic zone. Glenn and Arthur (1990) are the only authors to have considered the peloids to be reworked. They also suggested that the source of the phosphorus could have been fluvial input from a deeply weathered continental platform to the south. Bioclasts are generally considered to be a minor component (El-Kammar et al., 1979; El-Shazly et al., 1979; Germann et al., 1985; Soliman et al., 1986, 1989; Glenn and Arthur, 1990) and their importance and genetic relationship with the phosphatic peloids have been largely overlooked.

We have examined the composition of the Egyptian phosphorites by detailed petrographic, mineralogical and chemical analyses. Sequence stratigraphic analysis of the phosphorite-bearing interval was also carried out to examine the relationship between sea-level changes and phosphorite deposition. The results suggest that the phosphorites are composed of bioclasts, “peloids” and lithoclasts, and that the “peloids” are actually well-rounded clasts of phosphatic mud. It is also demonstrated in this paper that all of the phosphatic grains are of reworked origin and were probably derived from pre-existing offshore authigenic phosphorites. The formation, reworking, and concentration process of the phosphorites are discussed with special emphasis on their genetic relation to sea-level changes.

2. Geological setting and localities studied

The basement complex in Egypt, composed of granite, gneiss, schist and metamorphic rocks of Precambrian age, forms a series of rugged hills and is exposed mainly in the extreme southwestern corner of Egypt, Sinai, and along the Red Sea coast. It is covered by Upper Cretaceous to Lower Cenozoic sedimentary rocks to the north (Fig. 1).

The phosphate deposits of the Duwi Formation are a part of the Upper Cretaceous–Lower Cenozoic sedimentary sequence, and are widely distributed in the Eastern Desert, Nile Valley, and Western Desert areas. The Duwi Formation unconformably overlies the fluvial shale sequence of the mid Campanian Qusseir Formation, and is overlain conformably by the deep marine shales and marls of the mid Maastrichtian Dakhla Formation. Thus, deposition of the Duwi Formation represents an initial stage of the Late Cretaceous marine transgression in Egypt. The precise age of the Duwi Formation is poorly known; generally it is considered as either late Campanian or early Maastrichtian (Glenn and Arthur, 1990). In the Eastern Desert, the formation is conformably overlain by the Dakhla Formation, which is referable to the Maastrichtian planktonic foraminiferal *Globotruncana gansseri* Zone and the calcareous nannoplankton *Arkhangelskiella cymbiformis* Zone (El-Dawoody and Barakat, 1973). The ammonites *Bostrychoceras polyplocum* and *Libycoceras* sp., which are indicative of a late Campanian age, occur in the lower member of the Duwi Formation in the Nile region, and in the Red Sea coast areas (Issawi, 1972; Abd El-Razik, 1979). Schrank and Perch-Nielsen (1985) estimated a late Campanian–early Maastrichtian age for the upper part of the Duwi Formation in the Eastern Desert on the basis of the palynomorph assemblage. Late Campanian calcareous nannofossils were also identified in the Nile Valley section in Abu Had (Glenn and Arthur, 1990). Thus, the age of the Duwi Formation most likely ranges from late Campanian to early Maastrichtian.

According to Issawi et al. (1999) the lower and middle parts of the Adabya Formation in the Eastern Desert are equivalent to the Duwi Formation whereas the upper part is equivalent to the mid Maastrichtian Dakhla Formation. Khalifa (1977) considered the Ain Giffara Formation in the Bahria Oasis, Western Desert to be equivalent to the Duwi Formation.

Detailed fieldwork has been conducted within the phosphorite-bearing sequence in order to examine the stratigraphy of the phosphorite deposits, their mode of occurrence and their depositional environment. Five localities were studied: Adabya and Red Sea in the Eastern Desert, Nile Valley, and Abu-Tartur and Bahriya oases in the Western Desert (Fig. 1). We concentrated on the Red Sea, Nile Valley and Abu-Tartur localities since in these areas the Duwi Formation is well developed and well exposed, and phosphorites are economically mined.

3. Samples and methods

Phosphorites and associated rocks were sampled from the upper part of the Qusseir Formation, the Duwi Formation, the lower part of the Dakhla Formation, and their equivalents at the five localities in order to examine the temporal and spatial variations