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Calcretes and palustrine carbonates in the Oligo-Miocene clastic–carbonate unit of the Farafra Oasis, Western Desert, Egypt: Their origin and paleoenvironmental significance

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ABSTRACT

The origin and paleoenvironmental significance of the calcretes and palustrine carbonates in the Oligo-Miocene clastic–carbonate unit that outcrops at the eastern sector of the Farafra Depression (Western Desert, Egypt) have been discussed based on field and petrographic investigations. The calcretes–palustrine carbonates assemblage occurs above a siliciclastic/distal alluvial-floodplain facies. The calcretes represent the transition from the underlying siliciclastic/distal alluvial-floodplain facies to the overlying palustrine carbonates. The calcrete-host rocks are muddy sandstones and sandy mudrocks.

This study reveals the occurrence of groundwater calcretes with an upward gradational maturity pattern, ranging from incipient to nodular and to massive calcretes. The calcretes micromorphological analysis suggests that they were originated in vadose and phreatic diagenetic environments by groundwater through evaporation, degassing with no biological activity. The palustrine carbonates are also recognized above the calcrete horizons. They occur in the form of micritic limestones displaying different features that indicate their modifications during pedogenesis and subaerial exposure. These features include clotted-peloidal texture, fenestral fabric, mottling, pseudo-brecciation, desiccation cracks, pseudomicrokarst, root traces and silicification of the lime mud. The calcretes–palustrine carbonates assemblage records a progressive decrease in the terrigenous supply and a continuous rise of the groundwater table associated with local subsidence in a semi-arid to sub-humid climate. A model is suggested for the development of calcretes and palustrine carbonates in the study area.

1. Introduction

Calcrete (syn. caliche) is a term used to describe a near surface, terrestrial accumulation of predominantly calcium carbonate ($CaCO_3$), which occurs in a variety of forms ranging from powdery to nodular and to highly indurate crust (hardpan) on and/or within sedimentary rocks, sediments and soils (Goudie, 1983; Alonso-Zarza and Wright, 2010a; Kaplan et al., 2013). The carbonate is introduced by replacive, displacive mechanisms and/or passive precipitation (Wright and Tucker, 1991; Alonso-Zarza and Wright, 2010a). Calcrete is developed in arid to semi-arid climate with annual rainfall of about 500 mm (Goudie, 1983). It may be of pedogenic and/or groundwater origins (Wright and Tucker, 1991; Pimentel et al., 1996; Wright, 2007). The pedogenic (beta-type/biogenic) calcretes form in soil profiles in the vadose zone, whereas groundwater (alpha-type/abiogenic or phreatic) calcretes develop around the water-table in both vadose and phreatic zones (Alonso-Zarza, 2003). Pedogenic calcretes need long time of subaerial exposure to form (several thousands to millions of years), whereas groundwater calcretes do not need subaerial exposure for its formation (Alonso-Zarza, 2003). Detailed reviews on calcretes development are provided by Wright and Tucker (1991), Singh and Tandon (2002), Alonso-Zarza (2003) and Alonso-Zarza and Wright (2010a).

The term palustrine deposits has been proposed for low-gradient marginal lacustrine deposits which have been subjected to subaerial exposure and pedogenesis in semi-arid to sub-humid climates (Freytet, 1973; Platt and Wright, 1992; Alonso-Zarza et al., 2012). Palustrine carbonates are characterized by a range of sedimentary and pedogenic features including root traces, pseudo-microkarstification, mottling, desiccation, brecciation, and nodulation (Freytet, 1973, 1984; Freytet and Plaziat, 1982; Alonso-Zarza et al., 1992; Platt and Wright, 1992; Freytet and Verrecchia, 2002). The subaerial exposure time needed to form palustrine carbonates may by relatively short (even a season) (Alonso-Zarza, 2003). The genesis, different facies, and factors

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controlling the development of palustrine carbonates are presented in comprehensive reviews of Alonso-Zarza (2003), Alonso-Zarza and Wright (2010b).

Interest in calcretes–palustrine carbonates association has increased over the last 20 years due to their palaeoenvironmental significance; e.g., climate, tectonics, sedimentation rate and hydrology (Alonso-Zarza, 2003; Alonso-Zarza and Tanner, 2006; Pla-Pueyo et al., 2009; Singh et al., 2009; Alonso-Zarza and Wright, 2010a,b; Tanner, 2010). Calcretes–palustrine carbonates assemblage widely occurs throughout the stratigraphic record in many continental basins as an important archive of paleoclimatic, paleotectonic and paleohydrological information (e.g., Tandon and Andrews, 2001; Alonso-Zarza, 2003; Huerta and Armenteros, 2005; Alonso-Zarza and Tanner, 2006; Tofalo and Pazos, 2010; Alonso-Zarza et al., 2011, 2012; AlShuaibi and Khalaf, 2011; Alcicek and Alcicek, 2014). In Egypt, very little work has been done on the calcretes–palustrine carbonates association (Mahran, 1999; Gharieb, 2004; Khalaf and Gaber, 2008). In addition, there is no previous study on that subject in the Western Desert of Egypt. Therefore, the present work focuses on the characteristic facies, genesis and paleoenvironmental conditions of the exposed Oligo-Miocene calcretes–palustrine carbonates assemblage at the eastern side of the Farafra Oasis (Bir Karawein area), Western Desert, Egypt. A model of their development is also suggested. To achieve these purposes, detailed field and petrographic investigations of the studied rocks have been done.

2. Geological setting

The Farafra Oasis is situated in the middle of the Western Desert of Egypt between Lat. 26°45′ and 27°40′N and Long. 27°00 and 28°50′E. It is an oval- shaped depression with an area of 10,000 km^2. The Farafra Depression is bounded by scarps on the eastern, northern and western sides, while it is open to the south (Said, 1962). Its floor is covered by the Dakhla Shale in its southern part, and is dominated by the Khoman Chalk in the northern part (Hermina, 1990). The eastern part of the depression is covered by sand sheets with some dunes on top. Structurally, the Farafra area represents a minor dome along the Stable-Unstable Shelf contact (Said, 1962). The domal axis runs through its length in the northeast–southwest trend. The Farafra Depression forms the southernmost extension of the Syrian Arc System (Omara et al., 1970).

The studied Oligo-Miocene clastic–carbonate unit constitutes the uppermost part of the stratigraphic succession in the Farafra

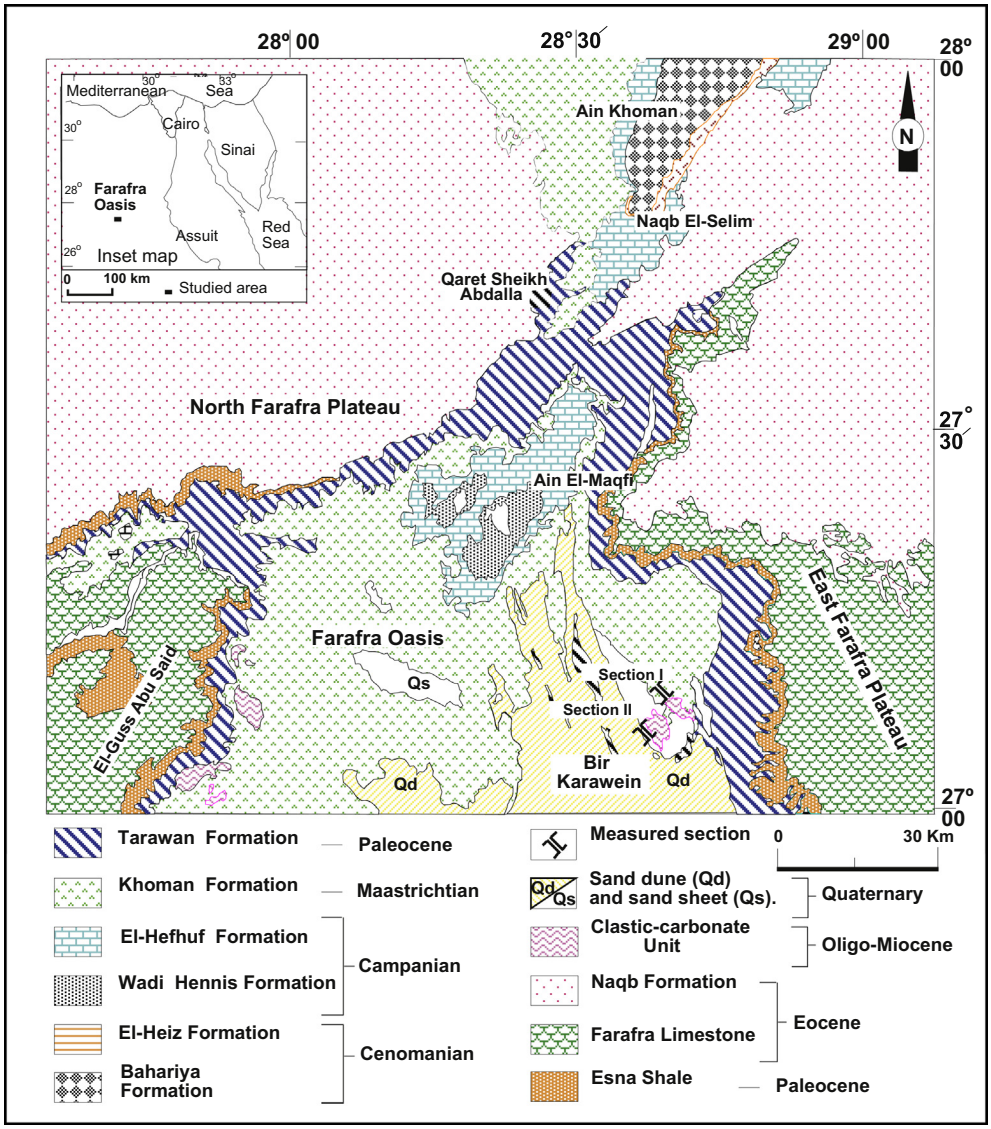

Fig. 1. Geological map of the studied area (modified after Conoco, 1987).