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Distribution of carbonate cements within depositional facies and sequence stratigraphic framework of shoreface and deltaic arenites, Lower Miocene, the Gulf of Suez rift, Egypt

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ABSTRACT

This study aims to unravel the spatial and temporal distribution of diagenetic alterations of the Mheiherrat Member, the Rudeis Formation (lower Miocene) of the Gulf of Suez rift, Egypt within depositional facies and sequence stratigraphy. The Mheiherrat member is represented by shoreface calcarenites and hybrid arenites (transgressive and highstand systems tracts; TST and HST; respectively) and deltaic rudites and coarse-grained calcarenites and hybrid arenites (lowstand systems tracts; LST). Petrographic, stable O- and C-isotopes, mineral chemical and geochemical analyses have revealed that the arenites are pervasively cemented by eogenetic carbonates and, to small extent, by zeolite and pyrite as well as by telogenetic palygorskite. The shoreface TST and HST calcarenites and hybrid arenites were dominantly cemented by microcrystalline grain-rimming and inter- and intragranular pore-filling calcite ($\delta^{18}O_{V\text{-}PDB} = -3.6‰$ to $-0.3‰$ and $\delta^{13}C_{V\text{-}PDB} = -2.3‰$ to $-0.7‰$) and rhombic dolomite ($\delta^{18}O_{V\text{-}PDB} = -3.9‰$ to $+0.9‰$ and $\delta^{13}C_{V\text{-}PDB} = -2.5‰$ to $-0.7‰$). These cements are interpreted to be formed by marine to brackish waters with $\delta^{18}O_{V\text{-}SMOW}$ $-1.2‰$ to $+3.2‰$ at temperature of 20–55 °C. The deltaic LST coarse-grained calcarenites and hybrid arenites were dominantly cemented by coarse-crystalline, inter- and intragranular pore-filling calcite ($\delta^{18}O_{V\text{-}PDB}$ $-4.4‰$ to -2.3% and $\delta^{13}C_{V\text{-}PDB} = -2.8‰$ to $-1.3‰$), which are interpreted to have precipitated from pore waters with $\delta^{18}O_{V\text{-}SMOW}$ $+3.5‰$ to $+5.5‰$ at temperatures of greater than 55 °C. Such pervasive cementation by carbonates is attributed to the occurrence of abundant intrabasinal carbonate grains. The carbonate cement texture is suggested to be controlled by changes in pore-water chemistry owing to transgression and regression events. This case study revealed that better understanding of factors controlling the extent and textural habits of carbonate cements can be achieved when it is linked with depositional facies and sequence stratigraphy.

1. Introduction

Sequence stratigraphy is a powerful tool for predicting the spatial and temporal distribution of reservoirs, seals and source rocks, which is controlled by the interplay between the rates of sediment supply, basin-floor physiography, and the rate of changes in relative sea level (Posamentier and Allen, 1993, 1999). Parameters controlling the sequence stratigraphy of siliciclastic successions have also strong control on parameters influencing diagenesis, such as pore-water chemistry, residence time, and detrital composition (Zuffa et al., 1995; Morad et al., 2000). For instance, changes in pore water chemistry between meteoric, mixed meteoric-marine, and marine across the continental shelf occur as a result of transgression and regression events (Morad et al., 2000; El-Ghali et al., 2006a,b; El-Ghali et al., 2009). Rate of deposition affects residence time of sediments under certain near-

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surface geochemical conditions, such as on the seafloor or during subaerial exposure (Taylor et al., 1995; Ketzer et al., 2003; Ketzer and Morad, 2006; El-Ghali et al., 2006b). Accordingly, integration of diagenesis and sequence stratigraphy paves the ground for better understanding of the distribution eogenetic alterations (Morad et al., 2000).

This paper aims to unravel and discuss the distribution of diagenetic alterations in deltaic and shoreface calcarenites and hybrid arenites within the context of sequence stratigraphy of the Mheiherrat Member, the Rudeis Formation (lower Miocene), Suez rift, Egypt (Figs. 1 and 2). Special emphasis is put on unraveling parameters controlling variations in the texture and geochemical composition of carbonate cements.

The shoreface and deltaic calcarenites and hybrid arenites, Lower Miocene succession, the Gulf of Suez rift, Egypt is a potential analogue for the study of other transitional reservoirs in similar basinal settings in which reservoir quality assessment is of considerable importance.

Diagenetic regimes used in this study, which are sensu Morad et al. (2000), include: (1) eodiagenesis (<70 °C; depth < 2 km), during which pore water chemistry is controlled by surface waters (i.e. depositional and/or meteoric waters); and (2) mesodiagenesis (>70 °C; depth > 2 km), which is mediated by evolved formation water and elevated temperature (Morad et al., 2000).

2. General geologic setting

The study area is located in Wadi Wasit area, Gulf of Suez (Fig. 1), forming the northern extension of the Red Sea, which is intra-continental Neogene rift system, approximately 300 km long and 80 km wide. Rifting occurred during the separation of the African and Arabian plates is the latest Oligocene to the Miocene (Patton et al., 1994; Steckler et al., 1998). The syn-rift Miocene sediments show rapid lateral variations in facies and thickness due to differential movements in the pre-Cambrian blocks (Sellwood and Netherwood, 1984; Scott and Govean, 1985; Youssef, 2000). The syn-rift Miocene sediments include two groups, namely Gharandal and Ras Malaab (NSSC, 1974; Evans, 1988). The Lower-Middle Miocene Gharandal Group is divided from base to top into Nukhul, Rudeis and Kareem formations. The Middle-Upper Miocene Ras Malaab Group includes, from bottom upward, the Belayim, South Gharib and Zeit formations.

The Rudeis Formation, which is Burdigalian in age (Evans, 1988; El Beialy and Ali, 2002), overlies unconformably the Nukhul Formation and underlies unconformably the Kareem Formation (Carr et al., 2003). The Rudeis Formation, which has been deposited in open marine conditions (Evans, 1988; El Beialy and Ali, 2002), is composed of highly fossiliferous mudstones and marls interbedded with thin arenite beds (El Beialy and Ali, 2002; El-Azabi, 2004). The formation is divided into four members including, in stratigraphic order, Mheiherrat (Fig. 2), and Hawara (lower Rudeis), Asl, and Mreir (upper Rudeis) (Gawad et al., 1986; El-Azabi, 2004). Evans (1988) considered that Mheiherrat Formation deposited during Late Aquitanian–Late Burdigalian. The lower part of formation is characterized by a high content of nannoplankton, and was probably deposited in an open marine environment up to 200 m water depth under hot semi-arid climate and during periods of high detrital input (El-Azabi, 2004). Shallower marine conditions (5–20 m) prevailed in marginal area during the deposition of the upper part of the Rudies Formation. The transition from the lower part to the upper part of Rudeis Formation is marked by an unconformity, which has been suggested to be associated with regional tectonic uplift. The upper part of the formation is characterized by deposition of fan deltas along fault block margins and submarine fans in hanging-wall depocentres (Evans, 1988; Smale et al., 1998).

The onset of movement on the Dead Sea-Aqaba transform fault approximately 15.5 Ma inhibited further rifting in the Gulf of Suez. This quiescence in subsidence, combined with a lowered global sea

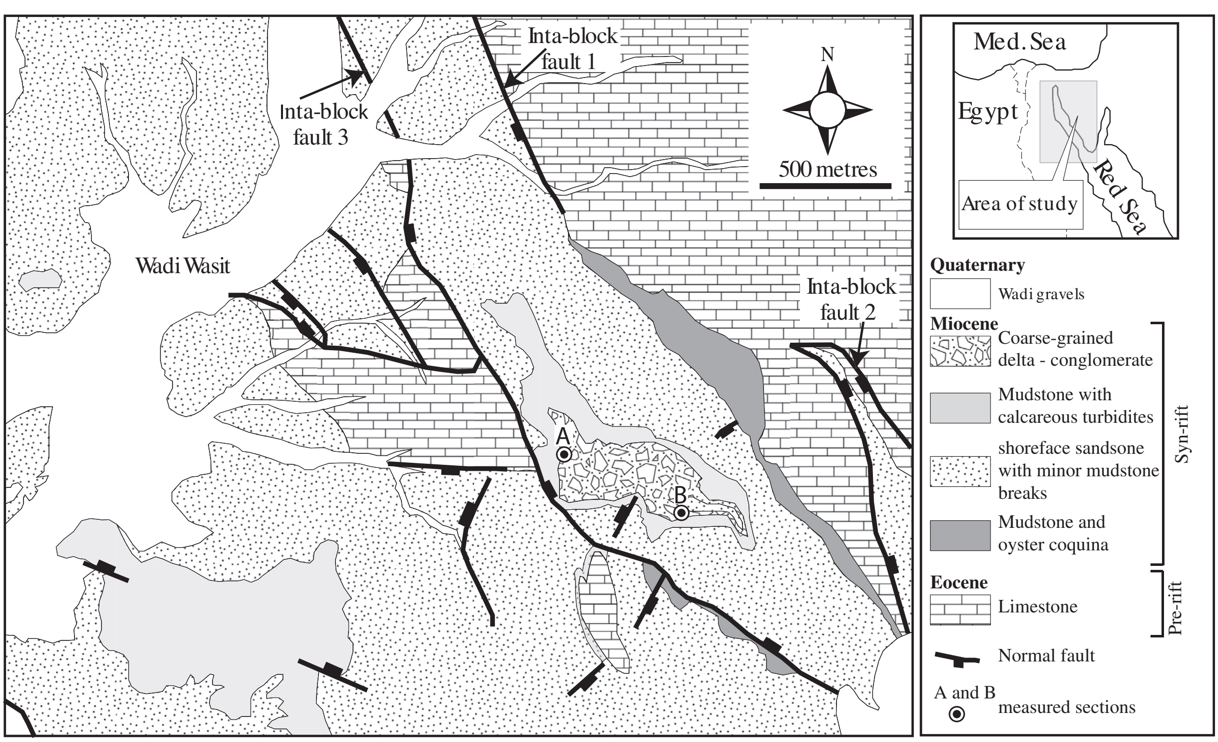

Figure 1. Map showing geology of the study area and distribution of the Miocene synrift lithofacies encountered in the Lower Rudies Mheiherrat Member, Wadi Wasit area (modified after Young et al., 2000).