Journal of Geochemical Exploration 143 (2014) 163–173

Contents lists available at ScienceDirect

Journal of Geochemical Exploration

journal homepage: www.elsevier.com/locate/jgeoexp

Geochemical constraint on the origin of the multi-mineralogic carbonate cements in the subsurface Middle Jurassic sandstones, Central Sinai, Egypt

Ahmed S. Mansour [a,*], Rifai I. Rifai [b], Mohamad N. Shaaban [a]

[a] Geology Department, Faculty of Science, Alexandria University, Alexandria, Egypt
[b] Environmental Studies and Research Institute, Sadat City University, Egypt

ARTICLE INFO

Article history:
Received 5 January 2013
Accepted 21 April 2014
Available online 2 May 2014

Keywords:
Carbonate cementation
Sandstones
Jurassic
Stable isotopes
Elemental composition
Egypt

ABSTRACT

This paper deals with the genesis of the carbonate cements in the Bajocian–Bathonian sandstones of Wadi El-Giddi sequence, Central Sinai, Egypt. The recorded cements comprise four carbonate minerals: dolomite, calcite, ankerite and siderite. The emplacement of these cements is ascribed to two diagenetic stages; early shallow marine/meteoric stage and late mesogenetic burial stage. The variations in the chemistry of the precipitated porewater, timing of precipitation and burial history of the rock sequence are reflected in the variation in the texture, mineralogy, geochemical and stable isotopic compositions of the diagenetic cements.

The microcrystalline non-stoichiometric calcian dolomite was probably formed in early diagenetic stage from marine-dominated mixed fluid after the invasion of meteoric water into the shallow marine sandstones and mixed with the marine water. This is evidenced from the typical marine $\delta^{18}O$ (31.7 to 32.2‰, VSMOW) values and moderate Sr (av. 376 ppm) content. Meanwhile, the relatively high Sr (av. 565 ppm), Fe (av. 3.3 mol%) and Mn (av. 0.48 mol%) contents, low Mg content (av. 1.3 mol%) and low $\delta^{18}O$ (22.0 to 22.7‰, SMOW) values of the calcite cement reveal that it might be formed as a result of stabilization of early diagenetic marine metastable $CaCO_3$ mineral by the effect of fluids of relatively warm meteoric-dominated composition and rich in Fe and Mn during shallow burial diagenesis.

On the other hand, the high ^{18}O-depleted signature, high Fe and Mg contents, the coexistence of chalcopyrite, sphalerite and Ti-oxide minerals and the fluid inclusion data suggest that the late replacive carbonate cements including ankerite and siderite, in addition to the coarse crystalline dolomite have been formed in burial conditions during a mesogenetic phase via the replacement of early diagenetic carbonate cement by the influence of hydrothermal and/or deep formation water.

The $\delta^{13}C$ values of the carbonate cements (−7.7 to 3.3‰) suggest that the carbonate carbon was derived from inorganic source such as the ambient seawater and dissolution of carbonate allochems encountered within the sandstones with minimum influence of ^{13}C-depleted carbon derived from biogenic degradation of organic matter in shallow depth as in the case of dolomite, or thermal maturation of organic matters during burial as in the case of the other cements.

1. Introduction

The Jurassic siliciclastic rock sequence at north Sinai, Egypt displays some distinctive early and burial diagenetic alterations, which have a high impact on reservoir-quality evolution during progressive sediment burial. Rapid fluctuations of the relative sea level resulted possibly in repeated changes in porewater chemistry between meteoric, mixed and marine water compositions, where the Jurassic sediments were emplaced within different successive near surface diagenetic settings. These fluctuations, which are controlled primarily by eustasy, basin subsidence and uplift, are reported during the Jurassic and Cretaceous periods in Egypt (e.g. Keeley and Wallis, 1991; Kerdany and Cherif, 1990; Miller et al., 2005; Rifai et al., 2007) and in the adjacent areas (e.g. Ayalon and Longstaff, 1995; Calvo et al., 2011). Also, burial has a major impact on the diagenesis of the Jurassic sandstones in Sinai. During burial, other factors like temperature, burial history of the basin, chemistry of subsurface waters and water–rock interaction control the late burial diagenesis. The interaction of these parameters led to changing of the formation water geochemistry, which is reflected in the geochemical composition of the diagenetic minerals in the host rocks (Longstaffe, 2000; Morad, 1998).

Carbonate cementation is one of the most striking diagenetic features affecting the subsurface Middle Jurassic sandstone sequence at Wadi El-Giddi, Central Sinai, Egypt (Fig. 1). The variations in the

* Corresponding author at: Geology Department, Faculty of Science, Alexandria University, 21511, Moharam Beih, Alexandria, Egypt. Tel.: +20 1115270148 (mobile).
E-mail address: ah_sadek@hotmail.com (A.S. Mansour).

http://dx.doi.org/10.1016/j.gexplo.2014.04.009
0375-6742/

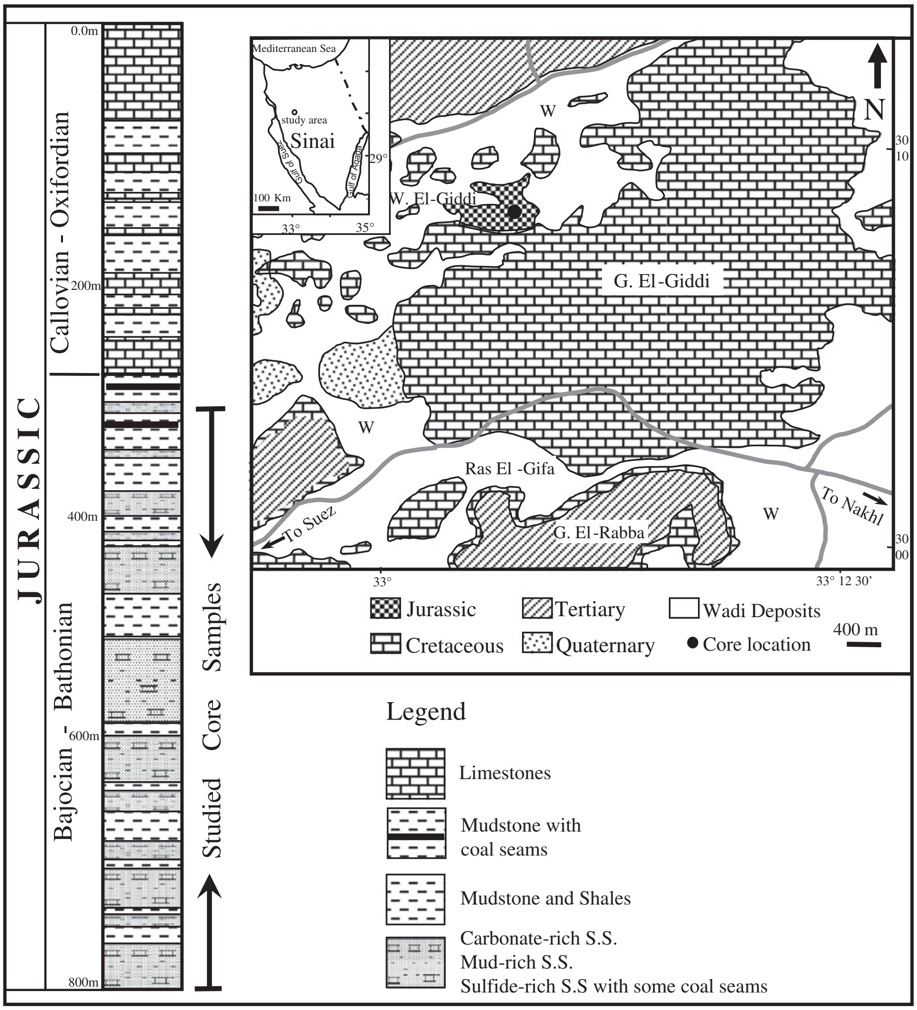

Fig. 1. Location and geological maps and simplified stratigraphic section of Wadi El-Giddi borehole (G. R-2) at El-Giddi area, Sinai. Modified after GSE and Rifai et al. (2007).

petrographic, mineralogic, isotopic and elemental compositions of the carbonate cements reflect the origin, timing, and geochemical conditions under which the carbonate cements were precipitated (cf. Moore, 1989; Morad, 1998; Morad et al., 2000; Mozley and Hoernle, 1990). On the other hand, Jurassic strata are widely known for their prolific oil, gas and coal production in Egypt and all over the world. Both reservoirs and source rocks are detected in many Jurassic basins. These hydrocarbons and coal beds are regarded as sources of organic carbon, which may incorporate in carbonate minerals during their formation. This organic carbon may leave some fingerprints on the isotopic composition of the carbonate cements of the sandstones.

The present study has the aim of integrating petrographic, isotopic and geochemical data in order to examine the carbonate cements of the Middle Jurassic subsurface sandstone sequence at Wadi El-Giddi and hence unraveling their origin and mode of emplacement and elucidating the paragenetic sequence of the different phases of carbonate cements.

2. Geological setting and depositional history

The Jurassic rocks are widespread in both surface and subsurface throughout Sinai. They comprise, in most instances, continental siliciclastic facies toward the south and shallow to deep marine carbonate facies toward the north (Jenkins, 1990; Said, 1962). Jurassic sequences in Sinai display an overall cyclical pattern of a number of repeated stages of sedimentation. The alternation between marine and non-marine sediments and the changes in the distribution of facies were controlled by the interplay of different competing factors including eustatic Tethyan sea level change, intermittent subsidence in response to local and regional tectonics, and supply of siliciclastic sediments from the southern basement massif and Nubian sediments (Jenkins, 1990; Keeley and Wallis, 1991).

The most complete and thickest Jurassic sequence in Sinai is well exposed at El-Maghara area, northeast of the study area. Al-Far (1966) classified the Jurassic sequence of Gebel El-Maghara (~1900 m thick) into six formations arranged in ascending order as: Mashabba, Rajabiah and Shusha Formations (Early Jurassic), Bir Maghara and Safa Formations (Middle Jurassic) and Masajid Formation (Late Jurassic). The present study focuses on the subsurface, extensively cemented, Middle Jurassic (Bajocian–Bathonian) sequence of the Bir Maghara and Safa Formations examined from core samples collected from the El-Giddi Rig borehole no. 2 (G. R-2) located 65 km to the east of Suez City, near the Wadi El-Giddi Village (Fig. 1) and drilled by the Geological Survey of Egypt. The thickness of the studied succession reaches about 500 m and is represented by thick coal-bearing siliciclastic sequence of shale and sandstone, deposited in deltaic, estuarine and shallow marine environments (Rifai et al., 2007). This siliciclastic sequence may be correlated with the Safa Formation and the top 300 m of the Bir Maghara Formation of Al-Far (1966). The contact between the Bir Maghara and Safa Formations in the core samples is difficult to recognize. The siliciclastic rocks are followed by 300 m of shallow marine carbonates of Callovian–Oxfordian age (Kerdany and Marzouk, 1971).