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Microfacies and diagenesis of the reefal limestone, Callovian Tuwaiq Mountain Limestone Formation, central Saudi Arabia

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ABSTRACT

In order to document the microfacies and diagenesis of the reefal limestone in the uppermost part of the Callovian Tuwaiq Mountain Limestone Formation at Khashm Al-Qaddiyah area, central Saudi Arabia, scleractinian corals and rock samples were collected and thin sections were prepared. Coral framestone, coral floatstone, pelloidal packstone, bioclastic packstone, bioclastic wacke/packstone, algal wackestone and bioclastic foraminiferal wacke/packstone were the recorded microfacies types. Cementation, recrystallization, silicification and dolomitization are the main diagenetic alterations affected the aragonitic skeletons of scleractinian corals. All coral skeletons were recrystallized, while some ones were dolomitized and silicified. Microfacies types, as well as the fossil content of sclearctinian corals, bivalves, gastropods, brachiopods and foraminifera indicated a deposition in environments ranging from shelf lagoon with open circulation in quiet water below wave base to shallow reef flank and organic build up for the uppermost reefal part of the Tuwaiq Formation in the study area.

1. Introduction

The Jurassic succession in Saudi Arabia is subdivided into seven formations. These are from older to younger: Marrat, Dhruma, Tuwaiq Mountain Limestone, Hanifa, Jubaila, Arab and Hith formations. Jurassic outcrops in central Saudi Arabia are arranged in a convex arc hinged in Al-Riyadh region with the horns of the arc oriented to the northwest and to the south. The total outcrop length is in excess of 1000 km, the width nowhere exceeds 85 km and with a greatest outcrop thickness of 1100 m (El-Asa'ad, 1989; El-Sorogy et al., 2014; El-Sorogy and Al-Kahtany, 2015; Al-Dabbagh and El-Sorogy, 2016).

The Callovian Tuwaiq Mountain Limestone Formation is one of the most organic rich rocks that form the major source formation in the anoxic basins of the Middle East in central Saudi Arabia near Riyadh city (Powers, 1968; Powers et al., 1966; Vaslet et al., 1983; Al Sharhan and Magara, 1995; El-Sorogy et al., 2014; Youssef and El-Sorogy, 2015). It was deposited on a carbonate platform developed across the intra-shelf basin (Ziegler, 2001). Fischer (2001) divided this formation into three main paleoenvironments: outer lagoon paleoenvironment which is corresponded to the lower part of the Formation, back-reef paleoenvironment which is corresponded to the middle part and the reef paleoenvironment which is corresponded to the upper part. Also, Al-Qahtani (2013) divided the Tuwaiq Mountain Limestone Formation to three main paleoenvironments (open platform, high energy shoals and restricted carbonate platform). He mentioned also that these three paleoenvironments have been distributed in the whole section.

Many workers have been studied Tuwaiq Mountain Limestones from the geological, paleontological and paleoecological points of view, among those are, Steineke et al. (1958), Powers et al. (1966), Powers (1968), Moshrif and El-Asa'ad (1984), Manivit (1987), Al-Dabbagh (2006), Hughes (2002, 2004a, 2004b, 2005, 2008), Hughes et al. (2009), Al-Husseini and Matthews (2005), El-Sorogy et al. (2014), Youssef and El-Sorogy (2015).

Previous works on the Tuwaiq Mountain Limestone have focused mainly on lithostratigraphy, biostratigraphy, paleoecology and paleontology; however, detailed sedimentological, microfacies and diagenetic works are still needed. Therefore, the main objective of the present work is to document microfacies and diagenetic alterations affected reefal limestone in the uppermost part of the Callovian Tuwaiq Formation at Khashm Al-Qaddiyah area, central Saudi Arabia.

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2. Materials and methods

Khashm Al-Qaddiyah is located about 35 km from the city of Riyadh. A section was measured in detail at 24° 38′ N and 46° 40′ E (Fig. 1). Scleractinian corals and rock samples were collected from the upper most reefal limestone of Tuwaiq Formation at the study area (Figs. 1–3). 79 thin sections were prepared for microfacies analysis, coral identification and diagenetic alterations. Due to high porosity of coral samples, they impregnated with resin under vacuum. Thin sections are investigated and photographed using Polarizing Microscope. The classification of carbonate rocks followed the nomenclature of Dunham (1962), Embry and Klovan (1972) and the energy index classification of Plumely et al. (1962).

All diagenetic studies were carried out on thin sections of the scleractinians, *Actinastraea pseudominima* (Koby, 1897), *Enallocoenia crassoramosa* (Michelin, 1843), *Isastrea hemisphaerica* Gregory, 1900, *Ovalastraea caryophilloides* (Goldfuss, 1826), *Stylina kachensis* Gregory, 1900 and *Collignonastraea grossouvrei* Beauvais, 1972 (Fig. 4), which have been previously identified with other benthic invertebrates from the study area (El-Sorogy et al., 2014). Fossils are stored in the Museum of the Geology and Geophysics Department, College of Science, King Saud University.

3. Geologic setting

The Tuwaiq Mountain Limestone Formation overlies unconformably the Bathonian-Callovian Dhruma Formation and consists mostly of shallow-marine lagoon and stromatoporoid carbonates of Middle to Late Callovian age with a combined thickness of 295 m and is disconformably overlain by the Oxfordian Hanifa Formation with apparent paraconformity in the outcrop (Manivit et al., 1990; Al-Qahtani, 2013). Vaslet et al. (1983) has divided the Tuwaiq Mountain Limestone Formation into three informal members comprising Baladiyah (T1), Maysiyah (T2) and Daddiyah (T3). However, Powers et al. (1966) and Powers (1968) have subdivided it into two informal members.

At Khashm Al-Qaddiyah, the Tuwaiq Formation (Figs. 2 and 3) attains about 190 m thick, mostly of shallow-marine lagoon and stromatoporoid carbonates. The upper part is massive bedded, chalky limestone intercalated with chert layers and lenses. The upper most 25–40 m thick of the studied section (Fig. 3B) is coral bearing bioturbated limestones with isolated coral heads hemispherical and globular forms, reaching 20–50 cm in diameter (Fig. 3C, D)

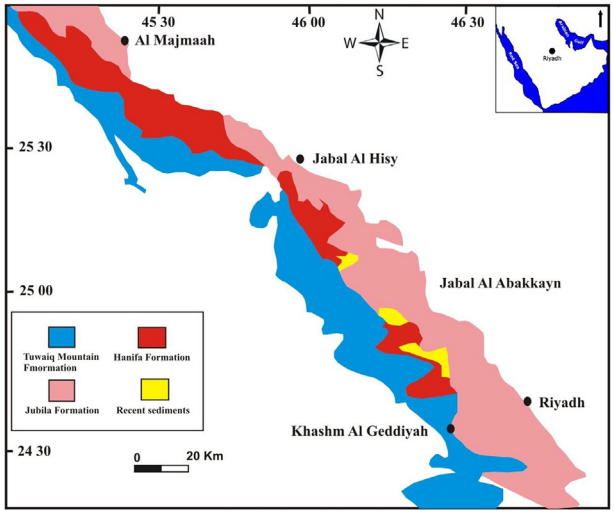

Fig. 1. Location map of the study area.

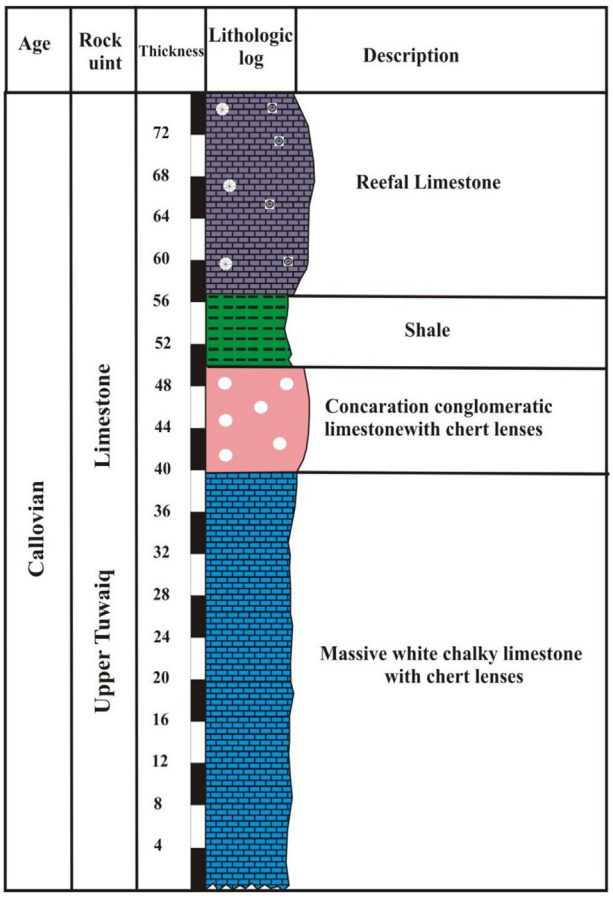

Fig. 2. Composite section of Tuwaiq Mountain Limestone at Khashm Al-Qaddiyah section.

Power et al. (1966) on the basis of ammonites and foraminifera, allotted the lower beds of the Tuwaiq Mountain Limestone to the Callovian but the upper beds of the Formation, depending on distinctive foraminifera, to the Oxfordian. Also, Al Sharhan and Magara (1995), Al-Dabbagh (2006), Basyoni (2003) accepted the Power et al. (1966) opinion.

Fischer (2001) studied the gastropod zones in the Jurassic rocks in Saudi Arabia with great accuracy and he concluded that all beds of the Tuwaiq Mountain Limestone belong to the middle and upper Callovian. Hughes (2008) stated that the Tuwaiq Mountain Limestone Formation is Middle Callovian based on ammonites, nautiloids, brachiopods and nannoflora. Also El-Sorogy et al. (2014), and Youssef and El-Sorogy (2015) reached the same conclusion as Fischer (2001) and Hughes (2008). Thus, in this paper, depending on the deep field and laboratory studies, we agree that all the beds of the Tuwaiq Mountain Limestone Formation are of Middle and late Callovian age.

4. Results and discussion

4.1. Microfacies

Seven microfacies types were distinguished from the reefal limestone of the Tuwaiq Mountain Limestone Formation, these are: coral framestone, coral floatstone, pelloidal packstone, bioclastic packstone, bioclastic wacke/packstone, algal wackestone and bioclastic foraminiferal wacke/packstone (Figs. 5 and 6). The coral