

LITHOFACIES AND DEPOSITIONAL ENVIRONMENTS OF THE LOWER JURASSIC SEDIMENTS IN CENTRAL SAUDI ARABIA

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سحنات وبنية ترسيب صخور الجوراسي السفلي في وسط المملكة العربية السعودية

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يتناول هذا البحث تفسير بنية ترسيب متكون مرات، حيث يُقسّم متكون مرات والذي يتبع الجوراسي السفلي إلى ثلاث أعضاء (من الأقدم إلى الأحدث):

عضو مرآت السفلي، عضو مرآت الأوسط وعضو مرآت العلوي، وتتكون رواسب متكون المرات الفاتية الجيرية من صخور تسودها الصخور الطينية التي تتخللها بعض طبقات الرمل والحجر الجيري الذي تزيد نسبته باتجاه العضو العلوي لمتكون مرآت. وقد تم تقسيم متكون مرآت إلى اثني عشر نوعاً من السحن الصخرية الدقيقة خمس منها تتبع عضو مرآت السفلي وثلاثة تتبع عضو مرآت الأوسط وأربع تتبع عضو مرآت العلوي. واستخدم هذا التقسيم في تفسير بنية ترسيب متكون مرات والذي يُعتقد بأنه كان ما بين منطقة المد ومنطقة ما تحت المد أو المد السفلي.

Key Words: Jurassic, lithofacies, microfacies, paleoecology, Saudi Arabia.

ABSTRACT

The lithofacies, microfacies and sedimentary environments of the surface Lower Jurassic sediments in central Saudi Arabia are studied. The Lower Jurassic is represented by the marine clastic Marrat Formation which is subdivided into twelve microfacies associations. The lithofacies characters of different units are discussed and used to interpret the environmental conditions prevailed during deposition of these units. The Lower Jurassic sequences in Central Saudi Arabia are believed to be deposited in tidal flat gradually changed to subtidal setting.

INTRODUCTION

The Jurassic system in eastern Arabian Peninsula is well developed and represented mainly by shallow marine limestones, dolomites, anhydrites, sandstones and siltstones. Our study is focused on the Lower Jurassic successions in Central Saudi Arabia. In this area, the Lower Jurassic is only represented by the Toarcian age while the lower and middle Lias rocks are absent. The Lower Jurassic successions in Central Saudi Arabia are represented by Marrat Formation. They are exposed 100 Km west of the city of Al-Riyadh (Fig. 1). The extensions of these outcrops are about 362 Km NW and 700 Km SW of the city of Al-Riyadh (Powers et al, 1966). These sequences are a part of a major sedimentary transgressive cycle within the Tethyan Sea inundation (Murriss, 1980).

LITHOSTRATIGRAPHY

The Marrat Formation takes its name from Marah town which is located about 125 Km. north-west of Al-Riyadh city (Fig. 1). The Marrat formation was treated as a member of the Tuwaiq Formation (Steineke, 1937). Bramkamp and Steineke (1945) raised the Marrat to formation status. They subdivided the Marrat Formation into three informal members: lower, middle and upper. Its thickness in the type locality is 111 meters. In this study, sixty three samples were collected and three sections were measured at Khashm Al-Dhibi escarpment (the lower Marrat member), Al-Qarain area. (the middle Marrat member) and at Al-Quwairah area (the upper Marrat member; fig. 1). The total measured thickness of the Marrat Formation in the studied areas is 115 m.

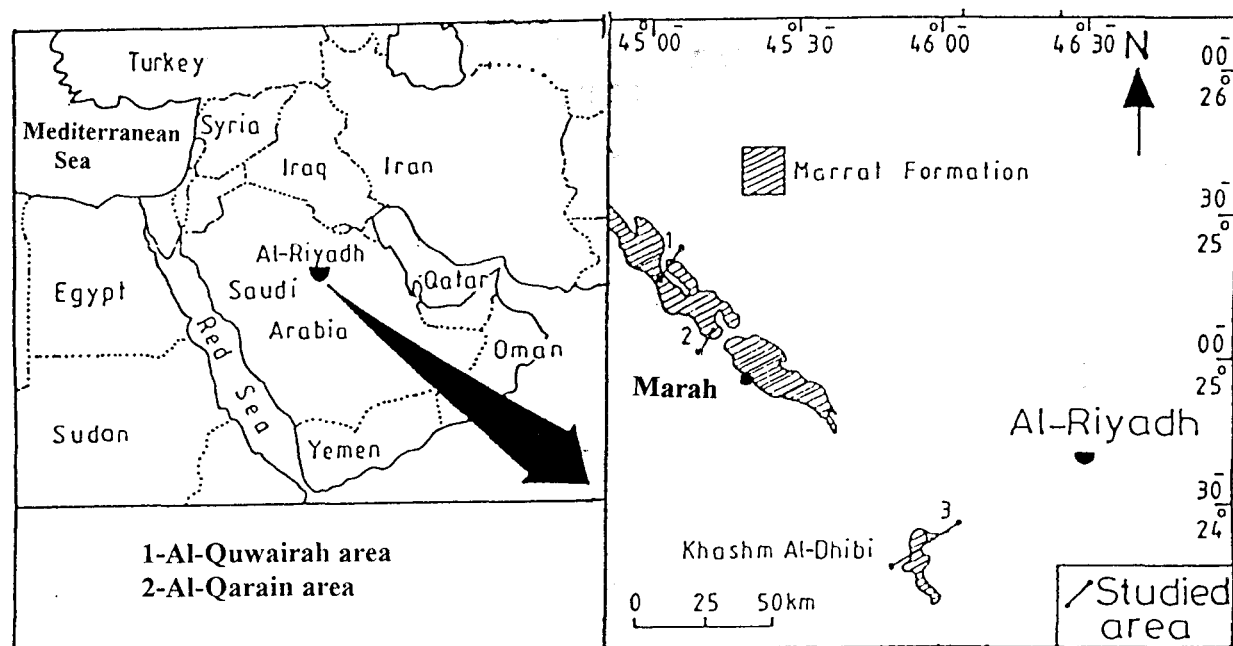


Figure (1). Location map of the studied area

This sedimentary cycle starts with the deposition of marine clastics and terminated by the deposition of platform limestones at the end of the Jurassic time (Murriss, 1980). A major unconformity surface separates the Triassic and Jurassic (Lias) systems due to the effect of epeirogenic uplifts in the Arabian plate (Beydoun, 1988). The lithologic characters and stratigraphic contacts of the Jurassic units in Central Saudi Arabia are previously studied by Steineke (1937), Steineke and Bramkamp (1952 b), Steineke et al (1958), Powers et al (1966), Powers (1968), Moshrif (1987) and Enay et al (1987).

The Marrat Formation is easily identified in the field by its dark red colour which dominates the middle part of the formation. It is mainly composed of siltstones intercalated with sandstone, limestone and shale bands (fig. 2). It is marked by some sedimentary structures such as horizontal lamination and oscillation ripples. The lower Marrat member, 39 m. thick, is composed mainly of shaly siltstone intercalated with bands of sandstones and ended with dolomitic limestone. This member is measured at Khashm Al-Dhibi escarpment. The middle Marrat member is easily defined by the rich occurrence of the red clay beds

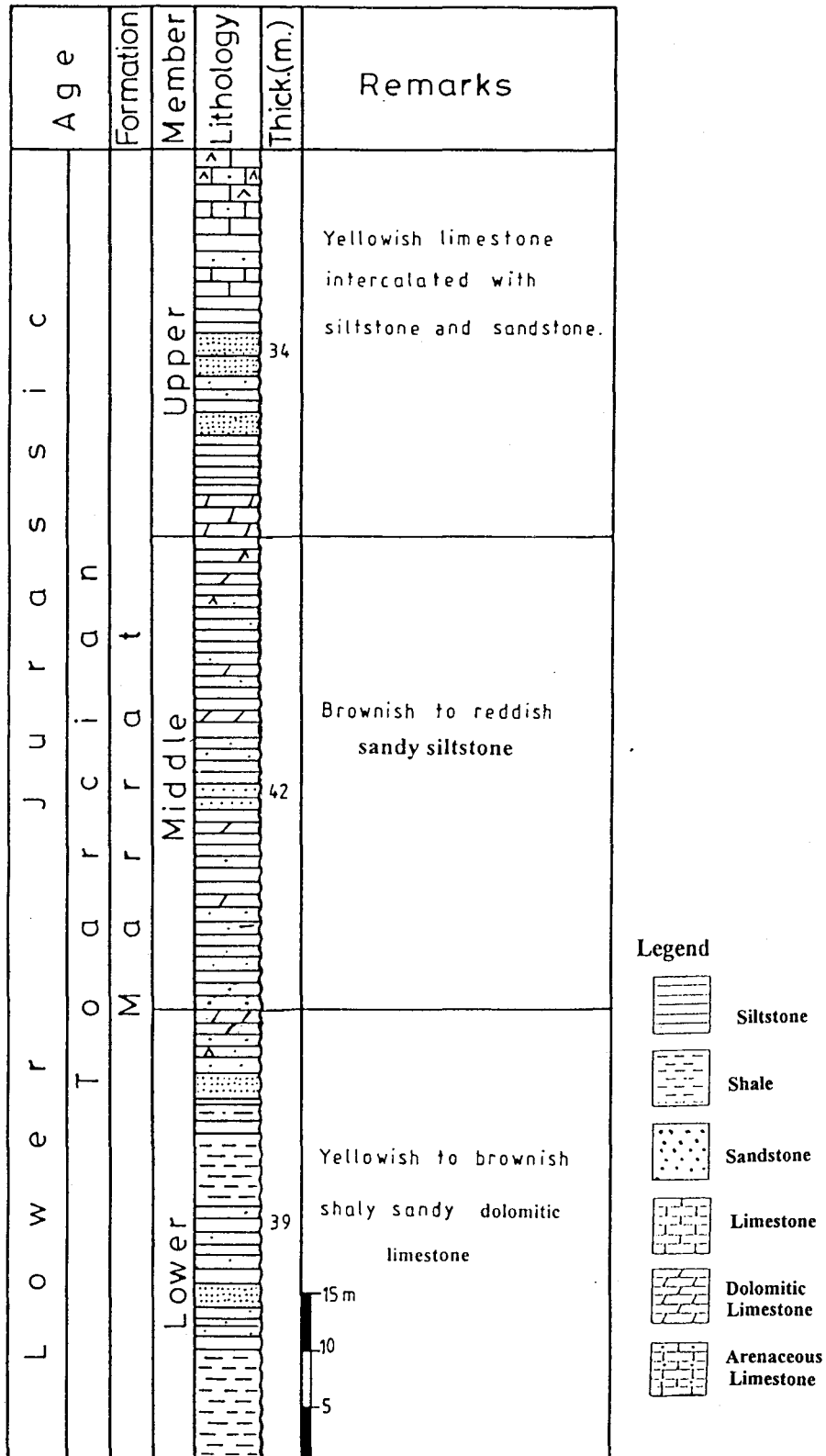


Figure (2). Stratigraphic composite section of the Marrat Formation.

throughout the member.

It is composed mainly of ferruginous sandy siltstone. The middle Marrat member is about 42 m. thick. The upper Marrat member is composed mainly of silty limestone intercalated with sandstone bands. This unit is about 34 m. thick.

The lower boundary of the Marrat Formation is taken at the contact between the off-white, creamy to light brown or tan, cross-bedded, poorly cemented ferruginous sandstones of the Minjur Sandstone (below) and the greenish shales of the Marrat Formation (above). This contact is considered a surface of unconformity which is clearly recognized at Khashm Al-Dhibi. The upper boundary of the Marrat Formation is considered conformable and taken at the change from the tan to brownish, gypsiferous silty limestones of the upper Marrat Formation (above). The contact between the lower Dhurma member and the underlying Marrat Formation is not very

clear due to the quarrying work of the limestones in the outcrop area.

MICROFACIES ANALYSIS

A detailed microfacies analysis for the Marrat Formation through 53 thin-sections covering all member and lithologic variation was carried out. The definitions of carbonates microfacies follow the work of Dunham (1962) while those for clastic rocks follow Selley (1976).

As mentioned before, the Marrat Formation in Saudi Arabia was subdivided, from base upwards, into three informal members: lower, middle and upper. The following is the microfacies description of these members.

LOWER MARRAT MEMBER :

The lower Marrat member comprises 5 microfacies types which are represented by 8 units (fig. 3). The following is the description of these microfacies types.

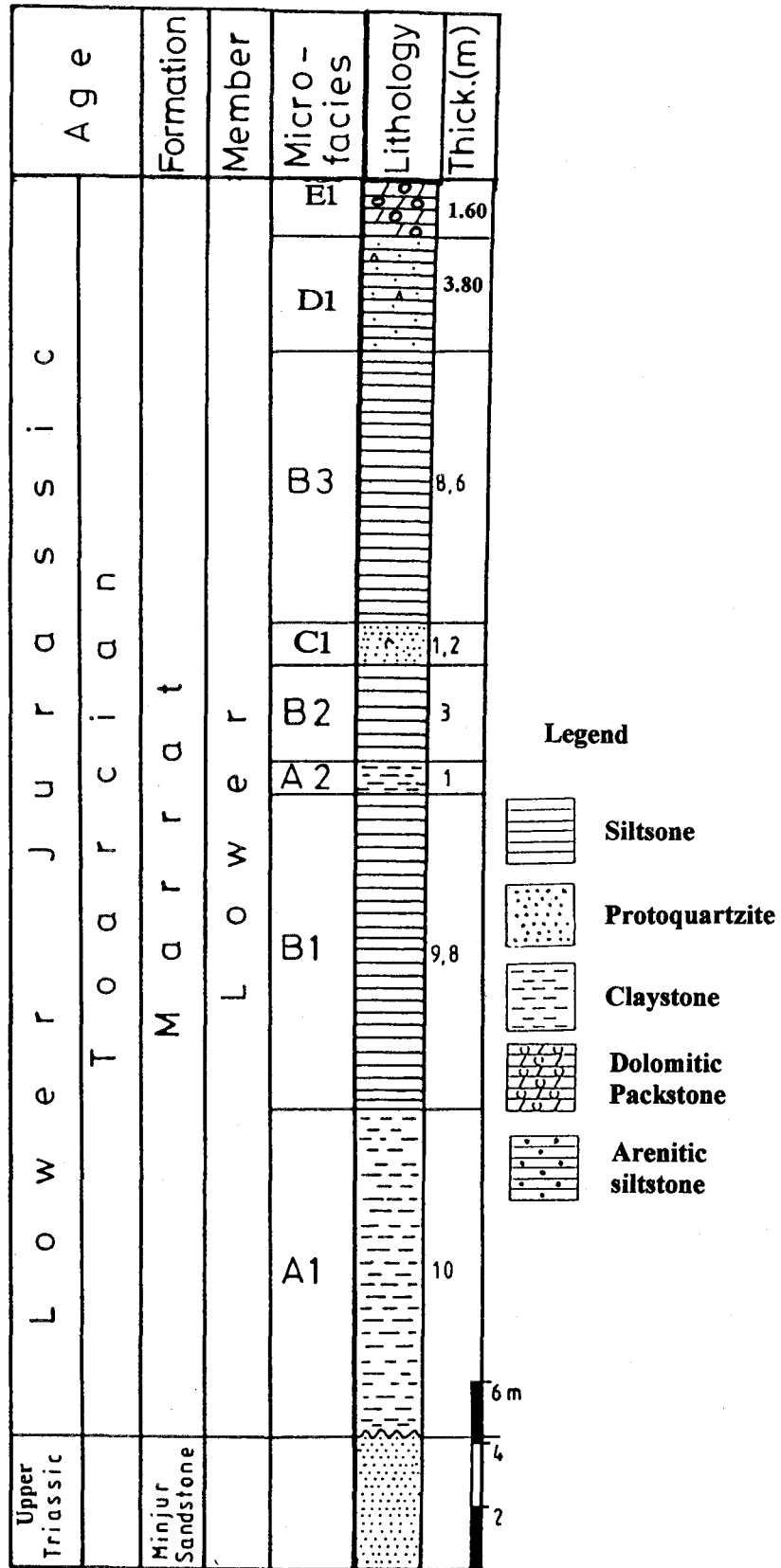
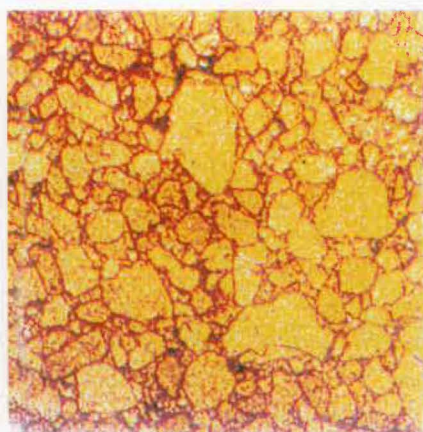
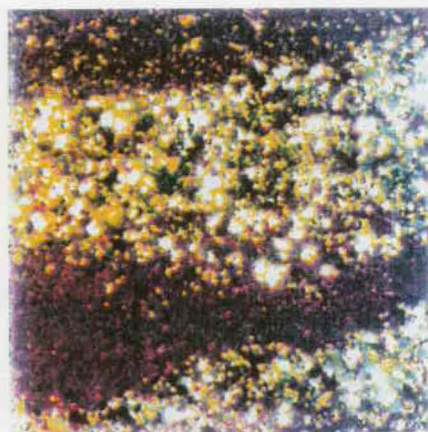


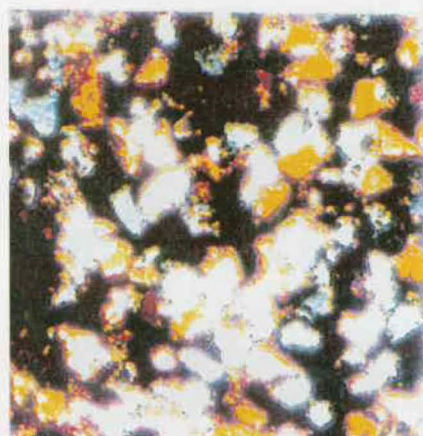
Figure (3). Microfacies of the lower Marrat member at Khashm Al-Dhibi area.



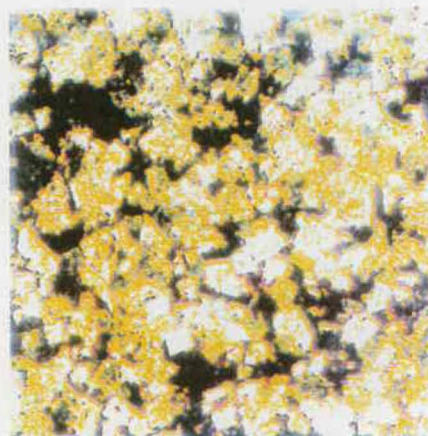
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Plate, 1 :

Fig. (1). Protoquartzite.

Angular to subrounded medium to coarse-grained quartz; microfacies C; lower Marrat member; Marrat Formation; X25; crossed nicols; section 3.

Fig. (2) Arenitic siltstone.

Thin bands of fine to medium-grained quartz in clayey matrix; microfacies D; lower Marrat member; Marrat Formation; X25; crossed nicols; section 3.

Fig. (3). Silty arenite.

Angular to subangular medium to coarse-grained quartz floating in silty matrix; microfacies C; middle Marrat member; Marrat Formation; X 40; crossed nicols; section 1.

Fig. (4) Dolomitic packstone.

Medium-grained dolomitic packstone; microfacies E; lower Marrat member; Marrat Formation; X 40; crossed nicols; section 1.

Microfacies (A). Claystone.

This microfacies type is repeated two times in the member (A1 and A2) and composed of unfossiliferous greenish claystone with medium to coarse-grained quartz. It is recorded in the lower part of the member by 10 m. thick (A1) and in the middle part of the member by 1 m. thick (A2).

Microfacies (B). Siltstone.

This type is repeated three times in the studied member (B1, B2 and B3) and composed of reddish siltstone with some carbonates as a cementing material. The carbonates are represented by very fine calcite and/or rare dolomite filling the tiny cavities with rare pelecypod debris. The total thickness of this type is 21.40 m.

Microfacies (C). Protoquartzite.

It is represented only by one unit (C1) and characterized by gray to light brown, angular to subrounded, coarse-grained quartz with some clays and carbonates as cementing materials. The thickness of this unit is 1.20 m. (p1. 1; 1).

Microfacies (D). Arenitic siltstone.

It is represented only by one unit (D1) and formed of reddish angular, elongated fine to medium-grained quartz floating in silty matrix. The size of quartz grains is gradually increases towards the top of the unit which is considered as the top of the lower Marrat member. Some rare gastropod fragments are recorded. The thickness of this unit is 3.80 m. (p1. 1; 2).

Microfacies (E). Dolomitic packstone.

It is represented only by one unit (E1) and formed of hard gray medium to coarse-grained, crystalline, dolomitic packstone. The thickness of this unit is 1.60 m. (p1. 1; fig. 4).

Middle Marrat member:

The middle Marrat member comprises 3 microfacies types which are represented by 13 units (fig. 4). The following is a description of the different units from base to top.

Microfacies (A). Arenitic siltstone

This type is repeated four times in the studied member (A1, A2, A3 and A4). It is formed of reddish to gray siltstone with very fine streaks of quartz. The quartz grains are subangular, subrounded and rounded. The unit A3 is strongly stained by iron oxides. The total thickness of this unit is 9.40 m.

Microfacies (B). Arenitic Siltstone.

This type is repeated four times in the studied member (B1, B2, B3 and B4) and composed of very hard, compact reddish fine-grained siltstone with some mica flakes and fine-grained quartz. This type of facies represents about 53% of the total thickness of the member. The total thickness of this unit is 22.60 m. (p1. 2; 1).

Microfacies (C). Silty arenite.

This type is repeated five times in the studied member (C1, C2, C3, C4 and C5). It consists of gray to light red, sub-angular rounded, medium to coarse-grained quartz which are floating in silty matrix. The total thicknesses of this unit is 10 m. (p1. 1; 3).

Upper Marrat member :

The upper Marrat member comprises 4 microfacies types which are represented by 5 units (fig. 5). The following is a description of the different units from base to top.

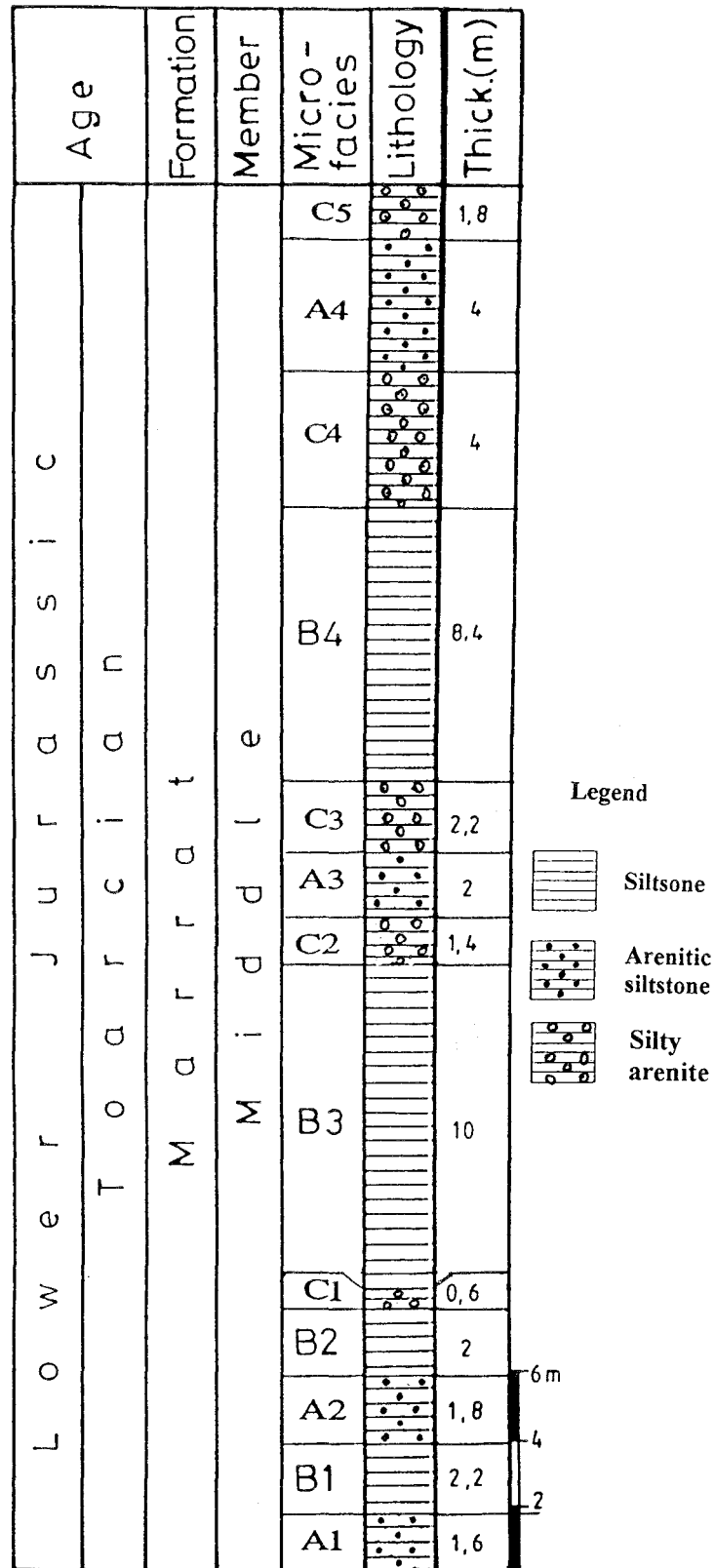


Figure (4). Microfacies of the middle Marrat member at Al-Qarain area

Microfacies (A). Arenitic dolomitic wackestone.

It is only represented by one unit (A1) and formed of yellowish fossiliferous, dolomitic wackestone with some medium-grained quartz. In general, this unit seems to be coarsening up-wards. The main fossil groups are pelecypods, echinoderms and microgastropods. The thickness of this unit is 3 m. and represents the basal part of the member (pl. 2; fig. 3).

Microfacies (B). Siltstone.

This type is repeated two times in the studied member (B1 and B2) formed of reddish, very fine-grained, compact siltstone with some fine-grained quartz. The total thickness of this unit is 13.60 m.

Microfacies (C). Arenitic siltstone.

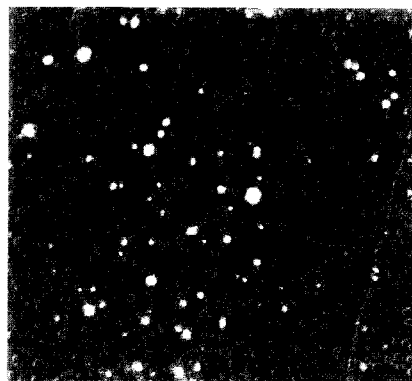
It is represented only by one unit (C1) and consists of reddish, fine-grained, subrounded, well-sorted quartz grains floating in silty matrix and ferruginous materials. The thickness of this unit is about 7 m.

Microfacies (D). Arenitic wackestone.

It is represented only by one unit (D1) and formed of yellowish wackestone with some subrounded, fine-grained quartz. This unit changed gradually to grainstone. The total thickness of this unit is 10.40 m. (pl. 2; fig. 2).

PALEOECOLOGY

This study includes the use of the lithostratigraphy and microfacies characters to establish a paleoecologic interpretation for the Lower Jurassic Marrat Formation in Central Saudi Arabia. The eastern Arabian Peninsula was the shelf basin of the Tethys Sea that extended from the present day Mediterranean Sea to the Himalays region. The Jurassic sequences in eastern Arabia represents major sedimentary trasgression cycle within the Tethyan Sea which took place from the Toarcian and continued till the Late Jurassic (Beydom, 1988). The Lower Jurassic in Central Saudi Arabia is believed to be accumulated over a vast shallow shelf environment.



1



2



3

Plate, 2 :

Fig. (1). Siltstone.

Compact ferruginous siltstone with fine-grained quartz; microfacies B; middle Marrat member; Marrat Formation; X 40; crossed nicols; section 1.

Fig. (2). Arenitic wackestone.

Subangular, coarse-grained quartz floating in very fine compact wackestone matrix; microfacies D; upper Marrat member; Marrat Formation; X 40; crossed nicols; section 2.

Fig. (3). Dolomitic arenitic wackestone.

Medium-grained quartz floating in the dolomitic wackestone matrix; microfacies A; upper Marrat member; Marrat Formation; X 40; crossed nicols; section 3.

In this study, the Lower Jurassic Marrat Formation in Central Saudi Arabia is subdivided into three ecozones equivalent to its three informal member. The following is a discussion for these ecozones arranged from older to younger.

A-Ecozone 1 (lower Marrat member)

The lower Marrat member consists of clastic sediments in which the fine clastic siltstone and shale are the major components while the coarse clastic sandstone and the non-clastic limestone are the minor components. These clastic sediments were deposited during a period of sea level oscillation as indicated from the presence of cyclic repetition of shale and siltstone sediments. This is followed by a minor transgressive sequence started by sandstone and ended by limestone (fig. 6). Some ammonite faunal elements of the group *Bouleiceras* and *Protogrammoceras* were recorded at the top part of the lower Marrat member by Arkell (1952) and Imlay (1970). The shale-siltstone facies of the whole lower Marrat

member in addition to the occurrence of the the proper marine nature of its environment of deposition which become deeper upwards. The lower Marrat member matches sea level fluctuation with sediments deposited in a minor regressive / transgressive cycle. Thus, the depositional setting of the lower Marrat member is a subtidal shelf environment (fig. 6). This unit may be equivalent to the shelf lagoon open circulation environment (belt 7) of Wilson (1975).

B-Ecozone 2 (middle Marrat member)

The middle Marrat member is composed mainly of fine clastic siltstones in sandstones in some levels of the member. This ecozone was found barren from any fauna. According to Walker (1967), the red beds have formed as diagenetic product of alteration of iron in hot arid or semi-arid climates. The lack of fauna in this unit may be attributed to the rich iron oxides in the sea water which may played the main role in changing the water to be toxic during deposition of this unit. The lack of fauna and the

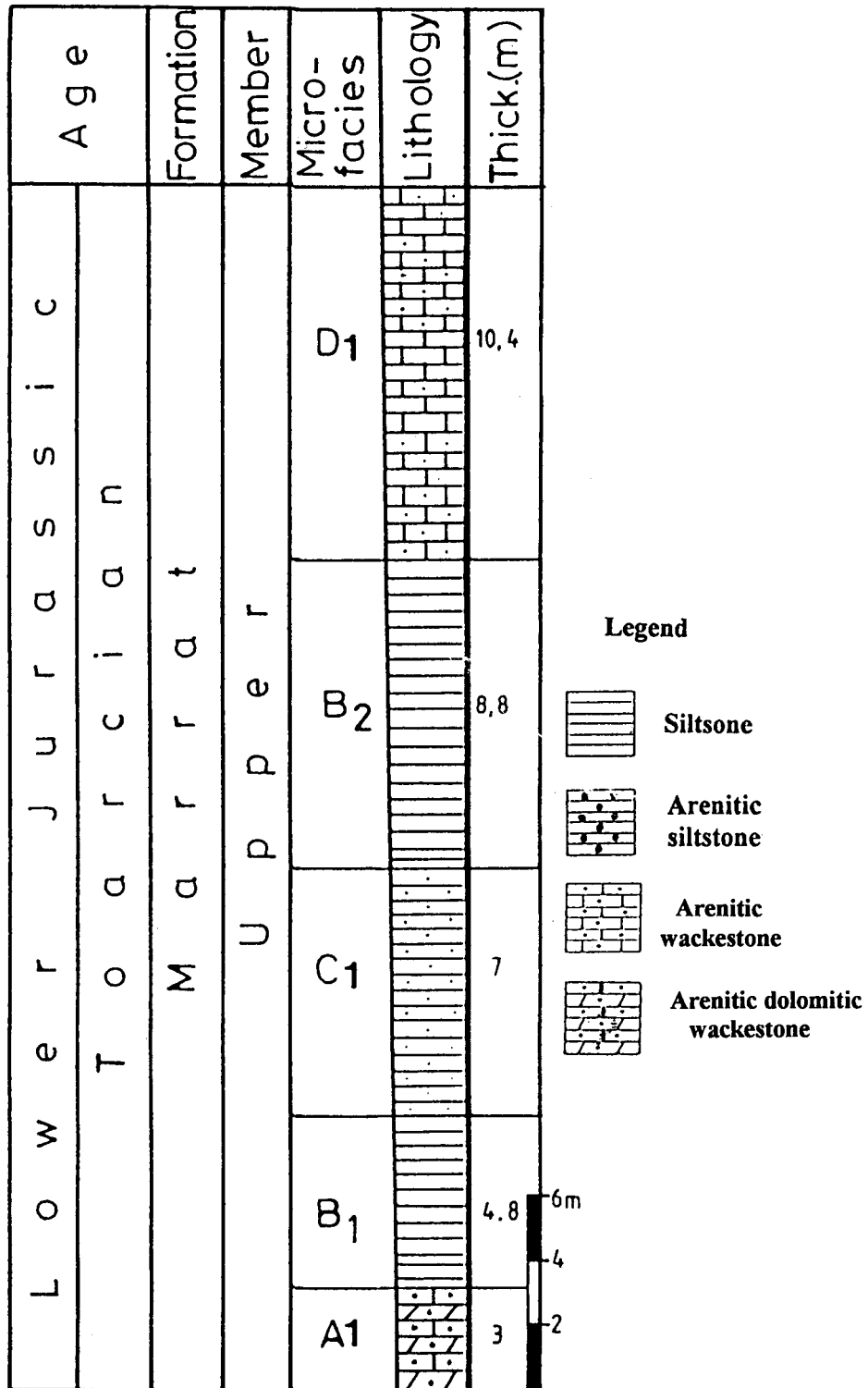


Figure (5). Microfacies of the upper Marrat member at Al-Quwairah area

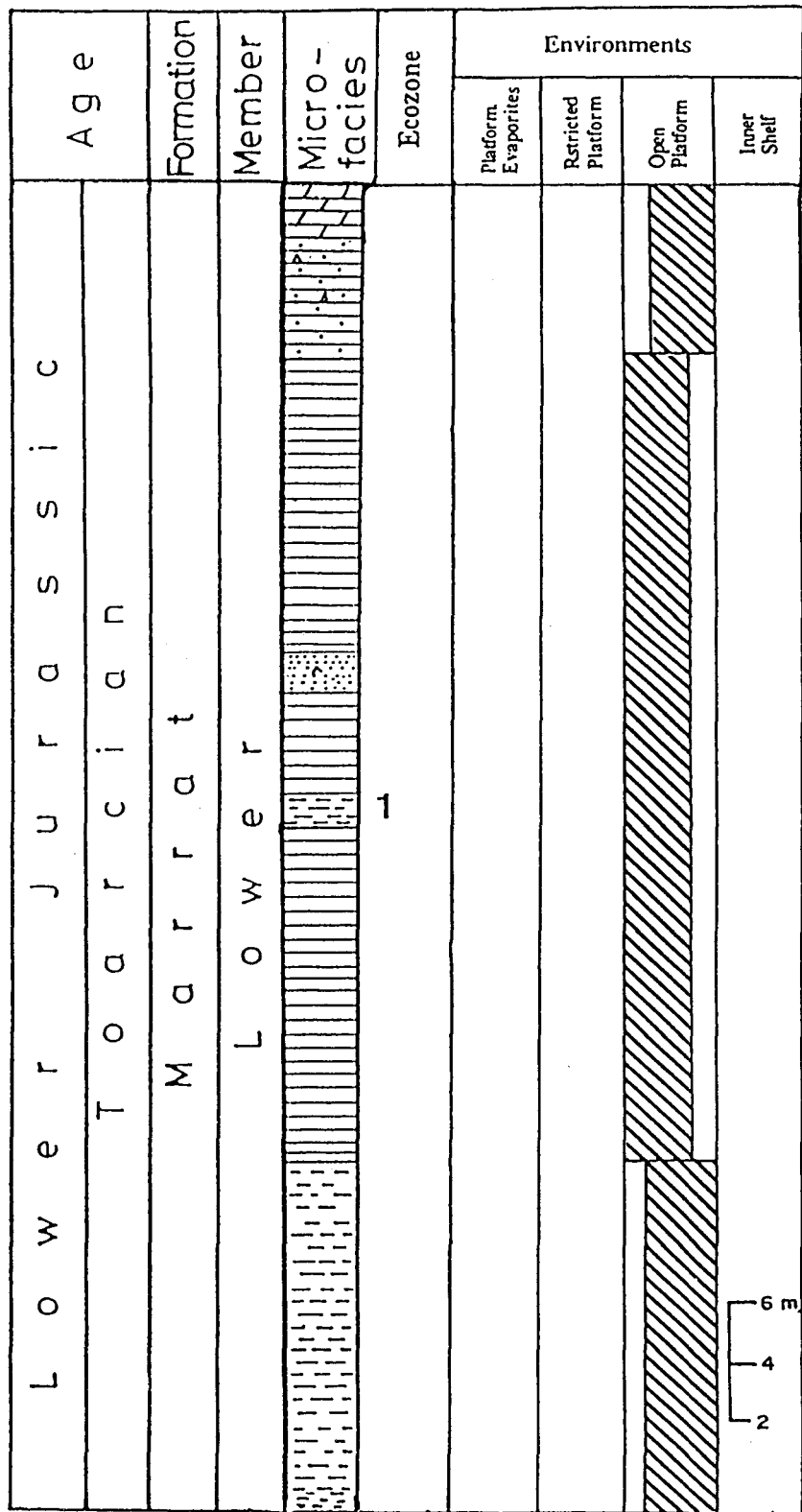


Figure (6). Microfacies, sea level oscillation and ecozone of the lower Marrat member (for legend, see fig. 3).

presence of abundant terrigenous materials indicate a very shallow somewhat restricted tidal setting for this ecozone (fig. 7). In general, the middle Marrat member matches a sea level fluctuation with sediments deposited in a minor regressive cycle. This unit may be equivalent to restricted circulation shelf environment (belt 8) of Wilson (1975).

C-Ecozone 3 (upper Marrat member)

The upper Marrat member is composed mainly of fine clastic siltstone with dolomitic sandy limestone (wackestone) facies at the lower and upper parts of the

member. Rare ammonites of the group *Nejdia* and Hildaites, were recorded nearly at the lower part of the member (Arkell, 1952 and Imaly, 1970). This member matches a sea level fluctuation with sediments deposited in a short-lived transgressive / regressive phase matching a retreat in the sea level. A subtidal environment like that of unit 1 of the lower Marrat member with very low energy and normal marine water environment is suggested for this ecozone (fig. 8).

In conclusion, the depositional setting of the Marrat Formation ranges from very shallow tidal to subtidal zones.

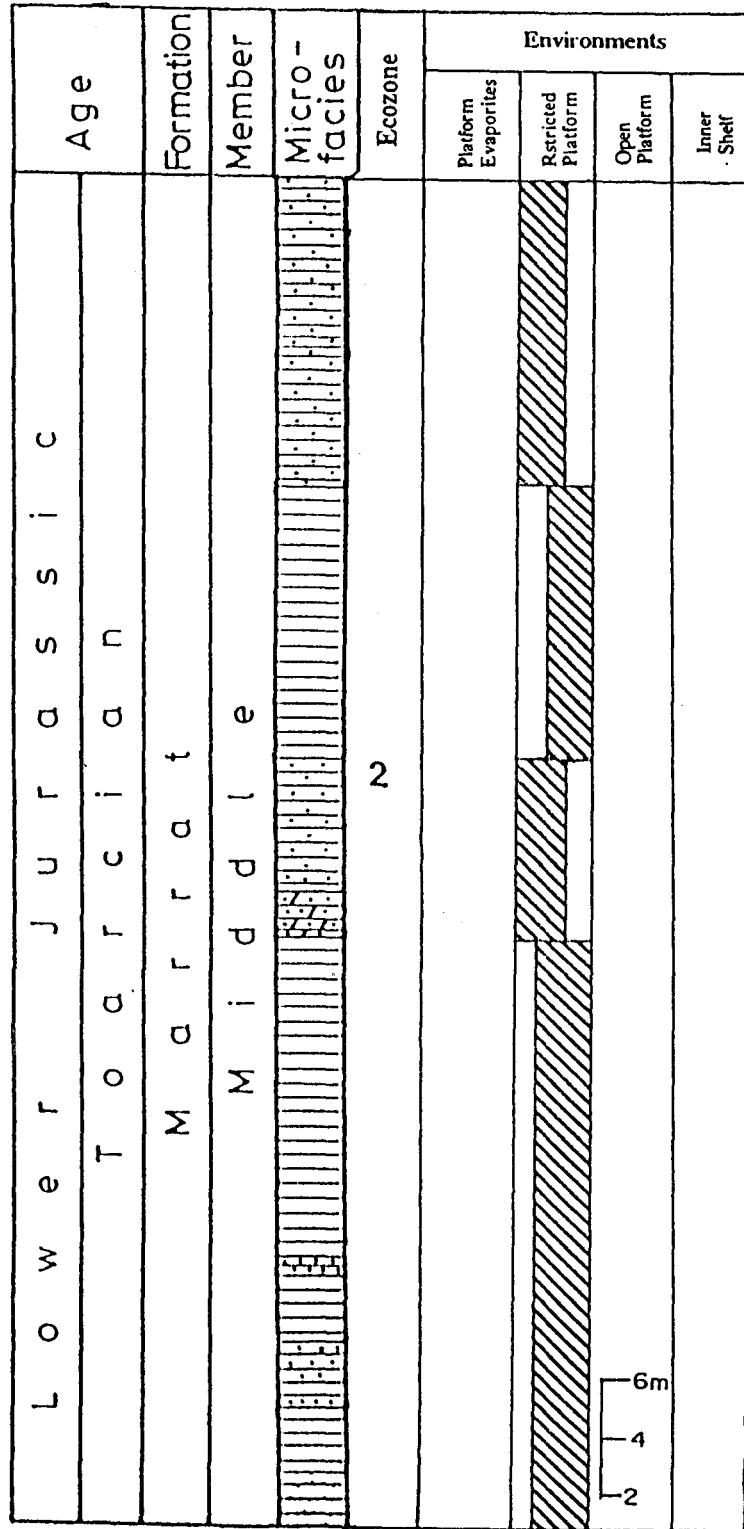


Figure (7). Microfacies, sea level oscillation and ecozone of the lower Marrat member (for legend, see fig. 4).

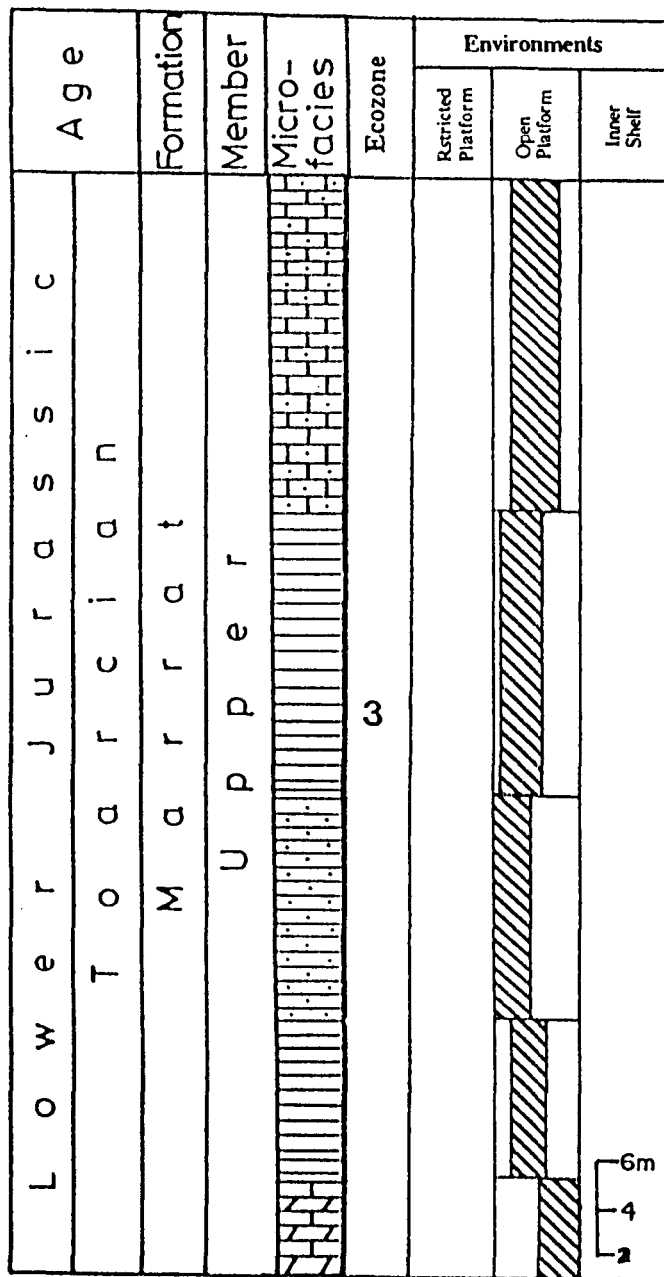


Figure (8). Microfacies, sea level oscillation and ecozone of the upper Marrat member (for legend, see fig. 5).

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