Early Triassic intertidal/subtidal patterns of sedimentation along the southern margins of the Tethyan seaway, Jordan

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Abstract

The early Triassic Dardur Formation, exposed along the northeastern margin of the Dead Sea area, comprises some 63 m of siliciclastic and carbonate rocks, arranged in two coarsening-upward sequences. Each sequence begins with a heterolithic facies (silty shale dolomite and marlstone) and terminates with a sandstone facies.

The occurrence of mixed carbonate-dominated clastic coarsening-upward facies sequences, containing pelecypode and ostracode fossils and trace fossils is attributed to deposition in a tidally-dominated environment. Bedload traction transport was responsible for deposition of the sandstone facies in a permanently submerged, shallow subtidal zone, whereas the presence of small scale interference oscillation ripple marks, tidal rhythmites and mudcracks in the heterolithic facies indicate deposition under more fluctuating intertidal conditions.

The organization of heterolithic and sandstone into vertically-stacked, coarsening-upward marine facies sequences is attributed to a deepening-upward trend from intertidal to subtidal conditions, in response to a series of minor local transgressions and regressions along the southern margins of the Tethyan seaway during early Triassic times. © 2000 Elsevier Science Ltd. All rights reserved.

1. Introduction

The Triassic succession was divided by Bandel and Khoury (1981) into eight formations. These formations are from bottom to top: Ma’in, Dardur, Ain Musa, Hisban, Mukheiris, Iraq el Amir, Umm Tina and Abu Ruweis. The Dardur Formation outcrops at the northeastern margin of the Dead Sea between Wadi Mukheiris and Wadi Abu Khusheiba (Fig. 1). It was divided by Bandel and Khoury (1981) into four members: lower carbonate, lower sandy, upper carbonate and upper sandy, which were deposited under shallow marine conditions and on intertidal mudflats.

Amireh (1987) recognized three facies in the Dardur Formation: bedded sandy dolomite, bedded medium-to fine-grained sandstone and laminated mudstone, shale and marl, which were deposited under intertidal to supratidal conditions.

In this study a complete outcrop section of the Dardur Formation was measured in Wadi Nahkla, which is located about 1.5 km to the south of Wadi Dardur (Figs. 1 and 2). It attains a thickness of up to 63 m, conformably overlies the Ma’in Formation and is conformably overlain by the Ain Musa Formation (Fig. 1).

In this study (cf. Bandel and Khoury, 1981, Amireh, 1987), the Dardur Formation is divided into a sandstone and heterolithic facies, and component subfacies based on field description and thin section analysis. The two facies are arranged in coarsening-upward sequences, each sequence comprising a finer grained heterolithic facies overlain by a sandstone facies (Fig. 2).

2. Heterolithic facies

The heterolithic facies comprises three subfacies: marlstone, silty shale and sandy dolomite.
2.1. Marlstone subfacies

This subfacies comprises massive greenish grey, nodular marlstones. The uppermost marlstone bed is sharply truncated by the low relief erosive base of the sandstone facies above. The bounding surface is marked by the presence of load-casts along the base of the sandy facies (Fig. 3a).

2.2. Silty shale subfacies

The silty shales are varicoloured (pale grey, yellowish, violet, deep maroon, brownish and greenish) thinly bedded, horizontally laminated or rippled. Bedding planes show horizontal and vertical trace fossils (burrows), and occasional sand-filled mudcracks. The silty-shales show surface weathering oxidation process and carbonaceous features. Intraformational clasts ranging from granule size up to 4 cm in diameter occur in the basal part of the subfacies. Some green, glauconitic claystones alternate with yellowish fine-grained sandstones. Ripple marks are of the oscillatory and interference types, and range from 3–10 cm in wavelength and 3–10 mm in amplitude. The ripple crest-lines are sinuous or bifurcating and show a general E–W trend, approximately parallel to the inferred palaeoshoreline (Makhlouf, 1998).

2.3. Sandy dolomite subfacies

The dolomitic nature of this subfacies was determined by staining slides of the subfacies with Alizarin Red S. These rocks are interbedded with the marlstone and silty shale subfacies. They are yellowish to cream coloured and thin to medium bedded. Shell fragments and fossils (mainly ostracodes and gryphaea) are abundant, and bedding planes are extensively burrowed and marked by a variety of trace fossils. Based on petrographic study, this subfacies includes two microfacies; oolitic bioclastic dolomite, and silty/sandy dolomite microfacies.

The oolitic bioclastic dolomite show microsparitic texture, and comprise spherical and ellipsoidal ooliths, showing concentric structure with subordinate radial structure. Bioclasts of microfossils (foraminifera), bivalve and ostracoda fragments are abundant. Rounded to subrounded quartz and opaque grains occur; evaporite minerals are also present. Anhedral dolomite microcrystals form the major matrix constituents.

The silty and sandy dolomite microfacies comprise
silt and sand size and very fine-to fine-grained subangular quartz grain size (0.03–0.3 mm). Dolomite occurs as a major constituent throughout some beds, and is present as matrix, displaying subhedral to euhedral forms. Well-defined crystal rhombs occur, occasionally growing into each other, thereby loosing their euhedral shape. Ferroan dolomite occurs as matrix and oriented laminae.

Fig. 2. Measured section through the Dardur Formation at wadi Nakhla (see Fig. 1 for location).
3. Sandstone facies

The sandstone facies comprises fine- to coarse-grained, cream to light brown coloured, thin- to thick-bedded, parallel-laminated and cross-bedded, carbonate-cemented sandstones, associated with subsidiary siltstones (Fig. 3a). Three subfacies were recognized.

3.1. Fine- to coarse-grained sandstone subfacies

This subfacies consists of fine- to coarse-grained, cream-coloured, thin to medium-bedded sandstone. Some sandstones are trough cross-bedded (up to 45 cm thick and 4 m wide), others are 10–15 cm thick and 30–50 cm wide, they show a northwesterly unidirectional palaeocurrent trend with a vector mean of 280°. Thin-bedded sandstones are horizontally-laminated and ripple cross-laminated. Ripple marks are oscillatory, bidirectional and with crestlines orientated 100°–280° (Fig. 3b). Others are flat-topped 3–5 cm wide and 0.5–1 cm high, and obliquely orientated (140°–320° and 80°–260°), these sandstones commonly show load-casts where they overly finer grained lithologies.

The coarse-grained sandstones tend to occur either as thin beds or as small lenses or wedges, pinching and swelling laterally. These beds are bounded by horizontally-laminated (rarely rippled) fine-grained sandstones or siltstones. This subfacies shows minor burrowing and flaser bedding. A few beds are highly bioturbated, and as a result no bedding or sedimentary structures can be seen. Tube-like horizontal and vertical trace fossils are locally abundant.

3.2. Granular sandstone subfacies

The granular subfacies occurs mainly in the lower third of the sandstone facies. It consists of varicoloured quartz granules and small pebbles (up to 1 cm in diameter), associated with up to 5 cm in diameter intraformational sandstone and siltstone clasts (Fig. 3c). Individual beds are medium to thick bedded with erosional bases, internally trough cross-bedded and show fining-upward trends.

3.3. Sandy stromatolite subfacies

This subfacies occurs within the sandy facies at the top of the lowermost coarsening-upward sequence in the succession (Fig. 2). Three stromatolite types were recognized: (i) spherical and hemispherical forms, ranging in diameter from 5–45 cm; (ii) solitary; and (iii) linked dome-forms. Internally they show a concentric lamination. Other stromatolites reveal a wavy and slightly undulatory lamination.

4. Discussion and conclusions

The heterolithic and sandstone facies are arranged into two vertically stacked sequences, each beginning with a heterolithic facies and terminating in a sandstone facies, suggests a periodic shifting of the strandline position, which may be related to a relative fall
and rise of sea level, and/or a change in the rate of detrital influx (Fig. 4). The coarsening-upward facies sequences, their associated carbonates, fossils, trace fossils and internal architecture provides positive evidence of deposition in a marine tidal setting, beginning with a periodically exposed tidal flat and culminating in a shallow subtidal shelf zone as transgression occurred (Hayes and Kana, 1976) (Figs. 4 and 5).

The sandstone facies with it’s variable grain textures, traction current structures and marine fossils is consistent with deposition in a tide-dominated environment. The predominance of sand, and the lack of subaerial emergence features during deposition, such as mud-cracks and late stage run-off features (Klein, 1977) supports the idea of deposition along a transitional zone between the shallow subtidal shelf zone and the sand flat of the intertidal zone (Tankard and Hobday, 1977).

Fig. 4. Block diagrams to illustrate the development of the vertically-stacked, coarsening-upward marine facies during the Dardur time, in response to the local transgressions and regressions.

Fig. 5. Schematic depositional model of the Dardur Formation at Wadi Nakhla.
In contrast, the presence of bidirectional cross-bedding in the heterolithic facies indicates deposition under the influence of reversing tidal currents. The presence of oscillatory ripple marks implies wave action with the ripple wavelengths of 3–10 cm indicative of short period shallow water waves (Harms et al., 1975). Interference ripples are interpreted to have been produced by late stage emergence run-off phenomena prior to exposure (Klein, 1977), and the presence of mudcracks, near the basal part of the lower heterolithic facies consistent with subaerial exposure in the intertidal zone.

Sandstone and siltstone clasts represent the intraformational products (Fig. 3c), formed by the action of waves and tidal currents. The load-casts on the underside of sand beds at the interface between sandy and marly lithologies reflect differential loading between sediments of different densities.

The granular components in the sandy beds indicate the influence of the continental hinterland supplying detritus to the shallow marine environment. Tidal currents and waves were responsible for the accumulation of detritus along the lower sand-dominated tidal flat sub-zone (low tide) close to the subtidal zone, whereas the presence of silty shale, oolitic, bioclastic and stromatolitic subfacies suggest deposition within a mixed mid tidal flat sub-zone located between the high tide mud flat and lower sand flat of the intertidal environment. The development of a heterolithic facies implies that sand and silt were available and that periods of current activity alternated with periods of slack water. Therefore, the alternation and mixing of both fine and coarse lithologies by tides produced rhythmic and lenticular bedding typical of that regime (Reinech and Singh, 1973).

The sandy dolomitic subfacies with its high fossil content indicates the shallow water marine nature of the depositional environment, characterized by sufficient shallowing and agitation to produce oolitic subfacies.

The repetition of sandstone and heterolithic facies suggests a series of minor local transgressions and regressions. This situation explains the oscillatory nature of the strandline (Figs. 4 and 5), which was roughly orientated E–W, as determined from the crestline trend of the oscillatory ripple marks. The strandline trend of the Dardur formation with land to the south (Arabian-Nubian shield) and the sea (Tethys) to the north is consistent with palaeogeographic reconstructions for the early Triassic which was initiated by a major transgressive event (Bandel and Khoury, 1981; Makhlouf et al., 1990). This interpretation is substantiated by subsurface data, in that the facies analysis shows that the carbonate component changes northwards where it is dominated by limestone and shales, in response to increasing marine influence (Andrews, 1992).

The depositional relationships of the Dardur formation to the adjacent formations are similar. The lowermost formation of the Triassic succession the Ma’in Formation, conformably overlies the Permo-Triassic fluvial Umm Irna formation, and records the earliest Triassic transgression of the Tethys sea. Oscillating shallow marine depositional conditions continued during Dardur times and during deposition of the overlying Ain Musa formation, as indicated by the arrangement of facies, fossil content and internal sedimentary structures (Makhlouf, 1998).

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References


