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DOCUMENTATION AND SIGNIFICANCE OF TECTONIC EVENTS IN THE NORTHERN TABAS BLOCK (EAST-CENTRAL IRAN) DURING THE MIDDLE AND LATE JURASSIC

KAZEM SEYED-EMAMI[1], FRANZ T. FÜRSICH[2] & MARKUS WILMSEN[2]

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Abstract. Apart from global sea-level fluctuations, the sedimentary pattern of the northern Tabas Block during the Middle and Late Jurassic was mainly governed by tectonic events of varying intensity and areal extent. These events took place during the Middle Bajocian (mid-Cimmerian tectonic phase), Early Bathonian, Late Bathonian, Early Callovian, Late Oxfordian, and Late Kimmeridgian. The importance and extent of each event and its influence on the facies pattern of the northern Tabas Block is briefly discussed and demonstrated by some examples.

Riassunto. A parte le fluttuazioni globali del livello marino, l'evoluzione sedimentaria del Blocco di Tabas settentrionale durante il Giurassico medio e superiore è stata dominata principalmente da eventi tettonici di varia intensità ed estensione areale. Questi eventi hanno avuto luogo nel Bajociano medio (fase tettonica medio-Cimmerica), Bathoniano inferiore, Bathoniano superiore, Calloviano inferiore, Oxfordiano superiore e Kimmeridgiano superiore. L'importanza e l'estensione di ogni evento e la sua influenza sullo schema delle facies del Blocco di Tabas settentrionale viene brevemente discussa e dimostrata da alcuni esempi.

Introduction

The Tabas Block, sandwiched between the Yazd Block in the west and the Lut Block in the east, is part of the so-called Central-East Iranian Microcontinent (CEIM; Takin 1972) (Fig. 1), a segment of the Iran Plate (Davoudzadeh & Schmidt 1984), which in turn is part of the Cimmerian Continent collage (Sengör et al. 1988; Sengör 1990). Originally part of eastern Gondwana (Arabian Plate), parts of the Cimmerian Continent, among them the CEIM, became detached during the Late Permian/Early Triassic and moved northwards to collide with Eurasia (Turan Plate) in the early Late Triassic. The evolution of the Late Triassic/Jurassic sedimentary basins of the CEIM were largely governed by the Late Triassic collision of the Iran Plate and subsequent rotational and lateral movements (e.g. Davoudzadeh et al. 1981; Soffel et al. 1996; Alavi et al. 1997). The thick post-collisional molasse-type sediments of the Upper Triassic/Lower Jurassic Shemshak Group and their wide distribution across the Iran Plate indicate that during this time the Iran Plate behaved as a more or less coherent tectonic unit.

The onset of fragmentation of the Iran Plate and facies differentiation within and between its individual structural segments (blocks) is related to the important inter-regional tectonic movements around the Early/Late Bajocian boundary (mid-Cimmerian; Seyed-Emami & Alavi-Naini 1990). The combination of extensional, rotational, lateral, and compressional block movements along the CEIM, and especially within the Tabas Block, produced a variety of facies patterns during the Middle and Late Jurassic.

Aim of this paper is to review the extent and significance of the various tectonic events, which can be deduced by analysing the stratigraphic arrangement and facies pattern of the Jurassic sedimentary package in the northern Tabas Block. We distinguish three different magnitudes of tectonic events, depending on their distribution:

(1) Inter-regional events are large-scale and affected the entire Iran Plate, whereas
(2) regional events are restricted to the Tabas Block.
(3) Local events are restricted to smaller segments of the Tabas Block and are only of local importance (Table 1).

1 Faculty of Engineering, University of Tehran, P.O.Box 11365-4563, Tehran, Iran. E-mail: k.seyedemami@kavosh.net.
2 Institut für Paläontologie der Universität Würzburg, Pleicherwall 1, D-97070 Würzburg, Germany. E-mail: franz.fuersich@mail.uni-wuezburg.de; m.wilmsen@mail.uni-wuerzburg.de.

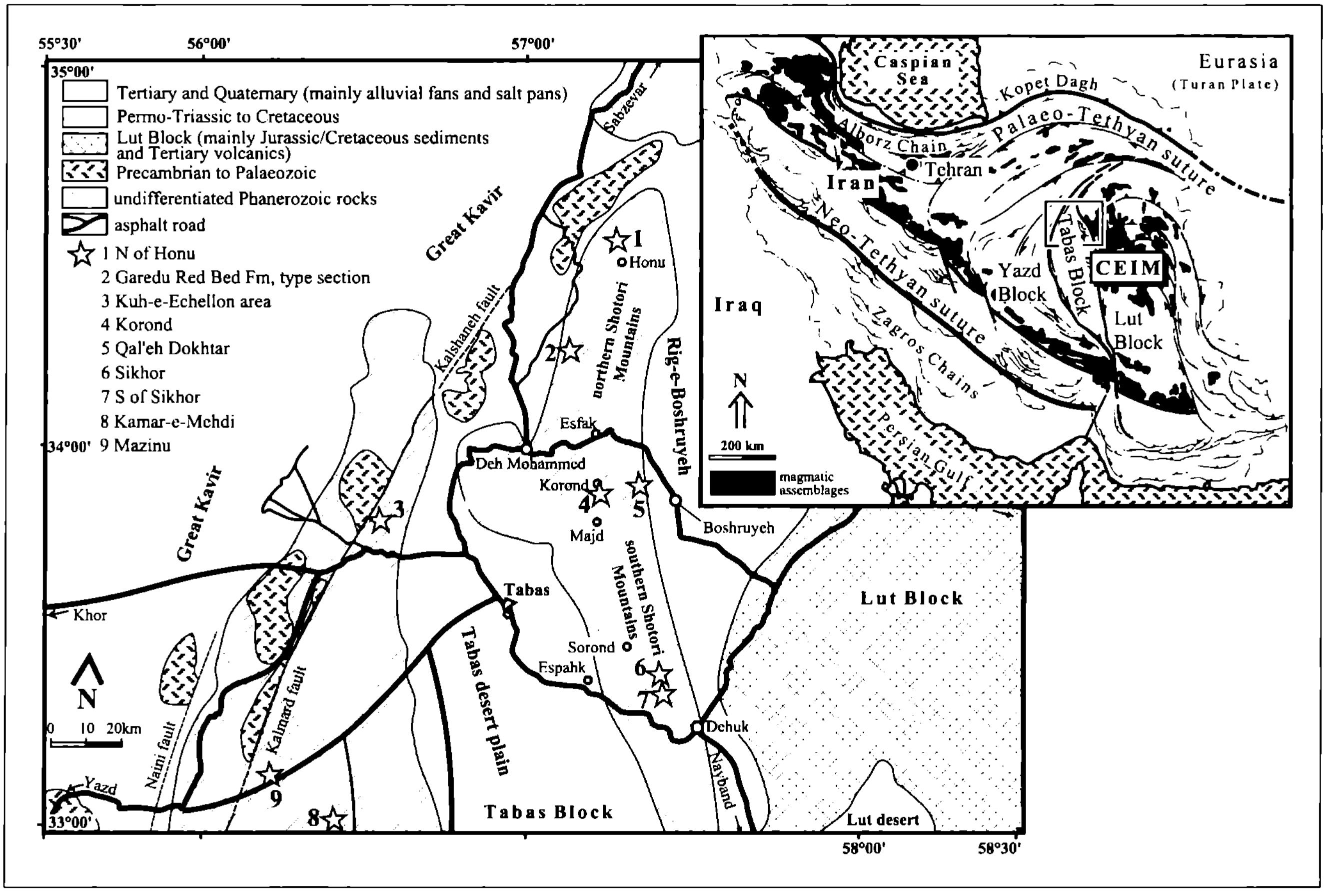


Fig. 1 - Tectonic framework of Iran (right) showing the position of the three blocks that constitute the Central-East Iranian Microcontinent (CEIM) and geological sketch map of the northern Tabas Block (left) with positions of the localities mentioned in the text.

The stratigraphic position of each event was reconstructed largely with the help of ammonites. The biostratigraphic significance and taxonomy of Jurassic ammonites in the study area has been discussed by Seyed-Emami et al. (1991, 1997, 1998, 2000, 2002) and Schairer et al. (2000, 2003).

In order to achieve our goal, extensive field work and detailed palaeontological, stratigraphical and sedimentological studies were needed. They were carried out in the last ten years by teams from the Tehran University, the Geological Survey of Iran, Würzburg University, Munich University, and Erlangen University. Localities discussed in the text are indicated in Fig. 1. An up-to-date lithostratigraphic framework of the Middle to Upper Jurassic Magu Group is provided in Fig. 2.

Main tectonic events

Early Late Triassic (early Cimmerian tectonic phase; inter-regional)

After the Late Triassic collision, the Iran Plate was part of a large landmass at the southern border of Eurasia, stretching from eastern Europe to Pamir and Central China. In the Late Triassic, a new tectono-sedimentary cycle (Shemshak Group) began, lasting until the Early Bajocian (Seyed-Emami et al. 2001). The wide distribution of the molasse-type sediments of the Shemshak Group (Norian - Lower Bajocian) across the entire Iran Plate indicates that during this time interval the Iran Plate acted as a coherent tectonic unit without fragmentation into various blocks as largely believed (e.g. Sengör 1990). The thick molasse-type sediments are also evidence of large-scale erosion of areas that were uplifted as a result of the early Cimmerian collision (Cimmerides). With some local variations in facies and thickness the predominantly siliciclastic sediments of the Shemshak Formation are well developed on the northern Tabas Block except in the southern Shotori Mountains where they are completely absent. This uplift possibly indicates the first activation of the so-called „Shotori Swell" (Stöcklin et al. 1965). The persisting importance of this topographic high on the Middle and Late Jurassic facies pattern of the northern part of the Tabas Block (Shotori Mountains) will be demonstrated below.

Early/Late Bajocian (mid-Cimmerian tectonic phase; inter-regional)

The important inter-regional Mid-Cimmerian tectonic phase is of crucial importance for the further structural and sedimentological development of the Iran Plate (Seyed-Emami & Alavi-Naini 1990). It is the onset of fragmentation and differentiation of the Iran Plate into a number of individual miniplates and blocks of varying sizes, caused by an anti-clockwise rotation of the plate that led to extensional, transform, and compressional movements. It is also the beginning of a new tectono-sedimentary megacycle (Magu Group, Fig. 2; Aghanabati 1977) lasting until the Late Jurassic (Seyed-Emami et al. 2001).

The tectonic movements created a varied facies pattern, especially in the northern Tabas Block, during the Middle and Late Jurassic. In this area, the lower boundary of the Magu Group is documented by an inter-regional unconformity characterised by variable signatures.

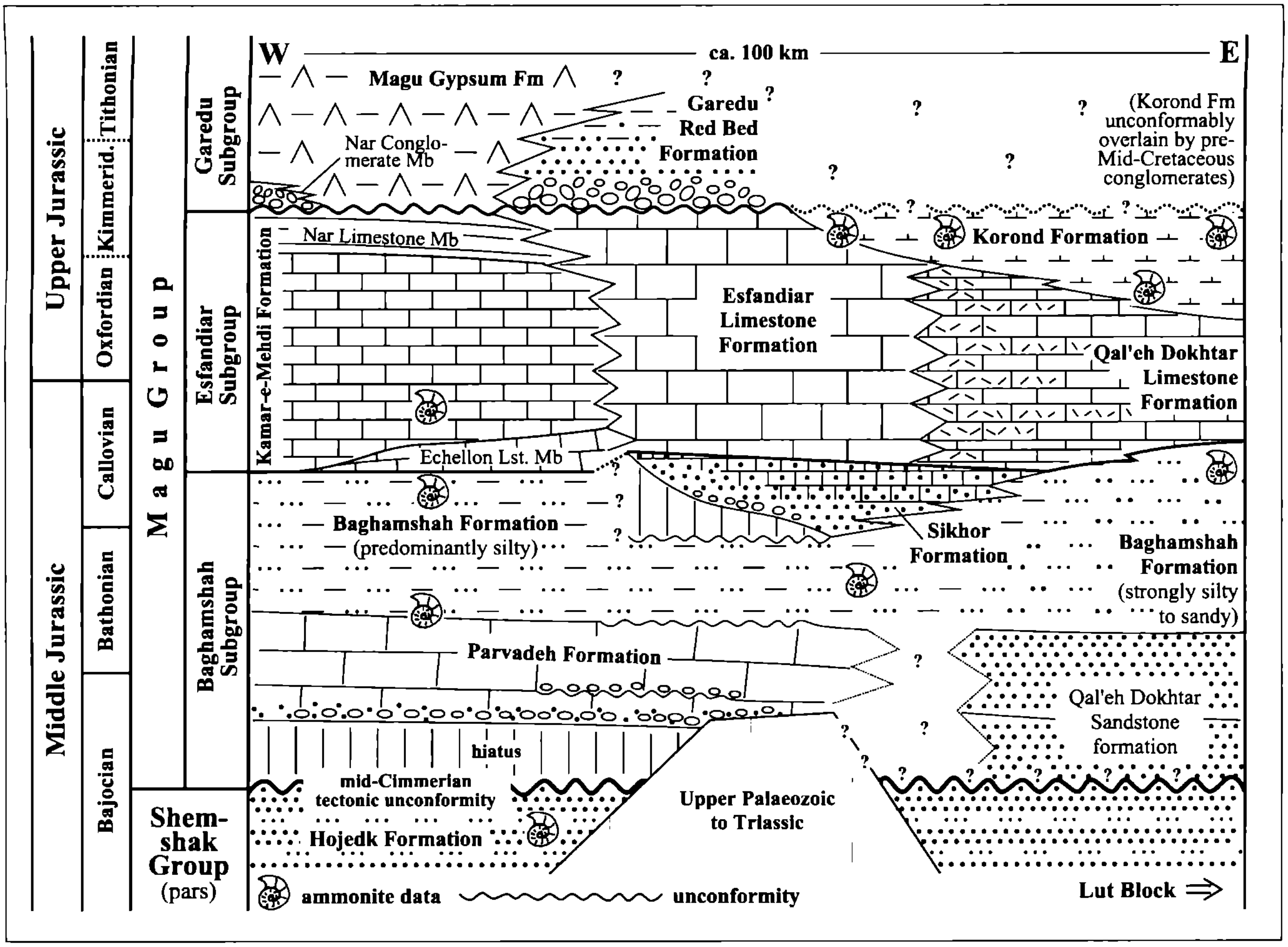


Fig. 2 - Lithostratigraphic subdivision of the Upper Bajocian to Tithonian Magu Group of the northern Tabas Block (modified after Wilmsen et al. 2003).

The most conspicuous unconformity occurs in the southern Shotori Mountains, south of Sikhor. There, the oolitic limestones of the Parvadeh Formation (?Upper Bajocian - Middle Bathonian) transgress with angular unconformity and a few metres of coarse conglomerates, containing pebbles of Permian origin, on quartzites and limestones of the Permian Jamal Formation (Pl. 1, fig. 3). Obviously, the Mid-Cimmerian unconformity was intensified by local block movements along the Shotori Swell. In most regions of the northern Tabas Block, the Parvadeh Formation rests unconformably and with a transgressive conglomerate on the predominantly fluvial Hojedk Formation (Bajocian) (Fig. 3; Pl. 1, fig. 2). At Mazinu, about 60 km WSW of Tabas, the Parvadeh Formation transgresses unconformably on the folded Hojedk Formation (Pl. 1, fig. 1). In contrast, along a narrow N-S trending strip, west and southwest of Esfak (central Shotori), where the Hojedk Formation represents fully marine environments (Seyed-Emami et al. 2000), the boundary to the overlying Parvadeh Formation is inconspicuous and marked only by few decimetres of quartzose fine conglomerate. At the easternmost border of the Tabas Block (at Qal'eh Dokhtar, west of Boshrouyeh; locality 5 in Fig. 1) a nearly 200 m thick package of sandstone of a local extent (the former Qal'eh Dokhtar Sandstone Member of Schairer et al. (2000), now considered as lateral equivalent of the Parvadeh Formation (Wilmsen et al. 2003)) is developed. Probably it had its source in the western Lut Block, which was uplifted during the mid-Cimmerian tectonic activity.

?Early Bathonian (local)

South of Sikhor, in the southwestern Shotori Mountains where the Parvadeh Formation overlies with angular unconformity the Permian strata, numerous pebble horizons with pebbles of Permian origin are found in the lower part of the formation. Apparently the source of the material was a very close landmass with high relief and steep cliffs, so that pebbles derived from older rocks could become mixed with the oolitic sediment of the Parvadeh Formation. This again is an indication of tectonic uplift along the Shotori Swell, continuing in pulses for some time after the Late Bajocian transgression.

?Late Bathonian (local)

Near the locality mentioned above, the top of the Parvadeh Limestone Formation exhibits signs of extensive karstification (Pl. 1, fig. 4). These include depressions up to 20 m deep and 10-20 m wide, with vertical iron-stained walls, a fill of ferruginous silt, local silicification of the surface, local development of iron crusts and patches of thin red sandstones. These features point to an extensive subaerial phase, caused by local tectonic uplift along the Shotori Swell. The overlying Baghamshah Formation is present in its normal basinal facies (marly silt) but greatly reduced in thickness (less than 10 m as in contrast to several 100 m elsewhere). This reduction in thickness was partly also caused by ongoing tectonic unrest and erosion of the top part of the formation, in connection with renewed uplift during the Early Callovian (see below).

Early Callovian (regional)

On a narrow, N-S elongated strip in the central part of southern Shotori Mountains, a prominent siliciclastic unit, up to 300 m thick, is intercalated between the underlying marly silts of the Baghamshah Formation and the carbonates of the overlying Esfandiar Limestone and

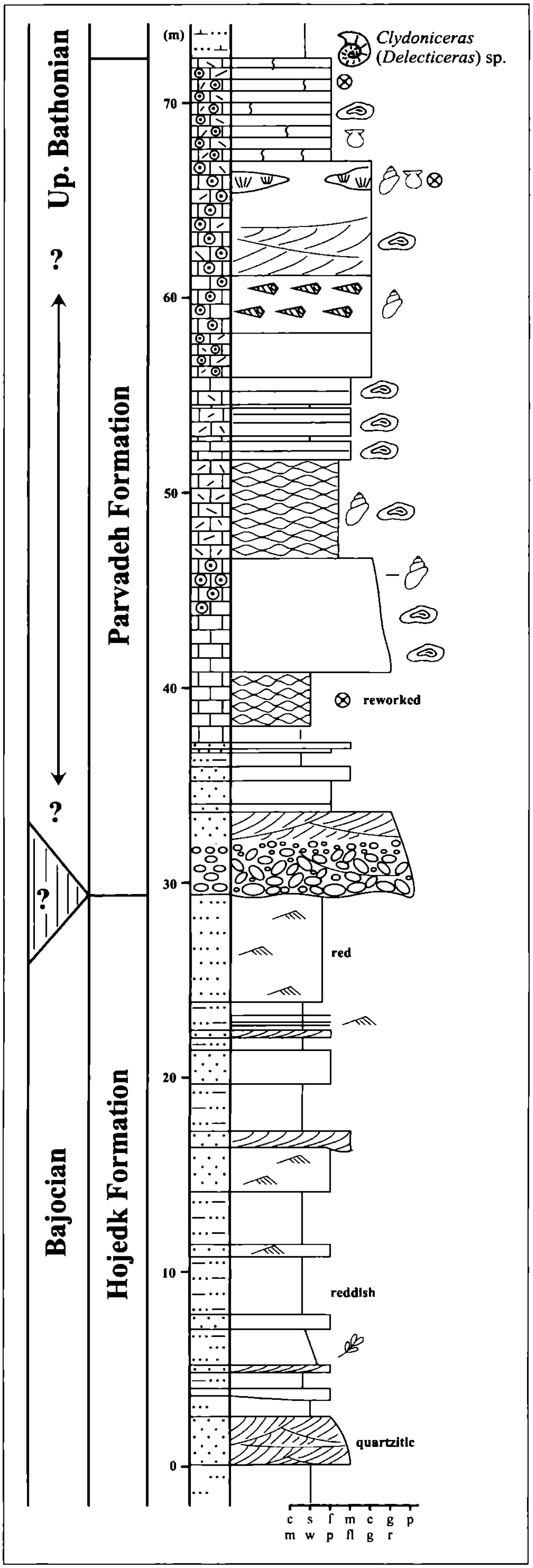


Fig. 3 - Lithology of the top of the Hojedk Formation and the Parvadeh Formation, west of Kuh-e-Echellon (Fig. 1, locality 3). The terrestrial siliciclastics of the Hojedk Formation are overlain, with erosional unconformity, by the basal quartz conglomerate of the predominantly calcareous Parvadeh Formation. For key of symbols see Fig. 5. Scale in metres.

Qal'eh Dokhtar Limestone formations (Fig. 2). This sequence, composed of conglomerates, sandstones, siltstones and mixed carbonate-siliciclastic sediments has been named Sikhor Formation (Fürsich et al. 2003a). Evidence of erosional truncation of the underlying Baghamshah Formation (Fig. 4, Pl. 1, fig. 5) and confinement to a relatively narrow, N-S elongated strip, suggest that the formation had its origin in the strongly asymmetric uplift of a tilted fault block in the southwestern Shotori Mountains that shed its sediments in a northern and eastern direction. The Sikhor Formation is evidence of an extensional tectonic event at the very beginning of the Early Callovian, that affected the southwestern part of the Shotori Mountains. A similar tectonic pulse apparently affected areas further to the southwest (south of Parvadeh) where conglomerates and red sandstones are intercalated between the Baghamshah und Kamar-e-Mehdi formations (S.A. Aghanabati, pers. comm. 2002) as well as further south in the Lakar Kuh area (Kluyver et al. 1983). This indicates that the tectonic movement was of regional rather than just of local significance.

In the southeastern Shotori Mountains, after erosional levelling, the former uplifted areas were overgrown by the highly productive Esfandiar carbonate platform, possibly facilitated by a global sea-level rise in the Middle Callovian (Hallam 2001).

Late Oxfordian (regional)

Following a phase of mainly siliciclastic sedimentation during the Early and Middle Jurassic, a carbonate system was established in the northern Tabas Block around the Early/Middle Callovian, persisting with local variations until the Late Oxfordian/Early Kimmeridgian (Esfandiar Subgroup; Wilmsen et al. 2003). This coincides with a global sea-level rise and transgression in the Middle Callovian (Hallam 2001). This is also the time of a relative tectonic quiescence, during which three parallel but different sedimentary areas were established in the northern Tabas Block (Fig. 2). In the west, a shelf-lagoon with bedded limestones and silty marls (Kamar-e-Mehdi Formation; Wilmsen et al. 2003), a carbonate platform along the eastern margin of the Tabas Block (Esfandiar Limestone Formation; Fürsich et al. 2003b) in the centre, and a slope-basinal system with slope and hemipelagic sediments (Qal'eh Dokhtar Limestone Formation; Schairer et al. 2000) in the east.

The high carbonate productivity phase was terminated, in the Late Oxfordian, by the partial drowning of the Esfandiar carbonate platform, indicated by hardgrounds and a condensed drowning unconformity on the top of the eastern occurrences of the Esfandiar Limestone Formation (Pl. 1, fig. 6). The cause was probably regional tilting and block tectonics along the Shotori Mountains. This is supported by emersion features in the western platform areas and the increasingly restricted (hypersaline) nature of the shelf lagoon (Nar Limestone Member of the Kamar-e-Mehdi Formation) west of the Esfandiar Platform. The stratigraphic and sedimentological evidence clearly indicates differential subsidence rather than the global sea-level rise in the Late Oxfordian (Hallam 2001) as controlling mechanism.

Following the drowning phase, the carbonates of the Qal'eh Dokhtar Limestone and Esfandiar Limestone formations were onlapped from east to west by the deep water marls of the Upper Oxfordian - Lower Kimmeridgian Korond Formation (Schairer et al. 2003).

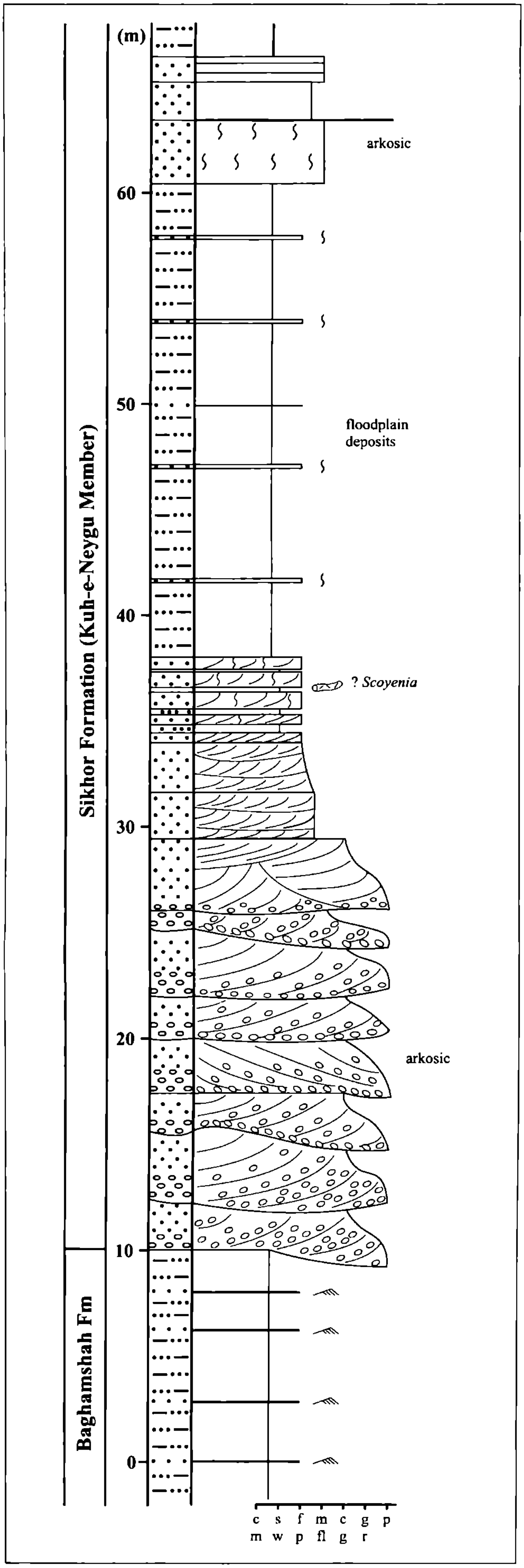


Fig. 4 - Lithology of the erosional contact between the Baghamshah and Sikhor formations at Sikhor (locality 6 of Fig. 1, type locality of the Sikhor Formation). Scale in metres. At the erosional unconformity, large-scale trough crossbedded conglomeratic sandstones of fluvial origin cut into the underlying basinal silty marls. For key of symbols see Fig. 5.

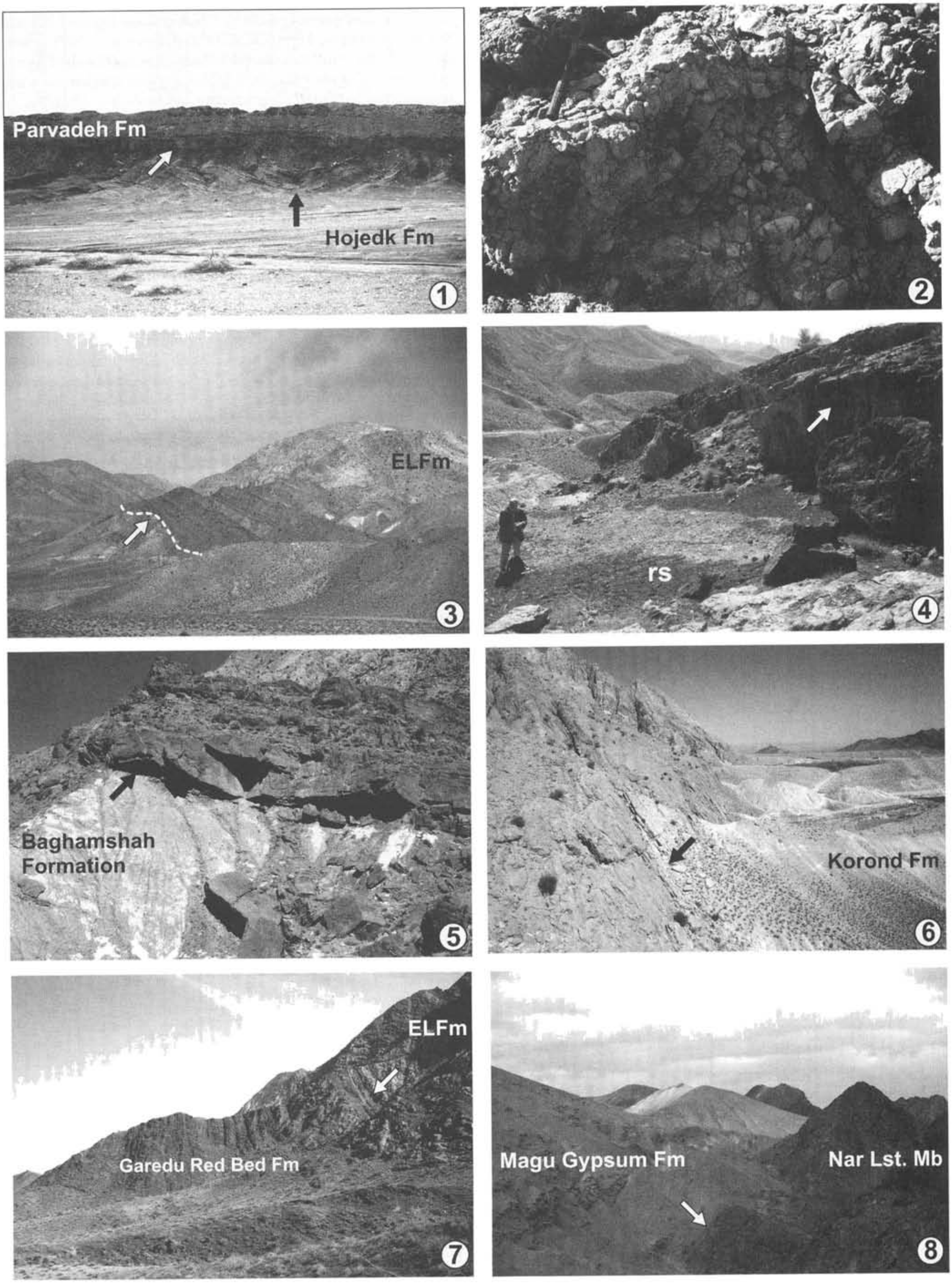
?Late Kimmeridgian (?late Cimmerian tectonic pulse; inter-regional)

In the northwestern part of the Shotori Mountains, the carbonates of the Esfandiar Limestone and Qal'eh Dokhtar Limestone formations are covered unconformably by a thick molassic sequence (Garedu Red Bed Formation; Ruttner et al. 1968; Wilmsen et al. 2003). Here, the Garedu Formation attains thicknesses of several hundred metres and consists of shallow marine, reddish calcareous conglomerates and siltstones and red fluvial conglomerates and sandstones (Pl. 1, fig. 7). The conglomerates are coarse and apparently of local origin and consist exclusively of limestone pebbles derived from the underlying Esfandiar Limestone and Qal'eh Dokhtar Limestone formations. Towards the south, they become finer-grained and the thickness decreases to zero. At some localities in the Shotori Mountains, marine mid-Cretaceous strata transgressively overlie either the eroded Esfandiar Limestone or Garedu-type non-marine rocks. West of the Shotori Mountains, in the northwestern part of the Tabas Block, the conglomerates have been found only in a restricted area at Kuh-e-Echellon, where they unconformably overlie the Nar Limestone Member of the Kamar-e-Mehdi Formation (Fig. 5). At this locality the conglomerates have a thickness of a few to up to 15 m and consist exclusively of pebbles and cobbles derived from the Nar Limestone Member. Towards the south and southwest, the conglomeratic layer is not developed and the upper Nar Limestone Member of the Kamar-e-Mehdi Formation is unconformably overlain by a thick sequence of red, continental fine-grained sandstones, siltstones and clays with thick intercalations of gypsum of sabkha origin (Magu Gypsum Formation, Pl. 1, fig. 8; Aghanabati 1977; Wilmsen et al. 2003).

The age of the Magu Gypsum and Garedu Red Bed formations can only be estimated as ?Late Kimmeridgian to Tithonian, perhaps ranging into the Early Cretaceous.

The tectonic activity at the base of the Garedu Subgroup (Fig. 2; Wilmsen et al. 2003) can probably be referred to the early stages of the inter-regional late Cimmerian tectonic phase, which involved almost the entire Iran Plate during the Late Jurassic - Early Cretaceous. This Late Cimmerian tectonic phase resulted in widespread regression, evidenced in most areas of Central and North Iran by red continental and gypsiferous sediments or by extensive hiatuses.

The rather restricted occurrence of the Garedu conglomerates to the northwestern Shotori Montains and their pinching towards south and west indicates strong block movements of regional extent along the northwestern Shotori Mountains during the Late Kimmeridgian/Tithonian.


Parvadeh Fm
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1
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Garedu Red Bed Fm
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Magu Gypsum Fm
Nar Lst. Mb
8

Conclusions

The northern Tabas Block was a tectonically unstable area throughout the Jurassic. Apparently, the tectonic instability intensified considerably after the important mid-Cimmerian phase and the fragmentation of the Iran Plate in the early Middle Jurassic. The subsequent persisting tectonic unrest strongly affected the sedimentation pattern of the area throughout the Middle and Late Jurassic.

PLATE 1

Fig. 1 - Angular unconformity (white arrow) between the folded Hojedk Formation and the horizontal Parvadeh Formation. The black arrow points to a broad synclinal fold in the Hojedk Formation. South of Tabas-Yazd road at Mazinu (locality 9 in Fig. 1).

Fig. 2 - Quartzitic conglomerate at the base of the Parvadeh Formation west of Kuh-e-Echellon (locality 3 in Fig. 1). Hammer for scale.

Fig. 3 - Mid-Cimmerian unconformity (arrowed) between Permian quartzites and the Parvadeh Formation south of Sikhor (locality 7 in Fig. 1). ELFm: Esfandiar Limestone Formation.

Fig. 4 - Steep-sided (arrowed) karstic depression at the top of the Parvadeh Formation south of Sikhor (locality 7 in Fig. 1), filled with red siltstone (rs).

Fig. 5 - Sharp erosional contact (arrowed) between the basinal Baghamshah Formation and fluvial conglomerates of the overlying Sikhor Formation at Sikhor (locality 6 in Fig. 1).

Fig. 6 - Boundary (arrowed) between the Esfandiar Limestone Formation (left) and the overlying Korond Formation (right). The sharp change in facies is due to partial drowning of the Esfandiar Platform in connection with block faulting.

Fig. 7 - Basal part of the Garedu Red Bed Formation overlying the Esfandiar Limestone Formation (ELFm) north of Honu (locality 1 in Fig. 1). The boundary between the two formations is marked by the arrow.

Fig. 8 - Sharp contact (arrowed) between the Lower Kimmeridgian Nar Limestone Member (right) and the Magu Gypsum Formation (left) probably signifies the onset of the late-Cimmerian tectonic phase. Kamar-e-Mehdi area (locality 9 in Fig. 1).

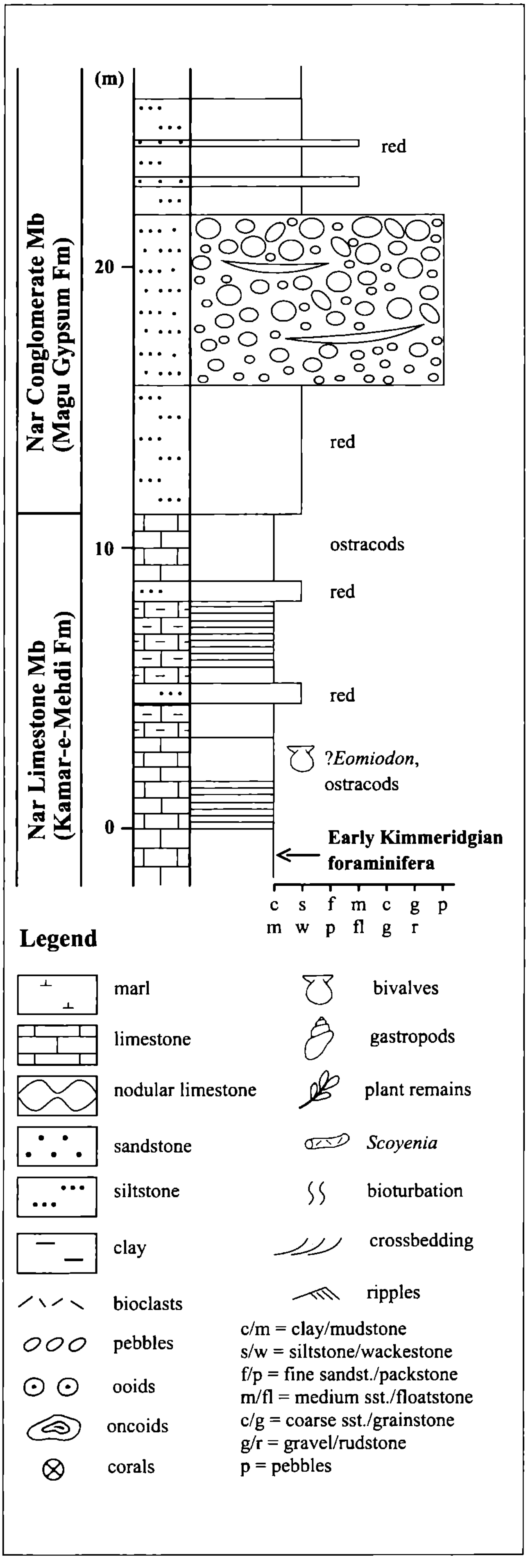

Fig. 5 - Lithology of the contact between the Nar Limestone Member and the Nar Conglomerate Member northwest of Echellon (locality 3 of Fig. 1). The pebbles of the conglomerate consist exclusively of carbonates of the Nar Limestone, which must have been eroded in close-by areas.

One of the important structural features, influencing the sedimentation pattern of the area throughout much of the Jurassic, is the Shotori Swell of Stöcklin et al. (1965). At present day, it is represented more or less by the NNW – SSE striking Shotori Mountains, along the eastern margin of the Tabas Block (Figs. 1, 2). The movements and displacements along the Shotori Swell appear to have been more significant in the southern part of the Shotori Mountains during the Middle Jurassic. The late Cimmerian movements affected all of the Shotori Mountains.

In the northern Tabas Block, the sedimentation pattern was influenced not only by the tectonic activities, but also by global sea-level fluctuations and climate. During the Jurassic, the palaeobiogeographic relations of the ammonites clearly indicate a palaeogeographic position of the Tabas Block and of the entire CEIM at the north-eastern border of the Tethys (Seyed-Emami et al. 2001), in close connection with the Lut Block in the east and the Yazd Block in the west.

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Lithostratigraphic position	**Age**	**Evidence**	**Extent**
Esfandiar/Magu Subgroup boundary	?Late Kimmeridgian (late Cimmerian)	unconformity, block tilting, erosion, conglomerates, evaporites	inter-regional
top of Esfandiar Limestone Fm	Late Oxfordian	block tilting, drowning of Esfandiar Platform, hardground	regional
base of Sikhor Fm	Early Callovian	unconformity, fluvial conglomerates overlying open shelf sediments	regional
top of Parvadeh Fm	?Middle/Late Bathonian	karst features	local
intra-Parvadeh Fm	?Early Bathonian	conglomerate layers	local
base of Parvadeh Fm (base of Magu Group)	Bajocian (mid-Cimmerian)	angular unconformity, conglomerate layer, hiatus	inter-regional
base of Shemshak Group	early Late Triassic (early Cimmerian)	unconformity, karst features, erosion, molasse sediments	inter-regional

Tab. 1 - Jurassic tectonic phases and their sedimentary evidence in the northern Tabas Block.

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