The Jurassic succession of Ras Sharwayn, South-eastern Yemen

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ABSTRACT: Four Jurassic stratigraphic units have been recognised at Ras Sharwayn, about 300 km east of Al-Mukalla along coast of the Gulf of Aden.

The Kohlan Formation (60 m) unconformably overlies the crystalline basement. Its lower and middle part consist of fluviatile sandstone and conglomerate. The upper part is made up of transitional coarse- and fine-grained sandstones and siltstones. The sequence ends with shallow marine fine-grained sandstones. The Shuqra Formation (71 m) can be divided into two members. The lower Calcareous-marly Member (45 m) consists of grey bioclastic limestone and subordinate nodular marl (inner to mid ramp). Its age is Late Oxfordian. The upper Carbonate Member (26 m) changes from basal reddish marly limestones (mid ramp) to thick beds of red-brown, coarsely crystalline limestones and dolomites (inner ramp). The topmost beds contain fossils of colonial organisms, essentially stromatoporoids. Its age is Late Oxfordian, and possibly earliest Kimmeridgian. The Madbi Formation (>30 m) consists of yellowish marl alternating with marly limestone and bioclastic limestone (coquinas) corresponding to storm layers (mid to outer ramp). With regard to its age, a specimen of *Orthosphinctes* sp., collected a few metres from the base, possibly refers to the Early Kimmeridgian. The Madbi Formation ends with an unconformity surface. The informal Clastic unit (56 m) (including the Naifa Formation) consists, from bottom upwards, of: red-brown dolomite; grey detrital limestone with quartz grains; massive, white conglomerate with well rounded limestone clasts, quartz and bioclasts (*e.g.* colonial organisms). The last lithotypes are gravity flow deposits, accumulated at the base of a scarp possibly tectonic in origin, approximately at the Jurassic-Cretaceous boundary.

This detailed lithological, sedimentological and biostratigraphical study has provided revised litostratigraphical subdivision and nomenclature and improved the stratigraphic control.

INTRODUCTION

The Jurassic successions of the southern part of the Arabian Shield, Yemen in particular, reflect the tectonic evolution of the Horn of Africa after the breakup of the Gondwana Supercontinent and the opening of the Indian Ocean, The crustal extension gave rise to a series of faulted basins in a Mesozoic rift system, first filled with continental sediments and then inundated by a Jurassic sea at different ages from southern areas (Pliensbachian to Toarcian in Kenya and Somalia: Buscaglione *et al.* 1993) to the North (Callovian-Oxfordian in Eritrea, Ethiopia and Arabia: Sagri *et al.* 1996; Bosellini *et al.* 1997; Martire *et al.* 2000; Fazzuoli, Carras in press; Simmons, Al-Thour 1994; Beydoun 1997). The wide-spread Late Jurassic marine episode, activated by the sea encroaching the Africa and Madagascar-India block, was short-lived because of the Early Cretaceous upwarping of the Horn of Africa, as the consequence of a distal interplate effect of the opening of the South Atlantic (Bosellini 1992). The marine units were then overlain by continental deposits which capped the Jurassic sequences in the Ethiopian and Arabian areas, below the mid-Cretaceous marine transgression.

In Northern-Central Yemen, the so-called Amran Group unconformably overlies the continental Kohlan Group and exhibits both carbonate and clastic facies with fossiliferous limestones and dolomites intercalated with marls and shales; they represent a moderately deep shelf environment. In turn, the Cretaceous continental Tawilah Group closes the Mesozoic cycle. According to foraminiferal assemblages, the age of the onset of the marine sedimentation for the Amran basal units in the Sana'a area is referred to as ?Callovian-Oxfordian (Simmons and Al-Thour 1994; Beydoun 1997)

Beydoun (1964) identified four Jurassic formations in the Southern Yemen coastal belt: the continental Kohlan Fm. overlain by the marine Shuqra, Madbi and Naifa formations. The Jurassic stratigraphy of Ras Sharwayn, in the eastern Southern Yemen, appears limited with undetected gaps.

REGIONAL GEOLOGICAL SETTING

The Jurassic to lowermost Cretaceous marine successions of the Yemen were intensively investigated late last century for hydrocarbon exploration (Richardson *et al.* 1995; Bunter *et al.* 1998). In accordance with the outcrops and subsurface data, the main Mesozoic structures of Southern Yemen, roughly NW-SE oriented, are, from West to East: the Marib-Shabwa-Hajar basins, the Mukallah High, the Sayun and Masilah basins and the Fartaq High (Bosence 1997) (Fig. 1).

The Wadi Hajar Basin, already cited by Beydoun (1964) and recently revised by Howarth and Morris (1998), constitutes the core of the Marib-Shabwa-Hajar Basin. In detail, the succession, about 600 m thick, is as follows: the calcareous Shuqra Formation above the arenaceous Kohlan Formation is of Callovian age. The argillaceous Madbi Formation contains rare Oxfordian ammonites. The Naifa Formation, Billum Member is calcareous with rare Upper Oxfordian to Upper Kimmeridgian ammonites; the Kilya Member is

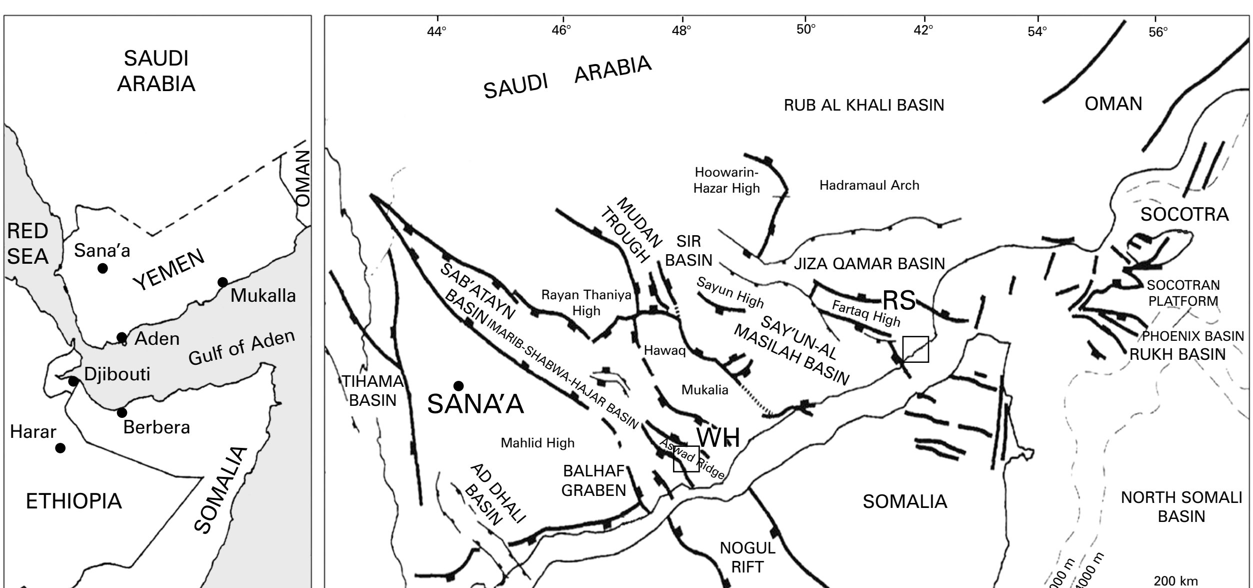


Fig. 1. Mesozoic to Early Cenozoic rift basins on a pre-Gulf of Aden rift scheme (modified after Bosence, 1997): WH – Wadi Hajar; RS – Ras Sharwayn.

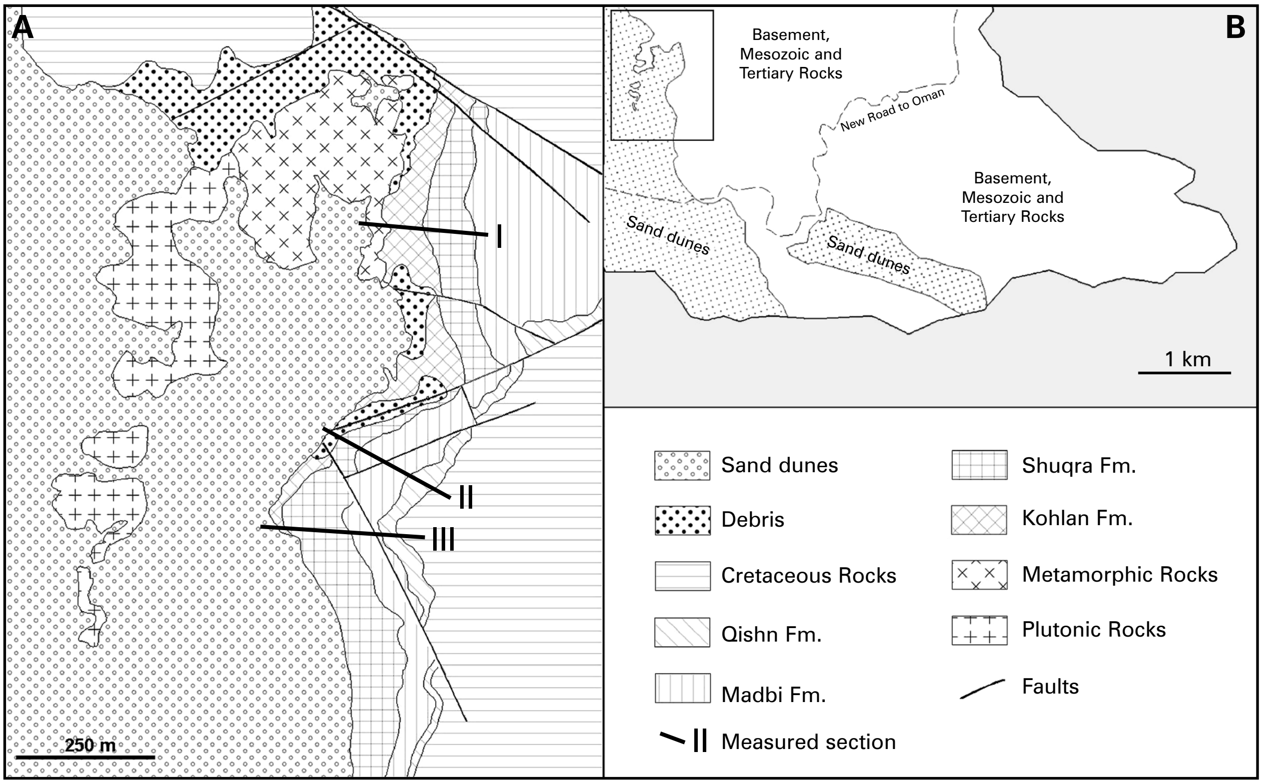


Fig. 2. Location (B) and geological sketch map (A) of the Jurassic outcrops at Ras Sharwayn. The map derives from original structural and stratigraphical analysis carried out in Ras Sharwayn hills, drawn up from high-resolution satellite images. I, II, III refer to the different stratigraphic sections mentioned in the text.

marly and contains Upper Kimmeridgian to Lower Tithonian ammonites. Above a disconformity surface, whose gap encompasses the Early Tithonian, the Hajar Formation, Arus Member, consists of limestones and marls with Upper Tithonian ammonites; the Mintaq Member is highly calcareous, with Upper Tithonian to mid-Berriasian ammonites. This succession is capped by the detrital Qishn Fm.

Only one Jurassic outcrop area is known eastwards of the structural High of Al-Mukalla: the hill complex of Ras Sharwayn, as part of the Fartaq High, some 300 km east of Al-Mukalla.

THE JURASSIC SUCCESSION OF RAS SHARWAYN

The aim of our research was to analyse and establish facies variations, palaeobiological characteristics, discontinuities, sequence organisation, chronostratigraphic assessment and depositional history of the marine Jurassic of Ras Sharwayn district. Previous knowledge of the Jurassic succession of this area was based on brief reports published by Beydoun (1964, 1966) and the geological map by Robertson (undated, possibly from the seventies). It was impossible to locate the section cited by Beydoun (1964) in the field and, moreover, the distribution of Mesozoic units in Robertson's map turned out to be completely wrong. Consequently we were forced to search for the Jurassic rocks on the extensive Ras Sharwayn hill complex: our field observations are summarised in the original, albeit rough map in Fig. 2.

Field observations allowed four Jurassic stratigraphic units to be distinguished:

a) the Kohlan Formation,
b) the Shuqra Formation,
c) the Madbi Formation, and
d) Clastic unit (informal) including Naifa Formation, unconformably overlain by
e) Dolomitic unit (informal), as part of the Cretaceous Qishn Formation.

The compound stratigraphic log in Fig. 3 derives from three different stratigraphic sections: Ras Sharwayn I: N 15° 21' 16",7 - E 51° 36' 12",3; Ras Sharwayn II: N 15° 20' 53",3 -E 51° 36' 08",8; Ras Sharwayn III: N 15°20' 58",6 - E 51 ° 36' 12",0. On the whole, the succession studied measures 255 metres; 32 samples were collected and labelled 04.Y.31 to 04.Y.62.

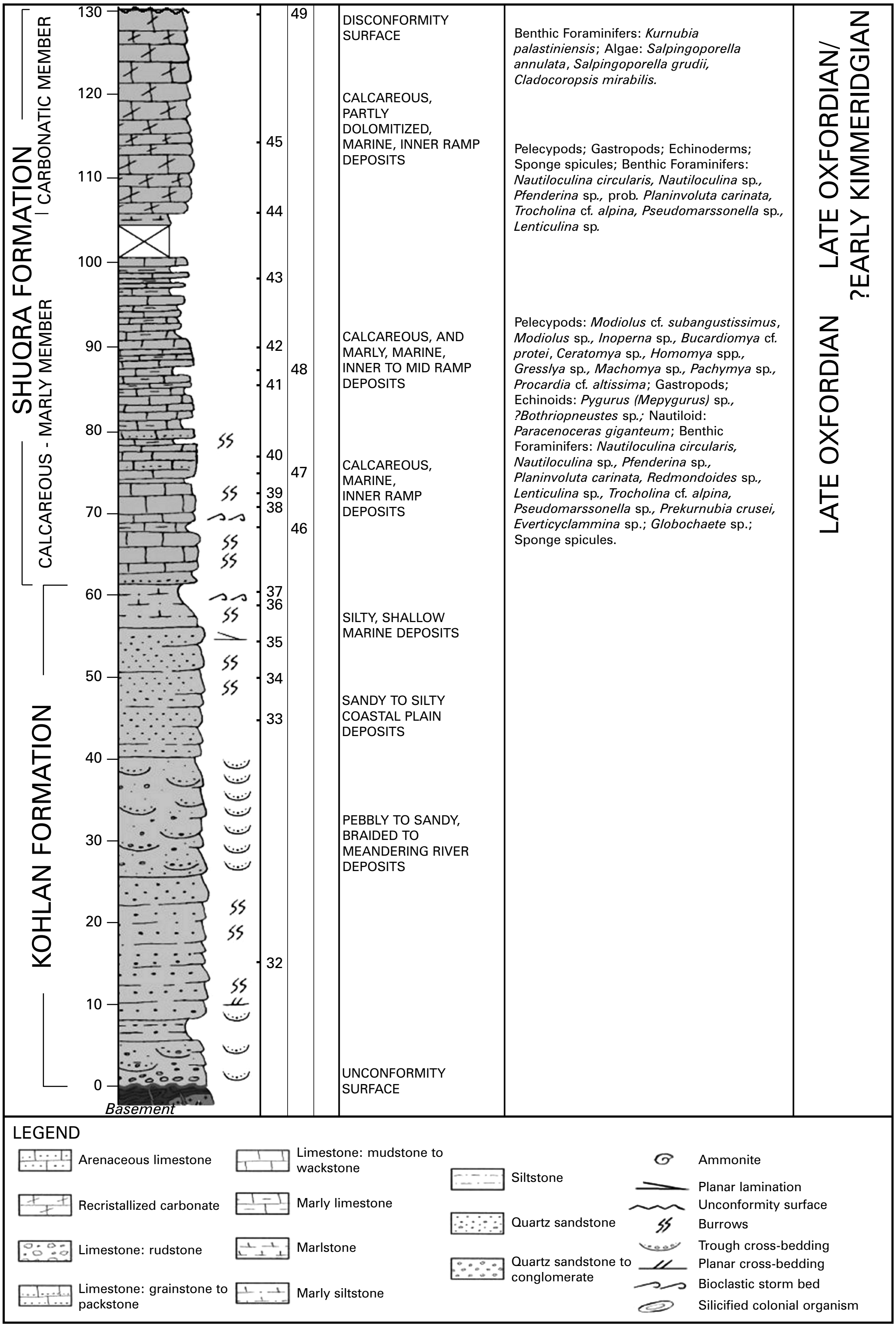
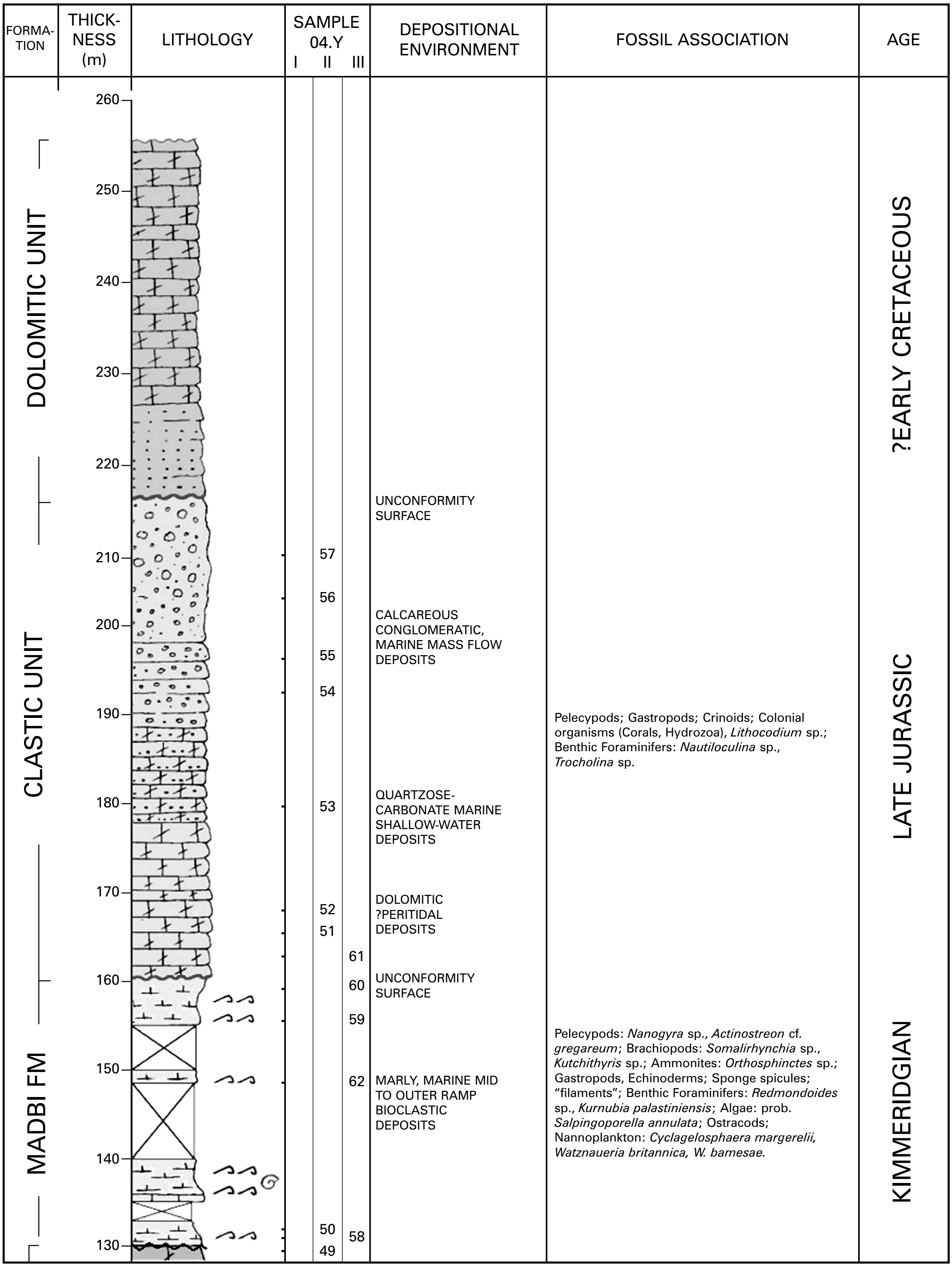


Fig. 3. Stratigraphic log of the Jurassic composite section of Ras Sharwayn. I, II, III refer to the different stratigraphic sections mentioned in the text. Inferred fault plane within the Madbi Formation.


FORMATION
THICKNESS (m)
LITHOLOGY
SAMPLE 04.Y
I II III
DEPOSITIONAL ENVIRONMENT
FOSSIL ASSOCIATION
AGE
DOLOMITIC UNIT
CLASTIC UNIT
MADBI FM
260
250
240
230
220
210
200
190
180
170
160
150
140
130
57
56
55
54
53
52
51
61
60
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62
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49
58
UNCONFORMITY SURFACE
CALCAREOUS CONGLOMERATIC, MARINE MASS FLOW DEPOSITS
QUARTZOSE-CARBONATE MARINE SHALLOW-WATER DEPOSITS
DOLOMITIC ?PERITIDAL DEPOSITS
UNCONFORMITY SURFACE
MARLY, MARINE MID TO OUTER RAMP BIOCLASTIC DEPOSITS
Pelecypods; Gastropods; Crinoids; Colonial organisms (Corals, Hydrozoa), *Lithocodium* sp.; Benthic Foraminifers: *Nautiloculina* sp., *Trocholina* sp.
Pelecypods: *Nanogyra* sp., *Actinostreon* cf. *gregareum*; Brachiopods: *Somalirhynchia* sp., *Kutchithyris* sp.; Ammonites: *Orthosphinctes* sp.; Gastropods, Echinoderms; Sponge spicules; “filaments”; Benthic Foraminifers: *Redmondoides* sp., *Kurnubia palastiniensis*; Algae: prob. *Salpingoporella annulata*; Ostracods; Nannoplankton: *Cyclagelosphaera margerelii*, *Watznaueria britannica*, *W. bamesae*.
?EARLY CRETACEOUS
LATE JURASSIC
KIMMERIDGIAN

Kohlan Formation

The Kohlan Formation unconformably overlies the crystalline basement, composed of meta-sediments intruded by granitoids (Fig. 4). In the measured sections, the formation is about 60 m thick; the lower and middle portions consist of coarse-grained sandstone and conglomerate, made-up of centimetre- to decimetre-sized pebbles. The upper part consists of coarse to fine-grained sandstones and subordinate yellowish siltstones; at the top, fine-grained sandstones are dominant. The upper part of the formation grades into the overlying Shuqra Fm. with no evidence of intervening stratigraphic or lithostratigraphic hiatus.

The sedimentary environment was fluviatile (braided to meandering rivers) in the lower and middle part of the succession, as evidenced by the planar and trough cross-bedded coarse-grained sediments, and transitional to shallow marine in the upper part testified by the occurrence of sandstones with abundant burrowing structures (domichnia) in turn overlain by fine-grained sandstones with planar laminations and small wave ripples.

Fragmented shells of pelecypods (coquina) occur in graded bioclastic storm layers at the top of the formation; undeterminable coprolites were observed also in the topmost beds but they provided no chronological informations.

Shuqra Formation

The formation measures over 70 m and can be divided into two members: a lower Calcareous-marly Member, 45 m thick, and an upper Carbonate Member, 26 m thick.

Calcareous-marly Member
The following lithofacies were observed:

16.5 m of predominantly grey bioclastic wackestone and packstone in beds 40-150 cm thick with subordinately nodular, bioclastic marly limestone and marls in centimetre to decimetre

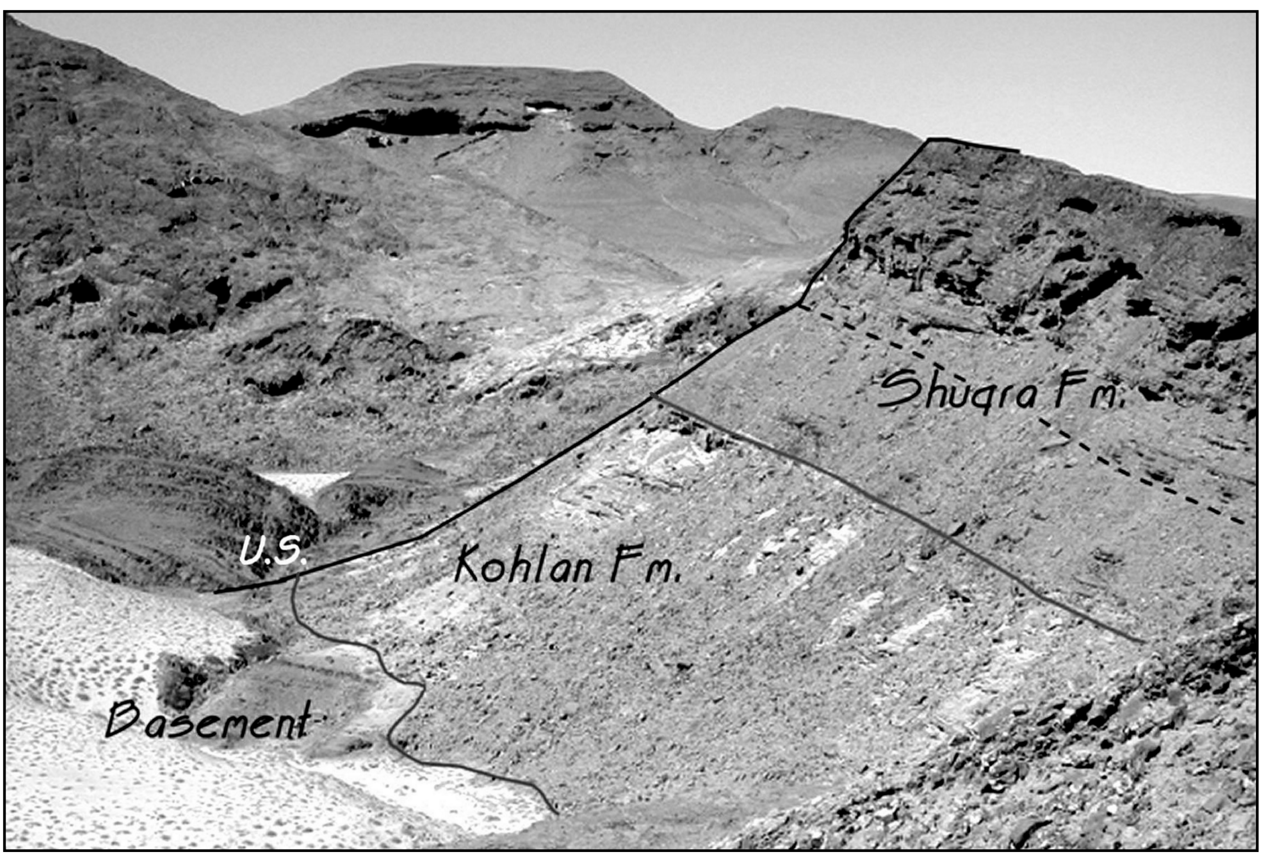

Fig. 4. Section Ras Sharwayn I (I in Fig. 2). It concerns the lower part of the Jurassic succession unconformably resting on the Precambrian basement. The stratigraphic thickness of the Kohlan Formation, between the basement and the Shuqra Formation, is about 60 metres. u.s.: basal unconformity surface.

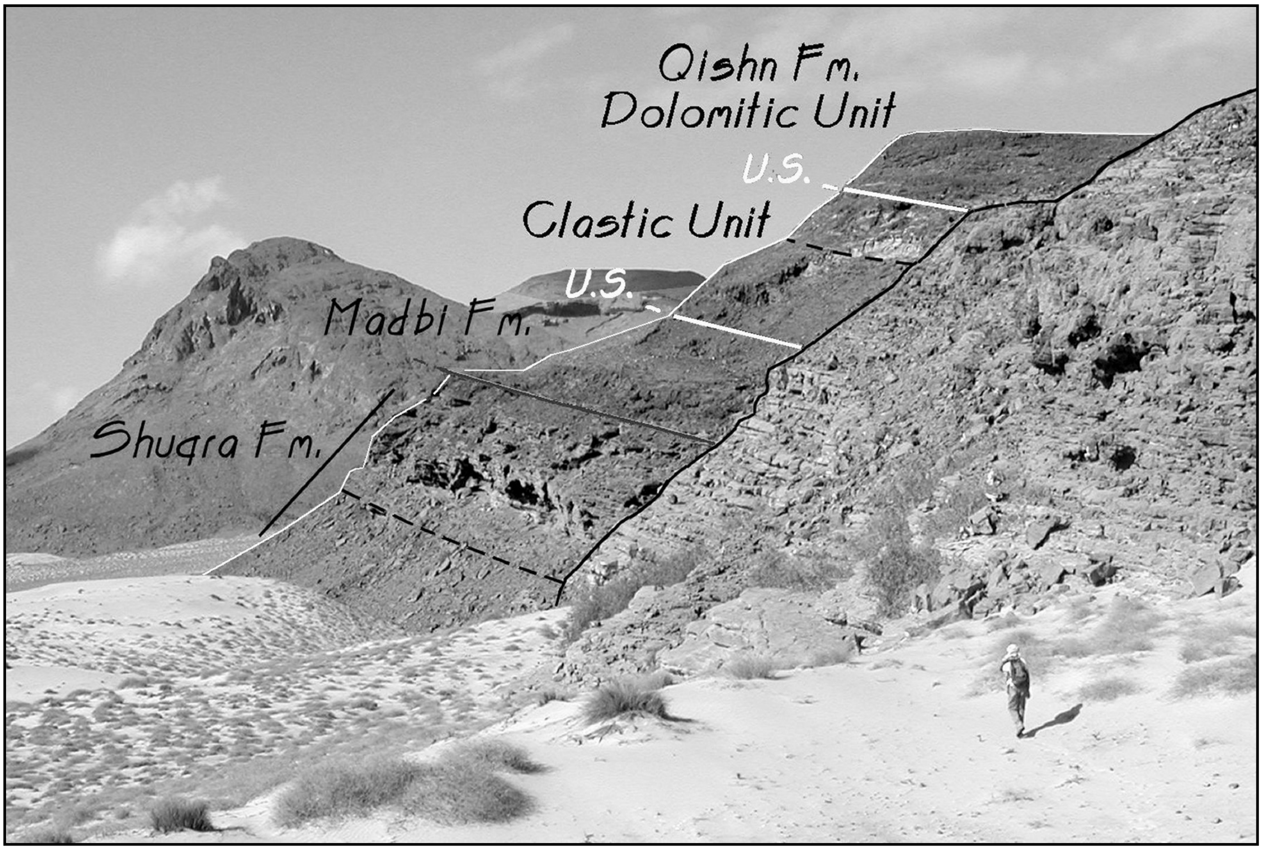

Fig. 5. Section Ras Sharwayn II (II in Fig. 2). The succession from Madbi to Qishn Formation was studied along the central slope. In the foreground, Marco Morelli. u.s.: unconformity surfaces.

thick beds; mottled bioturbation structures are abundant; bioclastic packstone to floatstone beds (storm layers) are present.

28.5 m of decimetre- to metre-thick beds of bioclastic wackestone to packstone alternating with decimetre-thick beds and metre-thick levels of nodular marl.

The sedimentary environment was a marine ramp (*sensu* Burchette and Wright 1992) with mixed carbonates and shales. The lower portion, more calcareous and with graded beds and bioclastic storm layers, was deposited on an inner (proximal) ramp, where the below mentioned palaeocommunity developed on a muddy bottom. The upper part, more marly and with thinner and finer-grained storm-layers, was deposited on a inner to mid ramp. A deepening upward trend is interpreted.

The fossil assemblage consists of pelecypods, gastropods, echinoderms, nautiloid *Paracenoceras giganteum* d'Orbigny, benthic foraminifers (*Nautiloculina circularis, Nautiloculina* sp., *Pfenderina* sp., aff. *Planinvoluta carinata* Leischner, *Redmondoides* sp., *Trocholina* cf. *alpina* Leupold, *Pseudomarssonella* sp., *Lenticulina* sp., *Prekurnubia crusei* Redmond, *Everticyclammina* sp.), *Globochaete* sp., sponge spicules. The fossils in the layer of sample 38 mostly lie in life position, are therefore clearly autochthonous and represent a palaeocommunity dominated by pelecypods of (1) the order Myoida, such as *Modiolus* cf. *subangustissimus* Dacqué, *Modiolus* sp., *Inoperna* sp., and (2) subclass Anomalodesmata, such as *Bucardiomya* cf. *protei* (Brongniart), *Ceratomya* sp., *Homomya* spp., *Gresslya* sp., *Machomya* sp., *Pachymya* sp., *Procardia* cf. *latissima* (Agassiz); brachiopods Rhynchonellida and Terebratulida and early Atelostomata echinoids (*Pygurus* [*Mepygurus*] sp., ?*Bothriopneustes* sp.) are also present. As regards the brachiopods, the common sulciplicate terebratulids belong to the single species *Somalirhynchia africana* Weir, suggesting a wide geographic diffusion during the Oxfordian-Kimmeridgian from central-northern Europe to central-eastern Africa and the Arabian Shield.

Rhynchonellids belong to two morphological stocks: one shows a well marked sulciplicate frontal commissure and belongs to the Bathonian-Kimmeridgian *Kutchithyris;* the second is dubiously referable to the Kimmeridgian genus *Somalithyris* on account of the gentle ondulated commissure.

As regards the biochronostratigraphy, information from benthic foraminifers (*Nautiloculina circularis, Trocholina* cf. *alpina, Prekurnubia crusei*) indicate a Bathonian to Oxfordian age. *Paracenoceras giganteum* is known from Upper Oxfordian to Kimmeridgian layers (Tintant 1994) and those irregular echinoids are not cited above Oxfordian (Durham *et al.* 1966). Among pelecypods, *Bucardiomya protei* is typical of the European Upper Oxfordian, whereas *Modiolus subangustissimus* seems to be confined to the Kimmeridgian (Dacqué 1910). In summary, the whole fossil assemblage indicates a Late Oxfordian age.

Carbonate Member

Due to the hardness of the rocks, this calcareous subunit forms a prominent cliff. The following lithofacies have been observed:

8 m of decimetre-thick beds of reddish marly limestones;

18 m of 50 to 200 centimetre-thick beds of coarsely crystalline limestones and dolomites and of red-brown dolomitic limestones, consisting of wackestone/packstone with bioclasts, intraclasts, fecal pellets, coated grains. The topmost beds consist of wackestone/packstone with colonial organisms, essentially stromatoporoids. The upward transition to the overlying Madbi Formation is very sharp and could be related to the disconformity between the Shuqra and Madbi formations already hypothesized by Beydoun (1966).

Based on the increasing scarcity of shaly levels a shallowing upward sequence is apparent. In spite of the rather strong recrysallisation that somewhere shades the sedimentary structures, the recognised textures and fossils indicate that this member was deposited on an inner ramp.

The fossil assemblage consists of indeterminable fragments of pelecypods, gastropods, echinoderms, sponge spicules and of benthic foraminifers (*Nautiloculina circularis* Henson, *Nautiloculina* sp., *Pfenderina* sp., prob. *Planinvoluta carinata* Leischner, *Trocholina* cf. *alpina* Leupold, *Pseudomarssonella* sp., *Lenticulina* sp. and, at the top, *Kurnubia palastiniensis* Henson), red algae (*Salpingoporella annulata* Carozzi, *Salpingoporella grudii* (Radoiãić) and *Cladocoropsis mirabilis* Felix).

The stratigraphic frame and the association of *Kurnubia palastiniensis, Salpingoporella annulata, Salpingoporella grudii* and *Cladocoropsis mirabilis* indicate for the top of the member a Late Oxfordian age, although the earliest Kimmeridgian cannot be excluded.

Madbi Formation

This formation is apparently about 30 m thick, but some fault lineations, crossing this formation, were detected by the satellite images (Fig. 2): the faults are not clear in the field as hidden by abundant debris (covered intervals in Fig. 3); the throw of the faults and therefore the actual thickness of the Madbi Formation are unknown. The lithology consists of decimetre- to metre-thick levels of rubbly yellowish marls alternating with decimetre-thick beds of marly limestone and marly bioclastic wackestone to packstone. Graded thin coquina beds, consisting mostly of fragmented shells of brachiopods and pelecypods, are frequent and correspond to storm layers. The topmost level of the formation consists of a centimetre-thick bed of red shaly siltite with concretions of Fe oxide, veinlets of calcite and small quarz crystals. The boundary with the overlying clastic unit is sharp, and so we consider the red shaly-silty layer as marking an unconformity surface.

The fossil assemblage consists of pelecypods, brachiopods, gastropods, ammonites (*Orthosphinctes*), echinoderms, sponge spicules, "filaments", benthic foraminifers (*Redmondoides* sp., *Kurnubia palastiniensis* Henson), algae (probable *Salpingoporella annulata* Carozzi), ostracods, nannoplankton: *Cyclagelosphaera margerelii* Noel, 1972, *Watznaueria britannica* (Stradner, 1963), *W. barnesae* Reinhardt, 1968. The layer of sample 04.Y.50 contains an oligotypical palaeocommunity dominated by a single giant rhynchonellid brachiopod, representative of the genus *Somalirhynchia* and characterized by its large size: adult pedicle valves are 44 mm long, 51.2 wide and 43.2 thick with a frontal fold 30.7 wide; it could represent a new taxon, endemic to the Arabian Kimmeridgian (*Somalirhynchia* ?n. sp). Other brachiopod taxa are scattered terebratulids (*Kutchithyris*) and rare oysters such as *Nanogyra* sp. and *Actinostreon* cf. *gregareum* (Sowerby).

Based on the abundance of marly levels and the occurrence of distal storm layers, the sedimentary environment is interpreted as a transition from mid ramp to outer ramp. The rich brachiopod assemblage at the base of the Madbi Fm. indicates an outer shelf with muddy bottom, where oyster shells offered a semi-rigid ground on which grew the *Somalirhynchia* palaeocommunity

The brachiopod palaeocommunity at the very base of the formation and the single specimen of *Orthosphinctes*, collected some seven metres above the base of the marly succession, indicate the transition from the Oxfordian to the Kimmeridgian stages of Mediterranean/Submediterranean subdivision. Nevertheless, though too fragmentary to give definitive biochronological information, this ammonite specimen shows a morphology very similar to that of the *Orthosphinctes* taxa described by Pavia *et al.* (1987) from the Lower Kimmeridgian, Strombecki Zone, of North Italy. In conclusion, the entire Madbi Fm. at Ras Sharwayn is possibly limited to the Kimmeridgian.

Clastic unit (informal)
(including Naifa Formation)

This unit is 56 m thick. The following lithofacies were observed, from the bottom upwards:

4.5 m of metre-thick beds of red-brown dolomitic limestone, consisting of mudstone/wackestone with abundant sand-sized quartz grains; ghosts of mottled bioturbation structures.

5 m of metre-thick beds of massive, possibly bioturbated, red-brown quartz sandstone with aboundant recrystallized dolomitic matrix, passing gradually and conformably upwards to:

11 m of grey, recrystallized, poorly bedded intraclastic and bioclastic grainstone with quartz grains; in the upper two metres, it appears to be less recrystallized and fossiliferous. This lithofacies passes upwards with regular transition to:

28 m of white, rather massive conglomerate with millimetre- to decimetre-sized, well rounded limestone clasts, quartz veins and bioclasts. The matrix is arenitic with calcareous and quartz grains. Clast size seems to increase from the second lithofacies upwards, but there is no evidence of sorting or gradation within the conglomerate. The top of the conglomerate is cut by a sharp surface, marked by iron concretions which we consider to be the main Jurassic/Cretaceous unconformity surface.

The Clastic unit comprises both the Naifa Formation and the (inferred unconformably) overlying “brecciated limestone interval” of Beydoun (1966).

Based on the textures and the occurrence of sand-sized quartz grains, the carbonate-quartzose lithofacies are considered to be deposited in marine, low-energy, very shallow water with terrigenous influx; the calcarenite and the conglomerate are marine gravity flow deposits, possibly sedimented at the base of a scarp tectonic in origin. The clastic sedimentation is connected with the onset of the tectonic phase that strongly deformed the Jurassic sedimentary basins and formed horsts and grabens approximately at the Jurassic-Cretaceous boundary.

The fossil assemblage is represented by pelecypods, gastropods, crinoids, colonial organisms (corals, Hydrozoa), *Lithocodium* sp. and benthic foraminifers (*Nautiloculina* sp., *Trocholina* sp.). The fossils do not allow with precision to interpret the age, but a Late Jurassic age is inferred by stratigraphic position and regional considerations (see below).

Dolomitic unit (informal)

Above the unconformity surface (Fig. 5), the portion of this unit, examined in brief, consists of 7.5 m of brown, cross bedded sandstones, overlain by 30 m of metre-thick beds of red-brown, recrystallized dolomitic limestones and dolomites. This unit must be considered the base of the Lower Cretaceous (Barremian-Aptian) Qishn Formation (Beydoun 1997), present at regional scale.

SEDIMENTARY EVOLUTION

The succession studied opens interesting questions on the tectonics-sedimentation relationships which controlled the deposition of these Jurassic units. The syn-rift structural model proposed by Bosence (1997) and the regional stratigraphic column by Beydoun (1997) allowed us to outline the following evolution:

Kohlan-time (?Early Jurassic-Oxfordian *p.p.*). Development of high-energetic grabens under demolition with production of thick alluvial mantle. Variations in river energy are possibly due to the recurrence of tectonic activity.

Shuqra-time (Late Oxfordian-?earliest Kimmeridgian). Marine ingression into subsiding sectors characterized by gentle ramp topography, with no morphological or sedimentary evidence of faults. Subsequent shallowing upward sequence and disconformity at the top.

Madbi-time (Kimmeridgian). Sudden rise in sea-level on a flooding surface followed by slow but differentiated subsidence into distinct basins at regional scale.

Top-Madbi (? uppermost Jurassic). Unconformity surface possibly due to fall of high sea level. Subsequent shallow marine deposition; onset of tectonic activity and sedimentation of the Clastic unit

Jurassic-Cretaceous boundary. Main tectonic activity (?transtensional/extensional) which affected the whole southern Arabian Shield. It caused deposition of coarse material in almost all the known basins (*cf.* Jebel Billum in Wadi Hajar), gave rise to the emersion of horsts (*e.g.* Al-Mukalla High) and generated the erosional unconformity surface at regional scale.

Qishn-time (Barremian-Aptian). Cretaceous marine ingression on a more or less peneplanised surface.

CONCLUSIONS

The succession representing the Jurassic stratigraphy of Ras Sharwyn reveals a rather different sedimentary evolution from the one previously described in literature, although it is still possible to partly use the same formational terms. Innovative aspects concern both lithostratigraphic analyses and some palaeontologic data useful for palaeoecologic and biochronostratigraphical interpretations.

Kohlan Fm. A 60 m-thick unit whose lithologic and sedimentologic features indicate the transition from fluviatile environments to shallow marine deposition. The recurrent episodes of high energy probably reflect pulses of synrift extensional activity.

Shuqra Fm. This is divided into two members for a total of 70 metres of mostly calcareous lithofacies. On the whole, lithologic and sedimentologic features reflect a deepening-shallowing cycle. In comparison with western successions, the upper Carbonate Member occupies the stratigraphic position of the Marly Unit assigned by Beydoun (1964). The disconformity at the top lacks evidence of subaerial exposure.

Madbi Fm. The 30 m-thick measured marly succession is in fact probably thicker, as thinned by faults, and may fit Beydoun's classical Madbi Formation. The fossiliferous marls at the base of the unit marks the flooding surface on the disconformity. The unconformity at the top of the Madbi Fm. corresponds to a sequence boundary.

Clastic unit – Beydoun (1966) reported the "dolomite limestone" as representing the Naifa Fm., whereas the "conglomerate" was thought to be the layer just above the "Jurassic Cretaceous disconformity". In fact the two facies represent a continuous and gradating deposition facies and, according to the stratigraphical position, can be referred to the upper(most) Jurassic. This unit is also closed by an unconformity, corresponding to a sequence boundary, the stratigraphic result of the widespread pre-Cretaceous tectonics found in any South-Yemen succession.

Dolomitic unit – This may correspond to the base of the Qishn Fm, dated in literature as Lower Cretaceous (Barremian).

Interesting points come from the biostratigraphic information provided by some unexpected fossil assemblages with biota (brachiopods, cephalopods, echinoids) previously unrecorded from Ras Sharwayn. These new data agree sufficiently well with the ages indicated by Beydoun (1966), but rejuvenate the lithostratigraphic units compared with the updated chronostratigraphic indications of Howarth and Morris (1998) from Wadi Hajar. In our case the age of the upper part of Shuqra Fm. is Oxfordian rather than Callovian, and the basal Madbi Fm. possibly dates to Early Kimmeridgian and not to the Oxfordian.

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