

## Jurassic ammonites from Central Saudi Arabia (Jebel Tuwaiq and adjacent areas)

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### Abstract

The mapping of Phanerozoic rocks at 1:250000 scale by the Saudi Arabian Deputy Ministry for Mineral Resources and the French Bureau de Recherches Géologiques et Minières, since 1980, covered most of the Jurassic outcrops in central Saudi Arabia. Stratigraphic, sedimentological and palaeogeographic studies provided a precise framework for the ammonite faunas which are the main purpose of the present monograph. These faunas have already been applied by the authors to build a biochronological scale specific to the Arabian province correlated with that of Western Europe, very different from the former scales of Arkell and Imlay. A first result of the palaeontological study is an update of the Arab biochronological scale (based on the faunas observable in the field) and correlations with Western Europe. In this paper 17 zones or horizons are recognized which, for the most part, are based on taxa specific to the Arabian Province, with two exceptions for which the low diversity forced to choose a Western Europe species (Stephani Zone and Athleta Horizon). The ammonites studied are more than 2143 specimens, of which 2013 could be determined on at least a generic level, and whose ages range from the Early Toarcian up to the Early Kimmeridgian. About 104 species are described (28 in open nomenclature), of which 10 are new. These are distributed among 45 genera including 3 new (*Eoermoceras*, *Saudisphinctes* and *Alienisphinctes*), within 14 families. These 14 families are represented, very unequally in relation to each other, but also for each of them in terms of the present and/or dominant genera. The five best represented families are the Hildoceratidae of the Toarcian (7 species), the Sonniniidae in the Bajocian (12 species, including 2 new ones), the Stephanoceratidae in the Bajocian (20 species including 15 for the Ermoceratinae, a new genus with 2 new species, and 2 other possibly new species), the Bajocian-Bathonian Oppeliidae (18 species, dominated by the Arabian genera *Micromphalites*, *Thamboceras* and *Thambites*, and *Rebouliceras*), and the Callovian Pachyceratidae (20 species) with two dominant Arabian genera, *Pachyerymnoceras* and *Kurnubiella*. The other families, Graphoceratidae, Hammatoceratidae, Strigoceratidae, Sphaeroceratidae, Spiroceratidae, Perisphinctidae, Tullitidae, Aspidoceratidae, and Ataxioceratidae (with a new genus and species), although less represented, include several forms known from Western Europe. These ammonites have a determinant role in correlations between the Arabic and European zonal scales. The palaeoenvironmental and palaeobiogeographical setting of the Arabian ammonite faunas is the purpose of the third part of the monograph. The geographic distribution and composition of the successive faunas compared with the palaeoenvironmental conditions are dealt with, as well as the monospecific or monogeneric composition opposite to the more or less diversified faunas. The endemic character of the Arabian types, and their migration outside the Arabian Province which, together with the arrival in the Arabic domain of NW and/or Indian-Madagascan taxa, played a major role in the correlation of the biostratigraphical scales.

### Keywords

Saudi Arabia, Shaqra Group, Jurassic (Toarcian-Kimmeridgian), ammonites, palaeontology, biostratigraphy, environments, palaeobiogeography.

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## FOREWORD

This monograph is the culmination of several years devoted to the study of Jurassic ammonites in Saudi Arabia. With C. Mangold a complete study of the faunas was decided for producing a picture of the Jurassic ammonite faunas in Saudi Arabia more complete than the previous papers in which many taxa appeared with provisional names, especially the possible new species or genera (Énay & Mangold, 1985, 1994; Énay *et al.*, 1986, 1987a, 2007; Manivit *et al.*, 1990). Various reasons delayed its realization and in the meantime the disease took away Charles Mangold before the project was even drafted (see p. 158 the obituary notice). There is no doubt that his contribution to this work remains essential, both for his contribution during the preliminary studies and for the notes he left. It is not debatable that he would be co-author of this monograph.

The strictly palaeontological part of the monograph (Part 2) is preceded by Part 1 which deals with the stratigraphic and palaeoenvironmental setting of the ammonite faunas, which is based on the previous work of Énay *et al.* (1986, 1987a). What concerns the ammonite fauna and their biostratigraphic interpretation, necessarily revised from the new results, has the same authors. On the other hand, although some changes (e.g. the new interpretation of the Wadi Ad Dawasir “delta” by Énay *et al.*, 2007, 2009) or supplements (e.g. citations of some recent works on the same topics) have been introduced, the text on Lithostratigraphy and Palaeoenvironments is essentially that of BRGM field team geologists, which justifies the mention “with the contribution of Yves-Michel Le Nindre, Jacques Manivit and Denis Vaslet”.

## INTRODUCTION

A large part of the Jurassic outcrops of Saudi Arabia have been studied by the French BRGM (Bureau de Recherches Géologiques et Minières) during a 1/250000 scale mapping and mineral-exploration program of the Phanerozoic rocks, extending to the east of the Proterozoic Arabian shield. This program was realized on the DMMR (Saudi Arabian Deputy Ministry of Mineral Resources, now the Saudi Arabian Geological Survey, SGS) behalf. It was included the Buraydah Quadrangle (Manivit *et al.*, 1985a), the Al Faydah Quadrangle (Vaslet *et al.*, 1985b), the Darmā' Quadrangle (Manivit *et al.*, 1985b), the Wādī ar Rayn Quadrangle (Vaslet *et al.*, 1983), the Wādī al Mulayh Quadrangle (Manivit *et al.*, 1985a) and the Sulayyimah Quadrangle (Vaslet *et al.*, 1985a). The study of the Jurassic has been completed by exploration on the Shaqrā' Quadrangle and south of latitude 21° N (Fig. 1). The Jurassic rocks are part of the southwestern edge of the Arabian shelf (e.g. the Tethys domain) and outcrop in a convex arc hinged on Ar Riyād, the horns of the arc being oriented to the northwest and to the south. The total outcrops length is in excess of 1000 km between 18° and 27° N, and the width nowhere exceeds 85 km, whole outcrops extending between longitude 43° and 47° E. This elongate outcrop distribution allows a simple system of location by reference solely to the relevant latitude.

The largest Jurassic outcrop width is in the Ar Riyād region which was also the closest area to the open-sea domain of the Tethys. This area also corresponds to the greatest Jurassic outcrop thickness (1020 m between latitude 24° and 25° N) and will be referred to as the median part of the basin. Thicknesses decrease southwards from latitude 24° N, the whole series being only 550 m thick at the southern margin of the basin at latitude 21° N, and northwestwards from latitude 25° N, the estimated thickness of the series being 300 m at the northwest margin of the basin at latitude 26°30' N. All observations in the monograph refer to Jurassic outcrops that were on the margin of the Tethys Basin; the open-sea domain of the basin extended on the northeast of Ar Riyād, presently underlying the Arabian Gulf.

## PART I – STRATIGRAPHIC AND ENVIRONMENTAL SETTINGS OF THE AMMONITE FAUNAS (Figs 2-6)

### 1. LITHOSTRATIGRAPHY OF THE JURASSIC

Stratigraphic assignments of the Jurassic series are based primarily on the ammonite faunas in the median part of the basin (Figs 1-2), where Brankamp & Steineke (in Arkell, 1952), Powers *et al.* (1966) and subsequently Powers (1968) defined the lithostratigraphic divisions. These

divisions are still broadly valid today and retained here. However, the BRGM studies (i) defined new members based on combined lithology and sedimentology, (ii) precisely established some stratigraphic boundaries, and (iii) established lithosedimentologic units as a function of sequential criteria. Recent reviews have been published by Al-Husseini (1997, 2009). Although these new definitions are the most satisfactory in the clayey-carbonate facies of the median part of the basin, it has been possible to follow each unit through the thickness and lateral facies changes southwards and northwestward about the predominantly sandstone facies of the margins of the basin (Fig. 3).

The lower and upper boundaries of the Jurassic in Saudi Arabia are somewhat uncertain, based on purely paleontological evidence. The base was placed by Powers *et al.* (1966) at the discontinuity between Late Triassic Minjur Sandstone and Early Jurassic Marrat Fm, but it is not possible to say whether the lowermost part of the Jurassic is missing or not and would be represented (i) in part within the top of the Minjur Sandstone as suggested by Powers (1968) from correlations with subsurface data based on microflora, (ii) entirely or in part within the Lower Marrat, or possibly (iii) partly in both these formations. Results from the BRGM work have shed no further light on this problem, and so the Triassic age for the entire Minjur Sandstone and a possible gap with lacuna of the first stages of Jurassic is retained. The top of the Jurassic is also subject to doubt. It is impossible to say, without characteristic fossils, whether the top of the Hith Anhydrite corresponds to the end of the Jurassic (Tithonian), which is the hypothesis retained where, or whether the overlying carbonate Sulay Fm is also Jurassic, or Jurassic and Cretaceous, or entirely Cretaceous.

Gaps with lacunae of more or less long duration are suspected within the Jurassic series, but are difficult to be proved and calibrated owing to the episodic occurrence of the ammonite faunas. This uncertainty is amplified by the endemic character of the Arabian taxa, ammonites and the other groups. Lithological evidences of breaks of sedimentation are scarce, save top of unit D5 where the only non-deposition surfaces of wide extent in the marine deposits (ferruginous layers) are observed, at least in the central part of the outcrops. Other non-deposition surfaces but of not so wide extent occur in the Tuwaiq Limestone Fm when they are overlapping the body sandstone, e.g. Wadi ad Dawasir "delta" (Manivit *et al.*, 1990, fig. 18; Énay *et al.*, 2009, fig. 6).

New data, especially on possible discontinuities related to sequence boundaries can be found in studies on sequence stratigraphy by Le Nindre *et al.* (1990b), Al-Husseini (1997), Kadar *et al.* (2015), Al-Mojel (2017), Farouk *et al.* (2018) and Simmons & Davies (2018).

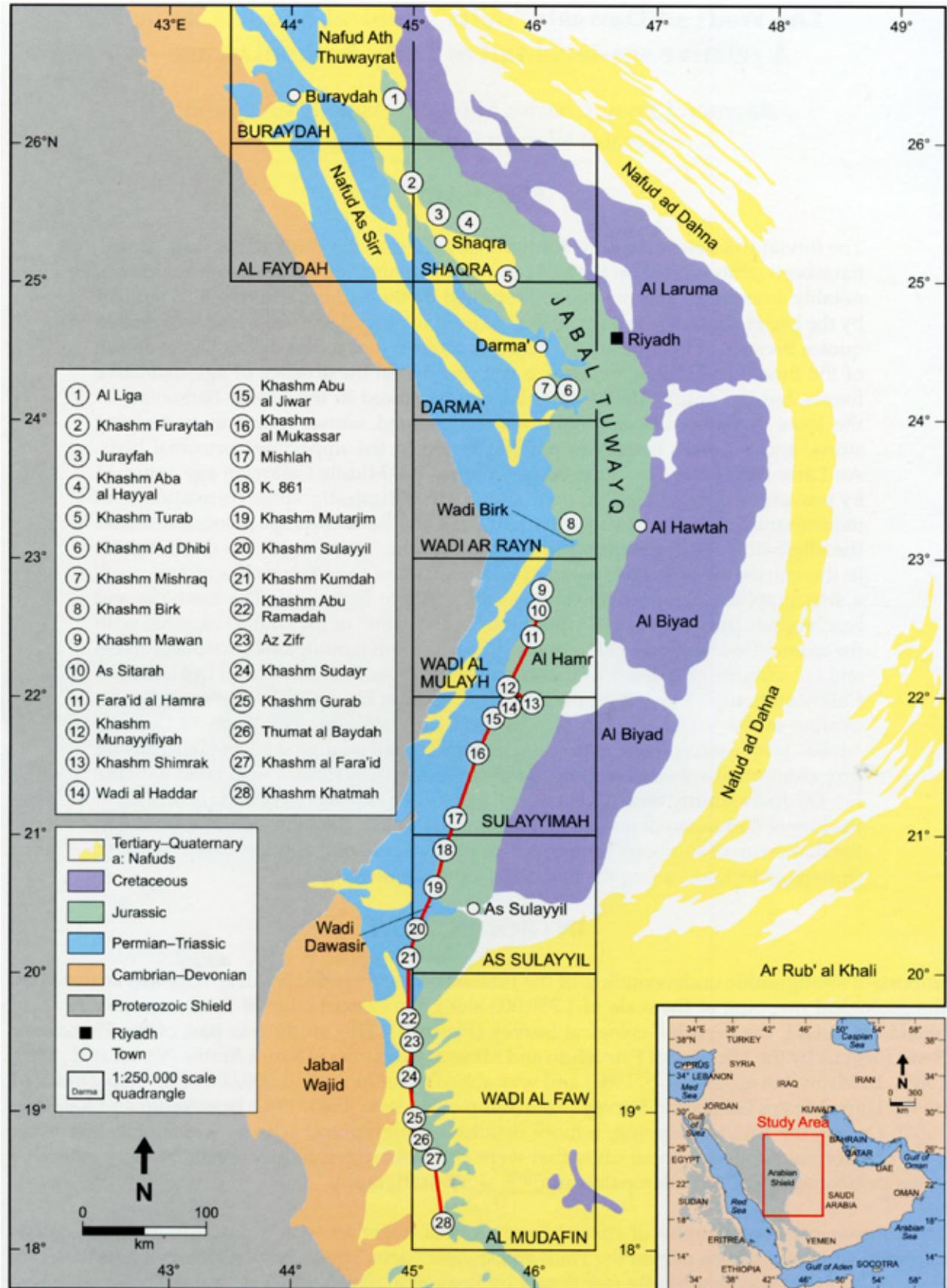


Fig. 1: Location map of Jurassic outcrops in central Saudi Arabia with the localities referred in the text and index map of relevant 1:250000 scale quadrangles. Modified from Énay *et al.* (2009, fig. 1).

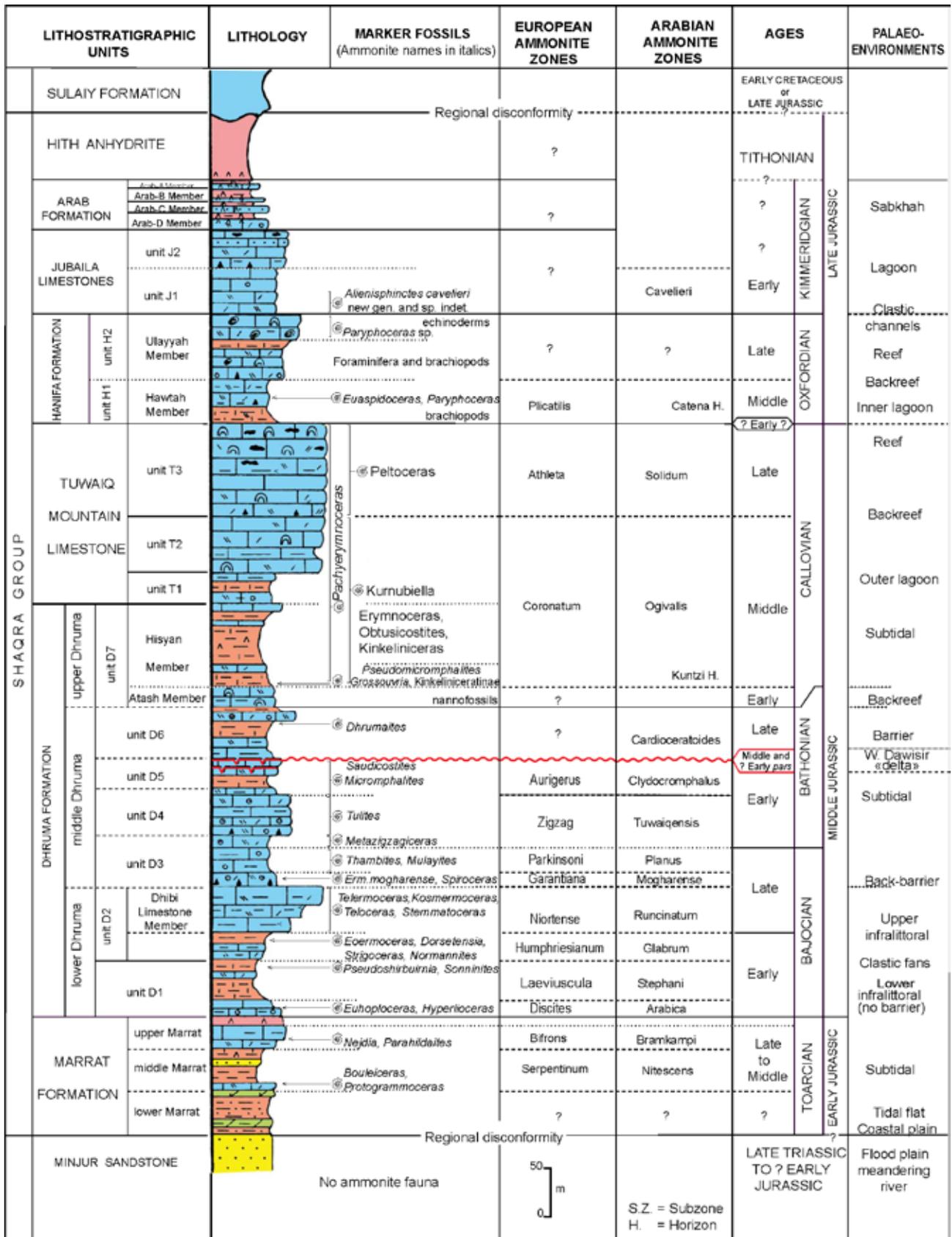


Fig. 2: Lithostratigraphy, biostratigraphy, chronostratigraphy and palaeoenvironments of the Shaqra Group. Composite reference section for Jurassic outcrops in the median part of the basin (Darmā' Quadrangle). Modified from Énay *et al.* (1986, 1987a), Énay & Mangold (1994), Énay *et al.* (2007, 2009), and Alméras *et al.* (2010).

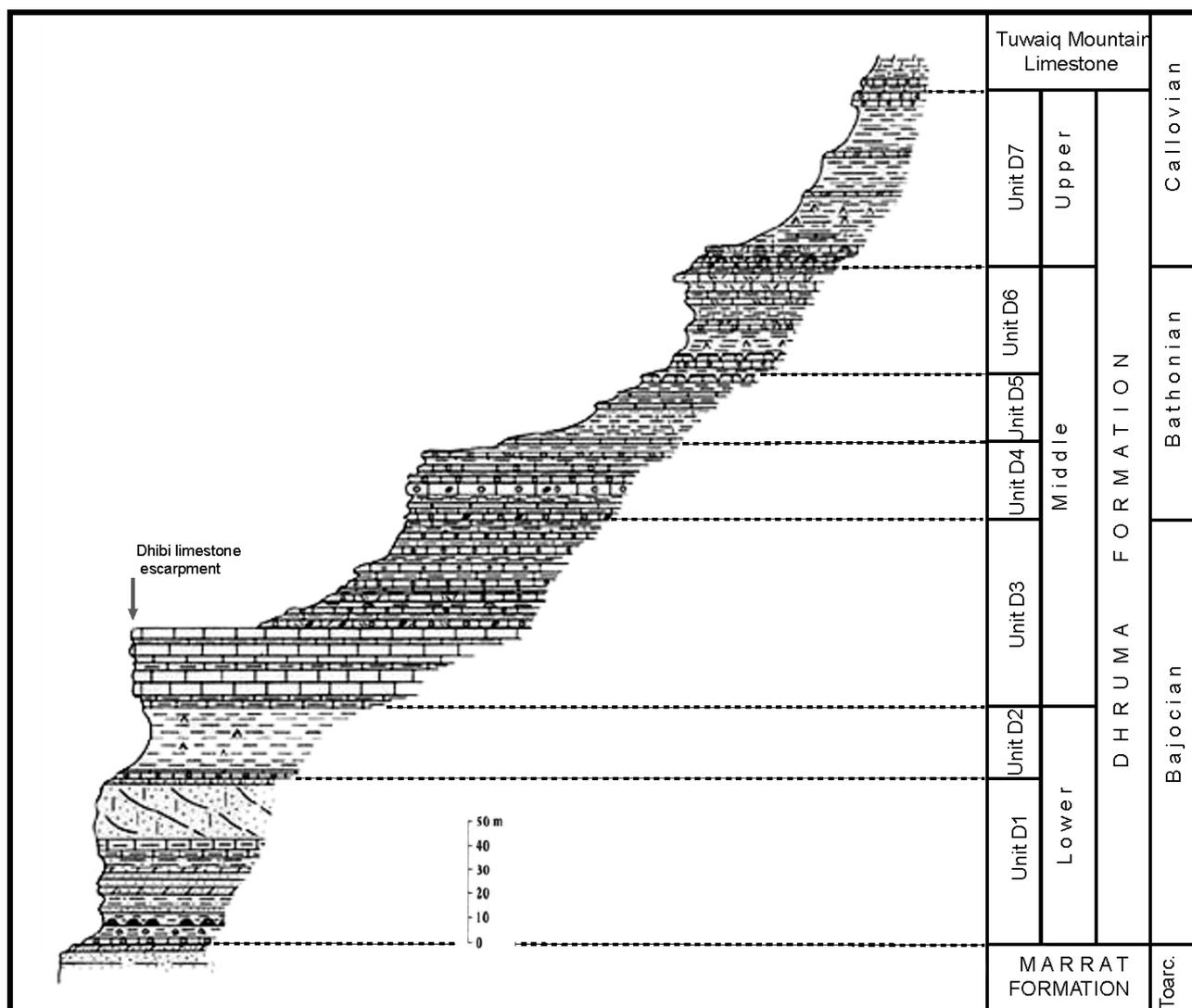


Fig. 3: Generalized lithostratigraphy of the Dhurma Fm (modified from Vaslet *et al.*, 1983). The Wadi ar Rayn Quadrangle map also based on Manivit *et al.* (1990, fig. 15) and Al-Mojel (2017, fig. 1.13).

### 1.1. Lithologic reference sections of the median region

#### 1.1.1. Marrat Formation

Defined by Brankamp & Steineke (in Arkell, 1952), near Marah (lat 25°04' N). It was formally established by Powers *et al.* (1966) and Powers (1968) from a reference section at Khashm adh Dh'ibī (lat 24°14' N), and subdivided the formation informally into lower, middle, and upper Marrat. The stratotype was latter revised by El-Assad (1973) who proposed the subdivisions of Shaqrā', Qarain, and Habbah members. Nevertheless, these names have not been accepted by DMMR. Detailed biostratigraphic and sedimentologic studies of the formation by Vaslet *et al.*, (1983) in the Wādī ar Rayn Quadrangle and by Manivit *et al.*, (1985b) in the Darmā' Quadrangle resulted in a modification of the reference section at Khashm adh Dh'ibī (lat 24°13' N),

in the median part of the basin (Fig. 2), albeit retaining the Powers (1968) division. The revised thickness of the Marrat Fm is 126 m, as opposed to a thickness of 102.5 m quoted by Powers (1968).

**Lower Marrat:** The lower Marrat, 47 m thick in the Khashm adh Dh'ibī section (Figs 1, 2 and 5), begins with sandstones and green and ochre claystones overlain by dolomite with mudcracks, solution cavities, and stromatolites. The sequence continues with gypsiferous clayey siltstones and sandstones with carbonate cement, and is completed by several beds of fossiliferous (bivalves, gastropods, echinoids, pelagic crinoids, foraminifers) dolomitic limestone alternating with sandstone.

**Middle Marrat:** The clearly individualized middle Marrat, 40 m thick at Khashm adh Dh'ibī (Figs 1, 2 and 5), is composed essentially by a monotonous series of

brick-red claystones and siltstones, with ochre nodular bioturbated dolomitic limestones very rich in ammonites (*Bouleiceras* and *Protogrammoceras*) at the base, and white or limonitic limestones containing bivalves at the top. The basal fauna-bearing beds are originally assigned by Brankamp & Steineke (in Arkell, 1952) and by Powers *et al.* (1966) to the top of the lower Marrat, but Énay *et al.* (1986, 1987a) and Énay & Mangold (1994) considered them to form the sequential base of the middle Marrat; they clearly represent marine sedimentation. Ammonite figured as *B. nitescens* in a more recent paper on the Marrat Fm (El-Sorogy *et al.*, 2017) is too weathered to be determined even generically.

The ammonite fauna of the basal beds of the middle Marrat is accompanied by brachiopods, gastropods, bryozoans, and sponges spicules, whilst echinoids and corals abound between lat 23°40' and 25° N. The microfauna consists of *Peudocyclamina liasica* Hottinger (P. Andreieff written communication, 1982) accompanied by ostracods.

**Upper Marrat:** The upper Marrat, 39 m thick at Khashm adh Dh'ibī, begins with bioclastic limestones, limonitic limestones, and green clay, overlain by brown claystones containing microgastropods and by ochre claystones containing *Nejdia*, the most abundant, and fewer *Parahildaites*. The sequence continues with an assemblage of cream nodular or laminated limestone containing rare gastropods, capped by about 10 m of massive gypsum with rare clayey intervals and small slabs of limestone containing bivalves. The massive gypsum was considered by Powers *et al.*, (1966) to represent the base of the Dhurma Fm. Énay *et al.* (1986, 1987a) and Énay & Mangold (1994) however, consider the gypsum to be the final phase of the upper Marrat sequence, and the Dhurma Fm sequence to begin with the overlying bed of limestone containing fibroradial oolites.

Like the *Bouleiceras* already mentioned, the so-called *Nejdia* figured by El-Sorogy *et al.* (2017) are unsuitable for definite identification.

### 1.1.2. Dhurma Formation

The Dhurma formation was defined by Brankamp and Steineke (in Arkell, 1952) and by Powers *et al.* (1966) and Powers (1968) who divided it into three main units the lower, middle, and upper Dhurma. Biostratigraphic and sedimentologic studies by Vaslet *et al.* (1983), Manivit *et al.* (1985c), and Énay *et al.* (1986, 1987, 1994) have led to a subdivision of the formation into seven lithosedimentologic units (D1 to D7) which are best developed in the Darma' Quadrangle (Manivit *et al.*, 1985c). A new reference section in the median part of the basin is located between Khashm adh Dh'ibī and Khashm Mishraq, along lat 24°13' N, where the formation reached its greater thickness of 447 m (Fig. 3).

**Lower Dhurma: Unit D1.** 57 m thick in the reference section unit D1 begins with a layer of limestone containing contiguous fibroradial, oolites, overlain by glauconitic claystone intercalated with bioclastic limestone containing a first sonniniid fauna (dominated by the subgenera *Sonninia* and *Euhoploceras* and the more limited occurrence of *Hyperlioceras*, *Haplopleuroceras* and *Fontannesia*) and stromatolitic dolomite. The unit continues with interbedded laminated dolomite, stromatolites, variegated siltstone, and sparry limestone, which have yielded a *Pseudoshirburnia-Sonninites* fauna. The remainder of the unit comprises a clayey sequence with thin limestone beds and a bioclastic calcarenite with a second sonniniid fauna.

**Unit D2.** In the Khashm adh Dh'ibī section, unit D2 is 86 m thick. The lower half (46 m) consists of green claystone, with a few intervals of cream, fauna-rich (*Spongina*) limestone near the base, and other nodular limestone. The first few metres contain the first (or "primitive") *Eoermoceras* fauna (new genus) and *Dorsetensia*, with *Normannites*, *Stephanoceras*, and some Sonniniids. The upper half (40 m) of the unit comprises white, massive, bioturbated limestone (Dhibi limestone member) with clayey intercalations and a second (principal) *Ermoceras* fauna, in which *Kosmerrmoceras* is largely dominant with a great diversity of species and other rarer stephanoceratids.

The macrofauna other than the ammonites is particularly rich in the lower Dhurma between lat 24° and 25° N. It consists of bivalves, brachiopods, sponges, echinoderms, and nautiloids. The microfauna in unit D1 is of no stratigraphic interest. However, the appearance of *Nautiloculina oolithica* (Möhler) from the base of unit D2 is characteristic, whilst *Haurania deserta* Henson and *Trocholina* sp. 1 appear in the Dhibi limestone member and continue into unit D3.

**Middle Dhurma: Unit D3.** The unit is 52.5 m thick in the reference section; it begins with several metres of yellow oolitic calcarenites containing intraclasts of fine-grained limestone. The unit as a whole is composed of pelletoid, bioclastic calcarenite, is fairly bioturbated and clayey, and contains a much diversified fauna. Two distinct ammonite faunas have been found in the median part of the basin; a third *Ermoceras* fauna (e.g. *E. gr. mogharensis*) and *Spiroceras* in the first 11 m, and a *Thambites* and *Rebouliceras avus* fauna above.

**Unit D4.** The unit is 44 m thick in the reference section and very calcareous. It begins with intraclastic biocalcarenite overlain by a fairly massive assemblage of nodular limestone, oolitic limestone, and bioclastic limestone. This unit has produced rare *Tulites*, a fauna of great extent in relation to other ammonite faunas in the Dhurma Fm.

**Unit D5.** The unit is 41 m thick in the reference section; it begins with fine-grained limestone and clayey limestone overlain by green and ochre carbonate claystone. The

upper part comprises calcarenite and white bioturbated limestone capped by a ferruginous hardground. The unit has produced a *Micromphalites* fauna at several levels.

**Unit D6.** The unit is 55.5 m thick in the reference section; it begins with bioclastic calcarenite containing a bivalve and gastropod fauna, and with clayey limestone. This is overlain by an assemblage of green platy claystone, the upper, calcareous part of which contains a *Dhrumaites* fauna. The unit is capped by a band of pelletoidal and oolitic calcarenite (“Riyadh stone”), overlain by a layer of claystone, and biolastic clayey limestone. Brachiopods are abundant, following a complete faunal change between unit D2 and D3, as are echinoids, which mark the break of sedimentation between the two units less clearly. Gastropods and bivalves are rather abundant, with species that have a fairly considerable vertical distribution. Unit D3 contains large nautiloids and, like unit D4, has produced an abundant fauna of mollusks, bryozoans, crinoids, and algae. The unit D5 contains abundant brachiopods, bivalves, and regular urchins, whilst unit D6 contains bivalves, pelagic crinoids, isolated corals, and algae. The microfauna is of no stratigraphic interest, with the exception of *H. deserta*, and *Trocholina* sp. 1 from the upper part of the lower Dhruma that continue into unit D3.

**Upper Dhruma:** **Unit D7.** The unit is 111 m thick in the reference section at Khashm Mishraq. It may be subdivided into two lithologic assemblages that correspond to the “Atash” and “Hisyan” members defined by Powers *et al.* (1966). The “Atash” Member, 26 m thick, begins with brown calcarenites containing corals and intraclasts, overlain by clayey and bioclastic limestones rich in fauna. This member has no yielded ammonites. The “Hisyan” Member, 85 m thick, begins with gray bioclastic, clayey limestones containing rare *Grossouvria*, overlain by a thick series of green claystones containing bivalves and incorporating a few calcarenite-beds about the top. The top of the unit is composed of fairly clayey and fossiliferous nodular limestones, containing an *Erymnoceras* and *Pachyerymnoceras* fauna with some Indian-Madagascan elements (*Pseudomicromphalites*, kenkeliniceratines). Contrary to what was stated previously (Énay *et al.*, 1986, 1987a), *Erymnoceras* is quite certain and frequent only in this unit (Hisyan Member) and absent from the overlying Tuwaiq Limestone Fm (T1 unit). The macrofauna other than ammonites consists of bivalves, gastropods, bryozoans, and echinoderms from the lowest “Atash” Member. The echinoderms show a renewal of part of the fauna from the base of the unit; the brachiopods display few new species, and spongiae and nautiloids abound. Echinoids and bivalves predominate in the Hisyan Member and are accompanied by gastropods, brachiopods, and algae. The microfauna is particularly interesting, and several foraminifers determining a biozone give greater emphasis to the biostratigraphic cut-off selected: *Trocholina*

*gr. elongata* Leupold, *Steinekella crusei* Redmont, *Praekurnubia crusei* Redmont, and *Pfenderina gracilis* Redmont (P. Andreieff, written communication, 1982).

### 1.1.3. Tuwaiq Mountain Limestone

Tuwaiq Mountain Limestone, formerly defined by Brankamp and Steineke (in Arkell, 1952) near latitude 24°50' N (Wādī al Hisyān), was amended by Powers *et al.* (1966) and Powers (1968) from subsurface data (Riyadh deep well). Vaslet *et al.*, (1983) have defined three lithosedimentologic units (T1 to T3) that can be recognized over the greater part of the basin; these have been redefined by Manivit *et al.* (1985c) in a new reference section at Khashm al Qaddiyah near ar Riyād (latitude 24° 31' N) where the formation is 184 m thick (Fig. 4).

**Unit T1.** The unit is 32 m thick in the reference section and throughout the median region, it comprises a series of fine-grained, fairly clayey limestone intercalated with beds of brown calcarenite and Hite bioturbated nodular limestone. Rare *Pachyerymnoceras* specimens have been found locally.

**Unit T2.** The unit is 56 m thick in the reference section, it comprises a monotonous assemblage of fine-grained or gravely bioclastic limestone, relatively bioturbated and clayey, containing isolated corals. This unit has also produced a scarce and poorly diversified *Pachyerymnoceras* fauna.

**Unit T3.** The unit is 96 m thick in the reference section, the unit consists of very extensive bioclastic limestone and calcarenite and is rich in silicified corals and stromatoporoids. It locally gives rise to reef forms with bioherms in the median part of the basin. Ammonites (*Pachyerymnoceras* and few *Peltoceras*) was rare until it was received the collection of Dr Al-Asa'ad's from the Al-Mu'ayshibah area, NW of Riyadh, about 25°34' N.

Other than ammonites, the Tuwaiq Mountain Limestone contains rich bivalve and gastropod faunas. Echinoids and pelagic crinoids are present, with the echinoids well developed in several layers of unit T3 (between latitude 25° and 22° N). Brachiopods are rarer and are restricted to units T2 and T3. Sponge spicules are common throughout the formation. Silicified corals and stromatoporoids abound in unit T3 where they are commonly large and give way to bioherms in the vicinity of Ar Riyād. Nautiloidea, common in all three units, represent forms endemic to the Arabian shelf (Tintant, 1987). Gastropods (Fischer *et al.*, 2001) and algae have been recorded in units T2 and T3.

The microfauna is also rich in the Tuwaiq Mountain Limestone. The foraminifers are benthic and delineate biozones that should be used with care because these organisms are commonly associated with given facies within the formation and thus with their evolution from the centre of the basin about the margins. Apart from

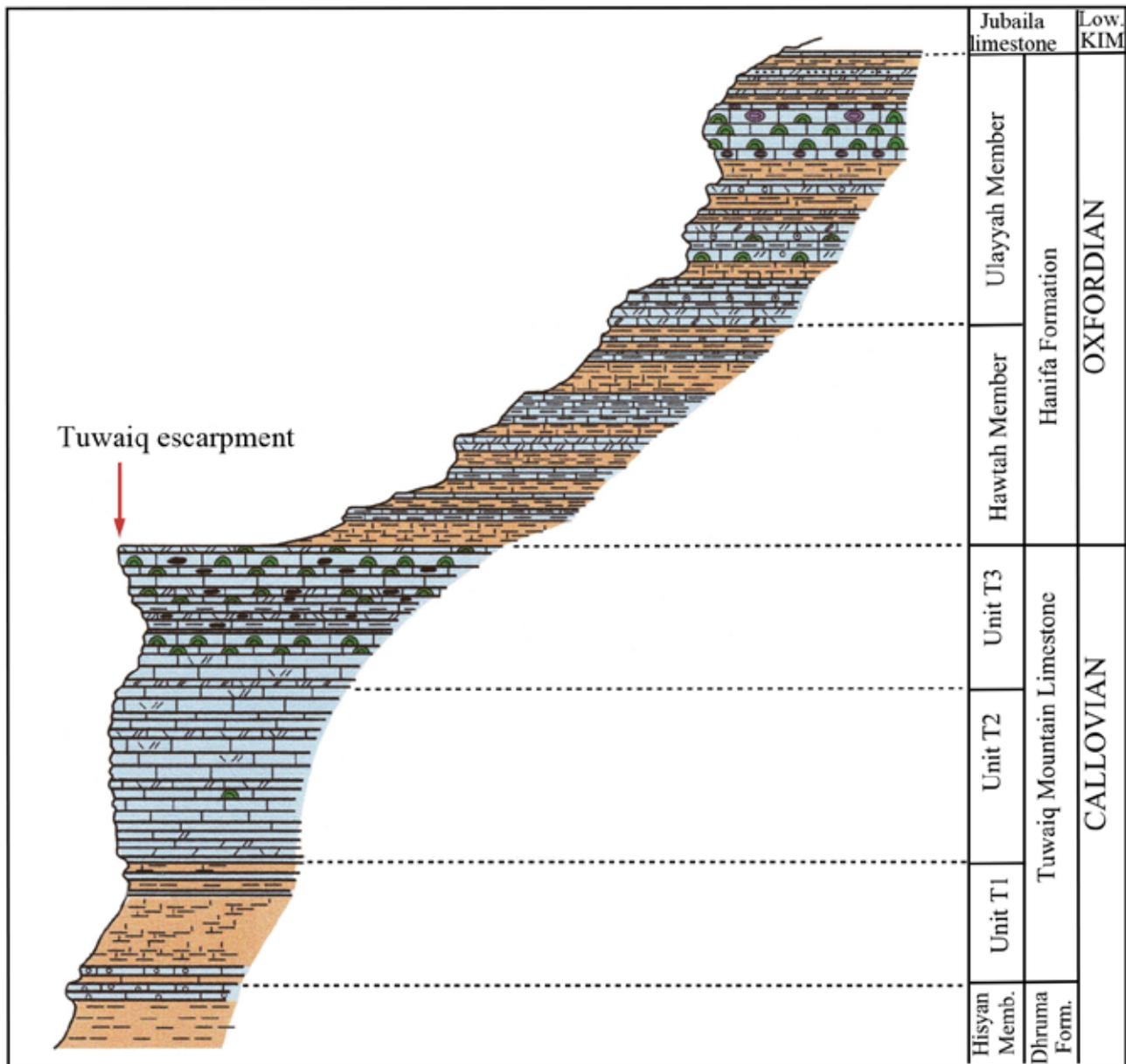


Fig. 4: Generalized lithostratigraphy of the Tuwaiq Mountain Limestone and Hanifa Fm [modified from Vaslet *et al.*, 1983, the Wadi ar Rayn Quadrangle; also based on Manivit *et al.* (1990, fig. 15) and Al-Mojel (2017, fig. 1.13)].

*T. gr. elongata* and *P. crusei*, already recorded from unit D7 of the upper Dhrama, Unit T1 contains *Kurnubia brankampi* Redmont and *Trocholina palastiniensis* Henson, which continue into unit T2 and T3. Unit T2 is characterized by the appearances of *Kurnubia gr. palastiniensis* Henson and *Trocholina sp. 2*. The distribution of *Steinekella steinekei* Redmont is directly associated with the extension of perireefal facies within the formation. This foraminifer appears at the base of unit T2 from Darmā' (latitude 24°30' N) northwards, but south of latitude 24° N it is limited strictly to the unit T3. *Kurnubia gr. wellingsi* Henson appears about the base of the unit T3 between latitude 25° and 24° N, appearing latter farther south.

#### 1.1.4. Hanifa Formation

The Hanifa Fm was defined by Brankamp and Steineke (in Arkell, 1952) and emended by Powers *et al.* (1966) and Powers (1968). A new section is given by Vaslet *et al.* (1983) who subdivided the formation into two informal members corresponding to lithosedimentologic units (H1 and H2) at Ulayyah (latitude 23°54' N), where the formation is 126 m thick (Fig. 4).

*Unit H1.* Unit H1 or the Hawtah member, 52 m thick in the reference section, begins with yellow clayey limestones overlain by pelletoid limestones rich in bivalves. It ends with bioclastic and bioturbated limestone with hardened surfaces. The upper part of unit H1 has yielded an

*Euaspidoceras* fauna with fragmentary casts of large possible *Paryphoceras* (first attributed to *Perisphinctes* l. s.).

**Unit H2.** Unit H2 or the Ulayyah member, 74 m thick in the reference section, begins with ochre, intraclastic, cross-bedded calcarenites containing bivalves. This is overlain by an alternation of bioclastic calcarenites and pelleted clayey limestones, in turn overlain by a finer grained, pelleted and oncolitic, clayey-carbonates assemblage. The uppermost calcarenite part of the member contains coral-bearing reef (bioherms and biostromes).

Ammonites are almost absent with a single specimen of a large and complete *Paryphoceras*. The Hanifa Fm contains a rich macrofauna with a complete renewal of the brachiopod fauna (which are rare in the underlying formation). Echinoids are fairly common in the lower part and accompany the reef facies of the Ulayyah member. Bivalves follow the same pattern, although some species known from the Dhurma Fm remain. Large nautiloids are common in the Hawtah Member (Tintant, 1987), whereas bryozoans and corals abound in the Ulayyah Member.

The microfauna enables the definition of two biozones: *Trocholina* sp. 2 in the Hawtah member, and the Ulayyah Member marks the appearance of *Alvaeosepta jaccardi* (Schrodt) from the base upwards.

### 1.1.5. Jubaila Limestone

The Jubaila Limestone, defined by Brankamp and Steineke (in Arkell, 1952) and revised by Powers *et al.* (1966) and by Powers (1968), is entirely carbonate in the median part of the basin. The reference section (24°53' N) was emended by Manivit *et al.* (1985c) who have defined two lithosedimentologic units (J1 and J2) over a total thickness of 87 m.

**Unit J1.** This unit, in the median part of the basin, begins with white and brown limestones that alternate with bioclastic and lithoclastic calcarenites, and is interrupted by several hardened surfaces. The first 20 metres yielded in several sites *Perisphinctidae* misidentified as *P. jubailensis* Arkell (Énay, 1986, 1987a), are partly new or close to a known form of Western Europe.

**Unit J2.** The unit displays clayey limestones, bioturbated calcarenites, and some stromatoporoid-bearing limestones, together with partially dolomitized layers alternating with beige fine-grained limestones.

Other than ammonites, the macrofauna of the Jubaila Limestone is rich: echinoids and crinoids are more abundant in the lower part; brachiopods, bivalves, and gastropods abound; sponge spicules are rarer; nautiloids are well represented. The microfauna is dominated by an association of *Kurnubia wellingsi*, *Alvaeosepta jaccardi*, and *Nautiloculina* sp. These are accompanied by ostracods, but unfortunately are of no precise stratigraphic value.

### 1.1.6. Arab Formation and Hith Anhydrite

The terminology proposed by Steineke (in Powers *et al.*, 1966) was revised by Powers (1968) who proposed a new definition based on drill-hole data in the Az Zahrān (Dharan) region where the Arab Fm is 127.5 m thick. Powers (1968) divided the formation into four members as follows, from bottom: Arab-D member, Arab-C member, Arab-B member, and Arab-A member. These members represent four depositional cycles (sequences) each with carbonate base and anhydritic top. The anhydritic part of the Arab-A member is very thick and is regarded by Powers (1968) as a separate formation, the Hith anhydrite, defined in outcrop from Dahl Hit section (90.3 m thick) and completed using drill-hole data (the formation being as much as 153 m thick in drill-holes).

**Arab-D Member.** The Arab-D member is represented by an assemblage of gray bioturbated platy limestones in which reworked layers contain ooliths and pellets and beige bedded dolomites. Algal laminites occurs in the upper part. The evaporitic assemblage is limited to a few outcrops of gypsum and solution residues.

**Arab-C Member.** The Arab-C Member is composed of an alternation of gray bedded limestone and pale lithoclastic and bioclastic calcarenite, in places oolitic and partially to fully dolomitized. Rare sandstone beds and stromatolitic gypsiferous limestone are intercalated in the upper part.

**Arab-B Member.** The Arab-B Member begins with pitted pelletoidal dolomitic limestone, and continues with cream or green gypsiferous clayey-carbonate facies, very dislocated and disseminated with solution breccia over the chaotic surface of the Arab-C Member.

**Arab-A Member and Hith Anhydrite.** The Arab-A Member and the Hith Anhydrite are hard to characterize. The discontinuous carbonate or evaporitic outcrops located between the clayey-carbonate facies of the Arab-B Member to the west and the Sulaiy Fm carbonates to the east have been assigned to this sequence.

The fossils recorded in the various members of the Arab Fm occur mainly at the base of each member. They are bivalves, echinoids, and pelagic crinoids, with rare gastropods that are most common in the Arab-B Member. The relatively abundant microfauna differs little from that of the Jubaila Limestone: *Kurnubia* gr. *wellingsi* and *Nautiloculina* sp. occur in the Arab-D and Arab-C members. No microfauna has been recorded in the Arab-B Member whereas the foraminifer *Everticyclammina* sp. is present in the Arab-A Member.

## 1.2. Lithological Evolution to the South

The isochrones used for relating sections is the boundary between unit H1 (or Hawtah member) and unit H2 (or Ulayyah member) of the Hanifa Fm (Fig. 4). This boundary marks the maximum transgression of the Late Jurassic, following the large transgressive episode of the

upper part (unit T3) of the Tuwaiq Mountain Limestone. It corresponds to a well-marked reworking at the base of the megasequence that ends with the evaporitic deposits of the Hith Anhydrit.

General evolution of Jurassic lithologies from the median region to the southern margin of the basin is from marine deposits to more or less continental deposits. Assignment of lateral facies variation southward is supported by faunal control or (when faunal control is not possible) by geometric control.

**1.2.1. Marrat Formation**

Southward from Khashm adh Dh'ibī the clayey layers of the lower Marrat become more silty and are invaded by fine- to medium-grained sandstones. At Wādī Birk (lat. 23°15' N) the lower Marrat is entirely sandy (clayey sandstones and coarse-grained sandstones with cross-bedding) and is only 12 m thick. At latitud 23° N the thickness is reduced to 6.5 m, with a lithology of coarse-grained sandstone arranged in festoons and pedogenized clayey sandstones containing plant debris and ferruginous beds. At Khashm Māwān (lat 22°50' N) the lower Marrat

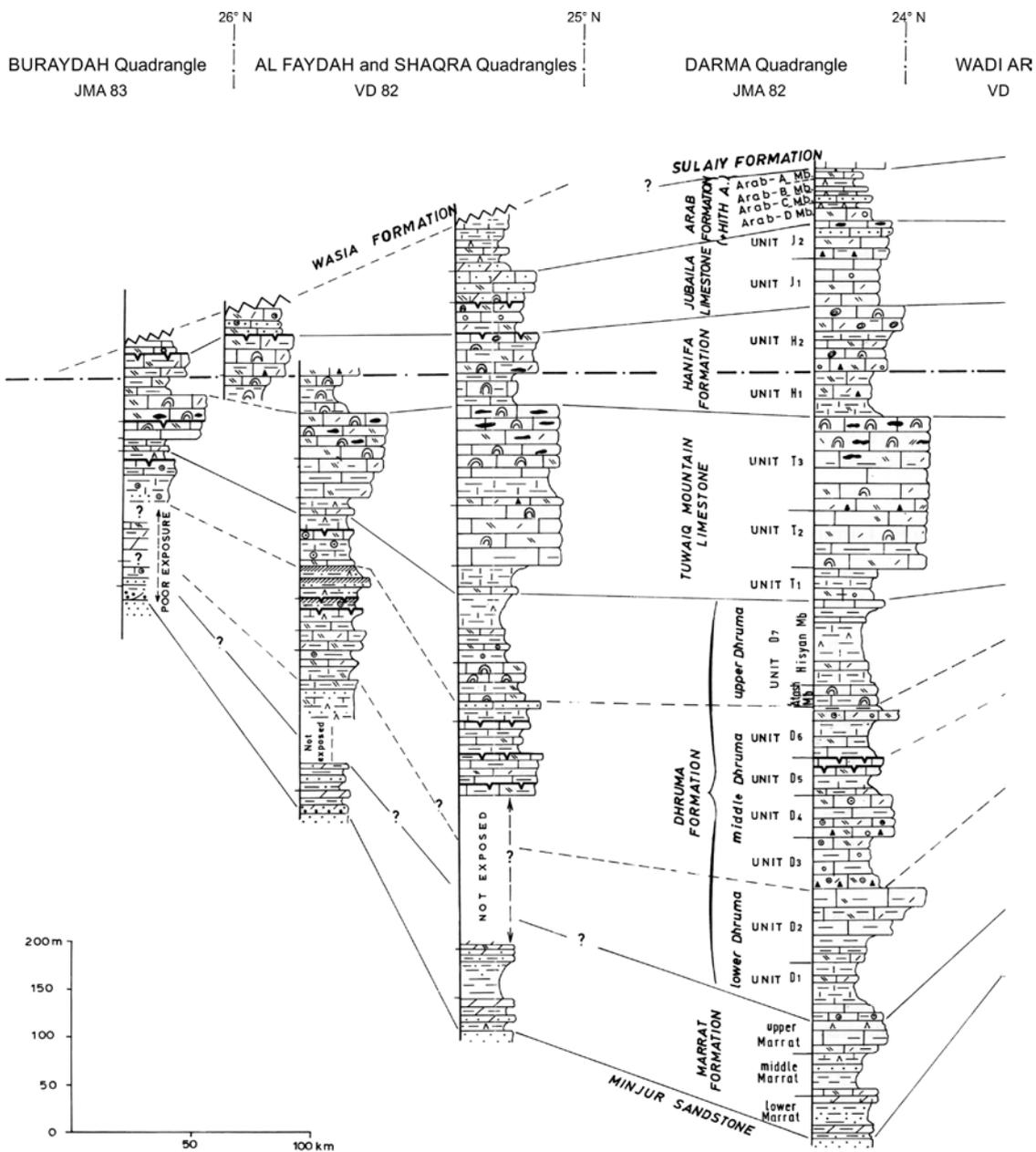


Fig. 5: Lithostratigraphic correlations among the Jurassic successions in central Saudi Arabia. Modified from Énay *et al.* (1986, 1987a) and Manivit *et al.* (1990).

comprises but a few meters of sandstone containing clay galls, and it disappears totally at the latitude of Al Ahmar (lat 22°30' N).

The Middle Marrat also decreases in thickness southward (29 m at lat 23° N) whilst becoming enriched in terrigenous material. The *Bouleiceras* beds do not extend south of lat 23°45' N, being replaced by ochre bioclastic and sandy dolomite containing ferruginous oolites. South of Wādī Birk (lat. 23°15' N) the basal beds are represented by "loaves" within brick-red sandy claystone very rich in ferruginous oolites; the upper third of the member at this latitude shows episodic influx of

coarse-grained sandstones with inclined bedding and characteristic crusts. The middle Marrat at Khashm Māwān (lat 22°50' N) displays red laminated sandstone, white or green claystone, and cross-bedded sandstone, whilst south of Al Ahmar (lat 22°30' N) the middle Marrat has become entirely sandy and can no longer be distinguished from the upper Marrat.

The basal *Nejdia*-bearing bed of the Upper Marrat disappears southward and is no longer visible south of lat 23°50' N. Detrital material becomes interbedded in the upper Marrat sequence south from Khashm al Khaltā (lat 23°35' N) until south of Wādī Birk (lat. 23°15' N),

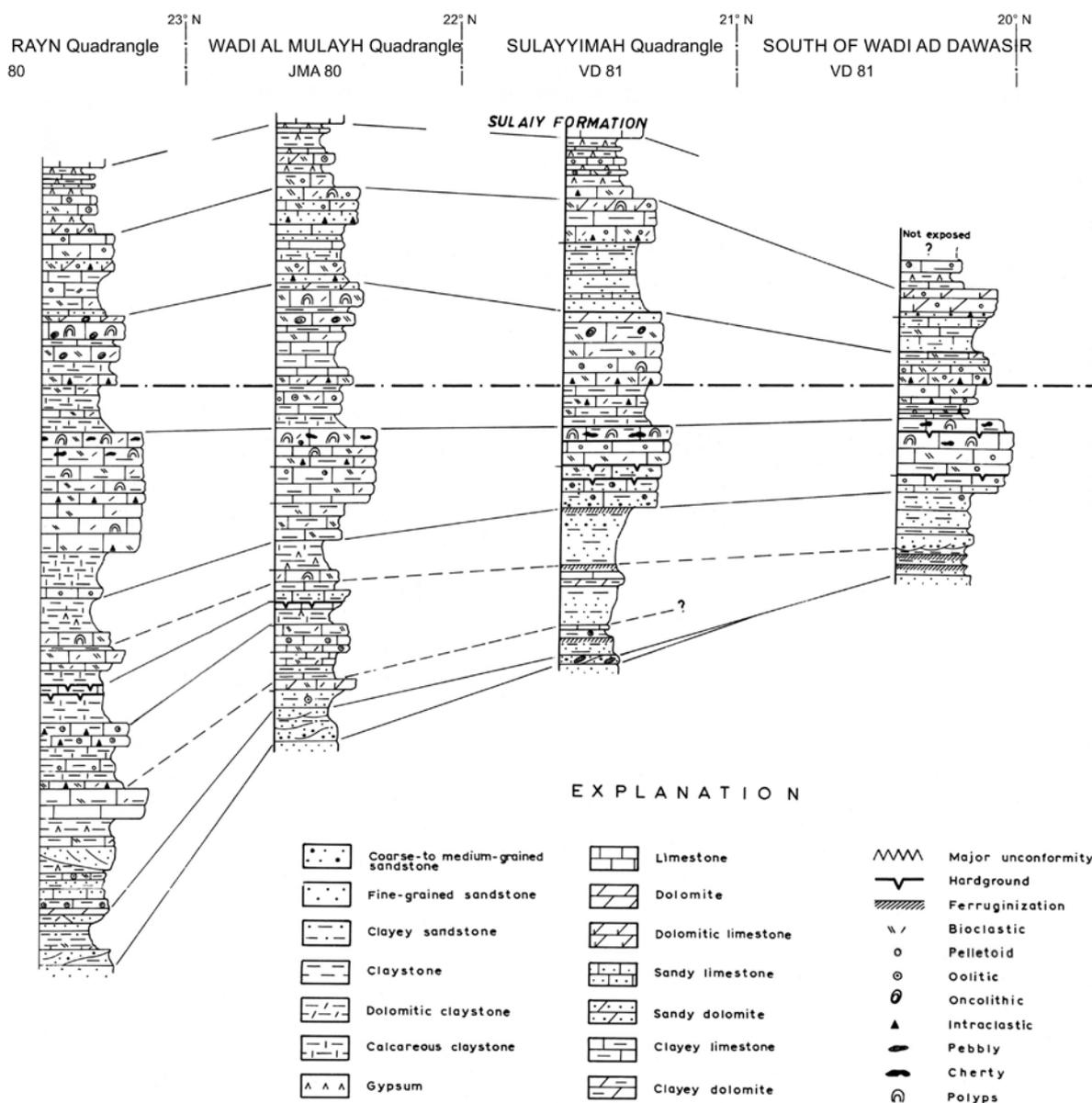


Fig. 5: Continued

there is a well-developed sandstone facies showing high-energy festoon bedding.

South of Al Ahmar (lat 22°30' N) the Marrat Fm is entirely sandy and cannot be differentiated; at Jabal Fahhāmāh (lat 22° N) the entire Marrat Fm is represented by only 16 m of heterogranular cross-bedded sandstones containing ferruginous oolites, gray claystone, and lenticular sandstone with plant remains. By Khashm al Mukassar (lat 21°35' N) the Marrat Fm is 9 m thick with pedogenized sandy and clayey facies, and it then abruptly disappears southward transgressed by the Dhurma Fm, which lies directly on Minjur sandstone south of this latitude.

### 1.2.2. Dhurma Formation

**Lower Dhurma Fm:** Unit D1 decreases in thickness southward Khashm adh Dh'ibī (41 m at Khashm al Khaltā – lat 23°35' N) and the first sonniniid fauna (*S. arabica*), as well as the underlying gypsum, disappear south of lat 23°30' N. The basal claystone becomes charged with ferruginous oolites, stromatolitic horizons become rarer, the dolomite becomes quartzitic and limonitic, and sandstone (either fine grained with inclined bedding, or heterogranular and lenticular) appears in place within the series; the second sonniniid fauna (*Pseudoshirbuirnia*) is encountered in the calcareous sandstone, which increasingly replace the nodular limestone at the top of the unit. By lat 23° N the series has been reduced to a thickness of 33 m and is entirely sandy-clayey with ferruginous oolites and surfaces. Limestone beds are no longer present and the third sonniniid fauna, located in bioturbated carbonate sandstone, disappears toward this latitude. At Jabal Fahhāmāh (lat 22° N) the unit D1 consists of 25 m of sandstone with a hematite cement and plant debris, and incorporates rare intervals of gray claystones and localized ochre dolomite containing ferruginous oolites at the top. The unit D1 is only 21 m thick at Khashm al Mukassar (lat 21°35' N) where it consists of sandstone bodies with flat sedimentation and ferruginous surfaces containing plant debris, and of red claystones containing ferruginous oolites in the upper part. South of this latitude, the unit D1 is entirely sandy and is no longer identifiable.

The unit D2 increases in thickness from 86 m to 91 m between lat 24° and 23° N and the clayey portion of the unit displays substantial facies variations. It is invaded by sandstone bodies, as much as 23 m thick, with inclined sets dipping very steeply to the northeast but becoming increasingly flat southward; this sandstone was emplaced above and at the same level as the first *Ermoceras* fauna. South from Wādī Birk, at lat 23° N, the entire clayey part of unit D2 becomes replaced by sandstone and the fauna disappears; the sandstone thickness is also considerably reduced and becomes nonexistent by lat 22°10' N. The carbonate portion of unit D2 (the “Dhibi limestone member”) displays a more consistent

evolution southward, with a progressive reduction in thickness from 40 m to 11 m at Al Ahmar (lat 22°30' N) where the facies become calcareous and dolomitic. The principal *Ermoceras* fauna can be recognized as far south as lat 22°15' N, beyond which the facies becomes clayey and gypsiferous, containing ferruginous oolites. These beds are overlain by ochre dolomite, which disappears by lat 21°48' N, thus marking the eastern boundary of the “Dhibi limestone member”. The units D1 and D2 cannot be differentiated at this latitude and are represented by a few metres of kaki gypsiferous claystones, fairly dolomitic, and with ferruginous oolites.

*Middle Dhurma.* The facies of the unit D3 does not change southward from Khashm adh Dh'ibī, but the unit thins to 36 m at lat 23° N and the *Ermoceras* gr. *mogharensis* and *Spiroceras* fauna have not been recognized south of lat 23°45' N. At the latitude of Wādī Birk (lat. 23°15' N) the first *Thambites* specimens were recorded from 5 m above the base of the unit. South of Khashm Māwān (lat 22°50' N) the facies becomes finer grained (biomicritic) and is associated with green or brown calcareous clay. Around Al Haddar (lat 22° N) and Khashm ash Shajarī (lat 21°50' N) the fauna is particularly rich in *Thambites*; the unit at this point is 26 m thick and ferruginous oolites are disseminated in the upper part. South of lat 21°48' N the unit is invaded by beige, fine-grained sandstones with flat or inclined stratification, and by micaceous siltstone; ammonites are no longer present. At lat 21° N unit D3 is entirely sandy and is no longer recognizable because of its confusion with the lower Dhurma facies.

The facies of the unit D4 becomes more pelletoidal and clayey southward from Khashm adh Dh'ibī. Near lat 23° N the unit is very bioturbated, contains dispersed ferruginous oolites, and has thinned to 28 m. It is 20 m thick near Al Haddar (lat. 22° N) where the limestone is finer grained and ubiquitously bioclastic with a brown indurated oolitic slab developing at the top. South of lat 22° N the unit D4 is hard to distinguish from the unit D5 because both two units are very similar in nature. The *Tulites* fauna, however, is recognizable to about 21°15' N in the white fine-grained limestone facies associated with green gypsiferous claystone.

The unit D5 decreases in thickness to 31 m at lat 23°45' N and 26 m at lat 23° N, with the facies varying only slightly southward to Ahmar (lat 22°30' N). The upper limestone then passes laterally southward to a hematitic crust containing ferruginous oolites, whilst the rest of the series becomes clayey with beds of bioclastic limestone containing rare *Micromphalites*. The *Micromphalites* fauna is not known south of lat 21°10' N. Despite the absence of ammonites, unit D5 is probably present with unit D4 in the clayey-calcareous series intercalated with rust-colored sparry dolomite that extends south of Khashm Mishlah (lat 21°05' N). Sandstone bodies occur south of lat 21°05' N, and eventually comprise the unit D4/unit D5 assemblage toward Khashm Kumdah (lat 20°10' N). The terminal hardground of the unit D5 is replaced by

an iron crust over sandstone around lat 20°20' N. South of lat 20°10' N (in the Al 'Ārid escarpment) the units D4 and D5 become more clayey, but are still sandy. They were first interpreted as Early Triassic Sudair Shale rocks by Powers *et al.* (1966), but the discovery of at least Middle Jurassic bivalves at the base of this assemblage proves this lateral variation of facies within the Dhurma Fm (Manivit *et al.*, 1990, p. 115 and fig. 18; Énay *et al.*, 2009, p. 32 a, d fig. 6).

The sandstone body Wadi ad Dawasir "delta" (22°30'-23°00' N) was formerly considered as lateral equivalent of the unit D6 and unit D7 (Le Nindre *et al.*, 1983, 1990a; Énay *et al.*, 1986, 1987a; Manivit *et al.*, 1990). Latter, the setting of this siliclastic deltaic body was reinterpreted and correlated with the discontinuity at the top of unit D5 (Énay *et al.*, 2007, 2009). The two possible interpretations of the Wadi ad Dawasir "delta" will be exposed below with the discontinuity at top of unit D5. Consequently, the D6-D7 sequence received also a new interpretation. The facies of unit D6 southward are comparable to those in the median region, but they thin to 32 m at lat 23° N. The *Dhurmaites* fauna, however, has not been recognized south of lat 23°18' N (Khashm Birk), further south than Al Mojel (2017, p. 26) claims (23°50' N). South of lat 22°20' N the ochre calcarenite at the top of the unit passes laterally to brown ripple-marked sandstone, soft sandstone, and red or green silty claystone. The unit is 16 m thick at Al Haddār (lat 22° N) and the claystone in the lower part becomes more gypsiferous. Toward Khashm al Mukassar (lat 21°35' N) the claystone becomes ochre or gray and contains ferruginous oolites, and the sandstone becomes lenticular with plant debris and ferruginous surfaces; the thickness remains at 16 m. South of lat 21° N the unit D6 is intensively pedogenized (roots, iron crust) and is only 11 m to a few metres thick; it is not differentiated south of lat 20° N.

From new data (Al-Mojel, 2017, p. 26 and Le Nindre, written communication, 03/01/2020) towards the south, at Khashm Ushayrah (21°37' N), the unit D6 presents two distinct parts, the lower dominated by shales, the upper made of grainstones interbedded with sandstone with crinoids and phosphate debris, which south of 22°02' N (Al Haddar) are replaced by sandstone with plant debris. This upper part would be the basis of the D7 transgression.

*Upper Dhurma.* Southward of Khashm adh Dh'ibī the unit D7 thins to 58 m near lat 23° N, where a rippled surface separates the 'Atash and Hisyan members. The facies evolve and continue thinning south of this, being 46 m near Al Haddār (lat 22° N). The 'Atash member at this point is composed of brown, massive, coral-bearing limestone, and the mainly clayey Hisyan Member ends with fine-grained indurated limestone. South from Al Ahmar (lat 22°30' N) the claystone is rich in gypsum and becomes progressively invaded by ferruginous oolites from the base upward.

Specimens of *Grossouvria* are recognized as far

south as the latitude of Wādī Birk (23°15' N), but the *Erymnoceras* fauna is not known south of lat 24° N. Beds of white sandstone and sandy calcarenite with ferruginous surfaces appear in the upper part of the unit D6 south of Khashm ash Shajarī (lat 21°50' N) but near Khashm al Mukassar (lat 21°36' N) these sandstone bodies are either spread out and flat, or occur in very thick channels. At Khashm Mishlah (lat 21°05' N) unit D7 is 58 m thick and is composed of an alternation of pedogenized claystone and sandstone bodies with ferruginous surfaces. Similar facies, with numerous sandstone bodies channeled in silty or clayey facies and locally pedogenized, are represented farther south with a decreasing thickness of the unit. Progradations, shown by oblique bedding in the sandstone, vary from northeast to southeast. Close to the lat 19°36' N, where the unit is 32 m thick, a dolomitic sandstone with reworked clay galls is located at the base of the sequence.

Age equivalence of the transgressive sequence D6-D7 with the sandstone body south of latitude 22° N, assumed in previous works (Le Nindre *et al.*, 1983, 1990a; Énay *et al.*, 1986, 1987a; Manivit *et al.*, 1990), has been questioned by Énay *et al.* (2009) and a new interpretation of the platform deltaic wedge has been proposed. The Dhurma Fm is pinched out by the Tuwaiq Mountain Limestone around lat 18°15' N.

### 1.2.3. Tuwaiq Mountain Limestone

The facies of unit T1 evolve and thin only slightly southward from Darmā' to Al Haddar (lat 22° N), where the unit is represented by 25 m of bioclastic and pelletoid clayey limestone with nodular jointing. The unit disappears south of Khashm ash Shajarī, near at latitude 21°45' N, being channelled by the detrital facies of unit T2.

Facies of unit T2 remain identical south from the median region, but the thickness decreases progressively to 33 m at Al Haddār (lat 22° N). Farther south the facies become more pelletoid and bioturbated. Near Khashm al Mukassar (latitude 21°35' N), where the unit is 43.5 m thick, the base of the unit is sandy, the carbonate facies contain quartz and ferruginous oolites, and hardgrounds appear.

Unit T3 decreases abruptly in thickness southward from Darmā', diminishing to 50 m near lat 23°40' N in direct relation to the southward extension of the reef forms; beds containing silicified corals remain abundant in the upper third of the unit. The base of the unit is marked by a layer of intraformational reworking between lat 24° and 22° N. Towards Khashm Mishlah (lat 21°05' N) the unit becomes very calcarenitic, 37.5 m thick, and displays oolitic layers alternating with bioturbated nodular limestone; bioclastic sandstones appear at the base.

Units T1-T2 vanish successively southwards and unit T3 only overlaps the deltaic wedge.

#### 1.2.4. Hanifa Formation

The facies of unit H1 (or Hawtah member) remain remarkably identical southward from Darmā' (lat 24°30' N) and the thickness of the member varies only as a function of the accumulations of pelletal limestone; 66 m at Wadi al Hawtah (lat 23°30' N), 45 m at Al Haddār (lat 22° N), and 36 m at Khashm Mishlah (lat 21°05' N). The thickness of unit H2 (or Hisyan member) between Darmā' (lat 24°30' N) and Al Ahmar (lat 22°30' N) ranges from 52 to 74 m, depending on the presence of reef bioherms, and the clayey and pelletal facies become more common southward, to the detriment of the reefal facies. The member is 67 m thick south of Al Haddār (lat 22° N) and contains bioturbated dolomite with a ferruginized surface; the upper layers, which are reefal to the north, become more oncolitic and pelletal and towards lat 21° N, where the member is 49 m thick, contains a high proportion of quartz.

#### 1.2.5. Jubaila Limestone

Southward, from lat 24° N the unit J1 begins with other bioclastic sandy limestone, which is overlain by the alternation of beige fine-grained limestone with a gray-blue patina and lithobioclastic calcarenites. A *Perisphinctes* fauna was recognized as far south as lat 20° N (south of Wādī ad Dawāsir) by Arkell (1952). South of Al Ahmar (lat 22°30' N) coarse-grained gravelly sandstone with inclined bedding is more abundant than limestone, and sandy facies becomes predominant between lat 21°50' N and 20°30' N. Near lat 21° unit J1 is 68 m thick and predominantly sandy.

The unit J2, from the vicinity of Ar Riyād to south of Al Ahmar, is calcareous (white dolomitized limestone and bluish platy limestone) with a layer of sandy-conglomeratic reworking at the base. Farther south the facies are mainly pelletal limestone, although strongly dolomitized south of Wādī ad Dawāsir.

#### 1.2.6. Arab Formation and Hith Anhydrite

The Arab Fm and the Hith Anhydrite display everywhere substantial thickness reductions and are very dislocated (collapse structures) in outcrop due to solution of the anhydrite. The four members can be identified with some caution, but possible facies variations are not recognizable. The apparent thickness of the formation in outcrop varies only slightly between 65 and 70 m southward from the median region. The large deposits of gypsum in the Aflaj (Laylā) area were assigned to the Hith Anhydrite by Powers (1968).

### 1.3. Lithologic Evolution to the northwest

Evolution of the Jurassic lithologies from the median region to the northwest are comparable in their main trends to their evolution towards the southern margin of the basin; a trend from marine to less marine and continental deposits (Fig. 3). The northwestward evolution is less continuous than the southern evolution and marine facies are still abundant as far north as lat 25°30' N. The Late Cretaceous pre-Wasia Fm erosional surface successively terminates the Jurassic series from top to base between lat 26° N and lat 28° N; a palaeosurface that shows local bauxitic occurrences as at Az Zabīrah and Qibā'.

#### 1.3.1. Marrat Formation

The type facies of the lower Marrat are recognizable northwestward from Khashm adh Dhi'bī to as far as Shaqrā' (lat 25°12' N), where they have a thickness of 52 m. Farther north, outcrops of the lower Marrat are rare as they occur between and below the "nāfuds": at lat 25°45' N. They comprise 21 m of white fine-grained sandstone with ferruginous surfaces, dolomite with algal films, and yellow clay capped by white fine-grained bioclastic limestone; towards lat 27-28° N only silicified or ferruginous sandstones, capped by siltstones and limestones, remain. The middle Marrat shows a reduced thickness to the northwest, and at lat 25°45' N there is substantial invasion of the red clayey facies by sandstone material; a few red sandy-clayey outcrops attributable to this member are visible in the Nafūd ath Thuwayrāt, toward latitude 27° N. The *Bouleiceras* fauna is not known northwest of the reference section.

The type facies of the upper Marrat is visible northwestward from Khashm adh Dhi'bī until, south of Shaqrā' (lat 25°12' N) where it still contains the *Nejdia* fauna. North of this latitude, however, the upper Marrat is only present in outcrop as a few basal nodular limestone beds, and at lat 28° N as ferruginous fine-grained sandstone.

#### 1.3.2. Dhurma Formation

**Lower Dhurma:** The unit D1 crops out in its totality northwest of the reference section. Its upper part shows sandstones with plant remains, sandy claystones and rare dolomitic beds near Al Jurayfah (lat 25°30' N). Occurrence of subbituminous coal associated with sandstone have been observed in agricultural wells between this latitude and Az Zilfī (lat 26°18' N). Some sandstones and gypsiferous claystones are attributed to the unit D1 north of lat 26°55' N.

The unit D2 does not occur in outcrops between lat 24°45' and 25°20' N. Near Al Jurayfah (lat 25°35' N) the lowest part of the unit shows calcareous claystones and a few calcarenite beds containing ferruginous ooliths

and *Eoermoceras* n. gen (first "*Ermoceras*") fauna and *Normannites* fauna. The upper part (equivalent to the "Dhibi limestone member") shows calcareous claystones containing ferruginous oolites and a very abundant *Telermoceras/Kosmermoceras* (principal "*Ermoceras*") fauna together with brachiopods and echinoderms; it is capped by a limestone bed less than 1 m thick, which is replaced northwestward by ripple-marked limestone; northwest of 25°45' N the unit D2 comprises only sandstone, sand dolomitic claystone.

**Middle Dhurma:** The unit D3 near Al Jurayfah (lat 25°35' N) is composed of yellow, ochre, and gray silty and carbonate claystone and of dolomitic claystone over a thickness of 21 m. The *Thambites* fauna is represented as far north as this latitude, but according to the BRGM team (in Énay *et al.*, 1986, p. 24 and 1987a, p. 28) the *Ermoceras* gr. *mogharensis* and *Spiroceras* fauna is not known north of the reference section.

Northwestward from the reference section the facies of the unit D4 are still typical at Wādī al Hisyān (lat 24°15' N), although reduced to a thickness of 26 m. At lat 25°15' N, however, the carbonate facies increases in thickness to more than 47 m and, in addition to *Tulites*, the uppermost layers contain a species of ammonite that had not been described hitherto (*Saudisphinctes arabicus* nov. gen. nov. sp.). Unlike the carbonate facies in the units D1, D2 and D3, those in D4 continue northwestwards, but thinning to 25 m at latitude of Al Jurayfah (25°35' N) where they contain an abundant *Tulites* fauna. The facies remain bioclastic, but become sandy at Al Ghāt (lat 26° N) where they are accompanied by yellow dolomitic claystone containing a bivalve fauna, and by white fine-grained sandstone. The *Tulites* fauna encountered in rare interdune outcrops in the Nafūd ath Thuwayrāt, near lat 27° N, is accompanied by a rich bivalve, gastropod, and echinoid fauna indicating a marine influence contrasting with the development of terrigenous influences on the northwestern margin of the basin northwest from lat 25° 10' N. Near Qibā (lat 27°29' N) the unit is only claystone, dolomitic claystone, and bioclastic-conglomeratic sandstone and is without ammonites.

The bioclastic clayey-carbonate facies of the unit D5 thins slightly north-westward from the median region to 37 m at lat 25°15' N, where it becomes replaced by dolomitic claystone and red claystone containing ferruginous oolites. The claystone displays an abundant *Micromphalites* fauna towards Al Jurayfah (lat 25°35' N). Farther north the clays become rich in fine-grained, carbonate-cemented sandstone arranged in beds with ripple marks and ferruginous surfaces, or in channels within the claystone. At Al Ghāt (lat 26° N) and near Az Zilfī (lat 26°12' N) unit D5 corresponds to 25 m of sandstone and siltstone, and the hardground at the top of the unit is still visible. The unit is covered by Quaternary deposits north of lat 26°15' N.

The unit D6 remains clayey and carbonated as far north as lat 25°15' N, except for the upper part which displays layers of sandstone with a carbonate and ferruginous cement associated with the calcarenite described in the reference section. Ferruginous oolites appear within the sequence. The unit becomes progressively richer in terrigenous material toward the northwest and sandstone facies predominate north of lat 25°35' N, where they alternate with layers of dolomitic claystone, at Al Ghāt (lat 26° N) the unit D6 is 42 m thick and is mainly clayey with few sandstone beds containing plant debris. It contains dispersed ferruginous oolites and the upper part is pedogenized and capped by a reddish layer. The *Dhurmaites* fauna has been recognized north to lat 25°05' N.

**Upper Dhurma:** Northwestward from Khashm adh Dh'ibī the basal part of the unit D7 (Atash Member) becomes thicker, being 41 m near 23°05' N, where it displays clayey and carbonate facies rich in corals and echinoderms. It becomes predominantly clayey with ferruginous oolites and sandstone beds near Al Jurayfah (lat 25° 35' N) where the thickness is reduced to about 10 m.

The Hisyan member in this part of the basin preserves its clayey character and varies only slightly in thickness. Carbonate layers, containing ferruginous oolites and a Kinkelineratid fauna near the base of the member, develop towards lat 25° 15' N invading the lower half of the member farther to the northwest; they are confined by a hardground.

From Al Ghāt (lat 26° N) to north of Az Zilfī (lat 26°12' N) the unit D7 is 51 m to 63 m thick and the Atash Member is no longer differentiable. It begins with bioclastic limestone and ochre limestone rich in ferruginous oolites and contains an abundant fauna (*Erymnoceras* and *Pachyerymnoceras*). The hardground is still well represented at the top of the assemblage, which is overlain by limestone and a thick series of greenish claystone. The unit is only visible over a thickness of 20 m at Qibā (lat 27°29' N) where it consists of claystones, dolomitic claystones, and bioclastic sandstones.

### 1.3.3. Tuwaiq Mountain Limestone

Northwestward from the latitude of Darmā' the unit T1 preserves the same facies as far as about Shaqrā' (lat 25°30' N), but it is no longer differentiable from the unit T2 north of Al Ghāt (lat 26° N). The *Pachyerymnoceras* fauna is represented in the unit T1 up to lat 25° N.

The unit T2, northwestward from the reference section, remains carbonatic and is locally rich in corals as far as lat 25°35' N, the *Pachyerymnoceras* fauna is known up to lat 25° N. At Al Ghāt (lat 26° N) it is present over 44 m of fine-grained, finely bioclastic and pelletoidal, bioturbated limestone containing abundant chert nodules

but no corals. The unit is only 16 m thick north of Az Zilfī (lat 26°12' N), where it comprises a bioturbated bioclastic limestone with scattered silicified corals. Near Qibā (lat 27°29' N) the unit T2 is about 20 m thick and shows fossiliferous (brachiopods) clayey and bioturbated pelletoid limestones with few corals.

The unit T3, north-westward from the median part of the basin, displays similar facies as the reference section, except at the base of the unit toward lat 25°30' N, where clayey facies occur. The unit is more calcarenitic at Al Ghāt (lat 26° N). No reef forms exist north of lat 24°45' N, but corals remain abundant in the upper third of the unit, which is only 38 m thick. Facies remain similar as far as lat 27°25' N, near Qibā, where the thickness is estimated to be about 25 m. No ammonites have been found in the unit T3 north of the reference section, but we have those collected by Dr. Al-Asa'ad's from the Al-Mu'ayshibah area, NW of Riyadh, at about 25°34' N.

#### 1.3.4. Hanifa Formation

The unit H1 (Hawtah member) displays perireefal facies with isolated corals in carbonate or clayey facies northwestward of At Al Ghāt (lat 26° N). The thickness decreases north of this latitude and the member is composed of calcarenites alternating with pelletoidal limestone as far as lat 26°30' N, beyond which the formation does not crop out. The *Euaspidoceras* fauna has been recorded as far north as lat 25°10' N. The unit H2 (Ulayyah member) becomes more clayey northwestward and is 67 m thick at lat 25° N. At Al Ghāt (lat 26° N) and to the north, where the member is more than 40 m thick, oncolitic and calcarenitic layers become abundant, whilst corals become less abundant.

#### 1.3.5. Jubaila Limestone

The type facies of the Jubaila Limestone persists northwestward from the median part of the basin to lat 26°30' N, where the formation is channeled by the pre-Wasia Fm erosion surface (Late Cretaceous). The *Perisphinctes* fauna has not been recovered north of lat 25° N.

#### 1.3.6. Arab Formation and Hith Anhydrite

The facies of the Arab Fm and Hith Anhydrite are persistent north-westwards up about lat 26°10' N, where the formations are pinched out by the Pre-Wasia Fm erosion surface. The Hith Anhydrite and evaporitic parts of the Arab Fm have been dissolved and outcrops show intense solution breccias and collapse structures, making it difficult to estimate residual thickness for each member. The total thickness of the Arab Fm at lat 25°40' N, where the upper part of the formation is already truncated by

the pre-Wasia unconformity, is estimated at about 50 m; the Arab-D member is calcarenitic, dolomitic and sandy, and the Arab-C and Arab-B members show breccias that include oolitic bioclastic calcarenite and dolomitic claystone.

## 2. PALAEOENVIRONMENTS

Here we refer to Le Nindre *et al.* (1983, 1984) and Énay *et al.* (1986, 1987a) but mainly Manivit *et al.* (1990, fig. 71). New data on the Shaqra Group biofacies and environments have been published by Hughes (2004, 2006, 2008) and Hughes *et al.* (2006), and Ziegler (2001) on palaeofacies evolution of the Arabian Plate.

### 2.1. Palaeoenvironments of the Marrat Formation

In the median part of the basin the Marrat Fm shows varied environments. The lower Marrat reflects a transition between the continental facies of the underlying Late Triassic Minjur Sandstone and the infralittoral deposits characteristic of the middle and upper Marrat and of the unit D1 of the Dhurma Fm. At the margins of the basin the Marrat comprises continental facies similar to those of the Minjur Sandstone, thus there is a diachronous passage outward from the median part of the basin from continental detrital assemblages to carbonate with a marine fauna. It represents an evolution between a coastal-plain environment with many channels (predominant between lat 23° and 22° N) and tidal flats facies (Le Nindre *et al.*, 1983). Ridges of ferruginous oolites are concentrated at the contact between the two domains (Le Nindre *et al.*, 1984).

### 2.2. Palaeoenvironments of the Dhurma Formation

As with the Marrat Fm, the lithology of the Dhurma Fm to a certain extent reflects the depositional environment. Terrigenous clastic facies form a vast deltaic pattern south of lat 22° N (Al Haddār), with the greater part of the formation being dominated by mollusk-bearing clayey limestones deposited in a proximal domain of the inner shelf. This is particularly well developed between lat 23° and 22° N. The most marine extreme is reached near lat 24°30' N (Darmā'') where the unit D2 contains ammonite-bearing marls deposited in a more detrital environment. This tendency is also marked by the development of reef facies in the Atash Member (around lat 25° N) and is confirmed by the richness of the fauna throughout the section.

To the northwest, beyond lat 25° N, the reduction in thickness of the series and the invasion by terrigenous facies indicate the presence of a littoral environment, albeit ammonites from the basin accumulated here.

### 2.3. Palaeoenvironments of the Tuwaiq Mountain Limestone

The Tuwaiq Mountain Limestone is less monotonous than might be suggested by the homogeneous appearance of the carbonate escarpment; the formation displays varied facies. Its main characteristic lies in the barrier deposits, which widely transgress the margins of the basin.

South of lat 21°30' N (Khashm al Mukassar) only the unit T3 preserves its carbonatic character clearly; the bioturbated limestone of the unit T2 (unit T1 having disappeared) passes progressively southwards to littoral sandstones at the contact with the deltaic bodies of the Dhurma Fm. South of lat 20°30' N (Wādī ad Dāwisir) the perireefal limestone in the unit T3 contrasts vividly with the underlying continental formations.

The Darmā'' region (lat 24°30' N) shows the development of true, metre-high reefs over a thickness of several tens metres. These reefs are particularly visible in the cutting made for the Ar Riyād to Jeddah highway.

North of lat 25° N up to lat 26°30' N (Az Zilfī), more proximal conditions are indicated with well-developed lagoon deposits and littoral bio-accumulations. The unit T3 still displays a perireefal character.

### 2.4. Palaeoenvironments of the Hanifa Formation

The Hanifa Fm marks the maximum extension of reef carbonates. The two members of the formation are clearly individualized between lat 23° and 25° N; the Hawtah member (unit H1) displays substantial and abrupt confinement in relation to the Tuwaiq Mountain Limestone, whereas abundant patch reefs (bioherms) have been mapped in the Ullayah member (unit H2). From the median part of the basin southwards the reef facies pass diachronously upwards in the stratigraphic series. It is of interest to note that, as in present-day examples, oncolites are not confined to the innermost part of the lagoon, but have a wider extension and form an integral part of the reef complex. Carbonate sandstones occur in large spreads or, more rarely, corresponding to channels.

### 2.5. Palaeoenvironments of the Jubaila Limestone

Sedimentary instability conditions are manifested within the Jubaila Limestone by the alternation of mudstones, grainstones, and sandstones. The widespread calcarenites mark high-energy pulsations with large sandy spreads in an infralittoral environment. Fine-grained limestones corresponding to lagoon facies predominates between lat 23° and 22° N. South of lat 22° N (Al Haddār) a substantial influx of quartzose sand was deposited in a marine domain (mid-infralittoral) either in channels or as littoral bars; the presence of fauna helps to confirm the depositional environment. The main characteristic of the formation is periodic reworking of the mudstone in

the form of microconglomerates. A thicker conglomerate marks the base of the upper unit of the Jubaila Limestone (unit J2). A north-south polarity in the southern part of the basin is, demonstrated by the northerly trend of the outcrops. Examination of the sandstone bodies, however, shows that the true orientation is easterly dip.

### 2.6. Palaeoenvironments of the Arab Formation and Hith Anydrite

The four members of the Arab Fm represent sequences of sabkha-type deposition of decreasing energy culminating in evaporates.

## 3. AMMONITE FAUNAS

The succession of Jurassic ammonite faunas in Saudi Arabia and the dating made by Arkell (1952) were largely confirmed and further refined by Imlay (1970). The results presented by Énay *et al.* (1986, 1987a, 2009), Énay & Mangold (1985, 1994) followed the same lines but, while adhering to the Arkell format as improved by Imlay, the authors have provided additional refinement based on new faunas collected from the studied region. New assessment of the existing data was possible in the light of information contributed by the new fauna and partially unpublished from outside Saudi Arabia (Israel, Morocco, Western Algeria, Tunisia). This monograph brings new elements based on the study of all collected material including forms that could not be taken into account in previous works.

In a recent paper on the Middle and Upper Jurassic of Gebel Maghara (Sinai, Egypt) Abdelhady & Fürsich (2015) used the Unitary Association Method of quantitative biostratigraphy, but most of the figured specimens were incorrectly named or undeterminable.

### 3.1. Faunal extension and relationships with litho-stratigraphic units (Tab. 1 and Figs 2 and 6)

The horizontal and vertical distribution of the successive faunal assemblages or faunas recognized is shown in Table 1. The species are not equally developed throughout the basinal area studied. For instance, the *Thambites* (unit D3) or the *Micromphalites* (unit D5) faunas are known to latitude 21°50' N (Khashm ash Shajari) and 21°20' N (south of Khashm Kumdah) respectively, whilst the *Perisphinctes jubailensis* fauna extends to latitude 20° N according to Arkell (1952). Northwards, the widest extensions are those of the *Tulites* (unit D4) and the *Pachyerymnoceras* (unit D7, Hisyan member) faunas, to 26°55' N (Nafud al Mazhur) and 26°26' N (Al Liqa), respectively. Other faunas are much more limited in extent.

The differences in horizontal distribution reflect a vertical discontinuity in the successive faunas that is directly associated with oscillation in their southwards distribution at various time-intervals. These distributions mainly reflect palaeoenvironmental influence and evolution: the environment commonly reaching the limit of tolerance for ammonites, which are almost exclusively represented by taxa with simplified septa, well known for being adapted to shallow environments (Ziegler, 1967, 1981). The monogeneric or monospecific nature of the fauna is another aspect here interpreted as adaptation to constraining environmental conditions.

Periods of relative widespread faunal extension are reflected in the units D2 (Dhibi limestone member), D3, D4 and D5 of the Dhurma Fm, the units T1 and T2 of the Tuwaiq Mountain Limestone Fm, and the Jubaila Limestone. Periods of limited extension coincide with deposition of the Marrat Fm, units D1, D2 (lower part), D6 and D7 of the Dhurma Fm, unit T3 of the Tuwaiq Mountain Limestone Fm, and the Hanifa Fm.

The most complete succession of faunas, however, remains in the median part of the basin between latitudes 23°50' and 25° N. The faunas become rarer southwards, but there is no substantial diachronism between the faunas and the boundaries of lithologic units. The few "anomalies" encountered led to a review of the lithostratigraphic boundaries, resulting in new conceptions of certain lateral facies variations. Thus, after revision of the boundary between the units D1 and D2, as supported by evidences from the fauna, sandstone bodies previously assigned to the unit D1 (Vaslet *et al.*, 1983) were relocated to the lower part of the unit D2 between latitude 22°30' N (Al Ahmar and 23°35' N (Khashm al Khalṭā'). The most important revision concerns the sandstone body described as "Wadi ad Dawasir" whose interpretation was revised by Énay *et al.* (2009) from the presence in the highest beds of the delta complex of an Early Bathonian nautiloid (Tintant in Énay *et al.*, 1987a).

### 3.1.1. *Bouleiceras* and *Nejdia* faunas

The *Bouleiceras* and *Nejdia* faunas described by Arkell (1952) correspond to two fossiliferous layers in the marine portion of the Marrat Fm. The first has been relocated in the lower part of the middle Marrat and the second at the base of the upper Marrat. The faunas display about the same extension from latitude 24°45' N in the north to latitude 23°45' N in the south. They disappear well before the complete wedging out of the formation between latitude 22° and 21° N.

### 3.1.2. *Sonniniidae* faunas

The lower beds (unit D1) of the lower Dhuma have produced more varied faunas than the single "*Dorsetensia*" *arabica* fauna originally identified by

Arkell (1952) and Imlay (1970). With the exception of the first of the sonniniid faunas, which occurs in the lower part of the unit D1 and which has the same extension as the fauna in the Marrat Fm, the sonniniid faunas farther up the sequence overlap fairly extensively with the *Bouleiceras* and *Nejdia* faunas southwards, reaching the latitude 23° N (south Wādī Birk). These ammonite faunas are not known beyond latitude 24°30' N (Darmā').

Énay *et al.* (1986, 1987a) distinguished four successive sonniniid faunas, but Énay & Mangold (1985, 1994) only two, the most recent ones being reunited with the first *Ermoceras* fauna. Thus:

1. The *Hyperlioceras* and *Euhoploceras* fauna at Khashm adh Dhi'bī (latitude 24°14' N) occurs in a layer of dolomitic bioclastic limestone with marly intercalations in the lower part of the unit D1, between the basal dolomitic marl and the overlying stromatolite-bearing beds (*Hypelioceras* sp. gr. *discites*, *Sonninia crassicostrae* n. sp.). *Sonninia* (*Euhoploceras*) *turbator* n. sp. occurs in the same facies and probably belongs to the same faunal assemblage, although they are isolated in the Darmā' graben zone. The species is also present at Khashm al Majhūla (latitude 23°48' N) where it is associated with *Haplopleuroceras* cf. *mundum*.
2. The *Pseudoshirbuirnia* and *Sonninites* fauna is well represented only near latitude 24° N (north of Faridat Balum, 23°50' N), hence the interest of the only specimen of the former species known to Khashm adh Dhibi where it is situated above the previous fauna (with *Euhoploceras* and *Hyperlioceras*) and below the first *Ermoceras*-bearing layers with the first *Ermoceras* fauna (*Eoermoceras* nov. gen.). At latitude 23°45' N (near Faridat Balum) *Pseudoshirbuirnia* is associated with an abundant fauna of new Sonniniids (*Sonninites* aff. *albidus*), a species totally absent in the site dominated by *Pseudoshirbuirnia*. So, despite the differences in composition of the fossil associations, these faunas are regarded as approximatively coeval and a same faunal assemblage.

Three localities on the Wadi ar Rayn Quadrangle (Wadi Birk, 23°12' N, VD80.563; north of Wadi Birk, 23°13' N, VD80.589; Faridat Balum, 23°42' N, VD80.528), corresponding to the top part of the unit D1, yielded only forms of the overlying *Dorsetensia* fauna of the lower unit D2. As a result, the D1/D2 boundary must be changed and located lower. If we add that the fauna of the locality VD80.541 (north of Wadi al Hawttah, lat. 23°37' N) is not significant (with *Euhoploceras* sp. only), the extension of the *Pseudoshirbuirnia* fauna does not exceed to the south the latitude 23°42' N (Faridat Balum).

### 3.1.3. *Ermoceras* faunas

Arkell (1952, 1956) recognized only one *Ermoceras* fauna in the upper part of the lower Dhurma (unit D2,

Dhibi Limestone member). This was referred by Énay *et al.* (1986, 1987a) as the “principal *Ermoceras* fauna”. This latter is quite distinct from the *Ermoceras* fauna associated with *Spiroceras* established by Imlay (1970) at the base of the unit D3, in the *Thambites*-bearing beds of Arkell. These two *Ermoceras* faunas were clearly identified in Sinai (Egypt) by Douvillé (1916).

A new *Ermoceras* fauna with the new genus *Eoermoceras*, the oldest now known, has been found in the lower part of the unit D2, well below the Dhibi limestone member, from which virtually no ammonites had hitherto been collected. Thus :

1. The *Eoermoceras* and *Dorsetensia* fauna includes faunas previously described as third and fourth Sonniniidae faunas (i.e., “*S. tessoniana* fauna, Sonniniidae, *Normannites* and *Stephanoceras* fauna” and the “first *Ermoceras* fauna” in Énay *et al.*, 1986, 1987a). This association is largely dominated by the genus *Dorsetensia* and the species *D. liostraca* (with its two subspecies *D. liostraca tecta* and *D. liostraca sublecta*). Southwards the fauna reaches the latitude 23°12' N (Wadi Birk) and its disappearance is probably associated with the development of large sandstone bodies that invade the lower part of the unit D2. To the north it was previously assumed (Énay *et al.*, 1986, 1987a) that the *Eoermoceras* fauna was not known for certain beyond latitude 24°14' N (Khashm adh Dhibi), probably due to the wedging out of the lower part of the unit D2 and to the poor outcrop conditions of the lower Dhurma in the graben sector northwest of Darmā'. But the few poorly preserved fragments northeast of Shaqrā' were confirmed latter (October 1986 and February 1987) by new, rich and various, samples from a totally isolated section south of Jurayfah around 26°22' N and 46°20' E (VD82.628 and 92).

*Normannites* and species of *Eoermoceras* nov. gen. are less common, but always associated with *Dorsetensia*: VD80.540 and 546 (Khashm al Hamra, 23°30' N), JMA82.166 (Khashm adh Dibi, 24°14' N) or separately: JMA82.372 (lonely place north of Khashm adh Dhibi about 24°22' N), VD82.92 and 628, (south of Jurayfah, 26°22' N/46°20' E). Thus, although the associations are not identical from one locality to another, they are considered as approximatively coeval and as forming a single faunal assemblage.

The same *Dorsetensia* fauna was also identified in Sinai at J. Moghara (Parnes, 1984), below the main *Ermoceras* fauna described by Douvillé (1916). The many new *Normannites* of Makhtesch Ramon (Israel) described by Parnes (1981) are in the same situation, but within a condensed series and perhaps with a gap.

2. The *Kosmermoceras* and *Teloceras* fauna (ex principal *Ermoceras* fauna) covers most known

species of *Ermoceras*, including those described by Douvillé (1916) in the first ammonite layers in Sinai and those described by Arkell (1952) from Saudi Arabia.

Most of the studied material comes from the Dhibi limestone member and particularly from the marly intercalations in the middle part near lat 22°38' N (locality JMA80.80, As Sitarah Khashm Ushayrah). The fossiliferous beds are more numerous between lat 23° and 23°45' N, although the fauna is clearly less rich and the less abundant sampling of specimens (commonly in the scree) from latitude 24° N (Khashm al Jufayr) northwards is probably due to the generally poor outcrop conditions of the Dhibi limestone member.

The fauna is again well represented in the layers containing ferruginous oolites, near Al Jurayfah (lat 25°35' N, VD82.478, 478A and 651, 651A), from which Arkell obtained virtually all the material of his new species (Purple red band or Purple-red ammonite bed, in Arkell, 1952). In these beds well-known *Kosmermoceras* of the upper unit D2 are associated with others of the overlying *E. mogharensis* and *Spiroceras annulatum* fauna. That disagrees with the statements of the BRGM that “the basal part of the unit D3 and the *Ermoceras* gr. *mogharensis* and *Spiroceras* fauna is not known north of the reference section”. From these data two possible hypotheses stand, either a condensed level with mixed faunas from the upper unit D2 and lowest unit D3 together, or these forms occupy different levels within the oolitic beds, but not divided when collected.

Thus, the principal *Ermoceras* fauna is known over more than 400 km between latitude 22° (Jabal Fahhamah) and 25°35' N (Jurayfah) and it is one of the faunas with the largest areal extension.

3. The *Ermoceras mogharensis* and *Spiroceras annulatum* fauna corresponds to the lowest beds of the unit D3 and the *Thambites* Zone of Arkell (1952), already subdivided by Imlay (1970) and within which Ermoceratids are still present.

This fauna has been identified at Khashm adh Dhibi (lat 24°114' N) for the first time by Imlay (1970), and farther south at lat 23°48' N (Khashm al Majulah), where it is only represented by *K. inerme* (Douvillé), but according to lithostratigraphic data, the corresponding beds continue south to latitude 22°30' N (Al Ahmar). Northwards the lowest unit D3 and the associated fauna are present as far as latitude 24°38' N (Graben Awsat). Moreover, as exposed just above (see principal *Ermoceras* fauna), near Al Jurayfah (lat. 25°35' N, VD82.478, 478A and 651, 651A), *K. inerme*, a species of the *Ermoceras mogharensis* and *Spiroceras annulatum* fauna is associated with species of the Principal *Ermoceras* fauna.



Table 1: Continued

STAGES		LATE BAJOCIAN			EARLY BATHONIAN		LATE BATH.
EQUIVALENT NW EUROPEAN ZONES		Niortense Zone	Garantiana Z	Parkinsoni Zone	Zigzag Zone Macrescens-Aurigerus Subzones		?
JUBAIL LIMEST.	J1	Cavelieri					
	H2	«Castroi»					
HANIFA FORMATION	Unit H1 <small>Hawani (Ulayy. mb)</small>	?					
	Unit H1 <small>Hawani (Ulayy. mb)</small>	Catena H.					
TUWAIQ MOUNTAIN LIMESTONE	T3	Solidum					
	T2	Ogivalis					
	T1	Ogivalis					
DHRUMA FORMATION	Upper	Unit D7 <small>(Alash (Hisyah mb))</small>	?				
		Unit D7 <small>(Alash (Hisyah mb))</small>	Kuntzi H.				
	Middle	D6	Cardiocerat.				
		D5	Clydocromph.				
		D4	Tuwaiqensis				
		Unit D3	Planus				
	Lower	Unit D2	Mogharensis				
		Unit D2	Runcinatum				
		Unit D2	Glabrum				
		Unit D1	Stephani				
MARRAT FORMATION	Mu	Arabica					
	Mm	Brankampi					
Distribution by quadrangle	S	Nitescens					
	N	Sulayyimah					
		Wadi al Mulayh					
		Wadi ar Rayn					
		Durma					
		Shaqra					
		Buraydah					
		Sedimentary break of Middle Bathonian age					
		Dhrumaites cardiocerotoides Arkell					3
		? Dhrumaites cardiocerotoides Arkell					8
							6



### 3.1.4. *Thambites and Rebouliceras avus* fauna

This fauna is widely distributed between lat 25°35' N (Al Jurayfah) and 21°50' N (Khashm ash Shajarī) and it is one of the faunas with the largest areal extension. This fauna occurs above the previous fauna at Khashm adh Dhi'bi. It appears abruptly, in contact with the unit D2 and the Principal *Ermoceras* fauna northwards, beyond lat 24°18' N (Awsat graben), where the underlying *E. mogharensense* and *S. annulatum* fauna is no longer represented, save the few localities near Jurayfah where *K. inerme* is associated with the principal *Ermoceras* fauna.

The numerous oxycones, somewhere very large and with acute lanceolate whorl-section, doubtfully assigned to *Thambites* by Arkell (1952) and ascribed to “*Clydoniceras*” (including *C. avus*) by Énay *et al.* (1986, 1987a) and Énay & Mangold (1985, 1994), are just as characteristic of this fauna as *Thambites*. Recently named as *Rebouliceras* by Branger (in Vadet *et al.*, 2011), and here renamed *Mulayites* nov. gen., they include, in part, the forms which Imlay (1970) termed *Dhrumaites*.

The *Thambites* and *Rebouliceras avus* fauna appears to be distributed throughout the unit D3 (with exception of the basal beds containing *E. mogharensense* and *Spiroceras*). The differences in faunal composition between the various localities appear not to be associated with their position within the formation since the association is sufficiently rich to eliminate the influence of random factors related to fossilization or sampling conditions. However, with more than 300 specimens collected, it appears that *Thambites* is more abundant in the highest beds.

The single specimen of the upper unit D3 cited by Énay *et al.* (1986, 1987a) and Énay & Mangold (1985) as *Zigzagiceras (Franchia)* sp. deserves special mention. Indeed, besides its early Bathonian age, it was made the holotype of *Metazigzagiceras subarabicum* Fernandez-Lopez & Pavia, 2013.

### 3.1.5. *Tulites, Micromphalites and Dhrumaites* faunas

These faunas have been already distinguished by Arkell (1952), but they are most perfectly identified in the middle Dhurma units D4, D5 and D6, respectively. Moreover, they consist virtually exclusively of species (and genus in some of them) unknown outside of Saudi Arabia or the surrounding regions (Sinai, Israel).

1. The *Tulites* fauna is known over virtually all the studied region, between latitudes 22°10' N (Jabal Shimrakh) and as far north as 26°55' N (Nafud al Mazhur). Thus, it represents the greatest northwards extension of Jurassic ammonites in Saudi Arabia, but determinable specimens are very few in the most part of the distribution area. The most abundant material, like that studied by Arkell (1952), comes from

northern regions near Jurayfah (VD82.482, 482B and 354A). Near Al Lughf (latitude 25°10' N) the beds near the boundary between the units D4 and D5 yielded an original faunule (6 specimens) of a new genus and species (*Saudisphinctes arabicus*), with a quite original *Tulites* form. Both are unknown out of this locality and the question arises about the right position of these beds and it was accepted that they were a local development of the highest beds.

2. The *Micromphalites* fauna is more widely represented than the *Tulites* fauna, although generally in the form of isolated specimens. They are scarce south of lat 23°15' N (Wadi Birk) and more common (86 specimens) to the north (VD82.484B and 357). The southernmost fossiliferous locality (VD81.246), south of Khashm Mishlah (lat 21°07' N), makes possible to precisely date the southward marine advance between the underlying lower sandstone bodies (equivalents of the units D1, D2 a, d, D3 pars) and the overlying upper sandstone body (Wadi ad Dawasir “delta”). The genus is again abundant only in the Al Jurayfah region, in beds that contain chocolate-brown limonitic fossils; these beds yielded the greater part of the material studied by Arkell (1952). The *Micromphalites* fauna is unknown north of lat 25°38' N.
3. The *Dhrumaites* fauna is represented by twelve specimens suitable for specific determination, eight of them from two beds on the same section (VD80.587, 588) at latitude 23°48' N (Khashm al Majulah). The facies of the unit D6 are relatively unfavourable for ammonites, but *D. cardioceratoides* is known between Khashm Birk (23°18' N) in the south and Khashm Turab (25°03' N) in the north. Thus, well beyond the maximal southwards extension assumed by Al-Mojel (2017, p. 26) whose assertion that *Dhrumaites* is not known south of Khashm al Jufayr (23°50' N) is now expanded. The genus is completely unknown outside Saudi Arabia where is even rare. The places VD80.559 (Wadi Birk, lat 23°18' N) and VD82.332 (Khashm Turab, 25°03' N) deserve a special mention because both yielded *Dhrumaites* together with *Micromphalites*. The former is placed in the upper D5 unit, according to the lithostratigraphic frame, and probably *Dhrumaites* (not *in situ*) comes from the overlying unit D6. For the second site, its high position within D6 makes it necessary to admit that *Micromphalites*, although rare, is still present there.

### 3.1.6. *Erymnoceras and Pacherymnoceras* faunas

Arkell (1952) recognized a single *Erymnoceras* fauna in the lower part of the Tuwaiq Mountain Limestone (unit T1). Imlay (1970) extended this zone downwards in the

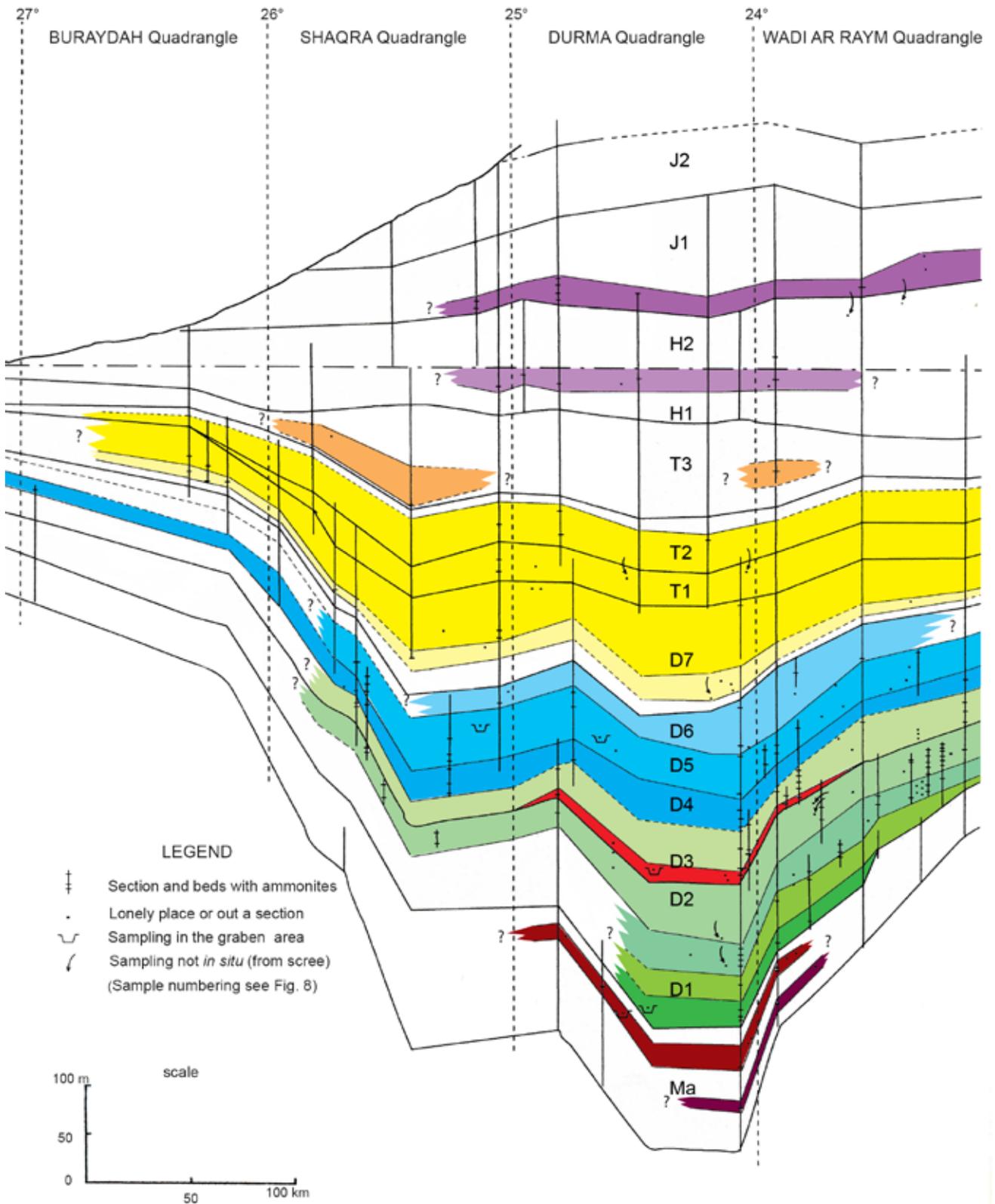


Fig. 6: Spatio-temporal distribution of the successive ammonite faunas on the Arabian Platform from Toarcian up to Lower Kimmeridgian (E = Early ; M = Middle ; L = Late). The sandstone body of the Wadi ad Dawisir delta from data in Manivit *et al.* (1990, figs 38 and 46).

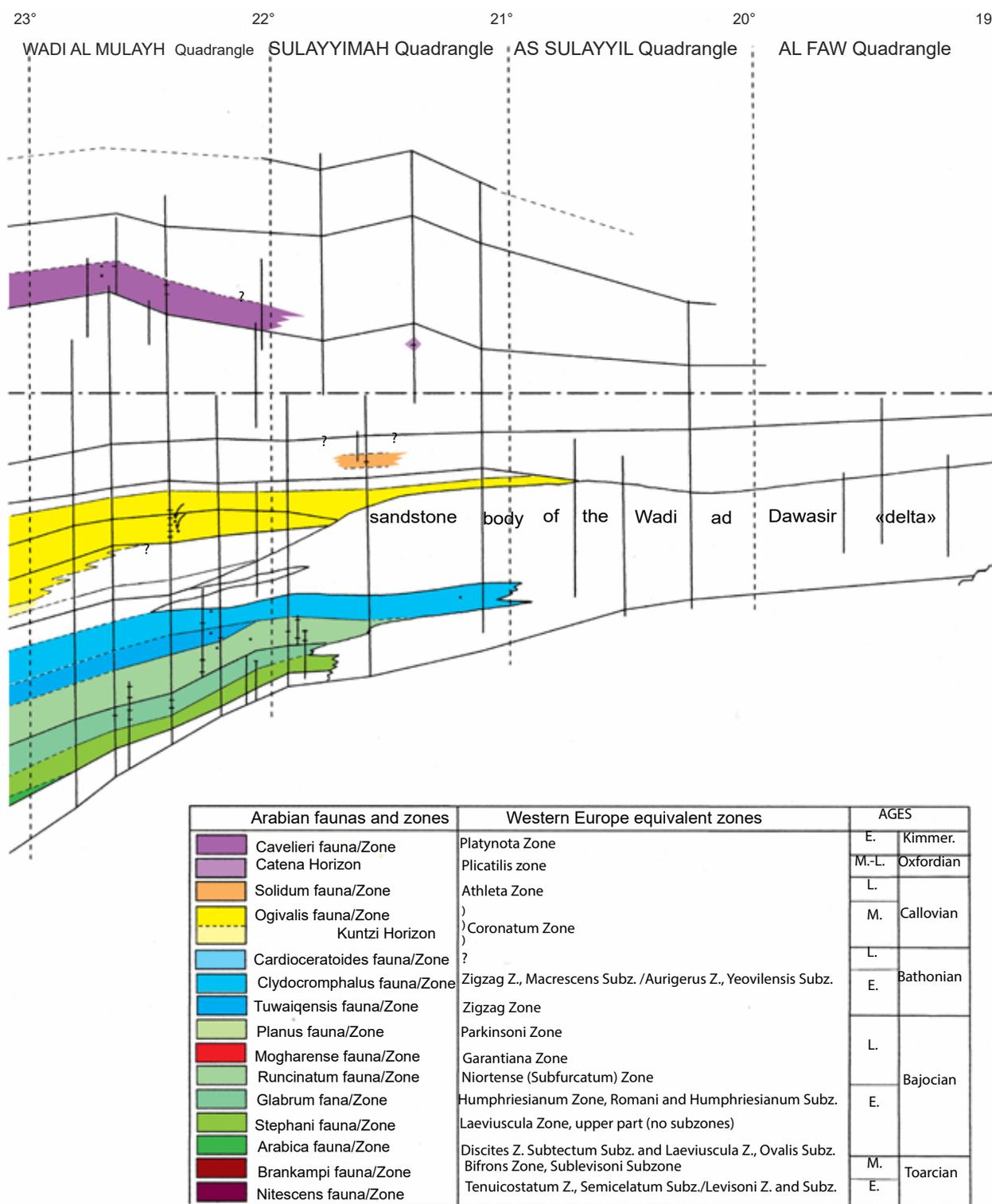


Fig. 6: Continued.

upper part of the upper Dhurma (unit D7) and for the first time recorded *Grossouvria* and *Pachyerymnoceras*.

Recent collections, from which the new time-correlations given in the present monograph are based, range from the base of the Hisyan Member (the upper part of unit D7) to the upper part of the Tuwaiq Mountain Limestone (unit T3). The provenance of the specimens ranges from latitude 26°26' N (Al Liqa) to latitude 21°36' N (Khashm al Mukassar), but the fauna is only (relatively) abundant north of lat 24° N.

Imlay (1970) positioned these first ammonite beds in the upper part of the Atash Member (the lower part of unit D7), whereas Énay *et al.* (1986, 1987a) in the upper part of unit D7 (the Hisyan Member). At the time it was thought that the misunderstanding was only on the position of the boundary between members in the units and that the beds were either the same or very similar. The successive faunas are fundamentally different, but are generally uneven in quantity and quality.

*Pachyerymnoceras* is particularly extensive, appearing in the upper part of unit D7, and continuing up to the unit T3, where the fauna was assumed to be poor by Énay *et al.* (1986, 1987a). But the situation has been totally changed with the addition of material collected by Dr. Al-Asa'ad's at Al-Mu'ayshibah area, NW of Riyadh, about 25°34' N. In the unit D7 the genus is associated with different *Erymnoceras* and there is no doubt that the genus appeared earlier than in Europe, as is the case in western Algeria (Mangold *et al.*, 1978; Mangold, 1988). Other components are more restricted in distribution, making it possible to separate three successive faunas:

1. The *Grossouvria* and *Pseudomicromphalites* fauna in the unit D7 is known south of Darmā' at Khashm adh Dh'ibī, where Imlay (1970) had already recorded it, and at latitude of Wasi Birk. In addition to *Erymnoceras* and the first *Pachyerymnoceras*, various places between Darmā' and Az Zilfi have yielded *Pseudomicromphalites kuntzi*, hitherto known only in Madagascar (Collignon, 1964, 1966) and *Kurnubiella*. This latter genus was established by Gill *et al.* (1985) for the so-called Lewy (1983) cardioceratids ("*Lamberticerias*", "*Prosicerias*" and "*Quenstedtoceras*"). Besides the Madagascan genus *Pseudomicromphalites*, it should be noted also the presence of forms of Subaustral affinities, in Madagascar (Collignon, 1966), *Obtusicoelites* (or *Sivajicerias*) and *Kinkelinerias*, especially known from Kutch (India), unfortunately in the state of nuclei and/or juveniles, except two large specimens with a new species.
2. The *Pachyerymnoceras* and *Kurnubiella* faunas in the Tuwaiq Mountain Limestone are relatively rich in the units T1 and T2. *Erymnoceras*, listed by Énay *et al.* (1986, 1987a), is not present in the units T1 and T2 (Énay *et al.*, 2009) and *Pachyerymnoceras* is more abundant and diverse, including species described

from Israel and/or Sinai and new species, together with *Kurnubiella*.

3. The *Pachyerymnoceras* and *Peltoceras* fauna in the unit T3 is richer. There were few specimens available (badly preserved with calcitized inner whorls) until we received the Dr Al-Asa'ad collection (Al Mu'ayshibah, 25°34' N). Many and often new *Pachyerymnoceras* are associated with rare *Peltoceras*. The fauna extends between lat 21°36' N (Khashm al Mukassar) and lat 25°22' N (Khashm Aba al Hayyal).

### 3.1.7. *Euspidoceras* and *Paryphoceras* faunas

1. A *Euspidoceras* fauna is recorded for the first time in Saudi Arabia and is restricted to the Hawtah member (unit H1) of the Hanifa Fm between lat 23°54' N (Ulayyah) and 25°03' N (Khashm Turab). The fossiliferous bed is located in the upper half of unit H1 and contains a monospecific fauna of large bituberculate *Euspidoceras* with trapezoidal whorl-section, similar to *E. gr. catena-perarmatum* (Sowerby). The same bed at latitude 23°50' N yielded several fragmentary casts, including living chamber, first assumed large-sized perisphinctids, then compared to the mayaitid *Paryphoceras* known in unit H2. The five localities of H1 with *Euspidoceras* fauna spread over a little more than 30' in latitude (between 24°30' and 25°05'). They are too similar to not be one and the same horizon and a single episodic settlement under briefly favourable conditions.
2. *Paryphoceras* fauna. This fauna is recorded here for the first time in the unit H2 which was well-known as being non ammonitiferous. A single nearly complete large specimen has been collected, close to the middle-upper Oxfordian mayaitid *Paryphoceras* of the Indo-Madagascan Province.

### 3.1.8. *Alienispinctes* Fauna

That is the last Jurassic ammonite fauna, formerly known as the "*Perispinctes*" *jubailensis* fauna, fairly widely distributed in the lower half of the Jubaila Limestone Fm (unit J1). It is missing south of lat 22°26' N (Al Hamr Wasit), but Arkell (1952) cited "*P.*" aff. *jubailensis* in exposures south of Wādi ad Dawāsir.

The overall fauna is richer and more varied than hitherto known. But, unlike to what was formerly assumed (Énay *et al.*, 1986, 1987a; Énay & Mangold, 1985, 1994), the true "*P.*" *jubailensis* is not present among the near thirty specimens collected in the lower half of the Jubaila Fm (unit J1). *Alienispinctes cavelleri* nov. gen. nov. sp. is more common and characteristic.

### 3.2. Biostratigraphy, correlations and ages

The singular character of the marine Jurassic Arabian faunas is well known for its endemic nature and is encountered in fairly prominent form in virtually all groups, not only ammonites. There were no major drawbacks in defining the regional faunal successions, where the major handicap is the discontinuity of data and lack of guidelines or indications concerning the evolution of the autochthonous groups. However, adding to the monogeneric or monospecific composition of faunal associations connected with palaeoenvironmental conditions, further complications in time-correlation arise.

Time-correlation with the W European and Mediterranean ammonite zonations (see Cariou & Hantzpergue, 1997) can be made only by reference to relationships in certain areas at certain times between European and Arabian-Indian-Madagascan faunas that have migrated or undergone faunal exchange. These are: (1) the presence of Arabian-Madagascan components that migrated to North Africa (Western Algeria, Morocco) to the Iberian Peninsula, and even exceptionnally to NW Europe (Nièvre, Normandy), and (2) the presence of components of European origin (or known in Europe) associated or intercalated with the Arabian-Madagascan fauna.

Age assignments, however, must be made with care: in both cases the possibility of chronologic offsetting of homotaxial components (particularly at the level of the genus) must be envisaged, related to continuation of the evolutionary process during or subsequent to migration. A new assesement of the data given in Énay *et al.* (1986, 1987a), Énay & Mangold (1994), and Énay *et al.* (2009) is given herein (Figs 2 and 7). Thus, only the zones defined for the Arabic domain are objective because they are based on the taxa collected in numerous stratigraphic sections as much detailed as possible. Their equivalence with the zones (and/or sub-zones) of the standard Western European scale remains speculative. The zones of the Western European scale have no real applicability in the Arabian domain and should not be used as sole referents as is the case in some recent works (Le Nindre *et al.*, 1990b, fig. 5; Al-Mojel, 2017).

#### 3.2.1. Toarcian

The Toarciann Stage is identified by two intercalations of marine fauna; one at the base of the middle Marrat Fm and the other at the base of the upper Marrat Fm.

- Nitescens Zone (Blaison, 1967). The Toarcian age of the first fauna, the *Bouleiceras* fauna, with *Protogrammoceras*, is well established since its discovery in Portugal and the Iberian mountains. The *Bouleiceras* fauna from Spain and Portugal was placed at the base of the Serpentinum Zone. The latter discoveries in Spain (Marin & Toulouse,

1972) agree with a late arrival of the Ibero-Moorish representatives, towards the end of the *Bouleiceras* biochron, already underlined by Guex (1974). A review of the vertical range of taxa common to Madagascar (Blaison, 1967), the Iberian Peninsula (Dubar & Mouterde, 1953; Dubar *et al.*, 1970; Mouterde, 1970; also Geyer, 1965, 1972; Behmel & Geyer, 1966; Geister & Geyer, 1968) and Morocco (Faugères, 1974, 1975) in relation to the zonal scales used in Madagascar (Blaison, 1967) and Submediterranean Europe (Guex, 1973a) was made by Énay & Mangold (1994). These latter authors used a Nitescens Zone with two subzones, from bottom to top, the Nitescens and Madagascariense Subzones. The Nitescens Zone is correlated with the upper part (Semicelatum Subzone) of the Tenuicostatium Zone and the lower part (Levisoni Subzone) of the Levisoni (or Serpentinum) Zone of the Submediterranean scale (Cariou & Hantzpergue, 1997).

- Brankampi Zone (Énay & Mangold, 1994). The *Nejdia* fauna, in places associated with *Parahildaites*, is assigned to the base of the Middle Toarcian. Guex (1973a, b) found *Nejdia* in Morocco in the Sublevisoni Subzone of the Bifrons Zone. The basal Upper Toarcian age assumed by Arkell (1952) was deduced from classification of the genus among the Phymatoceratinae. Nevertheless, *Nejdia* is now considered as a development of the Indo-Madagascan *Bouleiceras* in the direction of their European Tethyan descendants belonging to the Middle Toarcian (Guex, 1974). This latter hypothesis was recently supported by Rulleau *et al.* (2003), but in contrast to the opinion of Bardin *et al.* (2016).

The boundaries of the stage cannot be traced within the lower and upper part of the upper Marrat Fm because of the absence of ammonites.

#### 3.2.2. Bajocian

It is better represented than hitherto assumed and new data reinforce the first results presented previously (Énay *et al.*, 1986, 1987a; Énay & Mangold, 1994). The stage corresponds to the unit D1 (except perhaps for the lowest beds), the whole of the unit D2, and the greater part of D3 of the Dhurma Fm. Among the two possible subdivision of the Bajocian, in two or three substages, the first prevailed (Rioult *et al.*, in Cariou & Hantzpergue, 1997); so the stage counts two sub-stages and not three as previously assumed (Énay *et al.*, 1986, 1987a).

**Lower Bajocian:** The Lower Bajocian coincides approximatively with unit D1 and lower part of unit D2. Assignment by Arkell (1952) of unit D1 to the Middle Bajocian was based on the only species known at the time, "*Dorsetensia*" *arabica* Arkell, this being the age of species belonging to this genus in Europe. The species

is described herein as *Sonninia* (? *Sonninia*) *arabica* (Arkell). Three successive faunas are recognized and considered as zones.

- Arabica Zone (Énay & Mangold, 1994). The first recognized fauna is the *Hyperlioceras* and *Euhoploceras* fauna with dominant Sonniniidae including large *Sonninia* specimens assigned to *S.* (? *S.*) *arabica* (Arkell), *Euhoploceras* and *Fontannesia*. The index-species of the zone, *S.* (? *S.*) *arabica* (Arkell) is well representative of the most frequent elements of the first fauna or Sonniniidae, many of which are close to a form of Madagascar illustrated by Collignon (1958a, pl. 5, fig. 28). In a different facies, probably that of the more marly layers between the Sonniniidae-bearing bioclastic limestone, the same deposits have produced small *Hyperlioceras* specimens that are poorly preserved but close to the group of *H. discites*. This association corresponds to that known in Europe at the base of the Early Bajocian, the Discites Zone, Subtectum Subzone and Laeviuscula Zone, Ovale Subzone (Dietze *et al.*, 2005, 2007). *Sonninia* (? *S.*) *arabica* (Arkell), *Sonninia* (*Euhoploceras crassicostae* n. sp., *S. (E.) turbator* n. sp., *Haplopleuroceras mundum* Buckman and *Fontannesia* sp. are indicative of a higher level in the lower part of the Laeviuscula Zone (Ovalis Subzone).
- Stephani Zone (= *Shirbuirnia* Zone, Énay & Mangold, 1994). This fauna is well separated from the previous one in the upper part of unit D1. The characteristic species is often associated with *Euhoploceras*, *Dorsetensia liostraca* and *Sonninites* aff. *albidus*. The local occurrence (VD80.528, 563, 589) of *Dorsetensia* [e. g. "*D.*" *tessoniana* (d'Orb.)] in the upper part of unit D1 led Énay *et al.* (1986, 1987a) and Énay & Mangold (1994) to consider a fauna called "*Tessoniana* Fauna" occupying a distinct level and slightly higher than the *Pseudoshirbuirnia* fauna. However, it was not considered to be "*significantly different from the Shirbuirnia fastigata fauna* (e.g. *Pseudoshirbuirnia stephani*) and, at best, has horizon value in the upper part of the zone" (Énay & Mangold, 1994, p. 168). However, these *Dorsetensia* are never associated with either *P. stephani* or *S. albidus* so that is preferable to consider a misplacement of the D1/D2 limit in the concerned localities. Occurrence of *Sonninites* aff. *albidus* is limited to only one site where this species is the dominant one. The species is totally absent in the site dominated by *Pseudoshirbuirnia*, but at latitude 23°45' N (near Faridat Balum), *Pseudoshirbuirnia* is associated with an abundant fauna of *Sonninites* aff. *albidus* Buckman. *P. stephani* and *S.* aff. *albidus* are thus considered as the same faunal assemblage and of approximately coeval. In Southern England and Southern Germany, *P. stephani* is known in the Laeviuscula Zone, Trigonalis Subzone, *stephani* Horizon, but the genus may range

upwards in the Humphriesianum Zone, Romani or Cycloides Subzones (Dietze *et al.*, 2005, p. 56); *S. albidus* ranges from the Laeviuscula Zone upwards in the Propinquans Zone = Sauzei Zone in Howarth, 2013, p. 119). To conclude, this assemblage may be correlated with the upper part of the Laeviuscula Zone *l. s.* in northwestern Europe, without it being possible to refer to zones or sub-zones without more varied or more complete associations.

- Glabrum Zone (= Primitive *Ermoceras* Zone in Énay & Mangold, 1994 = *Eoermoceras* nov. gen.). This zone includes the *Normannites*, Sonniniidae and Stephanoceratidae fauna and the *Eoermoceras* and *Dorsetensia* fauna [e. g. the first *Ermoceras* (primitive forms) fauna (Énay *et al.*, 1986, 1987a)]. The zone is characterized by the constant presence of *Dorsetensia*, macroconch [*D. liostraca tecta* and *subtecta* (Buckman)] and microconchs forms [*D. regrediens* (Haug), *deltafalcata* (Quenstedt) and *schlumbergeri* (Haug)]. Although they are less widely present, it seemed preferable to choose the zonal index from the first Ermoceratids of the new genus *Eoermoceras* (*glabrum* and *angustidomus* n. sp.). The other elements of the association are *Normannites* aff. *braikenridgii* (Sowerby) quite frequent and the microconch *Teloceras* aff. *lepsiusi* (Gillet) much rarer. The same *Dorsetensia* fauna is known in Sinai, at J. Moghara (Parnes, 1984), below the *Ermoceras* of the principal *Ermoceras* fauna described by Douvillé (1916). The many new *Normannites* of Makhtesh Ramon (Israel) described by Parnes (1981) are in the same situation, but in a condensed series, perhaps with a gap. The most common species of *Dorsetensia*, *D. liostraca* and its subspecies (*tecta* and *subtecta*) are recorded from England (Buckman, 1892) and Scotland (Morton, 1972), from Germany by Dorn (1935), Buck *et al.* (1966), Huf (1968) and Dietze *et al.* (2011), from Poland by Kopik (1967), from SE of France by Pavia & Sturani (1968). The species is given as a characteristic of the lower part of the Humphriesianum Zone, Romani Subzone (GFEJ, 1997), except by Dorn (1935) who starts it from the Sauzei Zone (= Propinquans Zone). Thus, the Glabrum Zone and the first *Ermoceras*-fauna (*Eoermoceras* nov. gen.) are dated from the lower part of the Humphriesianum Zone, Romani Subzone and (?) Humphriesianum Subzone *pars*, due to the occurrence of rare *Teloceras* microconchs [*T.* aff. *lepsiusi* (Gillet)].

**Upper Bajocian:** The Upper Bajocian comprises the upper part of unit D2 and the greater part, if not all, of unit D3. Imlay (1970) has shown that the Bajocian includes part of unit D3 but the Bajocian-Bathonian boundary was misplaced (as it was already noticed by Arkell, 1952). Three successive faunas are recognized and taken as zones.

- Runcinatum Zone. (= Principal *Ermoceras* fauna) This fauna is the most widespread of all *Ermoceras* faunas and, outside Saudi Arabia and the Sinai Peninsula, it reached as far as western Algeria and the Moroccan Atlas (Arkell & Lucas, 1953; Du Dresnay, 1964b; Du Dresnay & Kuntz, 1964), where it is dated as basal Late Bajocian (Subfurcatum Zone). This age is in agreement with that of the surrounding fauna in Saudi Arabia. It is also compatible with the presence in the upper part of the unit D2 of *Stemmatoceras* aff. *frechi* (Renz), one of the few other elements found together with the Ermoceratins. *Teloceras* sp. quoted in Énay *et al.* (1986, 1987a) was a not well-preserved and misidentified *Ermoceras*.

Correlations with the European zonal standard are based on the more open marine forms known in Sinai and *Ermoceras* species of Arabic origin reaching to North Africa where they are associated with European elements. Thus, the main *Ermoceras* fauna and the Runcinatum Zone are correlated with the Niortense Zone of the lower Upper Bajocian.

- Mogharensis Zone (*Ermoceras mogharensis* and *Spiroceras annulatum* fauna). The specimens figured by Arkell (1952) as *E.* cf. *mogharensis* (Douvillé) has nothing to do with Douvillé's species (1916). The type-species of *Ermoceras* characterizes a fauna identified by Douvillé in Sinai, where it is clearly separated from beds containing *E. coronatum*, *E. coronatoides*, *E. deserti*, *E. splendens*, *E. runcinatum* and *E. elegans* (principal fauna). This fauna was recorded from Saudi Arabia only since 1970 (Imlay, 1970; Énay *et al.*, 1986, 1987a; Énay & Mangold, 1994). The more diversified association known in Sinai and *Spiroceras annulatum* allow a good correlation with the Garantiana Zone of the upper Bajocian. Sandoval (1983) in southern Spain gives a wider extension to the Annulatum Zone, but in the rest of Europe, according to Dietl (1978) *S. annulatum* is well limited to the Garantiana area. Several elements of Arabian origin of this fauna have been reported in Normandy, *Trimarginia sinaitica* (Riout, 1964) and *Thamboceras* (Riout *et al.*, 1991, 1997; Riout & Chirat, 1999), recently studied by Énay *et al.* (2012b).
- Planus Zone (*Thambites* and *Rebouliceras avus* fauna). Taking into account the corrections made by Imlay (1970), the Bajocian-Bathonian boundary has hitherto been placed to coincide with the appearance of *Thambites*, or of the association of *Thambites* and *Rebouliceras avus*. Taken on its own, this association does not indicate any specific age, and the Early Bathonian age subsequently assumed by Arkell (1952) was based solely on its position between the *Ermoceras* fauna date as Late Bajocian and the overlying *Tulites* fauna (unit D4) assigned to the Middle Bathonian. Following Arkell, the *Thambites* fauna (and subsequent faunas as well) were still

dated as Bathonian in Israel (Lewy, 1983; Gill *et al.*, 1985). The arguments for moving the Bajocian-Bathonian boundary to the top of the *Thambites* beds (a little below the D3 / D4 limit) and below the first *Micromphalites* have already been given; consequently, Arkell's point of view has already been corrected (Énay *et al.*, 1986, 1987a; Énay & Mangold, 1994). The same *T. planus* and *R. avus* fauna has been recorded from Morocco (Du Dresnay, 1969, 1974) above the (principal) *Ermoceras* fauna and below a fauna with European affinities consisting of *Gonolkites* and rare *Morphoceras* and *Ebrayiceras* of Early Bathonian age; also with *Oraniceras*, a genus recognized as Early Bathonian in age in western Algeria (Roman, 1933). Within the *Thambites* assemblage, the numerous large oxycones, doubtlessly ranged into "*Thambites*" (*Mulayites avus*) or "*Clydoniceras*" (*P. pseudodiscus*) by Arkell, and confused with *Dhrumaites* by Imlay, are just as characteristic as the true *Thambites* among which the zonal index was chosen. *M. avus* is also more widely present in Morocco than *Thambites* known from a single exposure (Du Dresnay, 1969, 1974; Énay *et al.*, 1986, 1987a). Another element in favor of the preference given to a species of *Thambites* is the probable phyletic relationship with the *Thamboceras* of the immediately underlying Runcinatum Zone.

Although they are not well-preserved and of uncertain systematic position two *Procerites* from the same locality and section a few metres from each other look near to species well-known in the uppermost Parkinsoni Zone (Bomfordi Subzone) (Riout *et al.*, 1997 in Cariou & Hantzpergue).

Finally, in Saudi Arabia, at the top of the unit D3, *Zigzagiceras* (*Franchia*) sp. (Énay *et al.*, 1986, 1987a) quoted as "*very close to a form described at the top of the Convergens Subzone in the Zigzag Zone at the base of the Early Bathonian in Europe*" (Énay *et al.*, 1986, p. 45; 1987a, p. 43) was identified as a new genus and species, *Metazigzagiceras subarabicum* by Fernández-López & Pavia, "*probably belonging to the latest Parvum and/or Macrescens subzones*" (Fernández-López & Pavia, 2013, p. 23) of the Lower Bathonian Zigzag Zone. To conclude, the *Thambites* Zone defined by Arkell (1952) should therefore be placed further back in time. It may reach the Early Bathonian at the top, but the greater part of the *Thambites* and *R. avus* fauna still belongs to the terminal Late Bajocian, Parkinsoni Zone of the European Zonal Standard (Énay *et al.*, 2007; Almería *et al.*, 2010).

### 3.2.3. Bathonian

Except the Arabian *Micromphalites*, now known from southern Morocco, in Spain, central and southeastern France, the Bathonian ammonite faunas of the Arabian province are poorly correlated (Énay *et al.*, 2001) with

those of Europe. The very presence of the middle and / or upper Bathonian is still in question.

**Lower Bathonian:** The Bajocian attribution of the *Thambites* fauna, and of the greater part (if not all, save locally) of unit D3 of the Dhurma Fm, raises even more specifically the problem of the age of the *Tulites* and *Micromphalites* faunas traditionally dated as Middle Bathonian by reference to its insertion within the succession of western European faunas. The only common point is the identical order of succession of the two genera, the species being virtually entirely different, particularly in the case of *Tulites*.

- Tuwaiqensis Zone (= *Tulites* fauna). The *Tulites* fauna yields almost exclusively species of this genus, created for species of Europe, and the index species is not the most abundant, but it is best distributed in the field studied. All these species are different from European Middle Bathonian ones and, with the exception of one specimen from Sicily (Galácz, 1999a, b), are known to date almost exclusively from Saudi Arabia.

The only and rare exotic elements are *Metazigzagiceras subarabicum* Fernández-López & Pavia, already cited, and an *Oxycerites* specimen with narrow umbilicus close to *O. fallax* (Guéranger), in good agreement with the Lower Bathonian age of the Tuwaiqensis Zone already proposed by Énay *et al.*, (1986, 1987a) and Énay & Mangold (1994). The correlation with the lower part of the Zigzag Zone is deduced from its position between the underlying Planus zones and the overlying Clydocromphalus Zone, these two zones being well correlated with the European Zonal Standard.

- Clydocromphalus Zone (= *Micromphalites* fauna). The well-calibrated European form of *Micromphalites micromphalus* (Phillips), type-species of the genus, which is different from the Arabian forms, dates from the upper part of the Middle Bathonian (the Morrissi Zone), also above *Tulites* (also with quite different species). The only other species already described in Europe, and represented by a very similar form in Saudi Arabia, is also the only form known from the Lower Bathonian (*M. busqueti*), as asserted from its proposal by Douvillé (1916) and wrongly challenged by Arkell (1952).

Arkell (1952) gave a full illustration of the species (or variants) of the *Micromphalites* fauna in Saudi Arabia, including the only known species in Sinai, *M. pustuliferus* (Douvillé, 1916). All were dated from the Middle Bathonian by reference to the European level of the type-species of the genus, *M. micromphalus* (Phillips, 1871), although the only form close to the Arabian types, *M. busqueti* (Douvillé), was already known from the Lower Bathonian (Douvillé, 1916).

The Arabian species are recorded on the migration route commonly used by the Arabian-Madagascan faunas

along the South Tethyan margin: *M. clydocromphalus* in Morocco (Colo, 1962; Du Dresnay, 1974, 1979; Énay *et al.*, 1987b), *M. pustuliferus* in southern Spain (Mangold, 1981) and France (Énay *et al.*, 2001), all from beds of Early Bathonian age. So it is clear that the only species of *Micromphalites* known in Middle Bathonian from Europe is the descendent of Arabian forms that arrived in Europe through migration from the Early Bathonian onward. The Arabian *Micromphalites* dates from the Early Bathonian, Zigzag Zone, Macrescens subzone and Aurigerus Zone, Yeoviensis Subzone, which also implies an Early Bathonian age for the underlying *Tulites* fauna, whose species are all different from those in the Middle Bathonian in Europe. The *Tulites* fauna must have undergone the same evolutionary process associated with migration toward Europe, with the single milestone of the specimen from Sicily in (Galácz (1999a, b).

**Upper Bathonian:** One exposure assumed to be in the upper part of unit D5 (VD80.559), yielded *Micromphalites* sp. and the index-species. Rather than considering a possible revision of the D5/D6 limit, it is assumed that the site is well in the upper part of D5 and that the specimen of *D. cardioceratoides* is derived from the overlying beds.

- Cardioceratoides Zone (= *Dhrumaites* Fauna). The *Dhrumaites* fauna is the only ammonite fauna connected to unit D6. Except a single citation without figuration in the Lower Callovian of Madagascar (Collignon, 1963) and not confirmed latter (Collignon, 1966), the genus *Dhrumaites* is unknown outside Arabia. So, by itself it is not significant of any given age; even its place in Middle and/or Upper Bathonian is uncertain and it is impossible to characterize the upper boundary of the Bathonian, owing the absence of any ammonite fauna proper to the Bathonian or to the Lower Callovian. The classification of *Dhrumaites* within Clydoniceratidae and its affinities to *Clydoniceras* do not constitute an argument to confirm a Late Bathonian age. In Madagascar the final development known of the family dates from the Early Bathonian (Collignon, 1958b, 1966), but Middle Bathonian marine deposits show a limited development, often invaded by the sandstones of Isalo ended by layers with corbules and a horizon with large dinosaurian (Collignon, 1963b). In Saudi Arabia, oxycones with simplified suture line of “*Clydoniceras*” type, poorly preserved, associated with Callovian forms in the Tuwaiq Mountain Limestone Fm, have been assigned to *Pseudoclydoniceras* (Collignon, 1958b) a Callovian genus.

An Early Bathonian age was assumed by Le Nindre *et al.* (1987, 1990a) based on the nautilids, *Ophionautilus* cf. *catonis* and *Eutrephoceras* cf. *waageni* also known in the underlying beds (Tintant, 1987) and ascribed to the Lower Bathonian beds because “*the absence*

of any new form” (Tintant, 1987, p. 71). But when Tintant (1987) established *Eutrophoceras globosum*, known only from unit D6, he did not firmly dismiss a Middle Bathonian age (Tintant, 1987, p. 124).

Out of ammonites and nautilids, brachiopods show a major change with unit D6 (Alm eras fauna 4) and Alm eras (1987, p. 174) suggested “a gap of the Middle Bathonian and, perhaps, of a part of the Upper Bathonian”, just above unit D5 and he added “no species otherwise known only from the Middle Bathonian has been observed”. So, the *Cardioceratoides* Zone would be of Late Bathonian age but equivalence with the European Zonal Standard shall not exceed more. This is the conclusion already adopted by  nay *et al.*, (2009, fig. 2) and taken up by Alm eras *et al.*, (2010, fig. 2 revised).

### 3.2.4. Callovian

Ammonites are missing in the lower part of unit D7 (Atash member), reappearing only in the upper member (Hysian Mb) with a fairly high diversity which is diminishing in the overlying Tuwaiq Mountain Limestone Fm. Thus, owing to the absence of properly Bathonian or Lower Callovian ammonites it is impossible to characterize the upper boundary of the Bathonian and the Bathonian-Callovian boundary. Only the Middle Callovian is well characterized. The present authors regard the Callovian as beginning with the lower part of the unit D7 (Atash member) but it is not impossible that a part of the Lower Callovian and also of the Upper Bathonian would be missing (see “faunal discontinuities”). Ammonite faunas are more diverse and with more forms of European origin in Sinai and Israel (Lewy, 1981a, b, 1983; Gill *et al.*, 1985). These latter authors have revised some of the statements of Lewy (1981a, b, 1983), assuming that most of the studied faunas and consequently the Arabian ones (in Arkell, 1952; Imlay, 1970) were Late Callovian in age, implying a major hiatus and unconformity from the Upper Bathonian (or probably Lower Callovian) up to the Upper Callovian (Lewy, 1981b). They also proposed detailed correlations with the European Zonal Standard, but not any zones proper to the Arabian Province, even when the original features are well underlined. Zones proper to the Arabian Province were latter introduced by  nay & Mangold (1994).

**Lower Callovian:** Lower Callovian ammonites have not been found in the lower part of the unit D7 (Atash member). The first ammonite of the lowermost beds of the Hysian member is uppermost Lower Callovian. As a result the Atash member is considered as being Lower Callovian.

#### Middle Callovian:

- Ogivalis Zone (= *Grossouvria-Pseudomicromphalites* and *Pachyerymnoceras-Kurnubiella* faunas). In

the studied area the zone corresponds to the upper member (Hysian) of unit D7 and the major part (units T1 and T2) of the Tuwaiq Mountain Limestone Fm, in Israel to the “faunas 1 and 2” of Gill *et al.* (1985), and less surely part of the “lower assemblage” of Lewy (1983). The selected index-species belongs to the genus *Kurnubiella* (Gill *et al.*, 1985). In Saudi Arabia *Kurnubiella* is a good marker of the upper part of the unit D7 (Hysian member) and the units T1 and T2 of the Tuwaiq Mountain Limestone Fm: the index-species *K. ogivalis* (m) was encountered in these units as well as the macroconch form, *K. fallax*, while *K. hatirae* and *compressa* have only been found in the unit T2.

The lowermost beds of the upper member (Hysian) of the unit D7 deserve special mention owing to the presence of *Pseudomicromphalites*. This latter justifies the distinction of a Kuntzi horizon ( nay & Mangold, 1994) from the species described from Madagascar and situated with doubt by Collignon (1966) in the uppermost Lower Callovian. Other genera of Subaustral affinities are *Obtusocostites* (or *Sivajiceras*) and *Kinkeliniceras*. Other components of the Ogivalis Zone assemblage are *Erymnoceras*, *Pachyerymnoceras*, *Grossouvria* and *Pseudomicromphalites*. After revision of previous data ( nay *et al.*, 1986, 1987a) by  nay *et al.* (2007), *Erymnoceras* is not as frequent as initially stated and is known from the upper unit D7 only. *Pachyerymnoceras* is recorded from units T1 and T2, but some specimens quoted from unit T1 but not collected *in situ* could be derived from unit T2. Association of *Pachyerymnoceras* with European Middle Callovian forms (*Grossouvria*) was already recorded in Saudi Arabia by Imlay (1970) and also recognized in western Algeria (Mangold *et al.*, 1978; Mangold, 1988). This association was denied by Lewy (1981a, b; 1983) because *Pachyerymnoceras* is not known in Europe before the Late Callovian. Consequently, Lewy (1981a) proposed the substantial discontinuity already quoted just above; this interpretation will be discussed latter. In Europe the Ogivalis Zone is equivalent to the Coronatum Zone in the upper Middle Callovian. Gill *et al.* (1985) have proposed for the faunas of Israel more accurate correlations of faunas 1 and 2 that correspond respectively to the Baylei and Leuthardt subzones. Concerning the following faunas 3 and 4 which represent the following Athleta Zone they did not specify whether there is a gap of the Rota Zone or inability to establish equivalence. As a result, we accept a global correlation with the upper part of the Middle Callovian, Coronatum Zone, of the Submediterranean Zonal Standard. Consequently, the lower part of the unit 7 would be of Early to Middle Callovian age.

#### Upper Callovian:

- Solidum Zone (= *Pachyerymnoceras* and *Peltoceras* faunas). The upper part (unit T3) of the Tuwaiq Mountain Limestone Fm was poor in fauna and this

did not appear to be very different from that of the rest of the formation. The situation has changed with the material collected by Dr Al-Asa'ad. The fauna of the T3 unit is very similar to that known in Israel and Sinai (Lewy, 1983) and faunas 3 and 5 of Gill *et al.* (1985). *Pachyerymnoceras* are the dominant forms of the association with large forms, *P. cf. magharensis* (Lewy), *P. cf. spathi* (Lewy) and a curious forms of *Pachyerymnoceras* reported by Énay & Mangold (1994) as: “with a tectiform and carinated ventral area”, very poorly preserved, described herein as *P. magnum* n. sp., as well as *P. spp. A, B, C, and D* (microconchs). Along with *Peltoceras trifidum* there is another large *Peltoceras* with a single row of outer tubercles in the adult stage. This was confused with *Paraspidoceras* (Gill & Tintant, 1975; Lewy, 1983) and Gill *et al.* (1985) established *P. (P.) pachygaster*, but this form does not appear to be really different from *P. (P.) solidum* Spath, described from Kutch (India) where the species is not rare (two other specimens, one collected by E. Cariou, R. Énay & J. Krishna, preserved at the University of Poitiers, the second by J.H. Callomon, preserved in the Oxford Museum). Thus, the equivalent of the Solidum Zone in the European Zonal Standard is the Upper Callovian Athleta Zone.

But there is no certainty about the presence of uppermost Callovian deposits. No ammonite fauna allows the recognition of a Lamberti Zone as erroneously stated by Manivit *et al.* (1990, fig. 33) and Le Nindre *et al.* (1990b, fig. 5). They have been neither mentioned in our publications (see references) nor in the reports we have sent to the BRGM in 1982-1984. The review by Manivit (in Manivit *et al.*, 1990, pp. 354-358) of groups other than ammonites shows no evidence in favour of the presence of the Lamberti Zone. All that remains is what he wrote in p. 350, concerning the El-Asa'ad collection, with reference to R. Énay and C. Mangold, of which I have no record in the afore mentioned reports as well as in our letters. Where has he been taking this from? It is worth to notice that (i) he did not cite any species from the Lamberti Zone, and (ii) those species cited from the Athleta Zone do not appear in our reports, but they are cited by Lewy (1983) and by Gill *et al.* (1985), with the work of which there seems to have been confused.

### 3.2.5. Oxfordian

Characteristic faunas of the Callovian-Oxfordian boundary are not known, thus it cannot be drawn on palaeontological bases. The first dated beds in the Hanifa Fm and in the upper part of the Hawtah member (unit H1) belong to the lower part of the Middle Oxfordian. So, the existence of deposits corresponding to the Cordatum Zone of the Lower Oxfordian of Western Europe is very doubtful. It is admitted with doubt by Manivit (in

Manivit *et al.*, 1990) and taken up by Fischer *et al.* (2001) and Al-Mojel (2017). This dating is based on two species of brachiopods. The former, *Ornithella gr. hudlestoni* (Davidson) is known from the Lower Calcareous Grit (Cordatum Zone) of England. Manivit *et al.* (1990, p. 426) reports a personal communication from Boullier and Delance, emphasizing “the identity of the individuals of Arabia with the type specimens”. But, it disagrees, first with approximate determination (gr. of), then that given by Boullier in the (palaeontological) atlas project (not realized) for the team of BRGM field geologists, e.g. “? *Ornithella gr. hudlestoni* (Davidson, 1878)”. Moreover, the species is not cited by Alméras, Boullier & Laurin (in Cariou & Hantzpergue, 1997, pp. 169-195) among the significant brachiopod species of the lower Oxfordian. The second species, *Somalirhynchya africana* Weir, is a form of East Africa from beds without ammonites for a precise dating.

### Middle Oxfordian:

- *Catena* Horizon (= *Perarmatum* Horizon in Énay *et al.*, 1986, 1987a; Énay & Mangold, 1994). The few fragmentary casts, first assigned to *Perisphinctes* then to *Paryphoceras* do not provide any help for dating. The index species is the only one present in the five known faunal sites with *Euspidoceras*. Distributed on less than 35' in latitude (between 24°30' and 25°05'), they are too similar by the fauna and the preservation to represent a single horizon and a single episodic incursion during favorable conditions. Whereas the lithosequential division of H1 (Manivit, 1987) leads to distributing them in at least three distinct units, implying three different successive colonizations, very limited geographically.

In Western Europe *E. catena* (Sowerby) and *perarmatum* (Sowerby) follow one another within the basal Middle Oxfordian Plicatilis Zone. The acme of *E. catena* is slightly earlier than that of *E. perarmatum*, but both species have a common vertical range within the Plicatilis zone. The same age was assumed by Arkell (1952, pp. 292, 299) for one fragment of a form from East Africa and *Perisphinctes africanus* (Dacqué), a species which is placed among the *Kranaosphinctes* known in Europe in the Plicatilis Zone. The suggested age does not correspond with Arkell (1952, p. 293), and despite rectification by Arkell (1956, p. 299), it was not applied in the synopsis by Powers *et al.* (1966) and Powers (1968) who assigned a Kimmeridgian age to the Hanifa Fm. The Middle Oxfordian age of the unit H1 was well established by Énay & Mangold (1994).

**Upper Oxfordian:** Previous dating (Énay *et al.*, 1986, 1987a) was based on the appearance of the foraminifer *Alveosepta jaccardi* (Schrodt) from the base of the Ulayyah member (unit H2). So, the only one well-preserved ammonite, a nearly complete macroconch *Paryphoceras* from the same unit (VD80.325, 23°54'N),

is of great interest. The vertical range of *Paryphoceras* in the Indo-Madagascan Province is from the Middle Oxfordian up to the Lower Kimmeridgian. Thus, the assumed equivalent age for the unit H2 is Upper Oxfordian, Planula Zone (Early Kimmeridgian according to Wierzbowski *et al.*, 2016). The exact upper boundary of the Oxfordian stage is hard to be drawn. It is placed at the limit of the Hanifa (unit H2) and Jubaila (unit J1) formation.

### 3.2.6. Kimmeridgian

#### Lower Kimmeridgian:

- Cavelieri Zone (= Jubailensis Zone Énay & Mangold, 1994). The last Jurassic ammonites in the lower part of the Jubaila Limestone (the *P. jubailensis* fauna in Énay *et al.*, 1986, 1987a and Énay & Mangold, 1994) have special peculiarities. The species is not reported with certainty; the studied specimens are assigned to *Alienispinctes cavelieri* nov. gen. nov. sp. and to other form (genus and species noves indet.), all believed Early Kimmeridgian (Platynota Zone). Among the Nautiloids (see Tintant, 1987), the occurrence of *Paracnoceras* aff. *wepferi* (Loesch) is consistent with an Early Kimmeridgian age.

Thus the lower limit of the Kimmeridgian is placed at the base of the Jubaila Fm, in agreement with Arkell (1952, 1956) but in contradiction with Powers *et al.*, (1966) and Powers (1968). It is not possible to take into account the “ammonite fauna unanimously identified as Lower Kimmeridgian” (Powers, 1968), recognized from a drill hole in the Fadhiili field within “a series of black schist and black impure limestone” which is regarded as a lateral equivalent of the Hawtah member (unit H1) in the Hanifa Fm. Not only this fauna has never been represented, but no specific determination has been given. Depêche *et al.* (1987), Manivit (1987) and Le Nindre *et al.* (1990), also placed the Oxfordian-Kimmeridgian boundary in the upper part of the Hanifa formation (unit H2) whose highest levels are dated from the Early Kimmeridgian and even more precisely Hypselocyclum Zone of the Submediterranean of W Europe. This dating was affirmed by Clavel in his reports (1982-1985, 1986), to which the present authors did not subscribe. It is based on four European species of regular echinids (*Rhabdocidaris orbignyana* Agassiz, *Acrocidaris nobilis* Agassiz, *Pseudocidaris mammosa* Agassiz and *Acropeltis aequituberculata* Agassiz) and one (*Monodiadema cotteaui* de Loriol) essentially subtethyan (North Africa) but known from Portugal. However, the review of the “Chronological and geographic distribution of Jurassic Echinids in France: Biostratigraphic use essay” by Thierry *et al.* (1997), of which Clavel is the second co-author, states that the four European species are known there from the Middle Oxfordian to the Upper Tithonian. The only southern Tethyan species is not mentioned,

but the new data provided by ammonites from unit J1 mentioned above are assumed for dating the lower part (unit J1) of the Jubaila Fm as Early Kimmeridgian. Hence, the Oxfordian/Kimmeridgian boundary is placed between the units H2 (Upper Oxfordian) and J1 (lower Kimmeridgian).

**Upper Kimmeridgian:** The upper part of the Jubaila Fm (unit J2) is assigned to the Upper Kimmeridgian without any other argument than its position above the unit J1 assumed to be lower Kimmeridgian. Concerning the overlying formations, in the absence of new time-diagnostic ammonites, the age suggested by Powers (1968) for the Arab Fm and the Hith Anhydrite is retained.

### 3.3. Faunal discontinuities

As a result of the time-correlations elaborated, it appears that either parts of a stage or even a whole stage (e.g. the Aalenian) have not been recorded and that the boundaries between successive stages cannot be accurately drawn everywhere (see Tab. 1). Therefore, the question arise as to the possible existence of true discontinuities within the Jurassic with the absence of deposits being the result of a break in sedimentation or intra-Jurassic erosion. This problem has been clearly posed in the case of the Marrat-Dhruma contact (Imlay, 1970) and in the case of the Bathonian-Callovia boundary (Imlay, 1970; Lewy, 1981a, b). The same applies to the Callovian-Oxfordian boundary between the Tuwaiq Mountain Limestone and the Hanifa Fm and also between the D5 and D6 units (Lower-Upper Bathonian boundary) owing to the new interpretation of the “delta” by Énay *et al.* (2007, 2009)

#### 3.3.1. The Marrat (Upper unit) – Dhruma (unit D1) discontinuity

Imlay (1970) suggested the existence of a discontinuity between the Marrat and Dhruma formations, with a hiatus including the Upper Toarcian and the Lower Bajocian. The first dated faunas from the unit D1, at the base of the Dhruma Fm, are now assigned to the lower part of the Lower Bajocian. The hiatus, if it exists at all, would therefore be shorter (at least where faunas have been recognized). However, the greater part of the upper Marrat Fm and the very first layers of the unit D1 below the *Hyperlioceras-Euhoplaceras* fauna have not been dated. The discontinuity cannot, therefore, be exactly calibrated within the reference scale, but it could correspond to a “regressive” episode during the Late Toarcian-Aalenian known in many other parts of the world. The Late Toarcian and the Aalenian may be at least partially represented by beds without ammonites in the upper Marrat Fm and possibly by the extreme base of the unit D1.

### 3.3.2. The D5/D6 Discontinuity, the Wadi ad Dawasir “Delta” and the Early Bathonian relative sea-level fall

Surfaces indicating a break in the sedimentation occur at several levels within the Jurassic series, but generally of local significance. Top of the unit D5 is the only non-deposition surface of wide extent observed in the marine deposits, at least in the central part of the outcrops (Énay *et al.*, 2009, p. 33, photo 8). The discontinuity at the top of unit D6, assumed by Manivit *et al.*, (1990), Le Nindre *et al.*, (1990a), Depêche *et al.* (1987), and Manivit (1987), are not of so large extension (Énay *et al.*, 2009). Concerning the D5/D6 discontinuity the palaeontological data do not allow a definite dating. It is likely to be post-Lower Bathonian by the *Micromphalites* fauna of the underlying unit D5 (Clydocromphalus Zone) known southward at the latitude 21°03'N (Wadi al Majami). Nevertheless, the overlying *Dhrumaites* fauna (Cardioceratoides Zone), shows a smaller extension and does not extend southwards beyond lat 23°18' N (Khashm Birk); moreover, the genus *Dhrumaites*, unknown outside the Arabic domain, does not allow precise dating. Apart from the ammonites, the nautilids and especially the brachiopods led to date the unit D6 as Late Bathonian (Alméras in Énay *et al.*, 2009; Alméras *et al.*, 2010). A very significant renewal of the brachiopod faunas occurs at the base of the unit D6, corresponding to the *Daganirhynchia daghaniensis* and *Eudesia (Sphrignaria) cardioides* Zone of Alméras (in Alméras *et al.*, 2010). The discontinuity at top of the unit D5 corresponds to a gap of the whole Middle Bathonian and possibly also a part of the Lower Bathonian. The discontinuity D5/D6 has been correlated with the setting of the siliciclastic deltaic body known as the Wadi ad Dawasir “delta” (Énay *et al.*, 1986, 1987a; Le Nindre *et al.*, 1987, 1990a; Manivit *et al.*, 1990), of which a new interpretation was given by Énay *et al.* (2007, 2009). The so-called “delta” is interpreted as a platform deltaic wedge and the discontinuity D5/D6 as a downlap surface, both resulting from an Early Bathonian relative sea-level-fall. The delta detrital body of Wadi ad Dawasir is dated as Early Bathonian on the basis of the nautilid, *Ophionautilus* aff. *zitteli* (Gemmellaro), a Lower Bathonian species in western Europe (Sicily and France) according to Tintant (1987, p. 88). This dating could be considered to be based on weak evidence and according to Le Nindre (written communication, 03/01/2020): “*Vaslet formally disagrees with the age assigned by Tintant to this fragment*”, but Professor H. Tintant is no longer there to defend his point of view. Another possibility, put forward by Le Nindre, that this nautiloid was reworked, has already been considered and not retained by Énay *et al.* (2009, p. 31). In his doctorate thesis, Al-Mojel (2017, p. 27) exposed the two interpretations, by Manivit *et al.* (1990), and Énay *et al.*, (2007, 2009) clearly adopting the former.

In addition, the great marine regression of the Middle Bathonian already recognized by Arkell (1956, p. 609)

produced the closure of the communication (Viking corridor of Doré, 1991, 1992) between the Arctic basin and the Tethys. This closure of communication produced the isolation of the boreal faunas which cease only in times with the transgression started in the Upper Bathonian and largely developed with the Callovian. Furthermore, as noticed by Énay *et al.*, (2007, 2009), the existence of deltaic deposits of Early Bathonian age in central Saudi Arabia is not an isolated fact. Early Bathonian deltaic or paralic deposits are known elsewhere in northern Sinai, Egypt (Al Far's, 1966; Keeley *et al.*, 1990) and Negev, Israel (Goldberg & Friedman, 1974; Hirsch, 1976; Picard & Hirsch, 1987; Hirsch *et al.*, 1998), north margin of the Arabian-Nubian Shield, as well as in S Tunisia (Freinex & Busson, 1963; Barale *et al.*, 2000; Énay *et al.*, 2002), northern margin of the Saharan Craton (see review by Énay *et al.*, 2007, 2009). This event is comparable with that which in Morocco led to the emplacement of red continental beds containing dinosaur and plant fossils (e.g. the El Mers Fm) overlying the last ammonite-bearing beds dated as Early Bathonian, and which brought into association of European forms and components of Arabian origin (Du Dresnay, 1974). The so-called “*Clydoniceras discus* fauna” (Roman in Termier & Dubar, 1940; Du Dresnay, 1963b, 1969, 1974; Jenny *et al.*, 1981) at the base of the El Mers beds might be possibly composed of forms of *Dhrumaites*. In Madagascar (Collignon, 1963a, b) marine Middle Bathonian deposits show a limited development commonly invaded by sandstones of the Isalo facies which ends with layers containing *Corbula* and skeletons of chelonians or even large dinosaurs. Thus, the same event with the same results would be well-known around the northern and eastern African parts of the Gondwana continent, but would be not present in Saudi Arabia. Why?

To answer this question is needed more field work seeking for more significant faunas than the single existing nautilid. Then, if this research would give the hoped-for results, the geometric relationships of the levels with these new faunas and the units all around these should be reviewed to decide what of the two hypotheses stands.

### 3.3.3. The Bathonian – Callovian discontinuity

After the discovery of new Callovian faunas in the upper layers of the Dhruma Fm (unit D7, Hisyan member), Imlay (1970) envisaged a discontinuity between the Bathonian and the Callovian (the middle and upper Dhruma Fm). This question was recently re-examined by Lewy (1981a, b, 1983) who has advanced disputable arguments. One of these is the misidentification of the so-called European cardioceratids of the Upper Callovian Lamberti Zone which has been already examined in connection with the Callovian. Other of his arguments was that the type-species of *Pachyerymnoceras* (and the only known species) is dated in W Europe from the Upper Callovian

(Athleta Zone). Thus, Lewy (1981a, b; 1983) dated the beds with *Pachyerymnoceras* of Sinai, Israel and Saudi Arabia as Late Callovian, although Imlay (1970) compared the association of the first representatives of this genus with Middle Callovian forms of W Europe. Thus, in these areas, Lewy asserted the existence of a large discontinuity with a gap in the Middle Callovian and part of the Lower Callovian (Sinai, Israel) or the entire Lower Callovian in Saudi Arabia. Following the works on Sinai (Gill *et al.*, 1985) and western Algeria (Mangold, 1988), where the first *Pachyerymnoceras* are in the upper part of the Coronatum Zone, it is clear that the genus appears earlier on the southern margin of the Tethys. In the Tethys the genus evolves several species different from the only known and ultimate species in Europe of a genus of Arabian origin. The Middle Callovian is now well characterized by the new faunas collected in central Saudi Arabia, but the problem of a gap in the Early Callovian, and possibly also in the Late Bathonian, can always be questioned. Furthermore, it cannot be solved from existing palaeontological data without disregarding the systematics and significance of known faunas. Below the oldest Callovian fauna, in the lowermost beds of the Hisyan member, about the Lower-Middle Callovian boundary, the last known fauna is the *Dhrumaites* fauna in the unit D6. The genus has no well-established age and the assumed Late Bathonian was based on a brachiopod assemblage. The lower part of the unit D7 (Atash member) has not yielded ammonites, the ones cited by Imlay (1970) have been assigned by Énay *et al.* (1986, 1987a) and Énay & Mangold (1994) to the base of the Hisyan member. The renewal of the sedimentary process above the discontinuity at the top of the unit D5 is associated with a change in palaeoenvironment towards less favorable conditions for ammonites. This is valid even for forms adapted to difficult or constraining environments. Among the consequences are the reduction of their ranges with the last *Dhrumaites* and their temporary disappearance. But the unit D7 shows a progressive trend towards open-marine environments with the result of renewal and diversification of faunas, first for brachiopods as soon as the unit D6 with Assemblage 4 (the *Daganirhynchia daghaniensis* and *Eudesia cardioides* Zone of Alméras *et al.*, 2010) and nannoplankton, latter for the ammonites. In conclusion, the present authors assume an Early Callovian age for the lower part (Hisyan member) of the unit D7, and then that there is not any major gap between the D6 and D7 units and the Bathonian-Callovian boundary.

### 3.3.4. The Callovian – Oxfordian discontinuity

In the absence of characteristic faunas, the Callovian-Oxfordian boundary could not be drawn on palaeontological basis. As pointed out above (see p. 36 no ammonite fauna allows the recognition of a Lamberti Zone as wrongly assumed by Manivit *et al.* (1990,

p. 350, figs 33, 41) and Le Nindre *et al.* (1990b, fig. 5). On the other hand, the Lower Oxfordian Cordatum Zone is completely doubtful. Thus, the existence or otherwise (hiatus) of the Lower Oxfordian, and possibly also of the terminal Callovian, can be assessed in approximately the same terms as are applied to the layers at the Bathonian-Callovian boundary. However, these may be represented by the unit T3 and by part of the unit H1 (Hawtah member) below the *Euspidoceras* horizon. The surfaces showing a break of sedimentation and/or ferruginous surfaces cited by Vaslet (in Manivit *et al.*, 1990) in the Tuwaiq Mountain Limestone Fm are related to the overlapping of the deltaic wedge (Wadi ad Dawasir “delta”) by the transgressive system track of the D6-T3 series, but not any discontinuity of wide extent at the top of the unit T3. Such a situation contrasts with that existing in the central Sinai and Negev (Bircher, 1940; Al Fars, 1966; Goldberg, 1963; Goldberg *et al.*, 1971; Parnes, 1981; Lewy, 1983; Picard & Hirsch, 1987; Hirsch & Roded, 1996; Hirsch *et al.*, 1998; Énay *et al.*, 1997). The highest known levels (Arousiyah/Zohar Fm in Sinai, Kidod Fm in Central Negev) dated by ammonites of the Late Callovian, Solidum Zone (= Athleta Zone), end by a discontinuity highlighting a break of sedimentation (equivalent of the lacking Lamberti Zone) of wide extent. On this surface lie the marls with pyritized fossils (Tauriat Fm in Sinai, Beersheba Fm in the central Negev) dated as Early Oxfordian and of the same age as the Madjal Shams Fm in Mount Hermon, Syria, with a Mariae Zone fauna (Noetling, 1887; Frebald, 1928 and Haas, 1955). The vast extent of this discontinuity, and related marls with pyritized fossils (Sinai, Israel, Syria), reflect important disturbances of the sedimentary environments at the Callovian-Oxfordian boundary.

## 4. SEDIMENTOLOGIC RECONSTRUCTION OF THE JURASSIC BASIN

The sedimentologic study of the Jurassic basin of central Saudi Arabia reveals a large range of depositional environments, all remaining within the shelf domain (see Manivit *et al.*, 1990, fig. 71). The succession of geological phenomena leads to definition of two periods. More information on the history of the basin is available in Le Nindre *et al.* (2003). This story combines both tectonic and eustatic processes.

### 4.1. First period or period 1

The first period lasted from the formation of the basin (Marrat Fm) in the Toarcian up to the emplacement of a barrier (Hawtah member of the Hanifa Fm) during the Middle Oxfordian. Sequential analysis makes it possible to divide the history of this periods in several stages.

#### 4.1.1. The Middle part of the basin

In the middle part of the basin the evolution is manifested by four assemblages of sequences separated by sedimentary discontinuities.

1. The first assemblage begins with the transgressive sequence (sequence 1: Lower Marrat Fm), ranging from a supralittoral to a mid-infralittoral domain. The subsequent regressive sequence (sequence 2: middle Marrat Fm) ranges from mid-infralittoral to intertidal. Sequence 3 (upper Marrat Fm) is similar to sequence 2, beginning with a mid-infralittoral domain and reaching the supralittoral. The base of the Dhurma Fm (unit D1) represents a new transgressive sequence (sequence 4), ranging from intertidal to distal-infralittoral. The assemblage ends (sequence 5) with a phase of slow confinement recorded by the unit D2, reaching maximum confinement recorded by the Dhibi Limestone member at the upper part of the lower Dhurma Fm.
2. The second assemblage begins with reworking, back-barrier facies, and distal-infralittoral influences characteristic of the unit D3 which, together with the unit D4, forms a regressive sequence (sequence 6) evolving toward a sheltered mid-infralittoral to proximal-infralittoral domain. Sequence 7 (unit 5) is of the same type, indicating more marked confinement in a proximal-infralittoral domain and ending with a generalized occurrence of hardgrounds.
3. A third assemblage is composed of two regressive sequences. The unit D6 (sequence 8) ranges from back-barrier to proximal-infralittoral, with a recurrence of barrier facies at the top (the "Riyadh stone" calcarenite). The unit D7 and the lower part (units T1 and T2) of the Tuwaiq Mountain Limestone (sequence 9) range from perireefal in the Atash member to mid-infralittoral, with confined episodes and terrigenous influences indicating proximal tendencies.
4. The fourth assemblage comprises one regressive sequence (sequence 10) incorporating the unit T3 and the Hawtah member (unit H1) of the Hanifa Fm. This assemblage begins with a layer of reworking and evolves from a reefal to a proximal-infralittoral (lagoon) domain with terrigenous influences.

#### 4.1.2. The southern margin of the basin

At the southern margin of the basin the transgressive character is progressively manifested from the base of the Marrat Fm up to the unit D5, and marine facies, although confined, overrun the margin of the basin. In this way, the ammonite-bearing (*Micromphalites* fauna) clayey limestone of the proximal-infralittoral domain extends as far as lat 21°07' N (North of Khashm Mishlah), and the

maximum extension of marine facies has been recognized in the bivalve-bearing (*Lopha solitaria*) sandstones dating from the Middle Jurassic at lat 18°43' N (Thulmat al Bayda). The sedimentary discontinuity at the top of the unit D5 (hardground) is marked by the contrast with the coastal-plain facies in the unit D6. A delta (Wadi ad Dawasir "delta") developed toward lat 21°30' N. This was first assumed to be in the unit D7, continuing southward into unit T1, whereas littoral sandstone is involved with back-barrier facies in unit T2 (Énay *et al.*, 1986, p. 58 and 1987a, p. 50; Le Nindre in Le Nindre *et al.*, 1987; Le Nindre in Manivit *et al.*, 1990). According to Énay *et al.* (2007, 2009) the setting of the prograding siliciclastic deltaic body (or wedge) is correlated with the discontinuity at the top of the unit D5 and is related to an Early Bathonian relative sea-level fall. Its age would be Early Bathonian in part but mainly Middle Bathonian. The transgressive sequence D7-T3 (and H1) is interpreted as a highstand system track onlapping on the platform deltaic wedge.

This series can be followed as far south as lat 18°30' N, where it is intensively reduced (with palaeosol and hardground). The unit T1 vanishes southwards at the latitude of Khashm Abu Jiwar (21°53'N). The unit T2 vanishes from Khashm Kumdah (20°15' N) southwards, and the T3 only overlaps the deltaic wedge.

#### 4.1.3. The northern margin of the Basin

The evolution at the northern margin of the basin is marked by the same fundamental discontinuities, but there is no equivalent of the platform deltaic wedge. The most important features are the reduction in low-energy marine deposits (mid-infralittoral as far north as latitude 25°30' N, northeast of Shaqrā'), the invasion of the series by terrigenous material, and the clear confinement of the unit T2 north of lat 25°30' N, indicating a monotonous succession of internal lagoon facies.

#### 4.2. Second period or period 2

The second period comprises the reef domain (Ulayyah member or unit H2) of the Hanifa Fm to the sabkha domain (Hith Anhydrite), from the Late Oxfordian to "Portlandian". Sequential analysis defines three assemblages of sequences, everywhere separated by sedimentary discontinuities, and the contrast between the median part of the basin and its margin is less evident.

1. The first assemblage begins with a sedimentary discontinuity at the base of the Ulayyah member (unit H2) of the Hanifa Fm. It is marked by the piling up of three regressive sequences (sequences 11-13) which evolve from mid-infralittoral to perireefal, or from a reef domain to an internal-lagoon proximal-

infralittoral domain, thus contributing to a progressive return of reef masses.

2. The second assemblage corresponds to the lower part of the Jubaila Limestone (unit J1) and ranges in character from mid-infralittoral to terrigenous proximal-infralittoral. However, the confined nature of this sequence 14, typically composed of lagoonal limestone, is diversified in detail by episodes of high-energy reworking (quartz sandstone and bioclastic calcarenite). Littoral sandstone invades the unit J1 on the northern margin between lat 22 and 21° N in the form of infralittoral channels or sandy beds.
3. The third assemblage ends with the Hith Anhydrite and covers five sequences. Major reworking (conglomeratic sandstone and calcarenite) marks the base of the upper part of the Jubaila Limestone (unit J2), deposited in a mid-infralittoral to terrigenous proximal-infralittoral domain (sequence 15). A recurrence of parareefal facies appears at the top of the Jubaila Limestone and, in places, marks the base of sequence 16, which mainly corresponds to the Arab-D Member. This is a sabkhah sequence evolving from a back-barrier deposit (mid-infralittoral) to lagoonal facies (proximal-infralittoral) and finally to sabkhahs (mediolittoral to supralittoral). The last three sequences (sequence 17, 18, and 19) correspond to the same carbonate-evaporite type, the assemblage being organized in a regressive series resulting in the Hith Anhydrite.

In conclusion, the Jurassic basin of central Saudi Arabia displays the same evolutionary stages as most other large basins (see the works by Aubouin summarized in Perrodon, 1977), displaying:

1. a young basin between the lower Marrat and the unit D5.
2. a phase of opening up and of basic structuring, comprising the formation of the basin, the progressive marine incursion, the extension of deposits beyond the margins, basin infill, and the end of this initial phase over a major discontinuity.
3. a mature basin between the unit D6 (Dhurma Fm) and the unit H1 (Hanifa Fm). An intermediate phase in the evolution of the basin, involving restructuring with associated rejuvenation of reliefs and resulting in the maximum extension of marine deposits.
4. an old basin between the unit H2 (Hanifa Fm) and the Hith Anhydrite. A phase of closing up, accompanied by epeirogenic phenomena and ending with the sabkhah landscape of the Hith Anhydrite.

At the southeastern margin of the basin the pulsations within the basin may be summarized as follows:

- Marrat to unit D5: Onlap process, with littoral sandstone (unit D3) where the highest energy marine facies reached the continent.

- Unit D6 to T1: Offlap process, with sandstone bodies progradation during the assumed D5/D6 discontinuity and contamination of the seaward facies by terrigenous material.
- Unit T2 to unit H2: Onlap processes, with littoral sandstone (unit T2) where a back-barrier facies migrate over the continent; maximum extension of marine deposits.
- Jubaila to Hith: Offlap processes, with progradation of sandy bodies and subsequent confinement and closure.

## PART II - PALAEOONTOLOGICAL DESCRIPTIONS

The material collected during the seasons of field work amount more than 2143 specimens (some of them, not well-preserved but useful for frequency diagrams, have collective number, distinguished by "a" to "n"). The numbering, e.g. 177 500/1-5, means five specimens; 177 500/a-c means three parts of a single specimen or internal plus external casts. The collection made by Dr G.A. Al-Asa'ad of King Saud University, Riyadh, replaced by D. Vaslet (in Manivit *et al.*, 1990, p. 350) at the base of member T3 of the Tuwaiq Mountain Limestone Fm, is also considered. All these specimens are housed in the collections of the University Claude Bernard-Lyon 1 with the numbers UCBL-FSL 177 001 to 179 144, that is 2143 specimens (including undeterminate pieces). Measurements are reported in Tables 2-58. Among the material collected, 2013 specimens were classified at least at generic level as shown in Tab. 59, which also indicates the percentage of Arab-Indo-Madagascan and European taxa within each assemblage or fauna. The geographic location of the studied sections is given in Fig. 7, the location of the samples with ammonites in Fig. 8.

Measurements and other descriptive data follow the traditional scheme: maximum or final diameter (**Dm**); actual or measured diameter (D); end of phragmocone diameter (ph); when the specimen is wholly septate (nucleus = n); (?) indicates where the end of the septate whorls is unknown; whorl height and ratio to the corresponding diameter (Wh; Wh/D); the whorl thickness or breadth and ratio (Wb, Wb/D), umbilicus width and ratio (Ud, Ud/D), the ratio Wb/Wh. Values in brackets indicate estimates. The following abbreviations are used in the synonymies and descriptions: (v) the corresponding synonymous specimen has been seen; (vm) plaster cast; (*pars*) partial synonymy; (?) doubtful synonymy; (*non*) synonymy not accepted; (m) and (M) microconch(s) and macroconch(s). With regard to the distribution of each species in the territory where it has been founded, the collection sites are given by quadrangle and from South to North: Sulayyimah (VD81), Wadi al Mulayh (JMA80), Wadi al-Rayn VD80), Durma JMA82), Shaqrā' (VD82) and Buraydah (JMA83). No ammonites were found in the



two southernmost quadrangles (Al Faw and Al Sulayyil). Distribution by quadrangle is given in Tabs 1 and 59.

The classification adopted (including the synonymies and correct names of higher taxa) is that of the Treatise on Invertebrate Paleontology. Psiloceratoidea, Eoderoceratoidea and Hildoceratoidea: Howarth (2013); Stephanoceratoidea and Spiroceratoidea: Howarth (2017); and Perisphinctoidea: Énay & Howarth (2019). Concerning the Haploceratoidea, currently under revision, the reference is Arkell *et al.* (1957), except for the families Thamboceratidae and Clydoniceratidae which are included in the Haploceratoidea.

#### Superfamily Hildoceratoidea Hyatt, 1867

[*nom. correct.* Hillebrandt, 2006, p. 229, *pro* Hildocerataceae Arkell *et al.*, 1957, p. 254, *nom. transl. ex* Hildoceratidae Hyatt, 1867, p. 99] [= suborder Harpoceracea Wedekind, 1918, p. 103; = Hammatocerataceae Schindewolf, 1964, p. 366].

#### Family Hildoceratidae Hyatt, 1867

##### Subfamily Protogrammoceratinae Mattei, 1974

#### Genus *Protogrammoceras* Spath, 1913

**Type species:** *Grammoceras bassanii* Fucini, 1901; SD Spath (1919, p. 174)

#### ***Protogrammoceras madagascariense* (Thévenin, 1908)**

Pl. I, figs 5, 6.

1908. *Harpoceras* (*Grammoceras*) *madagascariense*.– Thévenin, p. 7, pl. 1, fig. 7; pl. 3, figs 2-5.  
 1908. *Harpoceras* (*Grammoceras*) cf. *crassifalcatum* Dumortier.– Thévenin, p. 9, pl. 1, fig. 8.  
 1952. *Protogrammoceras madagascariense* Thévenin.– Arkell, p. 264, pl. 16, figs 4-8; pl. 17, figs 3-4.  
 1953. *Protogrammoceras madagascariense* Thévenin.– Mouterde, p. 96.  
 1958. *Protogrammoceras madagascariense* Thévenin.– Collignon, pl. 3, figs 16-17.  
 1958. *Protogrammoceras thévenini*, Collignon, pl. 3, fig. 18.  
 1967. *Protogrammoceras madagascariense* Thévenin.– Blaison, p. 60, pl. 6, figs 3-6.  
 1986. *Protogrammoceras madagascariense* Thévenin.– Énay *et al.*, tab. 1 (p. 33).  
 1987a. *Protogrammoceras madagascariense* Thévenin.– Énay *et al.*, tab. 1 (p. 34).  
 ? 2001. *Nejdia* sp. ind. Venturi & Ferri, p. 208.  
 ? 2010. *Nejdia* sp. ind. Venturi *et al.*, p. 324.

**Material:** 41 fragments from localities VD80.338 and JMA82.104.

**Description:** Planulate, moderately evolute, whorl compressed with flat sides, keeled venter acute or with sulci, sometimes tricarinate; ribs fine and numerous to coarse and distant, sinuous or falcoid, normally strongly projected on the venter.

**Discussion:** Both the species and the assignment to the

genus have been discussed at length by Arkell (1952) and Blaison (1967). It is not necessary to discuss again the variability of the species and the relationship with the European members of the genus, mainly of Pliensbachian age. The new material does not bring new data. The specimen assigned and figured as *Nejdia* sp. ind. by Venturi & Ferri (2001) and Venturi *et al.* (2010) has nothing to do with this genus; evolute coiling, falcoid ribbing, compressed whorl section, carinate venter with sulci close to *Protogrammoceras*, but simplified suture line, which explains why the specimen was erroneously assigned to *Nejdia* is not consistent.

**Distribution:** Middle Marrat Fm, Wadi ar Rayn Quadrangle: Locality VD80.338 (UCBL-FSL 178 949-969, 988), Khashm al Jufayr, 23°58' N Darmā' Quadrangle: JMA82.104, (UCBL-FSL 179 024), Khashm ADH Dhibi, 24°14' N.

**Age:** Early Toarcian, Nitescens Zone, Madagascariense Subzone (Western Europe Tenuicostatum Zone, lower Levisoni Subzone and Semicelatum Subzone, *pars*).

#### Subfamily Hildoceratinae Hyatt, 1867

[*nom. transl.* Buckman, 1887, pp. 15, 16, 21, *ex* Hildoceratidae Hyatt, 1867, p. 99] [=Mercaticeratinae Guex, 1973c, p. 472]

#### Genus *Parahildaites* Blaison, 1967

**Type species:** *Hildaites sanderi* Arkell, 1952; OD

#### ***Parahildaites sanderi* (Arkell, 1952)**

Pl. I, fig. 7; Tab. 2

1952. *Hildaites sanderi* Arkell, p. 265, pl. 16, figs 1, 2, 3, 9 (holotype), 10; pl. 18, fig. 2.  
 1967. *Parahildaites sanderi* (Arkell).– Blaison, p. 106.  
 1986. *Protogrammoceras madagascariense* Thévenin.– Énay *et al.*, tab. 1 (p. 33).  
 1987. *Protogrammoceras madagascariense* Thévenin.– Énay *et al.*, tab. 1 (p. 34).

**Material:** A single incomplete specimen with a quarter whorl of body chamber (152,5 mm in diameter) and nine fragments, more or less large, together with about forty fragments ascribed to *Parahildaites* sp.

**Description:** The new material from Saudi Arabia allows to supplement the Arkell description. Two specimens display the body chamber, a quarter whorl long in the better preserved and largest one (UCBL-FSL 178 884) and another half specimen with the last approximate four sutures and the living chamber half a whorl long (UCBL-FSL 178 885), reaching 138 mm and 155 mm in diameter, respectively; the aperture is not preserved. Slightly depressed whorl sides of the latter probably result of synsedimentary compression.

**Discussion:** *P. sanderi* (Arkell) was selected by Blaison (1967) as type species of the genus, only because the Madagascan species are of doubtful origin [*P. jolyi*

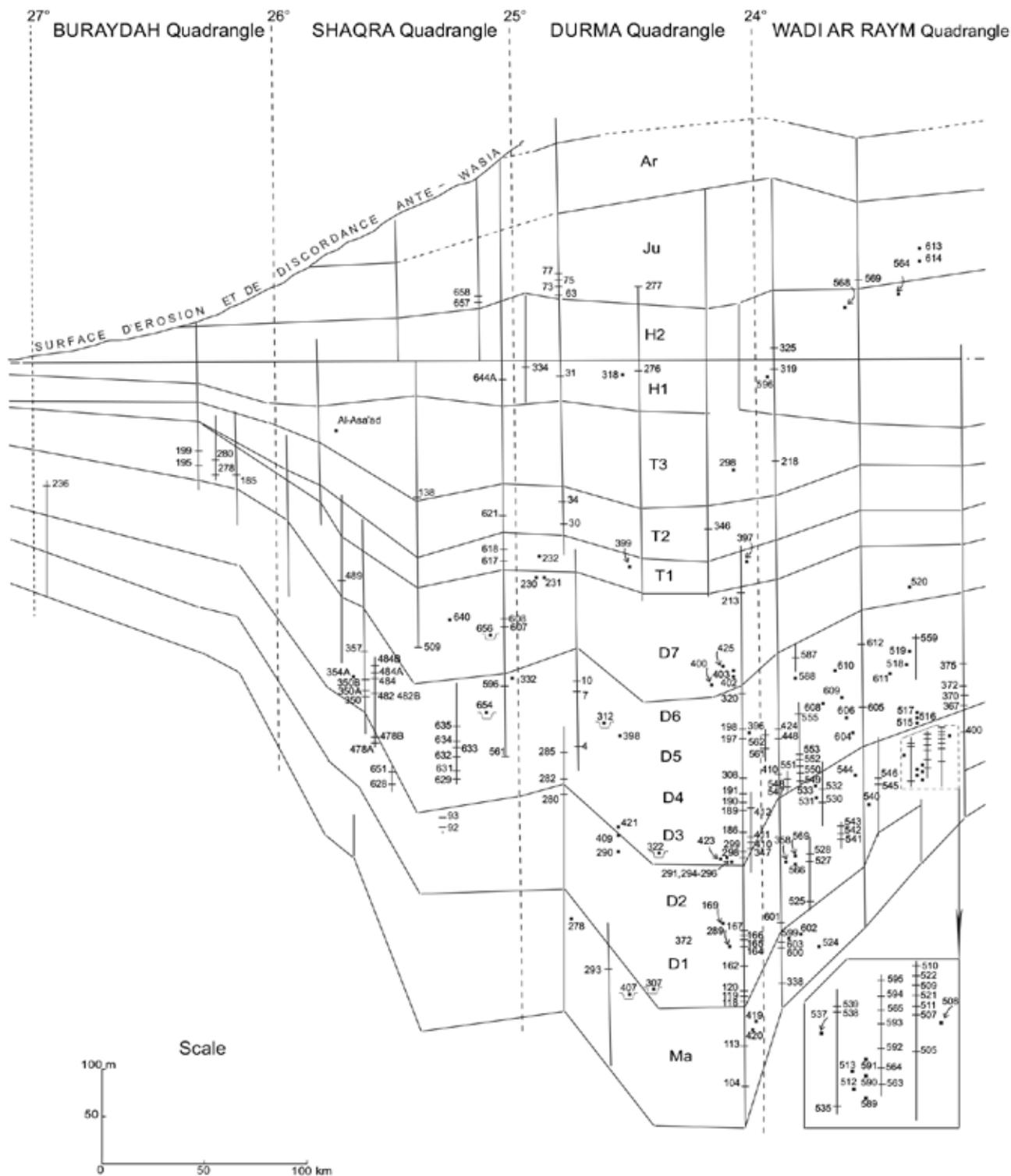
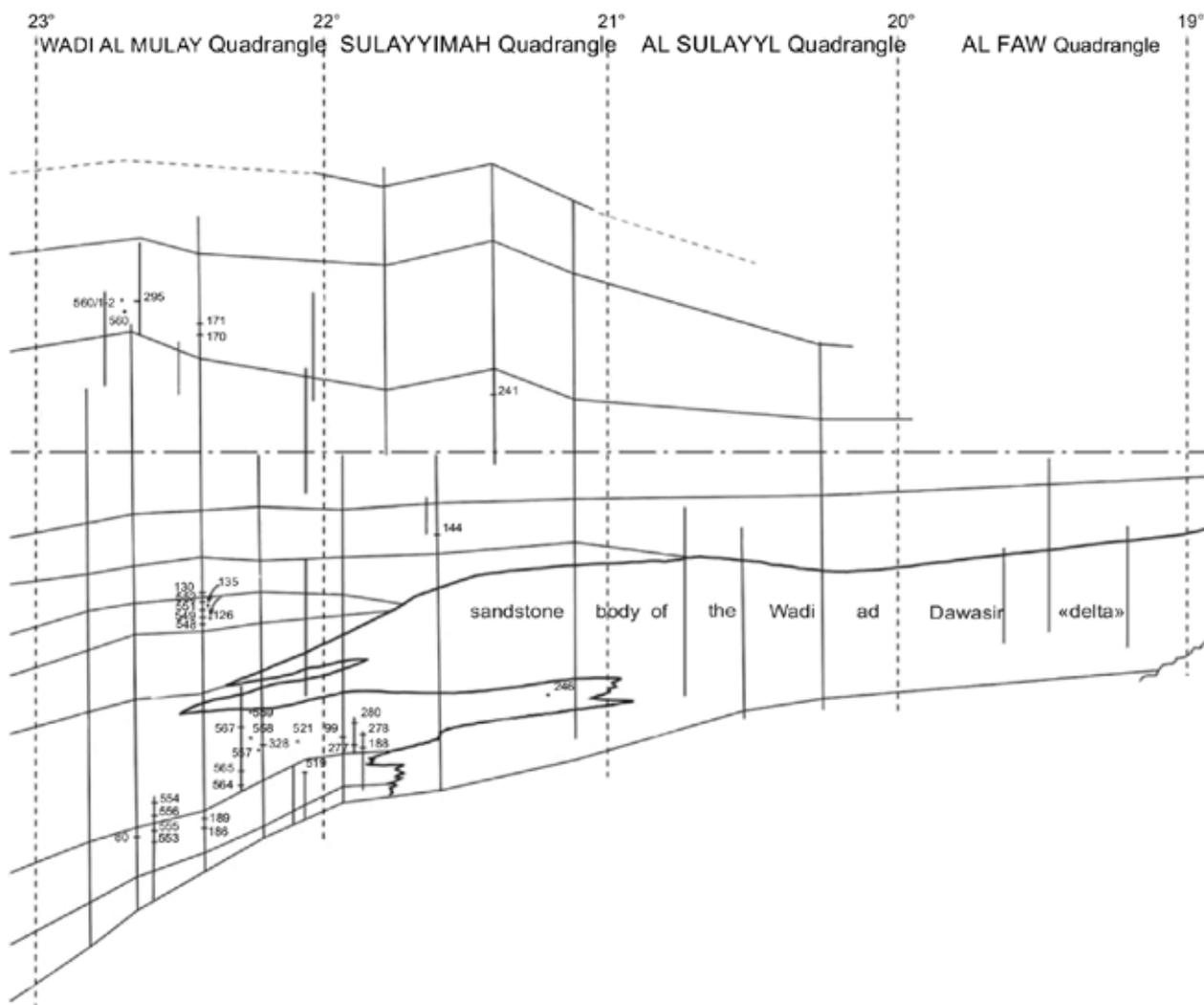


Fig. 8: Location of the ammonite-sampled points. Horizontal dash line indicates the base of the unit H2 (Ulayahn Member). The sandstone body of the Wadi ad Dawisir delta from data in Manivit *et al.* (1990, figs 38 and 46).



LEGEND

- ⊥ Section and beds with ammonites
- Lonely place or out a section
- ∨ Sampling in the graben area
- ✓ Sampling not *in situ* (from scree)
- Ar: Arab F.; J: Jubaila F.;
- H: Hanifa F.; Tu: Tuwaiq F.;
- D: Dhurma F.; Ma: Marrat F.
- 1 to 7: members within the formation

Fig. 8: Continued

Table 2: Measurements of *Parahildaites sanderi* (Arkell).

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 178 884 – JMA82.419	152	c 112	--	--	--	--	--	--	--
	119	--	55	0.46	34	0.28	49	0.41	0.61
	105	--	42	0.40	24*	0.23*	34.5	0.33	0.57*
	90	--	33	0.36	22*	0.24*	30	0.33	0.66*
Holotype, Arkell, 1952, pl. 16, fig. 9 a, b (SM. F10682).	110	n	38	0.34	22	0.20	48	0.43	0.57

(Thévenin)] or only known by a single specimen (*P. namakiense* Blaison), but these and especially the latter one are best situated well below the *Nejdia* Beds.

**Distribution:** Upper Marrat Fm, *Darmā' Quadrangle*: JMA82.419 (UCBL-FSL 178 880, 884-888) and JMA82.420 (UCBL-FSL 178 881-883), lonely place South of Khashm Adh Dhibi, about 24°08' N - Also ?*Parahildaites* sp. *Wadi ar Rayn Quadrangle*: VD80.599 (UCBL-FSL 178 752-760), lonely place between Khashm al Majulah, 23°48' N and Khashm al Jufayr, 23°58' N; VD80.600 (UCBL-FSL 178 837-840), Khashm al Jufayr, 23°58' N; *Darmā' Quadrangle*: JMA82.419 (fragments UCBL-FSML 178 857-879), lonely place South of Khashm Adh Dhibi, about 24°08' N.

**Age:** Later Early Toarcian, Brankampi Zone, lower part (Western Europe Bifrons Zone, Sublevisoni Subzone).

Subfamily Bouleicertinae Arkell, 1950

[Bouleiceratinae Arkell, 1950, p. 361] [=Paroniceratidae Schindewolf, 1964, p. 66]

**Remarks:** Although using the same cladistic approach, but based on a choice of different characters, at least in part, Rulleau *et al.* (2003) and Bardin *et al.* (2016) lead to different results concerning the phylogeny and systematic of Bouleiceratinae (and other related subfamilies) within the Hildoceratidae. Here the subfamily is used according to Howarth (2017), so in a broader sense than Rulleau *et al.* (2003) who separated Paroniceratinae and Leukadiellinae, but more restrictive than Bardin *et al.* (2016), who also included Leukadiellinae. The genera classified into these two sub-families are not represented in Saudi Arabia.

Genus *Bouleiceras* Thévenin, 1906

**Type species:** *B. nitescens* Thévenin, 1906

**Remarks:** 51 specimens from two localities (VD80.338 and VD80.524) on the Wadi ar Rayn Quadrangle, but most of them are wholly septate fragments of middle or outer whorls, the inner whorls not preserved. However, these are of great value (Blaison, 1968) to separate the species distinguished successively by Thévenin (1906, 1908), Arkell (1952) in part from Thévenin specimens, and Collignon (1958). Even it is impossible to identify

the uni- and bituberculate forms of Blaison (1968) and they are labelled as *Bouleiceras* sp.

### *Bouleiceras* cf. *nitescens* Thévenin, 1906

Pl. I, fig. 3

1906. *Bouleiceras nitescens* Thévenin, p. 171, figs 1-3.  
 1908. *Bouleiceras nitescens* Thévenin, p. 13, pl. 2, figs 6 (lectotype), 11.  
 1911. *Bouleiceras nitescens* Thévenin.– Haug, p. 995, fig. 308.  
 1952. *Bouleiceras nitescens* Thévenin.– Arkell, p. 261, pl. 15, fig. 5; text-fig. 4.  
 1953. *Bouleiceras* cf. *nitescens* Thévenin.– Mouterde, pp. 94-95, pl. 1, fig. 1a, b.  
 1953. *Bouleiceras* cf. *nitescens* Thévenin.– Dubar & Mouterde, p. 1980.  
 1953. *Bouleiceras* cf. *nitescens* Thévenin.– Mouterde, p. 95, pl. 1, fig. 1a, b.  
 1963. *Bouleiceras nitescens* Thévenin.– Blaison, p. 180, text-fig. 1.  
 ? 1965. *Bouleiceras* cf. *nitescens* Thévenin.– Davies & Gardezi, p. 27, pl. 2a, b.  
 ? 1966. *Bouleiceras* cf. *nitescens* Thévenin.– Bizon *et al.*, p. 901, pl. 27a, fig. 7a-c.  
 1970. *Bouleiceras* cf. *nitescens* Thévenin.– Mouterde, p. 164.

**Material:** A well-preserved fragment (UCBL-FSL 178 991).

**Description:** Well characterized specimen with the inner tubercles stronger than the outer ones.

**Distribution:** Middle Marrat Fm, *Wadi ar Rayn Quadrangle*: Locality VD80.338 (UCBL-FSL 178 991), Khashm al Jufayr, 23°58' N; VD80.524 (UCBL-FSL 178 013-017), lonely place South of Faridat Balum, 23°42' N.

**Age:** Lower Toarcian, Nitescens Zone, Madagascariense Subzone (Western Europe Tenuicostatum Zone, lower Levisoni Subzone and Semicaelatum Subzone, *pars*).

### *Bouleiceras elegans* Arkell, 1952

Pl. I, fig. 4

1908. *Bouleiceras nitescens* Thévenin, p. 13, pl. 2, figs 8 (holotype), 10.  
 1952. *Bouleiceras elegans*, Arkell, p. 264, pl. 15, fig. 9, 11.  
 1958. *Bouleiceras elegans* Arkell.– Collignon, pl. 2, fig. 15.

1965. *Bouleiceras* cf. *elegans* Arkell.– Geyer, p. 28, pl. 5, fig. 2.  
 1966. *Bouleiceras* cf. *elegans* Arkell.– Behmel & Geyer, p. 24.  
 1968. *Bouleiceras arabicum* Arkell.– Blaison, p. 48, pl. 1, fig. 8.

**Material:** Two wholly septate specimens (UCBL-FSL 179 018, 179 020), one fragment with the inner whorl preserved (UCBL-FSL 179 019) and thirteen fragments (UCBL-FSL 178 980-982, 178 998-179 004, 179 007, 008, 011).

**Description:** Bituberculate inner whorls, conspicuous only on a single fragment (UCBL-FSL 179 019) not on the larger specimens. The latter display middle and outer whorls with fine, dense ribbing, fading on the outer whorls, relatively involute coiling and rapidly increasing whorl height; high and compressed whorl section.

**Discussion:** The species is well separated from other *Bouleiceras* species by the coiling and the high compressed whorl section. It is on this basis that fifteen wholly septate middle and outer whorls have been determined as *Bouleiceras* cf. *elegans* Arkell.

**Distribution:** Middle Marrat Fm. *Wadi ar Rayn Quadrangle*: Locality VD80.338 (UCBL-FSL 178 980-983, 178 998-179 004, 179 007, 008, 011, 179 018-020), Khashm al Jufayr, 23°58' N.

**Age:** Lower Toarcian, Nitescens Zone, Madagascariense Subzone (Western Europe Tenuicostatum Zone, lower Levisoni Subzone and Semicelatum Subzone, *pars*).

#### *Bouleiceras arabicum* Arkell, 1952

Pl. I, fig. 1

1952. *Bouleiceras arabicum* n. sp. – Arkell, p. 262, pl. 15, figs 6, 8, 13, 14.  
 1958. *Bouleiceras arabicum* Arkell.– Collignon, pl. 2, fig. 10, 13, 14; pl. 3, figs 21, 24.  
 1965. *Bouleiceras arabicum* Arkell.– Geyer, p. 27, pl. 5, fig. 1.  
 1966. *Bouleiceras arabicum* Arkell.– Behmel & Geyer, p. 24.  
 1968. *Bouleiceras rectum* Arkell.– Blaison, p. 45.  
 1968. *Bouleiceras arabicum* Arkell.– Blaison, p. 48, pl. 1, figs 1-3.  
 1974. *Bouleiceras* aff. *rectum* Arkell.– Du Dresnay, p. 148.  
 1975. *Bouleiceras* aff. *arabicum* Arkell.– Faugères, p. 120, pl. 1, figs 1a-c, 2a-c.  
 1986. *Protogrammoceras madagascariense* Thévenin.– Énay *et al.*, tab. 1 (p. 33).  
 1987. *Protogrammoceras madagascariense* Thévenin.– Énay *et al.*, tab. 1 (p. 34).

**Material:** Five specimens, the larger consisting of middle and inner whorls (UCBL-FSL 178 993 and 179 021) and three fragmentary inner whorls (UCBL-FSL 179 021-023).

**Description:** Fragmentary inner whorls and one of the larger specimens with inner whorls preserved show a single row of inner tubercles and slightly rursiradiate

falcoid ribs fading on the middle whorls, first on the inner part then on the whole side.

**Discussion:** Arkell figured material displays only the inner and middle whorls. But as Arkell noticed, the two largest specimens are closely “resembling *Bouleiceras elegans*, from which middle and outer whorls may be indistinguishable”, save slightly less involute coiling and a little wider whorl section.

**Distribution:** Middle Marrat Fm. *Wadi ar Rayn Quadrangle*: Locality VD80.338 (UCBL-FSL 178 993, 179 021-023), Khashm al Jufayr, 23°58' N.

**Age:** Lower Toarcian, Nitescens Zone, Madagascariense Subzone (Western Europe Tenuicostatum Zone, lower Levisoni Subzone and Semicelatum Subzone, *pars*).

#### *Bouleiceras* cf. *rochi* Collignon, 1958

Pl. I, fig. 2

1958. *Bouleiceras rochi* nov. sp., Collignon, pl. 3, fig. 22.  
 1968. *Bouleiceras arabicum* Arkell.– Blaison, p. 48, pl. 1, fig. 4.

**Material:** A single specimen, wholly septate, the inner whorls well-preserved (UCBL-FSL 178 989).

**Description:** Inner whorls with a single row of distant inner tubercles from which fork strong widely distant V-shaped ribs; middle whorl compressed and relatively involute with falcoid fine and faint ribs looking near growing lines.

**Discussion:** The specimen would be assigned to *B. elegans* when looking the outer whorl, but that disagrees with the unituberculate inner whorls.

**Distribution:** Middle Marrat Fm. *Wadi ar Rayn Quadrangle*: Locality VD80.338 (UCBL-FSL 178 989), Khashm al Jufayr, 23°58' N.

**Age:** Lower Toarcian, Nitescens Zone, Madagascariense Subzone (Western Europe Tenuicostatum Zone, lower Levisoni Subzone and Semicelatum Subzone, *pars*).

#### *Bouleiceras* sp.

**Material:** Thirty two fragments of middle and outer whorls, including large wholly septate specimens without the inner whorls, making impossible to be ascribed either to the uni- or bituberculate group of species distinguished by Blaison (1968).

**Distribution:** Middle Marrat Fm. *Wadi ar Rayn Quadrangle*: Locality VD80.338 (UCBL-FSL 178 889-926, 970-979, 984-987, 992, 994-997, 179 005, 006, 009, 010), Khashmal Jufayr, 23°58' N; VD80.524 (UCBL-FSL 179 013-017), lonely place South of Faridat Balum, about 24°48' N

**Age:** Lower Toarcian, Nitescens Zone, Madagascariense Subzone (Western Europe Tenuicostatum Zone, lower Levisoni Subzone and Semicelatum Subzone, *pars*).

Genus nov.? sp.

1973. Gen. n. (?) sp. ind. Guex, p. 508, pl. 7, fig. 4; pl. 14, fig. 6; pl. 15, fig. 10.

**Material:** A single specimen encrusted and too badly preserved to be described. Both coiling and whorl section resembling specimen figured by Guex (1973a), but ribs hardly visible on one side are not so strong.

**Distribution:** Middle Marrat Fm. Wadi ar Rayn Quadrangle: Locality VD80.338 (UCBL-FSL 178 990), Khashm al Jufayr, 23°58' N.

**Age:** Lower Toarcian, Nitescens Zone, Madagascariense Subzone (Western Europe Tenuicostatum Zone, lower Levisoni Subzone and Semicelatum Subzone, *pars*).

Genus *Nejdia* Arkell, 1952

**Type species:** *Nejdia brankampi* Arkell, 1952, by original designation

**Remarks:** The same cladistic approach, according to Rulleau *et al.* (2003), on the one hand, and Bardin *et al.* (2016), on the other, leads to opposite results concerning the genus *Nejdia*. For the first, *Nejdia* belongs well to Bouleiceratinae, but for the second would be totally apart and ranked among the Harpoceratinae. But the reference species (*N. pseudogrineri* Thevenin) is not the type species of the genus and the discussion leads to questioning its position “do we need to change the generic attribution of *N. pseudogrineri*?” (Bardin *et al.*, 2016, p. 12). Indeed, the holotype of *N. pseudogrineri*, with the test preserved, has a hollow keel, which is not the case in the type species of the genus, preserved as internal cast, both for Arkell material and that studied herein. Therefore, *Nejdia* is well derived from *Bouleiceras* and belongs to Bouleiceratinae, as Rulleau *et al.* (2003) assumed. Two hundred specimens have been collected on the Wadi ar Rayn (92) and Darmā (108) Quadrangles, but many of them are wholly septate fragments or badly preserved specimens (weathered and/or flatened). All of them could be assigned to *N. brankampi* Arkell, but although some intraspecific variability seems evident from measurable specimens, these are too few for being ascertained.

***Nejdia brankampi* Arkell, 1952**

Pl. II, fig.1-3; Tab. 3

1952. *Nejdia brankampi* n. sp., Arkell, p. 267, pl. 17, figs 5-7; pl. 18, figs 3-6.

1986. *Nejdia brankampi* Arkell.– Énay *et al.*, tab. 1 (p. 33).

1987. *Nejdia brankampi* Arkell.– Énay *et al.*, tab. 1 (p. 34).

1994. *Nejdia brankampi* Arkell.– Énay & Mangold, p. 168.

2000. *Nejdia brankampi* Arkell.– Macchioni & Venturi, p. 335, pl. 4, fig. 6.

2003. *Nejdia brankampi* Arkell.– Rulleau *et al.*, p. 320.

**Material:** Two hundred fragments or more or less complete specimens from ten localities on Wadi ar Rayn and Darmā Quadrangles. Ten well-preserved specimens of large size from Wadi ar Rayn (4 specimens) and Darmā (6 specimens) Quadrangles give a better idea of the species. Several specimens have different portions of the body chamber, but no one preserves the aperture.

**Description:** A few well-preserved specimens allow accurate measurements (Tab. 2) which allows to identify different morphologies. The smaller figured specimen UCBL-FSL 178 833 (Pl. II, fig. 1) is nearly identical with the holotype (Arkell, 1952, pl. 17, fig. 5a-c), the ventral part of the sides slightly compressed, so increasing the lanceolate whorl section. Although only one side is preserved, the specimen UCBL-FSL 178 749 (Pl. II, fig. 3) shows the same involute, oxyconic, lanceolate and compressed whorl-section. Having a quarter whorl of body chamber preserved, it is the largest specimen available, but large fragments of body chamber whose whorl height is 83 mm (UCBL-FSL 178 867) and 95 mm (UCBL-FSL 178 732), prove that some specimens reached a larger size.

Besides these, specimens UCBL-FSL 739 (Pl. II, fig. 2) and 761 show thick whorl section ( $E/D = 0,36-0,42$  and  $E/H = 0,68-0,84$ ) and may be distinguished as “thick whorled morphotype” opposite to the normal “compressed whorled morphotype”, but specimen as UCBL-FSL 178 752 links the two morphologies.

**Discussion:** Compressed and thick morphologies are assumed to express intraspecific variability within the same biospecies. The small number of fully grown and complete specimens preclude any relation with

Table 3: Measurements of *Nejdia brankampi* Arkell.

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 178 749 – JMA82.278	198 160	155 -	87 71	0.44 0.44	- -	- -	51 36	0.25 0.22	- -
UCBL-FSL 178 739 – JMA82.419	137	122	69	0.50	49.5	0.36	c23	0.15	0.68
UCBL-FSL 178752 – VD80.602	135	n	70	0.51	43	0.32	21	0.16	0.61
UCBL-FSL178761 – VD80.599	114	n	57	0.50	48	0.42	19.5	0.17	0.84
UCBL-FSL 178 833– JMA 82 278	95	n	50	0.52	29.5	0.31	16	0.16	0.58

a possible dimorphic pair. *N. brankampi* differs from *N. pseudogrineri* in being more involute with more lanceolate whorl-section, as assumed by Arkell, but also by the lack of the falcoid growth-lines, stronger in the umbilical edge, but less visible and projected on the ventral part of the side, and the hollow keel, according to Bardin *et al.* (2016).

According to the septal suture line of the best preserved and larger specimens none of the 184 has been assigned to *S. furnishi* Arkell. Proposal of a different species on the basis of “*development of adventitious lobe in the first lateral saddle, and recession of last auxiliary lobe*” (Arkell, 1952) is unjustified. This variation seems to be related to the shape of the umbilical area (more or less rounded umbilical edge and steep or undercut umbilical wall).

**Distribution:** Upper Marrat Fm. *Wadi ar Rayn Quadrangle*: Locality VD80.602 (UCBL-FSL 178 752-760, 178 806), lonely place between Khashm al Jufayr, 23°58' N and Khashm al Majulah, 23°48' N; VD80.599 (UCBL-FSL 178 761-768), lonely place south of Khashmal Jufayr, about 23°57' N; VD80.600 (UCBL-FSL 178 786-788), 602 (UCBL-FSL 177 752-760) and 603 (UCBL-FSL 178 750-751), Khashm al Jufayr, 23°58' N; *Darmā' Quadrangle*: JMA82.419 (UCBL-FSL 178 721-749, 789-799, 807), lonely place south of Khashm adh Dhibi, about 24°08' N; JMA82.113 (UCBL-FSL 170 810-813), Khashm adh Dhibi, 24°14' N; JMA82.407 (UCBL-FSML 178 817-825), lonely place south of graben Awsat, about 24°35' N; JMA82.293 (UCBL-FSL 178 814-816), graben Awsat, about 24°38' N; JMA82.278 (UCBL-FSL 178 749, 769-785, 800-805, 826-836), lonely place south of Wadi al Hisyan, 24°49' N.

**Age:** Middle Toarcian, Brankampi Zone (Western Europe Bifrons Zone, Sublevisoni Subzone).

Family Graphoceratidae Buckman, 1905

[*nom. transl.* Arkell, 1950, p. 363, *ex* Graphoceratinae Buckman, 1905a, p. cxcviii]

Subfamily Graphoceratinae Buckman, 1905

[Graphoceratinae Buckman, 1905a, p. cxcviii] [= Darelleinae Buckman, 1905a, p. cxcviii; = Hyatteinae Buckman, 1905a, p. cxcviii; = Lucyinae Buckman, 1905a, p. cxcviii; = Ludwigellidae Spath, 1925, p. 113; = Ludwiginae Gérard & Bichelonne, 1940, p. 42]

Genus *Hyperlioceras* Buckman, 1889a

**Type species:** *Ammonites discites* Waagen, 1867; by original designation

***Hyperlioceras* sp. gr. *discites* (Waagen, 1867)**

Pl. III, fig. 1

**Material:** Thirty-five specimens, mainly of small size or fragments. The only one figured is a large wholly septate specimen (UCBL-FSL 178 635) found together 23 small

fragments in the same preservation from the same locality (JMA82.120).

**Description:** The largest wholly septate specimen (diameter 140 mm) shows the typical features of the genus, involute coiling, flat whorl sides with the greatest whorl breadth at the umbilical edge, tall unfloored keel, completely smooth. Small-sized fragmentary specimens from locality JMA82.119 bis display weak falcoid ribs fading shortly.

**Discussion:** The Arabian forms do not group with the more involute *Hyperlioceras* (e.g. *H. deflexum* Buckman), but may be part of the *H. discites* group; however, the incomplete preservation hampers the possibility to assume that it is conspecific with the type species of the genus.

**Distribution:** Lower Dhurma Fm, unit D1, basal part. *Darmā' Quadrangle*: locality JMA82.119bis (UCBL-FSL 178 662-673) and JMA82.120 (UCBL-FSL 178 635-658), Khashm adh Dhibi, 24°14' N.

**Age:** Lower Bajocian, Arabica Zone. In W Europe *H. discites* is the index-species of the Lower Bajocian Discites Zone, Subtectum Subzone and Laeviuscula Zone, Ovale Subzone of the Mediterranean Province.

Family Hammatoceratidae Buckman, 1887

[Hammatoceratidae Buckman, 1887, p. 15]

Subfamily Zurcheriinae Hyatt, 1900

[*nom. correct.* Howarth, 2013, p. 112, *pro* Zurcherinae Arkell, 1950, p. 361, *nom. transl. ex* Zurcheridae Hyatt, 1900, p. 577]

Genus *Haplopleuroceras* Buckman, 1892

**Type species:** *Amaltheus subspinatus* Buckman, 1881; by original designation

***Haplopleuroceras* cf. *mundum* Buckman, 1892**

Pl. I, fig. 8

1892. *Haplopleuroceras mundum* Buckman, p. 302, pl. 51, figs 11, 12.

1986. *Haplopleuroceras* cf. *mundum* Buckman.– Énay *et al.*, tab. 1 (p. 33), p. 35, pl. 2, fig. 1a, b.

1987. *Haplopleuroceras* cf. *mundum* Buckman.– Énay *et al.*, tab. 1 (p. 34), p. 37, pl. 2, fig. 1a, b.

1996. *Haplopleuroceras mundum* Buckman.– Linares & Sandoval, p. 293, text-fig. 4a-d; pl. 35, figs 6-8; pl. 36, figs 1-5 (cum synonymy).

**Material:** Two small specimens (greater diameter 34 mm), of which the best preserved, half a whorl long, was already figured by Énay *et al.* (1986, 1987a).

**Description:** Evolute coiling, whorl section quadrate and compressed with flat whorl sides; bisulcate venter with one keel; fine and numerous single ribs curve forward on venter, with ventrolateral tubercles.

**Discussion:** The small size of the specimens hampers the recognition of the adult features by which the assignment is provisional.

**Distribution:** Lower Dhurma Fm, lower unit D1. Wadi ar Rayn Quadrangle: VD80.525 (UCBL-FSL 178 708-709), Khashm al Majulah, 23° 48' N.

**Age:** Lower Bajocian, Arabica Zone. In W Europe *H. mundum* is commonly recorded in the Concavum (Late Aalenian) and Discites (Early Bajocian) zones of the Mediterranean Province.

Family Sonniniidae Buckman, 1892

[*nom. correct.* Arkell *et al.*, 1957, p. 267, *pro* Sonniniidae Arkell, 1950, p. 361, *nom. transl. ex* Sonniniinae Buckman, 1892, p. 287].

Subfamily Sonniniinae Buckman, 1892

[*nom. correct.* Callomon & Chandler in Chandler *et al.*, 2006, p. 367, *pro* Sonniniinae Buckman, 1892, p. 287]

Genus *Sonninia* Douvillé, 1879

Subgenus *Sonninia* Douvillé, 1879

*nom. nov. pro* *Waagenia* Bayle, 1878, pl. 84, *non* Kriechbaumer, 1874 (insect)

**Type species:** *Waagenia propinquans* Bayle, 1878

***Sonninia (Sonninia?) arabica* (Arkell, 1952)**

Pl. III, figs 1, 2, 3-4, 5, 6; Pl. IV, fig. 1; Tab. 4

1952. *Dorsetensia arabica* n. sp., Arkell, p. 269, pl. 19, fig 3-12 (holotype fig. 10).

1958. *Witchellia (Gelasinites) cf. gelasinus* (Buckman).– Collignon, pl. 5, fig. 28.

1986. *Sonninia (?) arabica* (Arkell).– Énay *et al.*, tab. 1 (p. 33), pl. 1, figs 2-4.

1987a. *Sonninia (?) arabica* (Arkell).– Énay *et al.*, tab. 1 (p. 34), pl. 1, figs 2-4.

**Material:** Fifty fragmentary or large size specimens, including badly preserved or weathered pieces, more or less complete, mostly wholly septate but two with the very beginning of the body chamber; small-sized, nearly complete specimens are assumed to be the microconchs.

**Description:** Innermost whorls evolute with whorl section compressed, with flat whorl sides and carinate venter without sulci; ornamentation composed of gently sinuous ribs, some single, some divided from the umbilical edge, and curved forward on venter.

Morphological changes during growth show a narrow range of variation. Involute all throughout, whorl section compressed, oval-shaped or keeled and shouldered, the ventral area narrow, acute in some specimens; umbilical wall normally vertical with angular edge, but more rounded in some specimens; well defined keel but no sulci; ribs occurring irregularly, most part of the phragmocone smooth. The microconch differs by having the growth stages shorter. Apertures not preserved in both dimorphs.

**Discussion:** *S. arabica* (Arkell) was described originally as *Dorsetensia* on account of the resemblance with the European members of the genus and consequently assigned to the Humphriesianum Zone. New material leads to assume that it is better placed in the genus *Sonninia* s.l., but the species of Arkell does not agree

Table 4: Measurements of *Sonninia (Sonninia?) arabica* (Arkell) [M&M], *Witchellia (Gelasinites) cf. gelasinus* [M] and *W. gelasinus* Buckman [M].

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 178 684 - JMA82.119 (M)	182	n	75	0.41	40	0.22	58	0.31	0.53
	123	-	49	0.39	25	0.20	42	0.34	0.51
	84	-	32	0.38	16	0.19	29	0.34	0.50
	39	-	15	0.38	9	0.23	13	0.33	0.60
	20	-	6	0.30	5	0.25	-	-	-
UCBL-FSL 178 685- JMA82.119 (M)	222	220	-	-	-	-	-	-	-
	220	220	86	0.39	49	0.22	68	0.31	0.60
	182	182	74	0.40	? 43	0.23	61	0.33	0.58
	135	135	?50	0.37	?29	0.21	46	0.34	0.58
UCBL-FSL 178 687 - JMA82.289 (M)	106	n	41	0.25	-	-	37	0.35	-
UCBL-FSL 178 703 - JMA82.119 (m)	54	37	21	0.38	13	0.24	20	0.37	0.62
UCBL-FSL 178 704 - JMA82.119 (?)	31	n	9	0.29	?7	0.22	15	0.48	0.77
<i>Witchellia (Gelasinites) cf. gelasinus</i> Collignon <i>non</i> Buckman (M)	158	122	-	-	-	-	-	-	-
	150	-	56	0.37	-	-	60	0.40	-
	121	-	42	0.35	28	0.23	51	0.42	0.66
	90	-	30	0.33	-	-	36	0.40	-
<i>Gelasinites gelasinus</i> Buckman (M)	115	n	45	0.39	25	0.21	41	0.35	0.55
	77	-	30	0.38	-	-	31	0.40	-

with any of the morpho-subgenera according Dietze *et al.* (2005, 2007): inner whorls with the spinous stage of *Sonninia s.s.* are lacking, as well as the papillae at mid-height on the whorl sides of *Papilliceras* or the strong rursiradiate ribs on middle and outer whorls of *Euhoploceras*.

Its placement in or close to *Fissiloboceras* was considered, but the evolute coiling and the simplified suture of *S. arabica* absolutely oppose it.

*Witchellia (Gelasinites) cf. gelasinus* (Buckman) in Collignon (1958), a well-preserved nearly complete specimen with a large part on the body chamber, was only illustrated, not described by Collignon, but the figure agrees so closely with the Arabian specimens that there is little doubt they are the same species. However, *W. cf. gelasinus* (Buckman) in Collignon (1958) has nothing to do with Buckman's species which differs by the spinous stage on the inner whorls and its more complex suture.

**Distribution:** Lower Dhurma Fm, unit D1, basal part. *Darmā' Quadrangle:* JMA82.118 (UCBL-FSL 178 210, with doubt), JMA82.119 (UCBL-FSL 178 677, 684-686, 688, 692, 696, 699, 700, 703-706 and with doubt 178 694, 695, 714-720), JMA82.119bis (UCBL-FSL 178 683, 691, 693, 697, 701 and with doubt 178 711) and JMA82.120 (UCBL-FSL 178 702, 712, 713), Khashm adh Dhibi, 24°14'N; JMA82.289 (UCBL-FSL 178 687, 690, 698 and 178 689 with doubt), lonely place North of Khashm adh Dhibi about 24°7' N; JMA82.307 (UCBL-FSL 178 679 with doubt), Graben South of Awsat Graben, about 24°32' N; JMA82.346 (UCBL-FSL 178 676), Khashm al Jufayr, 23°58' N.

**Age:** Lower Bajocian, Arabica Zone. In W Europe Discites Zone, Subtectum Subzone and Laeviuscula Zone, Ovalis Subzone of the Mediterranean Province.

#### *Sonninia (Sonninia?) sp.*

**Material:** Only two specimens not well-preserved, wholly septate (UCBL-FSL 178 675) or with the very beginning of the body chamber (UCBL-FSL 178 678).

**Description and discussion:** At first sight not very different from *S. (?) arabica* but the blunt falcoid ribs lasting on the middle whorls, the whorl section compressed but more quadratic and fastigate, a ledge-line separating the side, and the venter area well-defined.

**Distribution:** Lower Dhurma Fm, unit D1, basal part. *Darmā' Quadrangle:* JMA82.119 (UCBL-FSL 178 678) and JMA82.119bis (UCBL-FSL 178 675), Khashm adh Dhibi, 24°14' N.

**Age:** Lower Bajocian, Arabica Zone. In W Europe Discites Zone, Subtectum Subzone and Laeviuscula Zone, Ovale Subzone of the Mediterranean Province.

#### *Sonninia sp.*

**Material:** Two large specimens, juveniles or more probably inner whorls, developing the spinous stage absent or not preserved in most of the remaining specimens.

**Distribution:** Lower Dhurma Fm, Lower unit D2. *Wadi ar Rayn Quadrangle:* VD80.545 (UCBL-FSL 178 263, 264), Khashm al Hamra, 23°30' N.

**Age:** Lower Bajocian, Glabrum Zone. Assumed to be equivalent of the Humphriesianum Zone in the W European Zonal Standard.

Subgenus *Euhoploceras* Buckman, 1913

**Type species:** *Sonninia acanthodes* Buckman, 1889b, p. 658; OD [= *Stiphromorphites* Buckman, 1923a, pl. 398]; = *Sherbornites* Buckman, 1923a, pl. 411]

#### *Sonninia (Euhoploceras) turbator nov. sp.*

Pl. IV, fig. 2; Tab. 5

1986. *Sonninia (Euhoploceras) cf. omphalica* Buckman.–Énay *et al.*, tab. 1 (p. 33); pl. 1, fig. 1a, b. (*non* Buckman, 1893, p. 363, pl. 83, figs 5-9).

1987. *Sonninia (Euhoploceras) cf. omphalica* Buckman.–Énay *et al.*, tab. 1 (p. 34); pl. 1, fig. 1a, b. (*non* Buckman, 1893, p. 363, pl. 83, figs 5-9).

**Holotype:** The only specimen available (UCBL-FSL 178 659) figured in Pl. IV, fig. 2; well-preserved but not complete with part of the last whorl and the very beginning of the body chamber.

**Origin of name:** From the Latin *turbator*; *oris* = disturber.

**Description:** Evolute, compressed and fastigate whorl section, the maximal thickness just above the umbilical edge, narrow tabulate ventral area with a well-defined keel persisting to the end. Ribbing not preserved on the inner whorls; middle whorls with gently flexuous single ribs, few divided from umbilical edge, strongly curved forward on venter (about 35 a whorl at 80 and 122 mm in diameter); they are fading on the outer whorl on the basis of the preserved fragment of the final part of the phragmocone and the very beginning of the body chamber.

**Discussion:** Among the numerous species names created

Table 5: Measurements of *Sonninia (Euhoploceras) turbator nov. sp.*

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 178 659 – JMA82.119bis	c 182	172	-	-	-	-	-	-	-
	172		60	0.34	49	0.28	70	0.40	0.81
	122		42	0.34	32	0.26	48	0.39	0.76
	88		33	0.37	24	0.27	34	0.38	0.72

by Buckman, *S. omphalica* has been retained by Énay *et al.* (1987). But the new species is distinguished by its more fastigate whorl section and the smooth outer whorl.

**Distribution:** Lower Dhurma Fm, unit D1, basal part. *Darmā' Quadrangle*: locality JMA82.119bis (UCBL-FSL 178 659), Khashm adh Dhibi, 24°14' N.

**Age:** Lower Bajocian, Arabica Zone. In W Europe Discites Zone, Subtectum Subzone and Laeviuscula Zone, Ovalis Subzone of the Mediterranean Province.

***Sonninia (Euhoploceras) crassicostrae* nov. sp.**

Pl. V, figs 1-3, Tab. 6

? 1963a. *Sonninia (Sherbornites)* aff. *adicra* Waagen.– Blaison, p. 976, pl. 25, fig. 2.

1986. *Sonninia (Euhoploceras)* cf. *projectifer* Buckman.– Énay *et al.*, tab. 1 (p. 33), p. 34, pl. 2, figs 2-3.

1987a. *Sonninia (Euhoploceras)* cf. *projectifer* Buckman.– Énay *et al.*, tab. 1 (p. 34), p. 37, pl. 2, figs 2-3.

**Material:** Five specimens of different sizes, the largest with about a quarter whorl of the body chamber preserved but strongly weathered (holotype).

**Type specimens:** Holotype is the specimen figured by Enay *et al.* (1987: pl. 2, fig. 3a-d), here refigured in Pl. V, fig. 1a-c (UCBL-FSL 178 680). Paratype is the specimen in Pl. V, fig. 3a, b (UCBL-FSL 178 682).

**Origin of name:** From the Latin: *crassus*, *a*, *um* = thick and *costa*, *ae* = ribs.

**Description:** Large size, the end of the phragmocone between 190 mm in diameter (holotype) and c. 210-220 mm in diameter another specimen (UCBL-FSL 178 682a, b) made of a badly preserved impression and a quarter whorl still septate.

Inner whorls not preserved, save the plaster cast of the ventral area of the external mould on the preserved middle whorl. A very small sized specimen, 23 mm in diameter (UCBL-FSL 178 674) is supposed to be the innermost whorls of the new species, displaying a compressed quadratic whorl section, bisulcate and keeled, with fine, gently sinuous single ribs, sometimes bifurcating or bundled in the umbilical edge and curved forward on venter.

In the holotype the coiling is fairly involute with massive whorls expanding rapidly; whorl section depressed, with broad, rounded venter, wider than high; rudimentary ventral keel on the inner and middle whorls changing rapidly to a roof-shaped ventral area before disappearing on the outer whorl; ribs simple, straight but projected

strongly forward near venter and ending in a small tubercle at ventral edge, stronger on the last whorl. The adult ornamentation is better preserved in the paratype, from the same place (JMA82.307 ; UCBL-FSL 178 682, Pl. V, fig. 3a, b); sutures simplified, both lobes and saddles ceratitic.

**Discussion:** The comparison with *S. projectifer* (Énay *et al.*, 1987) was based mainly on the strength of the ribbing, but *S. projectifer* is well distinguished by the evolute coiling, tuberculate inner whorls, straight ribs not projected forward near the venter, and complex suture. The badly preserved specimens from Madagascar, first named *S. projectifer* (Buckman) by Blaison (1963a, p. 973), then described (p. 976) as *S. adicra* (Waagen), could probably belong to the new species.

**Distribution:** Lower Dhurma Fm, unit D1, basal part. *Wadi ar Rayn Quadrangle*: VD80.525 (UCBL-FSL 178 680-682), Khashm al Majulah, 23°48' N; *Darmā' Quadrangle*: JMA82.307 (UCBL-FSL 178 673, 674), Graben South of Awsat Graben, about 24°32' N.

**Age:** Lower Bajocian, Arabica Zone. In W Europe Discites Zone, Subtectum Subzone and Laeviuscula Zone, Ovalis Subzone of the Mediterranean Province.

***Sonninia (Euhoploceras)* sp.**

**Material:** 8 poorly preserved, fragmentary specimens, being part of the body chamber, with imprint or part of the earlier whorl.

**Description:** All specimens are more or less large parts of body chamber, some with the end of the septate whorls, the largest about 130 mm in diameter. The whorl section subrectangular, more compressed in some specimens with flat sides, the ventral area is wide with a blunt carina. Strong prorsiradiate ribs curve forward with local reinforcements on venter, tubercle-shaped in specimens with quadrate and flat-sided whorl section. Imprints or partly preserved inner whorls show compressed fastigate whorl section with a carinate ventral area but without sulci; prorsiradiate ribs bifurcate at mid-height with a tubercle-shaped strengthening.

**Discussion:** None of the large number of nominal species of Buckman (1889a), mostly revised by Sandoval & Chandler (2000), agree with the Saudi Arabian form described here which is probably a new species, but the scarce material available hampers its definition.

**Distribution:** Lower Dhurma Fm, upper unit D1. *Wadi ar Rayn Quadrangle*: VD80.527 (UCBL-FSL 178 593),

Table 6: Measurements of *Sonninia (Euhoploceras) crassicostrae* nov. sp. and *Sonninia (Euhoploceras) projectifer* Buckman.

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 178 680 - JMA 82 307	236 184	190 -	96 78	0.40 0.42	- -	- -	79 58	0.33 0.31	- -
<i>S. (E.) projectifer</i> Buckman, 1923, pl. 411.	263 149	230 -	34 37	0.13 0.24	30 36.5	0.11 0.24	40.5 36.5	0.14 0.24	0.88 1.00

Faridat Balum, 23°42' N; VD80.541 (UCBL-FSL 178 592), South of Faridat Balum, about 23°37' N; VD80.566 (UCBL-FSL 178 626-631), lonely place north of Faridat Balum, about 23°45' N.

**Age:** Lower Bajocian, Stephani Zone. In W Europe Laeviuscula Zone of the Mediterranean Province.

Genus *Sonninites* Buckman, 1923

**Type species:** *S. felix* Buckman, 1923b, pl. 428A, by original designation. = *Sonnites* Buckman, 1925, pl. 528A, *nom. null.*, misspelling; = *Dundryites* Buckman, 1926, pl. 687 (type, *D. albidus*, OD)

***Sonninites* aff. *albidus* (Buckman, 1926)**

Pl. VI, fig. 1-3, Tab. 7

- aff. 1926. *Dundryites albidus* Buckman, pl. 687.  
 1986. *Sonninia* (?) n. sp. 1 and n. sp. 2, Énay *et al.*, tab. 1 (p. 33).  
 1987a. *Sonninia* (?) n. sp. 1, and n. sp. 2, Énay *et al.*, tab. 1 (p. 34).  
 2007. *Dundryites* aff. *albidus* Buckman.– Dietze *et al.*, p. 13, pl. 3, fig. 1a, b.  
 aff. 2007. *Dundryites albidus* Buckman.– Dietze *et al.*, p. 13, pl. 3, fig. 2a, b.

**Material:** Twenty-six specimens from a single locality (VD80.527), most of them nearly complete body chambers with some part of the septate whorls; a single small-sized specimen could be the microconch form.

**Description:** Small-sized form. Complete specimens with the body chamber (one whorl long) between 145 and 165 mm in diameter. The small specimen (Pl. VI, fig. 3) is a possible microconch. Involute coiling, whorl section compressed, the umbilical edge rounded, the sides flat, the venter rounded or fastigate; the keel is well indicated on the inner whorls but disappears on the body chamber. Ornament limited to growth lines both on the inner whorls and the body chamber with, only on the best preserved specimens, weak undulations (*Sonninia* sp. 2 in Énay *et al.*, 1987). The aperture, partly preserved in

few specimens, is simple with plain mouth border. The suture is poorly preserved, apparently simpler than in the W Europe forms.

**Discussion:** The Saudi Arabian material enters well in the genus, save the suture line apparently simpler than in the W Europe forms. The type species of the genus is a larger form of the Sauzei Zone and, according to Dietze *et al.* (2007), the studied forms agree more closely with *S. albidus* which ranges from the Ovale Zone up into the Laeviuscula Zone (Dietze *et al.*, 2007, p. 13).

**Distribution:** Lower Dhruma Fm, upper unit D1. *Wadi ar Rayn Quadrangle:* VD80.527 (UCBL-FSL 178 563-588, 178 594), Faridat Balum, 23°42' N.

**Age:** Lower Bajocian, Stephani Zone. In W Europe Laeviuscula Zone of the Submediterranean Province, but the genus may range upwards in the Propinquans Zone = Sauzei Zone (in Howarth, 2013, p. 119).

Genus *Pseudoshirbuirnia* Dietze *et al.*, 2005

**Type species:** *Amaltheus? stephani* Buckman, 1883; by original designation

***Pseudoshirbuirnia stephani* (Buckman, 1883) (M)**

Pl. VII, fig. 1; Tab. 8

1883. *Amaltheus? stephani* Buckman, 1883, p. 138, pl. 1, fig. 1 (LT).  
 1986. *Shirbuirnia* cf. *fastigata* Buckman.– Énay *et al.*, p. 33 (tab. 1), p. 35, pl. 3, fig. 1a, b.  
 1987a. *Shirbuirnia* cf. *fastigata* Buckman.– Énay *et al.*, p. 34 (tab. 1), p. 42, pl. 3, fig. 1a, b.  
 1994. *Shirbuirnia* sp. Énay & Mangold, p. 168.  
 2005. *Pseudoshirbuirnia stephani* (Buckman)– Dietze *et al.*, p. 48, figs 27-29, 30b (cum synonymy).

**Material:** 23 specimens or large fragments from *Wadi ar Rayn Quadrangle:* VD80.527 (2 ex); VD80.566 (20 ex) and *Darmā' Quadrangle:* JMA82.162 (1 ex).

**Description:** All the studied specimens are wholly septate, the larger and more complete ones (UCBL-FSL 178 612 and 613) are 360 and 300 mm in diameter

Table 7: Measurements of *Sonninites* aff. *albidus* (Buckman) and *S. albidus* (Buckman).

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 178 577 - VD80.527 (M)	163 145	c 105 -	66 62	0.40 0.42	40 36	0.24 0.24	40 34	0.24 0.23	0.60 0.58
UCBL-FSL 178 580 - VD80.527 (M)	148	c 100	61	0.41	37	0.25	43	0.29	0.60
UCBL-FSL 178 565 - VD80.527 (M)	141	c 100	64	0.45	35	0.24	32	0.22	0.54
UCBL-FSL 178 569 - VD80.527 (M)	132	c 72	57	0.43	32	0.24	33	0.25	0.56
UCBL-FSL 178 570 - VD80.527 (? m)	89	?	40	0.44	23	0.25	18	0.20	0.57
<i>S.</i> aff. <i>albidus</i> Buckman	145	n	65	0.44	c 32	0.22	32	0.22	c 0.49
Dietze <i>et al.</i> , 2007, pl. 3, fig. 2	110	-	51	0.46	-	-	24	0.21	0.47
<i>S. albidus</i> Buckman, holotype	95	c 65	40	0.44	-	-	22	0.24	-
<i>S. albidus</i> Buckman, topotype, in Dietze <i>et al.</i> , 2007, pl. 3, fig. 2	89 65	n -	40 29	0.44 0.44	- -	- -	22 16	0.24 0.24	-

respectively. Involute, whorl section compressed, the sides slightly convex, fastigate and carinate venter, rounded umbilical edge. Most of the studied specimens do not show any ornament whatever the size, save two, the one already figured (Énay *et al.*, 1987a, pl. 3, fig. 1a, b; herein refigured in Pl. VII, fig. 1a, b) and the inner whorls of a larger specimen (UCBL-FSL 178 609). These show radial simple ribs, thickened at about two-thirds of the side and projected forward on the ventromarginal part of the side.

**Discussion:** According to Dietze *et al.* (2005; see their synonymy list), *S. fastigata* is a junior synonym of *S. stephani*. Assignment to *S. stephani* rather than *S. oechslei* is based on the occurrence of ribs on the inner whorls.

**Distribution:** Lower Dhurma Fm, upper unit D1. The species was collected in three places only of which one (VD80.566) yielded the main part of the studied specimens. *Wadi ar Rayn Quadrangle:* VD80.527 (UCBL-FSL 178 603), Faridat Balum, 23°42' N; VD80.566 (UCBL-FSL 178 605-624), lonely place North of Faridat Balum, about 23°45' N; *Darmā' Quadrangle:* JMA82.162 (UCBL-FSL 178 625), Khashm adh Dhibi 24°14' N.

**Age:** Lower Bajocian, Stephani Zone. In Southern England and Southern Germany, *P. stephani* is known in the Laeviuscula Zone, Trigonalis Subzone, *stephani* Horizon, but the genus may range upwards in the Humphriesianum Zone, Romani or Cycloides Subzones (Dietze *et al.*, 2005, p. 56).

Genus *Dorsetensia* Buckman, 1892

**Type species:** *Ammonites edouardianus* d'Orbigny, 1846; by original designation

***Dorsetensia liostraca* Buckman, 1892 (M)**

Pl. VII, figs 2-3; Pl. VIII, figs 1-3, Tab. 9

1892. *Dorsetensia liostraca* Buckman, p. 310, pl. 53, figs 11-16; pl. 54, figs 3-5; pl. 56, fig. 1.  
 1892. *Dorsetensia subpecta* Buckman, p. 309, pl. 54, figs 3-5; pl. 55, fig. 1, 2.  
 1892. *Dorsetensia tecta* Buckman, p. 311, pl. 56, figs 2-5.  
 1935. *Dorsetensia liostraca* Buckman.– Dorn, p. 101, pl. 11, fig. 5; pl. 22, fig. 3; pl. 27, fig. 1; text-figs 8/5-8; pl. 8, figs 5-8.  
 1935. *Dorsetensia subpecta* Buckman.– Dorn, p. 103, pl. 21, fig. 2; pl. 23, fig. 1; pl. 29, fig. 4; text-figs 8/9, 10; pl. 8, figs 9, 10.

Table 8: Measurements of *Pseudoshirburnia stephani* (Buckman).

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
UCBL-FSL 178 620 - VD80.566	169	n	77	0.46	41	0.24	33	0.19	0.51
UCBL-FSL 178 618 - VD80.566	185 144	n	85 73	0.45 0.50	44 34	0.23 0.23	38 23	0.20 0.16	0.51 0.46
UCBL-FSL 178 616 - VD80.566	213	n	103	0.48	57	0.26	39	0.18	0.55
UCBL-FSL 178 611 - VD80.566	303 212	n	146 108	0.48 0.50	83 47	0.27 0.22	62 47	0.20 0.22	0.56 0.43
UCBL-FSL 178 612 - VD80.566	320 248	c 325	164 130	0.51 0.52	87 65	0.27 0.26	55 37	0.17 0.15	0.53 0.5

Table 9: Measurements of *Dorsetensia liostraca* Buckman, forms *subpecta* and *tecta*.

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 178 216 – JMA82.372 (form <i>subpecta</i> )	115 90 70	93 - -	52 42 34	0.45 0.46 0.46	- - -	- - -	28 22 16	0.24 0.24 0.22	- - -
UCBL-FSL 178 252 - VD80.590 (form <i>subpecta</i> )	47 30	n -	20 13	0.42 0.43	13 -	0.27 -	13 9	0.27 0.30	0.65 -
UCBL-FSL 178 223 - VD80.564 (form <i>subpecta</i> )	48 25	n -	12 9	0.43 0.40	12 9	0.25 0.36	13 7	0.27 0.28	0.57 1.0
UCBL-FSL 178 224 - VD80.564 (form <i>subpecta</i> )	47	n	22	0.46	11.5	0.24	12	0.25	0.52
UCBL-FSL 178 219 – JMA82.166 (form <i>tecta</i> )	95 77	n -	52 40	0.54 0.51	22 16	0.23 0.20	12.5	0.13 0.11	0.42 0.40
UCBL-FSL 178313 – VD82.92 (forme <i>tecta</i> )	95 67	n -	53 36	0.55 0.53	21.5 -	0.22 -	7.5 4.5	0.08 0.07	0.40 -
UCBL-FSL 178313 – VD82.92 (form <i>tecta</i> )	80	n	39	0.48	16	0.20	-	-	0.41

1935. *Dorsetensia tecta* Buckman.– Dorn, p. 104, pl. 19, fig. 1; pl. 24, figs 1, 5; pl. 26, fig. 1a, b; text-fig. 9/1-3; pl. 9, figs 1-3.
1952. *Dorsetensia cf. listracca* Buckman.– Arkell, p. 270.
1967. *Dorsetensia listracca* Buckman.– Kopik, p. 25, pl. 6, fig. 4; pl. 7, figs 1-4.
1968. *Dorsetensia listracca listracca* Buckman.– Huf, p. 97, pls 30-40.
1968. *Dorsetensia listracca subsecta* Buckman.– Huf, p. 103, pls 41-46, pl. 47, fig. 1
1968. *Dorsetensia listracca tecta* Buckman.– Huf, p. 107, pl. 47, figs 2-4; pl. 48-51.
1972. *Dorsetensia listracca* Buckman.– Morton, p. 506, pl. 102; pl. 103, figs 1, 2; pl. 104, figs 1, 2.
1987. *Dorsetensia tecta* Buckman.– Énay *et al.*, tab. 1, p. 34; pl. 2, fig. 8; pl. 3, fig. 2.
1987. *Dorsetensia subsecta* Buckman.– Énay *et al.*, tab. 1, p. 34; pl. 3, fig. 3.
1987. *Dorsetensia cf. complanata* Buckman.– Énay *et al.*, tab. 1, p. 34; pl. 2, fig. 4a, b.
1987. *Dorsetensia edouardiana* (d'Orbigny).– Énay *et al.*, tab. 1 (p. 34).
1987. *Dorsetensia tessoniana* d'Orbigny.– Énay *et al.*, tab. 1 (p. 34), p. 38. [New figure in Fischer *et al.*, 1994, pl. 42, figs 3a, b].
1994. *Dorsetensia tessoniana* d'Orbigny.– Énay & Mangold, p. 168.

**Material:** 78 specimens (plus a few doubtfully assigned), more or less well-preserved from thirteen localities. Other sixty fragmentary or poorly preserved specimens from the same localities are left as *Dorsetensia* sp.

**Description:** Faint ribbing of the innermost whorls is preserved in UCBL-FSL 178 223-224, also in the large specimen 178 217, but disappears earlier in UCBL-FSL 178 252. Large specimens, wholly septate, save one with the very beginning of the body chamber (UCBL-FSL 178 216), are completely smooth. Far south from the other places with the same fauna, well-preserved specimens from Shaqrā' Quadrangle (VD82.92), illustrate the variability in relative umbilical diameter and whorl height, strength and duration of ornament on the inner whorls. On the material available the involute form (*D. listracca tecta*) is dominant (65 examples over the 19 examples of the more evolute *D. listracca listracca* and *D. listracca subsecta*).

**Discussion:** Formerly assigned to *D. edouardiana* and *D. cf. complanata* by Énay *et al.* (1987), the specimens UCBL-FSL 178 223, 178 224 and 178 252 are considered here inner whorls of bigger specimens of the same species. In this species we include the specimens assigned to *D. tessoniana* in Énay *et al.* (1986, 1987a) and Énay & Mangold (1994). Indeed, none of those specimens display the overhanging umbilical edge (e.g. "sous-cavé" in Gabilly, 1976) described by Rioult (in Fischer *et al.*, 1994).

**Distribution:** Lower Dhurma Fm, Lower unit D2. *Wadi ar Rayn Quadrangle:* V 80.505 (UCBL-FSL 178 492-496; 178 505-518; 178 543), Wadi Birk SU,

23°12' N; VD80.540 (UCBL-FSL 178 452-460), lonely place between Khashm al Hamra et Wadi al Hawtah, about 23°31' N; VD80.543 (UCBL-FSL 178 535), between Faridat Balum, 23°42' N et Wadi al Hawtah, 23°32' N, about 23°40'; VD80.545 (UCBL-FSL 178 479-491, 497), Khashm al Hamra 23°30' N; VD80.563 (UCBL-FSL 178 504) and VD80.564 (UCBL-FSL 178 223-224), Wadi Birk 23°12' N; VD80.528 (UCBL-FSL 178 595-597), Khashm al Majulah, 23°48' N; VD80.567 (UCBL-FSL 178 449-451), Khashm al Jufayr, 23°58' N; VD80.589 (UCBL-FSL 178 598-602) and VD80.590 (UCBL-FSL 178 252), lonely place north of Wadi Birk, 23°13' N; *Darmā' Quadrangle:* JMA82.164 (UCBL-FSL 178 256) and JMA82.166 (UCBL-FSL 178 218, 219, 448), Khashm adh Dhibi, 24°14' N; JMA82.372 (UCBL-FSL 178 216, 217), lonely place north of Khashm adh Dhibi about 24°22' N; *Shaqrā' Quadrangle:* VD82.92 (UCBL-FSL 178 306-324, 431), lonely place (isolated hills) south of Jurayfah South, about 25°22' N.

As *Dorsetensia* sp. *Wadi ar Rayn Quadrangle:* VD80.563 (UCBL-FSL 178 449-451) and VD80.564 (UCBL-FSL 178 235-237, 267, 268), Wadi Birk 23°12' N; VD80.589 (UCBL-FSL 177 589-602) and VD80.590 (UCBL-FSL 178 265, 266, 519-550), lonely place north of Wadi Birk, about 23°13' N; VD80.512 (UCBL-FSL 178 498-503), lonely place north of Wadi Birk about 23°14' N; VD80.535 (UCBL-FSL 178 541), Khashm Birk 23°18' N; VD80.546 (UCBL-FSL 178 205), Khashm al Hamra 23°30' N; VD80 542 (UCBL-FSL 178 443-447, 461-477), between Wadi al Hawtah, 23°32' N and Faridat Balum, 23°42' N about 23°40' N; VD80.528 (UCBL-FSL 178 595-597), Faridat Balum, 23°42' N; VD80.358 (UCBL-FSL 178 244), Khashm al Jufayr 23°58' N; *Darmā' Quadrangle:* JMA82.166 (UCBL-FSL 178 220-222), Khashm adh Dhibi, 24°14' N; *Shaqrā' Quadrangle:* V82.92 (UCBL-FSL 178 256-266, 519-534; 536-540), lonely place (isolated hills) south of Jurayfah about 26°22' N-46°20' E.

**Age:** Lower Bajocian, Glabrum Zone. In W Europe *Dorsetensia* is commonly quoted from the upper Lower Bajocian, Humphriesianum Zone of the Mediterranean Province. A little younger in the Jurayfah area (VD82.92) owing to the occurrence of *Teloceras*.

#### *Dorsetensia cf. deltafalcata* (Quenstedt, 1858) [m]

Pl. VIII, fig. 5.

1858. *Ammonites deltafalcatus* Quenstedt, p. 394, pl. 53, figs 7, 8.
1893. *Sonninia deltafalcata* (Quenstedt).– Haug, p. 293, pl. 9, fig. 8 (non figs 5, 9).
1968. *Sonninia deltafalcata* (Quenstedt).– Huf, p. 80, pl. 9, fig. 2, pl. 11, figs 2, 4, pl. 12, fig. 5.
1983. *Sonninia deltafalcata* (Quenstedt).– Pavia, p. 63, pl. 6, figs 1, 3, 4.

**Material:** Five well-preserved specimens, from a single locality on Shaqrā Quadrangle (VD82.92).

**Description:** Small size, possibly a nucleus, but not any visible suture-line; coiling fairly involute, whorl section subrectangular higher than wide; well-defined keel without sulci; falcate ribs, bifurcated at mid-flank, the primaries prorsiradiate, the secondaries curved forward at the periphery.

**Discussion:** By its relatively involute coiling the specimen is close to the one figured by Pavia (1983, pl. 6, fig. 3) although the ribs are not so well-marked.

**Distribution:** Lower Dhurma Fm, Lower unit D2; *Shaqrā' Quadrangle*: VD82.92 (UCBL-FSL 178 422-426), lonely place (isolated hills) south of Jurayfah South 25°40' N.

**Age:** Lower Bajocian, Glabrum Zone. In W Europe *Dorsetensia* is commonly quoted from the upper Lower Bajocian, Humphriesianum Zone, Blagdeni Subzone of the Mediterranean Province owing to the occurrence of a microconch of *Teloceras*.

***Dorsetensia cf. regrediens* (Haug, 1893) [m]**

Pl. VIII, fig. 6

1892. *Dorsetensia edouardiana*, Buckman, 1887-1907, p. 304, pl. 52, figs 8-17.  
 1893. *Witchellia regrediens* Haug, p. 318, pl. 10, fig. 7.  
 1933. *Dorsetensia cf. regrediens* (Haug).– Arkell, p. 333, pl. 13, fig. 2, 3.  
 1968. *Dorsetensia edouardiana* (non d'Orbigny).– Huf, p. 75, pl. 7, fig. 7, pl. 8, figs 1, 2.  
 1983. *Dorsetensia (Nannina) edouardiana* (Haug).– Pavia, p. 67, pl. 6, fig. 8.

**Material:** Four well-preserved specimens, from the same place as *Dorsetensia cf. deltafalcata*.

**Description:** Small-sized immature specimens or nuclei; evolute coiling, whorl section first quadrate rounded changing to more compressed; simple rectiradiate ribs curved forward at the periphery; well-defined keel with bordering flat-laid or sulci.

**Discussion:** The present specimens are closer to the holotype than to the specimen figured by Pavia (1983).

**Distribution:** Lower Dhurma Fm, Lower unit D2. *Shaqrā' Quadrangle*: VD82.92 (UCBL-FSL 178 427-430), lonely place (isolated hills) south of Jurayfah SU, South 25°40' N.

**Age:** Lower Bajocian, Glabrum Zone. In W Europe *Dorsetensia* is commonly quoted from the upper Lower Bajocian, Humphriesianum Blagdeni Subzone of the Mediterranean Province owing to the occurrence of a microconchiate *Teloceras*.

***Dorsetensia cf. schlumbergeri* (Haug, 1893) [m]**

Pl. VIII, fig. 4

1893. *Sonninia* (? *Poecilomorphus*) *schlumbergeri* Haug, p. 296, pl. 8, fig. 6.  
 1987. *Dorsetensia (Nannina)* sp., Énay *et al.*, 1987, ab. 1, p. 34; pl. 2, fig. 5a, b.

**Material:** A single specimen from the Wadi ar Rayn Quadrangle (VD80.512).

**Description:** Small-sized nucleus or immature specimen; fairly evolute coiling, whorl section rounded or elliptic, carinate; simple radial ribs thickened on the ventral part of the sides.

**Discussion:** Rounded tubercles on the ribs in the inner whorls described by Haug are absent or not obvious, but these are not well-preserved.

**Distribution:** Lower Dhurma Fm, Lower unit D2. *Wadi ar Rayn Quadrangle* VD80.512 (UCBL-FSL 178 289), lonely place North of Wadi Birk about 23°14' N.

**Age:** Lower Bajocian, Glabrum Zone. In W Europe *Dorsetensia* is commonly quoted from the upper Lower Bajocian, Humphriesianum Zone of the Mediterranean Province.

Subfamily Witchellinae Callomon & Chandler, 2006

Genus *Fontannesia* Buckman, 1902

**Type species:** *Dumortieria grammocerooides* Haug, 1887; by original designation

[= *Darellella* Buckman, 1904a, p. cvii; = *Nannoceras* Buckman, 1923b, pl. 445; = *Nannina* Buckman, 1927, pl. 752]

***Fontannesia* sp.**

Pl. IV, fig. 3

**Material:** A single, wholly septate specimen.

**Description:** Planulate, fairly evolute, high subrectangular whorls and carinate venter with sulci bordering the keel. Outer whorl with falcoid bifurcate ribs, twinned at the umbilical edge on the inner whorls.

**Discussion:** The present specimens is rather similar to some species of *Grammoceras*, but the sharp umbilical edge and the vertical umbilical wall point to *Fontannesia*.

**Distribution:** Lower Dhurma Fm, lower unit D1. *Darmā' Quadrangle*: JMA82.289 (UCBL-FSL 178 698), lonely place North of Khashm adh Dhibi 24°14' N.

**Age:** Lower Bajocian, Arabica Zone. The genus *Fontannesia* is known in the Lower Bajocian, Sowerbyi Zone (*auctorum*) of the Mediterranean Province.

Superfamily Haploceratoidea Zittel, 1884

[*nom. transl.* Arkell *et al.*, 1957 (*ex* Haploceratidae Zittel, 1884) [= *Oppeliacea* Buckman, 1919 (superfam.); *Oppeliaceae* Arkell, 1950 (superfam.)]  
 Family Strigoceratidae Buckman, 1924

**Remarks:** Hebetoxytidae Buckman, 1924 was included in the family by Arkell *et al.* (1957), but the lack of hollow keel and spiral ornamentation indicates these ammonites are not a strigoceratids, see Schweigert *et al.* (2007).

Genus *Strigoceras* Quenstedt, 1886

**Type species:** *Ammonites truellei* d'Orbigny, 1845; by original designation

[= *Stringoceras* H. Douvillé, 1916 (obj.)?; *Kleistoxytes* Buckman, 1922; *Strigites*, *Leptostrigites*, *Plectostrigites*, *Varistrigites* Buckman, 1924]

***Stringoceras* cf. *bessinum* Brasil, 1895**

Pl. VIII, fig. 14

1895. *Stringoceras besinum* nov. sp. Brasil, p. 43, pl. 4, figs 6-7.  
 2007. *Stringoceras besinum* Brasil.– Schweigert *et al.*, p. 20, figs 10-12 (cum synonymy).  
 2011. *Stringoceras pseudostrigifer* Maubeuge.– Rulleau, p. 64, pl. 26, fig. 3a, b.

**Material:** Two specimens from the same place (VD82.93; UCBL-FSL 178 271, 272), probably wholly septate, but suture not obvious in the larger one (d = c. 40 mm).

**Description:** Very involute with very narrow umbilicus; whorl section compressed and ogival; ventral area narrow with a well-marked keel, high and smooth; falcoid ribs, flexuous at mid-side, with a spiral depressed area, the primaries not well marked and the secondaries rursiradiate, flattened and enlarged on the ventral part of the side.

**Discussion:** The largest and best preserved specimen is similar to different species of the genus. The reason is probably that it is a wholly septate specimen. The similar forms are *S. septecarinatum* Buckman (in Buckman, 1924; see Schlegelmilch, 1985 and Schweigert *et al.*, 2007) and *S. pseudostrigifer* Maubeuge (1955, 1967), that Schweigert *et al.* (2007) consider as a junior synonym of *S. strigifer* (Buckman). It fits well with the specimens figured by Rulleau (1997, 2007, and 2011) as *S. strigifer* (Buckman) and *S. pseudostrigifer* Maubeuge, all specimens assigned to *S. besinum* Brasil by Schweigert *et al.* (2007). Our assignation agrees with the age indicated by the associated fauna.

**Distribution:** Lower Dhurma Fm, lower Unit D2. *Shaqrā' Quadrangle*: VD82.93 (UCBL-FSL 178 271, 272), lonely outcrops South of Jurayfah, about 25°22' N.

**Age:** Lower Bajocian, Glabrum Zone. According to Schweigert *et al.* (2007) the chronostratigraphic range of *S. besinum* is the basal Humphriesianum Zone. It is also the age given by Rulleau (1997, 2006, 2011) to the specimens assigned to *S. strigifer* and *pseudostrigifer*. The associated fauna with dominant *Dorsetensia* gr. *liostraca* favours an assignation to the upper part of the Lower Bajocian, Humphriesianum Zone. A little younger in the Jurayfah area (VD82.93) owing to the occurrence of *Teloceras*.

***Stringoceras* sp.**

**Material:** A single wholly septate, not well-preserved specimen (VD82.92; UCBL-FSL 178 270), probably just below VD82.93.

**Description:** Very involute, whorl section compressed

with a well-defined ventral keel. The only obvious ornament is a fine spiral strigation but no ribs, probably due to the small size of the specimen.

**Distribution:** Lower Dhurma Fm, lower Unit D2. *Shaqrā' Quadrangle*: VD82.93 (UCBL-FSL 178 270), control hills South of Jurayfah, about 25°22' N.

**Age:** Lower Bajocian, Glabrum Zone. Upper Bajocian is the time when the genus reached the maximum of diversity in the Mediterranean Province. The associated fauna with dominant *Dorsetensia* gr. *liostraca* favours an assignation to the upper part of the Lower Bajocian, Humphriesianum Zone. A little younger in the Jurayfah area (VD82.93) owing to the occurrence of *Teloceras*.

Family Oppeliidae Douvillé, 1890

Subfamily Oppeliinae Douvillé, 1890

Genus *Oxycerites* Rollier, 1909

**Type species:** *Ammonites aspidoides* Oppel, 1857 (= *Ammonites discus complanatus* Quenstedt, 1846-1849, p. 124, pl. 8, fig. 12)

*Oxycerites* aff. *fallax* (Guéranger, 1865)

1846. *Ammonites discus* d'Orbigny, p. 394, pl. 131.

1865. *Ammonites fallax* Guéranger, p. 187, pl. 2, figs 3, 4.

1951. *Oppelia (Oxycerites) fallax* (Guéranger).– Arkell, p. 56, text-figs 15, 16; pl. 5, figs 1-3 (cum synonymy).

1961. *Oppelia (Oxycerites) fallax* (Guéranger).– Stephanov, p. 345, pl. 1, figs 3, 5.

1966. *Oxycerites fallax* (Guéranger).– Elmi & Mangold, p. 148, text-figs 1-8, pl. 8, figs 1-2, 5-6, 9-10.

**Material:** One poorly preserved specimen from an isolated point.

**Description:** Very involute with narrow umbilicus visible only on the less well-preserved side; compressed whorl section, the larger thickness near the umbilicus edge and acute venter; the only ornament consists of distant arcuate ribs on the inner part of the flank.

**Discussion:** Separating the various species recognized within the genus *Oxycerites* is difficult even with very well-preserved material (Elmi & Mangold, 1987). In the case of a dated form of the Lower Bathonian by the associated *Tulites*, the specimen studied can be assumed as close to *O. fallax*, a species whose characteristics are well exposed by Arkell (1951) and Elmi & Mangold (1966).

**Distribution:** Dhurma Fm, D4 unit (*Tulites* Fauna). *Shaqrā' Quadrangle*: JMA82.354A (UCBL-FSL 177 417), lonely place between Jurayfah 25°30' to 32' N and Jurayfah South.

**Age:** Lower Bathonian, Tuwaiqensis Zone. The equivalence with the lower part of the Zigzag zone, Early Bathonian, in Europe is deduced from its position between the Planus Zone (*Thambites* and *Rebouliceras avus* Assemblage) of late Bajocian age and Clydocromphalus Zone (*Micromphalites* Fauna) well dated as Early Bathonian.

Subfamily Clydoniceratinae Buckman, 1924  
[= Thambocerotinae Arkell, 1952]

Genus *Thamboceras* Douvillé, 1916

**Type species:** *Thamboceras mirum* Douvillé, 1916; by original designation

**Remarks:** There are scarce occurrences of ammonites of this genus in Saudi Arabia, only four specimens of which only one is well-preserved and was previously figured by Énay *et al.* (2012b) for comparison with specimens from Normandy. These latter are larger than the small specimens from Sinai and Saudi Arabia.

***Thamboceras mirabile* Arkell, 1952**

Pl. XX, fig. 1

1916. *Thamboceras mirum* Douvillé, p. 22, pl. 2, fig. 12a, b only.  
1952. *Thamboceras mirabile* Arkell, p. 278, pl. 19, figs 13, 14; pl. 30, fig. 9 (holotype).  
1986. *Thamboceras* sp. Énay *et al.*, p. 33.  
1987a. *Thamboceras* sp. Énay *et al.*, p. 35 (tab. 1).  
non 1999. *Thamboceras* cf. *mirabile* Douvillé.– Rioult & Chirat, p. 54 (= *T. mirum* Douvillé).  
2011. *Thamboceras mirabile* Arkell.– Énay *et al.*, figs 4/4 and 5a, b.  
2015. *Thamboceras mirum* (sic!) Douvillé.– Abdelhady & Fursich, fig. 13/A, B.

**Material:** Three specimens of which only one is well-preserved.

**Description:** The only well-preserved specimen (UCBL-FSL 177 956) is rather small [D = 42 mm; H/D = 0,56, W/D = 0,21], U/D = 0,07, W/H = 0,38], wholly septate; but the whorl fragment figured in Arkell (1952: pl. 19, figs 13-14) and another one from Sinai (UCBL-FSL 177 958) indicate not less than 60 mm in diameter. Our specimen is involute with very narrow umbilicus and compressed whorl section; dense ribbing, weak (or not well-preserved) on the inner part of the side, bicarinate venter with a well-defined and deep ventral furrow.

**Discussion:** In the studied specimens the umbilicus is narrower in Douvillé (1916, pl. 2, fig. 12) but fits well with the holotype (Arkell, 1952, pl. 30, fig. 9) although the ribbing is denser as the specimen from the area of the type locality (Jebel Moghara) in Énay *et al.* (2011, fig. 4/4).

**Distribution:** Dhurma Fm, upper D2 Unit. *Wadi al Mulayh Quadrangle:* JMA80.553-1 (UCBL 177 954), lonely place between Fara'id al Ahmar (22°27'N) and As Sitarah Khashm Ushayrah (22°38' N). *Shaqrā' Quadrangle:* VD82.478B (UCBL-FSL 177 955, 956), Jurayfah South, about 25°22' N.

**Age:** Lowest Upper Bajocian, Runcinatum Zone. According to the association with European elements in Sinai and Northern Africa, Late Bajocian age, Niortense Zone (Arkell & Lucas, 1953; Du Dresnay, 1964; Énay *et al.*, 1987b; Énay & Mangold, 1994).

Genus *Thambites* Arkell, 1952

**Type species:** *Thambites planus* Arkell, 1952; by original designation

**Remarks:** The genus is herein limited to *T. planus* and *T. oxynotus*. These differ essentially in the line of suture, curved and convex forwards in *T. oxynotus*, straight in *T. planus*. The distinction is difficult, if not impossible, when the suture line is not finely preserved. Thus, of the 147 specimens sampled of *Thambites* only a part could be determined up to the species level while the remaining are attributed to *Thambites* sp. Specimen FSL 177 701 (described below) deserves special mention because in spite of its small size, the end of the preserved last whorl shows a clear uncoiling of the umbilical seam and suture approximation, suggesting that the specimen would be adult, and thus a possible microconch. *T. oxynotus* being very rare (only a single specimen), it is considered as the microconch of *T. planus*.

***Thambites planus* Arkell, 1952**

Pl. XX, figs 2-6; Tab. 10

1952. *Thambites planus* Arkell, p. 280, pl. 23, fig. 11; pl. 24, figs 1-6; text-fig. 8.  
1963b. *Thambites planus* n. sp., Arkell.– Du Dresnay, p. 890.  
1974. *Thambites planus* Arkell.– Du Dresnay, p. 149.  
1985. *Thambites planus* (Arkell).– Énay & Mangold, p. 644.  
1986. *Thambites planus* and cf. *planus* (Arkell).– Énay *et al.*, p. 33 (tab. 1), pl. 5, fig. 3.  
1987a. *Thambites planus* and cf. *planus* (Arkell).– Énay *et al.*, p. 35 (tab. 1), 43, pl. 5, fig. 3.  
1987b. *Thambites planus* (Arkell).– Énay *et al.*, pp. 111, 112, 113, figs 2 and 3.  
1994. *Thambites planus* (Arkell).– Énay & Mangold, p. 169.  
2011a. *Thambites planus* (Arkell).– Énay, p. 142, pl. 1, fig. 1a, b.  
2011b. *Thambites planus* (Arkell).– Énay, p. 97, fig. 7a1, a2.

**Material:** One hundred and twenty specimens and fragments more or less well-preserved.

**Description:** Large oxyconic shell, high and flat whorl-sides, the maximum thickness close to the umbilicus in the early stage, but changing to nearly central with the whorl-sides gently rounded, narrow venter, truly concave and bicarinate, with narrow ventral furrow, but without any trace of ribbing.

**Discussion:** There is little to add to the Arkell's description of the species. Sampled material is rich but specimens of large size with complete whorls are scarce. The few ones which allow to obtain measurements display some variability of the whorl thickness and umbilicus diameter. Specimens that are not distinguishable for the other characters differ in the width of the ventral groove, relatively broad in some and narrower in others. But there is no reason to believe that this particular feature distinguishes micro- and macroconch. A microconch would be two small specimens (UCBL-FSL 177 780 and

Table 10: Measurements of *Thambites planus* Arkell.

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 177 726 – VD81.277 (M)	159	n	80	0.50	33	0.20	23	0.14	0.41
UCBL-FSL 177 556 – VD81.188/1 (M)	158	n	88	0.55	34	0.34	12	0.07	0.38
	110		61	0.55	21	0.34	10	0.16	0.34
UCBL-FSL 177 712 – VD81.188/1 (M)	143	n	73	0.51	27	0.19	16	0.11	0.36
UCBL-FSL 177 701 – VD81.278 (?m)	95	n	52	0.54	19	0.20	7	0.07	0.36

177 566), with the body chamber not well-preserved, figured as *Thambites* sp. [m] (Pl. XX, fig. 7).

**Distribution:** Dhurma Fm, D3 Unit. *Sulayyimah Quadrangle:* VD81.188 (UCBL-FSL 177 657-659, 676, 756-759), 188/1UCBL-FSL 177 712-714, 720-725), 270 (UCBL-FSL 640-646 bis), 277 (UCBL-FSL 177 726-729), 278 (UCBL-FSL 177 647-655, 660-664, 701) and 279 (UCBL-FSL 177 753-755), South of Khashm Abu al Jiwar, about 21°50' N; VD81.99 (UCBL-FSL 177 780) as *Th.* sp. (m), Khashm Abu Jiwar, 21°53' N; *Wadi al Mulayh Quadrangle:* JMA80.521 (UCBL-FSL 177 675, 749), lonely place North of Khashm al Jiwar, about 22°05' N; JMA80.564 and 565 (UCBL-FSL 177 677-684), Khashm Munnayyiyah, 22°11' N; JMA80.554, 554/0, 554/1, 554/2, 554/3, 556 (UCBL-FSL 177 702-709, 715-719, 731-733, 743-745), between Fara'id al Ahmar 22°27' N and As Sitarah Khashm Ushayrah, 22°38' N; *Wadi ar Rayn Quadrangle:* VD80.370 and 372 (UCBL-FSL 177 685-691), Khashm al Hadafiyyah, 23°05' N; VD80.515 (UCBL-FSL 177 692-700), 516 UCBL-FSL 177 518, 519) and 517 (UCBL-FSL 177 665-67) lonely place at the same latitude as Khashm Birk 23°18' N; VD80.604, 605éb., 606 (UCBL-FSL 177 671-674), lonely place North of Wadi al Hawtah, about 23°36' N; VD80.553 (UCBL-FSL 177 747, 748), Khashm al Majulah 23°48' N; VD80.410 (UCBL-FSL 177 566) as *Th.* sp. (m), Khashm al Jufayr, 23°58' N; *Darmā' Quadrangle:* JMA82.395, 410, 411, 412 (UCBL-FSL 177 772, 773), Wadi al Jufayr, 24°05' N; JMA82.119bis (UCBL-FSL 178 701Khashm adh Dhibi, 24°14' N; JMA82.186, 299 (UCBL-FSL 178 776, 777), Khashm adh Dhibi, 24°14' N; JMA82.298 (UCBL-FSL 177 760, 761), lonely place North of Khashm adh Dhibi, about 24°14' N, JMA82.282 (UCBL-FSL 177 779), Wadi al Hisyan, 24°45' N; *Shaqrā' Quadrangle:* VD82.350 (UCBL-FSL 177 775), Jurayfah, 25°30' to 25°38' N.

**Age:** Uppermost Bajocian, Planus Zone. Previously dated as Bathonian (Arkell, 1952; Imlay, 1970; Lewy, 1983; Gill *et al.*, 1985) but revised as Uppermost Bajocian, Parkinsoni Zone (Du Dresnay, 1964b; Du Dresnay *et al.*, 1985; Énay *et al.*, 1986, 1987b; Énay & Mangold, 1994).

#### *Thambites oxynotus* Arkell, 1952

Pl. XX, fig. 2

1952. *Thambites oxynotus* Arkell, p. 281, pl. 21, fig. 13.

**Material:** A well-preserved quarter of whorl of a small wholly septate specimen.

**Description:** Oxyconic with convex flanks, the greatest thickness at mid-flank, whorl section compressed with fairly fastigate and narrow venter, concave and bicarinate. Smooth. Suture line curved and convex forwards.

**Discussion:** The studied specimen agrees closely matches the holotype, especially the curved and convex forward suture line characteristic of *Thambites planus*. However, the suture line seems to be not very curved but this could be due to the small size of our specimen compared to the holotype. Moreover, discrimination according to Arkell (1952), based on the whorl sides, gently *convex* in *T. oxynotus* but at first almost flat with the maximum thickness close to the umbilicus in *Th. planus*, is not so well marked.

**Distribution:** Dhurma Fm, D3 Unit. *Wadi al Mulayh Quadrangle:* JMA80. 554/2 (UCBL-FSL 177 730), between Fara'id al Ahmar 22°27' N. and As Sitarah Khashm Ushayrah, 22°38' N.

**Age:** Uppermost Bajocian, Planus Zone. Previously dated as Bathonian (Arkell, 1952; Imlay, 1970; Lewy, 1983; Gill *et al.*, 1985) but revised as uppermost Bajocian, Parkinsoni Zone (Du Dresnay, 1964b; Du Dresnay *et al.*, 1985; Énay *et al.*, 1986, 1987b; Énay & Mangold, 1994).

#### *Thambites nov. sp.*

Pl. XXI, fig. 1

**Material:** One wholly septate, well-preserved specimen, one half whorl long.

**Description:** The specimen is well separate from the other species of the genus, mainly by its umbilicus more open at the same diameter (about U/D = 0.20 versus 0.07-0.14). Other characteristic features are the larger ventral furrow and the thicker whorl width.

**Discussion:** The species is probably new, but the only specimen available prevents a specific assignment.

**Distribution:** Dhurma Fm, unit D3. *Wadi al Mulayh Quadrangle:* JMA80.521 (UCBL-FSL 177 749), lonely place North of Khashm al Jiwar, about 22°05' N.

**Age:** Uppermost Bajocian, Planus Zone. Previously dated as Bathonian (Arkell, 1952; Imlay, 1970; Lewy, 1983; Gill *et al.*, 1985) but revised as Uppermost Bajocian, Parkinsoni Zone (Du Dresnay, 1964; Du Dresnay *et al.*, 1985; Énay *et al.*, 1986, 1987b; Énay & Mangold, 1994).

Genus *Mulayites* nov.

**Type species:** *Thambites? avus* Arkell, 1952 [in p. 281, it is written “*?Thambites avus*”. This originally notation was intended to indicate doubtful generic assignment]

**Origin of the name:** From Wadi al Mulay, the name of the quadrangle with the outcrops that yielded the greatest number of specimens of the type species.

**Diagnosis:** Large and involute oxycone with narrow umbilicus, compressed whorl section, and rounded sides, but close together and ventrally pinched with a sharp and acute venter; inner whorls with weak, distant and radial simple ribs fading before the venter, smooth middle and outer whorls.

**Remarks:** In a former version of our manuscript we had accepted the proposal by Branger (in Vadet *et al.*, 2011) of the genus “*Rebouliceras*”, but this did not scrupulously respect the rules of the ICZN and was revised at the request of the editor. Branger (in Vadet *et al.*, 2011) proposed the genus “*Rebouliceras*” and the species *R. glabrum*”, based on specimens from Morocco (Middle Atlas range). Two specimens of the latter species were figured, but Branger did not explicitly designated a holotype, as required by the ICZN Code (1999, Art. 16.4), although under Art. 73.11, the sentence “Reboul 760 constitue l'échantillon type”, this specimen could be considered as the holotype by original designation. Moreover, Branger (in Vadet *et al.*, 2011) did not explicitly make a valid designation of a type species of the genus according to the Arts. 13.3 and 67.4. of the ICZN. *T. avus* Arkell, the first known species with a relatively wide distribution through the southern Tethyan margin (from Saudi Arabia to Morocco), an accurate stratigraphic position, and represented by numerous specimens from the type area, is a representative type species.

***Mulayites avus* (Arkell, 1952)**

Pl. XXI, fig. 2; Pl. XXII, figs 1-3; Tab. 11

1952. *?Thambites avus* n. sp., Arkell, p. 281, pl. 24, fig. 7.  
1963b. *Thambites avus* Arkell.– Du Dresnay, p. 890.

1969. cf. *Thambites avus* and ? *Thambites avus* Arkell.– Du Dresnay, pp. 142, 146.  
1970. *Dhrumaites cardioceratoides* (Arkell).– Imlay, p. D11; pls 3, 6, 7, 9.  
1974. *Thambites avus* Arkell.– Du Dresnay, p. 149.  
1985. “*Clydoniceras*” *avus* (Arkell).– Énay & Mangold, p. 644.  
1986. “*Clydoniceras*” *avus* (Arkell).– Énay *et al.*, pp. 37, 45; pl. 4, fig. 1, 2; pl. 5, figs 1, 2.  
1987a. “*Clydoniceras*” *avus* (Arkell).– Énay *et al.*, pp. 38, 39, 43; pl. 4, fig. 1, 2; pl. 5, figs 1, 2.  
1987b. “*Clydoniceras*” *avus* (Arkell).– Énay *et al.*, pp. 111, 112, 113, figs 2, 3.  
1994. “*Clydoniceras*” *avus* (Arkell).– Énay & Mangold, p. 169.

**Material:** One hundred and fourteen specimens of large ( $D > 200$  mm in diameter with body chamber) to small size, plus fragments more or less well-preserved.

**Description:** Large and involute, narrow umbilicus with high compressed lanceolate whorl-section and acute venter, widest near the umbilicus. The larger specimens with body chamber display obvious uncoiling of the outer whorl. Complete body chamber seems about one-half whorl long, slightly contracted dorsally, aperture missing (Pl. XXI, figs 2a, b). Ornamentation preserved only on some small specimens, made of weak, distant and radial simple ribs fading before the venter. Large specimens with smooth sides, but most of them are weathered. Suture line simple, but lobes and saddles well indented; first and second saddles broad, divided by a secondary lobe; the external lobe deep, the first and second “lateral” lobe broad and not very deep, larger in proportions of their length.

**Discussion:** The holotype is poorly preserved, but the new material allows to give a more complete description based on specimens at different stage of growth. The species displays original features justifying it was a long time and provisionally quoted as “*Clydoniceras*” *avus* (Énay & Mangold, 1985, 1994; Énay *et al.*, 1986, 1987a, b), in the clearly expressed expectation of the proposal of a new genus. Meantime, the genus “*Rebouliceras*” was established, just after I was asked by Branger for

Table 11: Measurements of *M. avus* (Arkell) and “*Rebouliceras*” *glabrum* Branger.

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 177 453 - VD81.188/1	294	234	142	0.48	75	0.25	37	0.12	0.52
			137	0.56	69	0.28	c 24	0.09	0.50
			128	0.54	61	0.26	c 21	0.08	0.47
UCBL-FSL 177 452 - VD81.188/1	277 208	n	149	0.53	63	0.22	32	0.11	0.42
			116	0.55	52.5	0.25	22.5	0.10	0.45
UCBL-FSL 177 487 - VD81.277	261	n	146	0.55	64	0.24	30.5	0.11	0.43
<i>R. glabrum</i> Branger in Vadet <i>et al.</i> , 2011 (0760).	158 118 117	c 107	77	0.48	35	0.22	21	0.13	0.45
			57	0.51	25	0.22	15	0.13	0.43
			60	0.51	27	0.23	16	0.13	0.45
<i>R. glabrum</i> Branger in Vadet <i>et al.</i> , 2011 (0760a).	123 100	n	61	0.49	31	0.25	18	0.14	0.50
			48	0.48	23	0.23	14	0.14	0.47

giving my view about specimen from Morocco he was undecided to ascribe to "*Dorsetensia*" (see Énay *et al.*, 2012b, p. 46, note 4).

Uncoiling of the outer whorl and approximation of the last septa show that the holotype of "*R.*" *glabrum* is a nearly complete and fully grown specimen, differing from *M. avus* by its smaller size, thinner whorl section and more simplified suture-line. Furthermore, its age being upper Lower Bajocian, Humphriesianum Zone and Subzone. If the species is retained within the genus "*Rebouliceras*", "*R.*" *glabrum* would be a forerunner of the genus outside Saudi Arabia.

**Distribution:** Dhurma Fm, D3 unit. *Sulayyimah Quadrangle*: VD81.188 (UCBL-FSL 177 478-483), VD81.188/1 (UCBL-FSL 177 426-455, 485, 486, 495-500, 512-517, 538-540), VD80.270 (UCBL-FSL 177 547-555), VD81.277 (UCBL-FSL 177 484, 487, 510, 511), VD81.279 (UCBL-FSL 177 488-494) and VD81.280 (UCBL-FSL 177 508), south of Khashm Abu al Jiwar, 21°50' N; *Wadi al Mulayh Quadrangle*: JMA80.521 (UCBL-FSL 177 456, 457, 473-475, 543-546), lonely place north of Khashm Abu al Jiwar, about 22°05' N; JMA80.57 (UCBL-FSL 177 469, 470), lonely place between Khashm Shimrakh 22°10' N and Khashm Munayyifiyah 22°11' N; JMA80.565 (UCBL-FSL 177 476), Khashm Munayyifiyah 22°11' N; JMA80.554/0 (UCBL-FSL 177 472), JMA80.554/1 (UCBL-FSL 177 458-468, 471, 501-504) and JMA80.556 (UCBL-FSL 177 531-535, 541, 542), lonely place between Fara'id al Ahmar and As Sitarah Khashm Ushayrah, about 22°34' N; JMA80.80éb. (UCBL-FSL 177 536), As Sitarah Khashm Ushayrah, 22°38' N; *Wadi al Rayn Quadrangle*: VD80.516 (UCBL-FSL 177 518, 519), lonely place at the same latitude as Khashm Birk, 23°18' N; VD80.606 (UCBL-FSL 177 520), lonely place north of Wadi al Hawtah, about 23°36' N; *Darmā' Quadrangle*: JMA82.410 (UCBL-FSL 177 505, 506) and JMA82.412 (UCBL-FSL 177 537), Wadi al Jufayr, 24°05' N; JMA82.299 (UCBL-FSL 177 509), Khashm adh Dhibi, 24°14' N; JMA82.322 (UCBL-FSL 177 507), lonely place, graben about 24°36' N; *Shaqrā' Quadrangle*: VD82.350 (UCBL-FSL 177 521-530) and 350A (UCBL-FSL 177 477, 785), Jurayfah 25°30' to 38' N.

**Age:** Uppermost Bajocian, Planus Zone. Previously dated as Bathonian (Arkell, 1952; Imlay, 1970; Lewy, 1983; Gill *et al.*, 1985) but revised as Uppermost Bajocian, Parkinsoni Zone by Du Dresnay (1964), Du Dresnay *et al.*, 1985; Énay *et al.* (1986, 1987b), and Énay & Mangold (1994).

Genus *Pseudoclydoniceras* Collignon, 1958

**Type species:** *Pseudoclydoniceras besairiei* Collignon, 1958; by original designation

[= *Levanticeras* Lewy, 1981a, p. 42, *nom. nudum*. and invalid under ICZN Code, 1999, Article 13.1.1; = *Levanticeras* Lewy, 1983, p. 21, preoccupied name (type, *L. levantinense* Lewy, 1983, p. 21, pl. 2, figs 1-3)].

**Remarks:** As previously noticed (Énay *et al.*, 1987, p. 44) the establishment of the genus *Levanticeras* in the form "*Levanticeras pseudodiscus* Arkell *nov. gen.*" is worth designation of Arkell species as the type-species of the genus; but *Levanticeras* is considered as a *nomen nudum* (thus invalid) because it was proposed after 1930 without description or definition in the original publication (ICZN 1999, Art. 13.1.1): The new proposal of *Levanticeras* (Lewy, 1983, p. 21), although following the requirements of the ICZN Code with a new type-species, *L. levantinense*, is also invalid by using an invalid preoccupied genus name.

Lewy did not retain *Pseudoclydoniceras* because of the unknown suture line. The figure of the type is very poor, but examination of the specimen in the collections of the University of Dijon (plaster-cast in the University of Lyon collection, UCBL-FSL 175 896) shows it is quite indistinguishable from that of the specimen figured by Lewy (1983, pl. 1, figs 29-30). Therefore, *Levanticeras* is considered here as a recent subjective junior synonym of *Pseudoclydoniceras*. Meantime, Gill *et al.* (1985, p. 711) assumed that the proposal of *Levanticeras* was not justified. They adopted the genus *Pseudoclydoniceras* but only as a subgenus of *Thamboceras*, considered as a grade within the *Thamboceras-Thambites-Pseudoclydoniceras* succession, corresponding to an anagenetic outcome of the evolution of the ventral region, first with a ventral furrow (*Thamboceras-Thambites*) leading to oxycone forms with acute venter (*Pseudoclydoniceras*). The opinion of Gill *et al.* (1985) is not accepted here. Lewy (1983) assumed that another genus, *Nubidites* Wiedmann & Kullmann (1979) (type-species: *Nubidites omariai*) could be identified with *Levanticeras*. This genus is based on a single and very young specimen from the Nubian Sandstone which ranges from Carboniferous up to Cretaceous; a Late Cretaceous (Early Cenomanian) age was assumed by the original authors on the basis of the suture-line, but considering the uncertainties of the field data and the very small size of the holotype of the type-species (D = 10 to 10.5 mm!), it seems best not to use the genus name *Nubidites*. After Arkell (1952) compared the suture line of "*Clydoniceras*" *pseudodiscus* compared with NW European *Clydoniceras* and S Tethyan *Thambites*, the use of the former genus for the Saudian species is questionable. Save the lack of any sign of ribbing, all other features (acute venter, narrow umbilicus and whorl section) are not different from *Pseudoclydoniceras*.

#### *Pseudoclydoniceras pseudodiscus* (Arkell, 1952)

Pl. XXII, fig. 4; Tab. 12

1952. *Clydoniceras pseudodiscus* Arkell, p. 282, pl. 24, fig. 8.  
 1986. *Clydoniceras pseudodiscus* Arkell, in Énay *et al.*, p. 33 (tab. 1).  
 1987a. *Clydoniceras pseudodiscus* Arkell.– Énay *et al.*, p. 36.

**Material:** Seventy nine specimens including fragments and complete specimens, often weathered loose in the scree, varying in diameter up to 200 mm and most of them are wholly-septate.

**Description:** The best preserved specimen is an incomplete phragmocone 100 mm in diameter, which does not show any difference with respect to the holotype: compressed whorl section, maximum thickness at about mid-side, acute venter, flanks smooth. Simplified suture line with a reduced external lobe, short and reduced lateral lobe and broad saddles.

**Discussion:** In addition to the morphological characters that differentiate them, *P. pseudodiscus* has the same stratigraphic range as *Thambites*, from the base to the top of the unit D3. The phyletic relations envisaged by Arkell (1952) are thus unlikely.

**Distribution:** Dhurma Fm, D3 unit. *Sulayyimah Quadrangle*: VD81.188/1 (UCBL-FSL 177 604-607), VD81.270 (UCBL-FSL 177 547-563) and VD81.278 (UCBL-FSL 177 564, 570-582, 588-598, 604-616), south of Khashm Abu al Jiwar, 21°53' N; *Wadi al Mulayyh Quadrangle*: JMA80.521 (UCBL-FSL 177 543-546), lonely place at the latitude of Khashlm Faridah, 22°05' N; JMA80.564 (UCBL-FSL 177 624-629), Khashm Munayyifiyah, 22°11' N; JMA80.554/1 (UCBL-FSL 177 622, 623) and JMA80.556 (UCBL-FSL 177 541), between Al Sitarah Khashm Ushayrah and Faid'id al Ahmar, about 22°34' N. *Wadi ar Rayn Quadrangle*: VD80.548 (UCBL-FSL 177 584-587), VD80.550 (UCBL-FSL 177 601), VD80.552 (UCBL-FSL 177 583) and VD80.553 (UCBL-FSL 177 599-600, 602), Khashm al Majulah, 23°48' N; VD80.605éb (UCBL-FSL 177 603), lonely place south of Wadi al Hawtah, about 23°36' N; *Durma Quadrangle*: JMA82.410 (UCBL-FSL 177 631, 632), Wadi al Jufayr, 24°05' N; JMA82.282 (UCBL-FSL 177 617-619), Wadi al; Hisyan, 24°45' N. *Shaqrā' Quadrangle*: VD82.350A (UCBL 177 633, 634), Jurayfak, 25°30'-38' N.

**Age:** Uppermost Bajocian, Planus Zone. Previously dated as Bathonian (Arkell, 1952; Imlay, 1970; Lewy, 1983; Gill *et al.*, 1985) but revised as Uppermost Bajocian, Parkinsoni Zone (Du Dresnay, 1964; Du Dresnay *et al.*, 1985; Énay *et al.*, 1986, 1987b; Énay & Mangold, 1994).

#### *Pseudoclydoniceras* sp.

1986. *Pseudoclydoniceras* sp. – Énay *et al.*, p. 33 (tab. 1).

1987a. *Pseudoclydoniceras* sp. – Énay *et al.*, p. 36.

**Material:** Five nuclei, four fragmentary pieces and a single large specimen (127 mm in diameter), with part of the body chamber but weathered (UCBL-FSL 177 635).

**Description:** All specimens show the same involute coiling, high and compressed whorl section with acute venter, but no carina save a small-sized specimen from the unit D7. Most of them without any ornament save two specimens from the unit D6. One of these latter with flexuous, fine and dense ribs curved forwards and strengthened on the venter; the other is smaller with coarse ribs on the shoulders and perhaps traces of a keel, so it was formerly assigned to *Pseudoclydoniceras* sp. Two fragmentary pieces display a well-preserved suture line which agrees with the species described by Lewy (1983) and Gill *et al.* (1985) from the Lower Bathonian up to the Upper Callovian.

**Distribution:** Dhurma Fm, D5 unit lower beds. *Wadi ar Rayn Quadrangle*: VD80.611 (UCBL-FSL 177 277), lonely place South of Al Hawtah, about 23°32' N. – D6 unit. *Darmā' Quadrangle*: JMA82.10 (UCBL-FSL 177 243), Section south of Wadi al Hisyan, about 24°40' N; *Shaqrā' Quadrangle*: VD82.332 (UCBL-FSL 177 247-249), lonely place south of Khashm Turab, 25°03' N. – D7 unit. *Shaqrā' Quadrangle*: JMA82.425 (crumbled specimen) (UCBL-FSL 177 213), lonely place North of Wadi al Jufayr, 24°05' N. – Tuwaiq Mountain Limestone Fm, T2 unit. *Darmā' Quadrangle*: JMA82.399éb. (UCBL-FSL 177 635), lonely place north of Khashm al Qaddiyah, about 24°33' N; JMA82.34 (UCBL-FSL 177 620, 621), Wadi al Hisyan, 24°55' N; *Shaqrā' Quadrangle*: VD82.621 (UCBL-FSL 177 150), Khashm Turab, 25°03' N. – T3 unit, lower part. *Shaqrā' Quadrangle*: Al-Asa'ad Collection (UCBL-FSL 177 100), Al-Mu'ayshibah area, NW of Riyadh, about 25°34' N.

**Age:** Lower Bathonian, Clydocromphalus Zone up to Upper Callovian, Solidum Zone (Lower Bathonian, Zigzag Zone up to Upper Callovian, Athleta Zone).

Genus *Micromphalites* Buckman, 1923

**Type species:** *Ammonites micromphalus* Phillips, 1871; by original designation

[= *Neactinoceras* Spath, 1924 (obj)]

**Remarks:** A detailed discussion of the genus, including its age and distribution around the world was given by Énay *et al.* (2001) based on collections of Early Bathonian *Micromphalites* in the Nevers region (France). Recently there were added two new specimens belonging to *M. clydocromphalus* and *M. elegans* figured in Jaffré *et al.* (2020, sheets 23 and 27). Saudi Arabian *Micromphalites* display a range of morphologies from discoidal with minute umbilicus and without periumbilical edge (subgenus *Clydomphalites* Arkell, 1952) to strongly ribbed with

Table 12: Measurements of *Pseudoclydoniceras pseudodiscus* (Arkell).

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 177 629 - JMA80.564	100	n	58	0.58	19.8	0.198	5	0.05	0.34

strong periumbilical edge (*busqueti/pustuliferus* group). These extreme morphologies are linked by transitional forms like *M. elegans* and *M. intermedius*. Thus, the subgenus *Clydomphalites* (type species: *Micromphalites (Clydomphalites) clydocromphalus* Arkell, 1952; OD) is not considered herein. All of them occur in a same outcrop on the Shaqrā' Quadrangle (VD82.387, VD82.484A and VD82.484B), near Jurayfah (25°30' to 38° N), not far or the same area where the specimens studied by Arkell (1952, p. 253, localities 16-20) come from. In these outcrops, the condition of collect by or together with the BRGM did not allow to decide whether these are successive forms of a same lineage (chronocline) or variants within a same species with a broad intraspecific variability. But in other localities *M. clydocromphalus* is known both from the lower and upper parts of the unit D5. From field data in Arkell (1952) on localities 16-18 (same reference), it seems that *M. clydocromphalus*, *M. elegans* and *M. intermedius* occur from the base to the top of the *Micromphalites* beds (locs. 16 and 18), but *M. cf. busqueti* and *M. vertebralis* were recorded only in the highest beds (loc. 18). Thus, (i) forms without periumbilical bulge (*M. clydocromphalus*) or only a slight one (*M. elegans* and *M. intermedius*) could be variants of a single species (questioning the value of the subgenus *Clydomphalites*) and (ii) it is possible that the strongly-ribbed species (*M. busqueti*, *M. pustuliferus*, and possibly *vertebralis*) with strong periumbilical edge, would be late end-forms.

#### ***Micromphalites clydocromphalus* Arkell, 1952**

Pl. XXIV, fig. 1-3; Tab. 13

1952. *Micromphalites (Clydomphalites) clydocromphalus* n. sp., Arkell, p. 287, text-fig. 9; pl. 26, figs 1-7; pl. 28, fig. 12.9.
1963. *Micromphalites (Clydomphalites) clydocromphalus* Arkell.– Lorenchet de Montjamont, p. 103.
1964. *Micromphalites (Clydomphalites) clydocromphalus* Arkell.– Lorenchet de Montjamont, p. 122.
1974. *Micromphalites (Clydomphalites) clydocromphalus* Arkell.– Du Dresnay, p. 149.
1986. *Micromphalites (Clydomphalites) clydocromphalus* Arkell.– Énay *et al.*, p. 33 (tab. 1); pl. 5, fig. 4a, b.

- 1987a. *Micromphalites (Clydomphalites) clydocromphalus* Arkell.– Énay *et al.*, p. 35; pl. 5, fig. 4a, b.
- 1987b. *Micromphalites (Clydomphalites) clydocromphalus* Arkell.– Énay *et al.*, pp. 113-115.
- non 1987. *Micromphalites (Clydomphalites) cf. clydocromphalus* Arkell.– Torrens, p. 98; pl. 1, fig. 9 (= *M. torrensi* Énay).
- ? 1995. *Micromphalites (Clydomphalites) cf. clydocromphalus* Arkell.– Pandey & Callomon, p. 127, pl. 1, figs 2, 3.
2001. *Micromphalites (Clydomphalites) clydocromphalus* Arkell.– Énay *et al.*, p. 510, pl. 1, figs 1-9; pl. 2, fig. 1.
- ? 2015. *Clydomphalites clydocromphalus* Arkell.– Abdelhady & Fürsich, fig. 13/P, Q.
2020. *Micromphalites (Clydomphalites) cf. clydocromphalus* Arkell.– Jaffré, Robineau & Verrier, p. 57, fiche 23 Bat.

**Material:** Forty-four specimens most of them nuclei, with different preservations, the best from red clay or chocolate cast bed of Jurayfah area (Shaqrā' Quadrangle); the largest, not well-preserved from pink limestone (Wadi ar Rayn and Darmā' quadrangles). Besides these, twenty eight strongly weathered specimens whose general aspect suggests they belong to the species.

**Description:** Well-defined species, characterized by its very narrow umbilicus and compressed whorl section, ribbing soon limited to the ventral part of the sides, fading at a diameter of about 70 to 80 mm, the shell becoming smooth. The many nuclei allow to follow the changes of ornamentation during the first stages of growth, from about 15 mm up to 45-50 mm in diameter. From nearly smooth whorls with 4-5 constrictions per whorl, the ribs pass to become more marked on the shoulders but from place to place appear primary flexuous spaced ribs with low relief, barely stronger than the associated growth lines, and fading out progressively.

**Discussion:** *M. clydocromphalus* was indispensable as a zonal index. It is the central species of the Arabian populations of *Micromphalites*, the most widespread and the easiest to determine. In addition, field data from Arkell (1952) and our work confirm that the extent of the species ranges up the whole of the unit D5.

**Distribution:** Dhurma Fm, unit D5. *Sulayyimah*

Table 13: Measurements of *M. clydocromphalus* Arkell. (\* From Arkell, 1952, p. 287).

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 177 314 - VD82.357	65	n	34	0.52	22.8	0.35	5	0.07	0.67
UCBL-FSL 177 317 - VD82.357	38	n	21	0.55	11.9	0.31	3	0.07	0.56
UCBL-FSL 177 316 - VD82.377	22	n	12.6	0.57	7.2	0.32	2	0.09	0.57
<i>M. clydocromphalus</i> Arkell, largest specimen SM.F10774	100	n	57	0.57*	22	0.22*	4	0.04*	0.386
<i>M. clydocromphalus</i> Arkell, holotype SM.F10773	79	n	43	0.54	22	0.27	3.5*	0.04	0.51
<i>M. clydocromphalus</i> Arkell, SM.F10775	36	n	21	0.585*	12.6	0.35*	3.0	0.085*	0.60

*Quadrangle*: VD81.246 (UCBL-FSL 177 281), lonely place north of Khashm Mishlah, 21°07' N; *Wadi al Rayn Quadrangle*: VD80.519 (UCBL-FSL 177 289), lonely place north of Wadi Birk, about 23°20' N; VD80.608 (UCBL-FSL 177 282), 610 (UCBL-FSL 177 289), lonely place north of Wadi al Hawtah, 23°35' N; *Darmā' Quadrangle*: JMA82.197 (UCBL-FSL 177 291), Khashm adh Dhibi, 24°14' N; JMA82.10 (UCBL-FSL 177 299), section south of Wadi al Hisyan, 24°40' N; *Shaqrā' Quadrangle*: VD82.634 (UCBL-FSL 177 286), Al Lughf, 25°10' N; VD82.484B (UCBL-FSL 177 347-350), Jurayfah South, about 25°28' N; VD82.357 (UCBL-FSL 177 314-333), Jurayfah, 25°30' to 38' N. Strongly weathered specimens from *Wadi al Rayn Quadrangle*: VD80.424 (UCBL-FSL 177 250/1-10 and 271/1-4); Khashm al Jufayr, 23°58' N; *Darmā' Quadrangle*: JMA82.308 (UCBL-FSL 177 251 a-l, 252-269, 270 a-e), Khashm adh Dhibi, 24°14' N.

**Age**: Lower Bathonian, Clydocromphalus Zone; equivalent to the upper part of the Zigzag zone, Macrescens Subzone and Aurigerus Zone, Recinctus Subzone in NW Europe, well established in the Nevers area (Énay *et al.*, 2001) and in Morocco (Du Dresnay, 1974, 1979; Du Dresnay *et al.*, 1985; Énay *et al.*, 1987b).

***Micromphalites* nov. sp. A**

Pl. XXV, fig. 4; Tab. 14

1986. *Micromphalites clydocromphalus* Arkell.– Énay *et al.*, p. 33 (tab. 1) (pars).

1987a. *Micromphalites clydocromphalus* Arkell.– Énay *et al.*, p. 36 (pars).

**Material**: Three specimens, only one nearly complete but crushed.

**Description**: The largest specimen (99 mm in diameter) shows on the last complete whorl preserved the imprint of the missing outer whorl strongly uncoiled. Eccentric umbilication and the contracted, final body chamber being considered, the maximum size would have been not less than 110 mm in diameter. Whorl section crushed, but in the better preserved specimen W/D = 0.30 at D =

82 mm. Arched venter with one keel. Smooth all through the ontogeny.

**Discussion**: The available material is not suitable for characterization of the new species. This form fall in the range of variation of the Early Bathonian *Micromphalites* at the end of the strongly ribbed with marked periumbilical edge morphotypes.

**Distribution**: Dhurma Fm, unit D5. *Shaqrā' Quadrangle*: VD82.484A (UCBL-FSL 177 363-365), Jurayfah South, 25°30' to 38' N.

**Age**: Lower Bathonian, Clydocromphalus Zone; equivalent of the upper part of the Zigzag Zone, Macrescens Subzone and Aurigerus Zone, Recinctus Subzone in NW Europe well established in the Nevers area (Énay *et al.*, 2001) and in Morocco (Du Dresnay, 1974, 1979; Du Dresnay *et al.*, 1985; Énay *et al.*, 1987b).

***Micromphalites* cf. *torrensi* Énay, 2001**

Pl. XXIV, fig. 12; Tab. 15

cf. 1986. *Micromphalites* n. sp. 1, Énay *et al.*, p. 33 (tab. 1).

cf. 1986. *Micromphalites* n. sp. 2, Énay *et al.*, p. 33 (tab. 1).

cf. 1987a. *Micromphalites* n. sp. 1, Énay *et al.*, p. 36.

cf. 1987a. *Micromphalites* n. sp. 2, Énay *et al.*, p. 36.

cf. 1987. *Micromphalites* (*Clydomphalites*) cf. *clydomphalus* Arkell.– Torrens, p. 98; pl. 1, fig. 9.

cf. 2001. *Micromphalites* (*Clydomphalites*) *torrensi* Énay *et al.*, p. 513, pl. 2, fig. 2.

**Material**: One incomplete specimen, wholly septate (UCBL-FSL 177 276) and a nucleus; all from the uppermost part of the unit D5 (UCBL-FSL 177 275).

**Description**: The innermost whorls are compressed with a carina and strong proverse ribs. Changes on the outers whorl concern the whorl section more compressed with acute venter and the ribbing fading leaving weak and widely spaced undulations. Very compressed and keeled whorl section changing to acute venter characterizes also the smaller specimen (nucleus).

**Discussion**: These two specimens could be the first evidence of *M. torrensi* in Saudi Arabia.

Table 14: Measurements of *Micromphalites* nov. sp. A. \* Specimen crushed.

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL177 363 - VD82.484A	99	?	53*	0.53	17.8*	0.18	9	0.09	0.33*
	82		4	0.56	14*	0.17	3.5	0.04	0.30*

Table 15: Measurements of *Micromphalites* cf. *torrensi* Énay

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
holotype	93		50	0.54	25	0.36	5	0.08	0.53
Énay <i>et al.</i> , 2001, pl. 2, fig. 2.	67.5	n	36	0.53	23	0.37	3.5	0.07	0.53
VD80.611- UCBL-FSL 177 276	C 80	n	43	0.53	23.8	0.30	10	0.125	0.55

**Distribution:** Dhurma Fm, D5 unit (lowermost and uppermost beds). *Wadi al Rayn Quadrangle:* VD80.611 (UCBL-FSL 177 276), lonely place north of Wadi al Hawtah, 23°35' N; *Darmā' Quadrangle:* JMA82.10 (UCBL-FSL 177 275), section South of Wadi al Hisyan, 24°40' N.

**Age:** Lower Bathonian, Clydocromphalus Zone; equivalent of the upper part of the Zigzag zone, Macrescens Subzone and Aurigerus Zone, Recinctus Subzone in NW Europe well established in the Nevers area (Énay *et al.*, 2001), in Morocco (Du Dresnay, 1974, 1979; Du Dresnay *et al.*, 1985; Énay *et al.*, 1987b) and in SE France (Torrens, 1987).

#### ***Micromphalites intermedius* Arkell, 1952**

Pl. XXIV, figs 9-11; Tab. 16

1952. *Micromphalites (Micromphalites) intermedius* Arkell, p. 286, pl. 28, figs 6, 7, 9.

1986. *Micromphalites intermedius* Arkell.– Énay *et al.*, p. 33 (tab. 1).

1987a. *Micromphalites intermedius* Arkell.– Énay *et al.*, p. 35.

**Material:** Sixteen specimens from Shaqrā' area (VD82.357 and 484B), including five large-sized but crushed specimens and seven better preserved inner whorls; four more specimens from Wadi ar Rayn and Darmā' quadrangles.

**Description:** Species of medium-sized individuals, with thick whorl-section and slight but well-defined periumbilical bulges, umbilical edge not tuberculate and lower half of the flanks with no ribs, but strong ribbing on the upper part. Beginning of the uncoiling of the outer whorl clearly visible on the largest but poorly preserved specimen.

**Discussion:** Described by Arkell (1952) as an intermediate form between the group of *M. clydocromphalus* (subgenus *Clydomphalites* Arkell) and *Micromphalites* s.s. (with periumbilical bulge and strong ribbing), the species is not very well defined. According to Arkell (1952) the umbilicus begins to widen at a diameter of about 90 mm, but none of the figured specimens reach this diameter. In the studied material, uncoiling of the outer whorl begins earlier, between 60 and 70 mm in diameter. Concerning the inner whorls the distinction from *Micromphalites elegans* is not easy for the criterion of W/H lower or greater than 1.00 is questionable.

**Distribution:** Dhurma Fm, D5 unit. *Wadi al Rayn Quadrangle:* VD80.518 (UCBL-FSL 177 283), lonely place north of Khashm Birk, about 23°20' N; VD80.609 (UCBL-FSL 177 274) lonely place north of Wadi al Hawtah, 23°35' N; VD80.562 (cf.) (UCBL-FSL 177 278), north of Kahashm al Jufayr, 23°59' N; *Darmā' Quadrangle:* JMA82.398 (UCBL-FSL 177 302), lonely place south of Wadi al Hisyan, 24°38' N; *Shaqrā' Quadrangle:* VD82.484B (UCBL-FSL 177 351-353), Jurayfah South, about 25°28' N; VD82.357 (UCBL-FSL 177 303-306, 317-319, 338, 339), Jurayfah, 25°30' to 38' N.

**Age:** Lower Bathonian, Clydocromphalus Zone; equivalent of the upper part of the Zigzag zone, Macrescens Subzone and Aurigerus Zone, Recinctus Subzone in NW Europe well established in the Nevers area (Énay *et al.*, 2001) and in Morocco (Du Dresnay, 1974, 1979; Du Dresnay *et al.*, 1985; Énay *et al.*, 1987b).

#### ***Micromphalites elegans* Arkell, 1952**

Pl. XXIV, figs 4-8; Tab. 17

1952. *Micromphalites (Micromphalites) elegans* Arkell, p. 286, text-fig. 9; pl. 26, fig. 8; pl. 28, figs 3, 5, 8.

1952. *Ammonites* cf. *busqueti* de Grossouvre.– Arkell, p. 284 (pars), pl. 27, figs 1a, b, 2 a-c.

1986. *Micromphalites elegans* Arkell.– Énay *et al.*, p. 33 (tab. 1).

1987a. *Micromphalites elegans* Arkell.– Énay *et al.*, p. 35.

2001. *Micromphalites (Micromphalites) elegans* Arkell.– Énay *et al.*, p. 515, pl. 2, figs 3-6.

2020. *Micromphalites (Micromphalites) elegans* Arkell.– Jaffré *et al.*, p. 65, fiche 27.

**Material:** Nineteen specimens from Shaqrā' area (VD82.357 and 484B), all wholly septate.

**Description:** Involute shell, a narrow umbilicus and rounded not tuberculate umbilical edge; inner whorls with a well-defined circum-umbilical edge and corresponding to the greater thickness; inner part of the whorl-sides unribbed and strong ribs on the outer part. Middle whorl (corresponding to the last septate preserved whorl) displays change in the whorl shape, high and compressed, the greater thickness still on the umbilical edge, but the circum-umbilical bulge disappeared.

**Discussion:** As noticed by Arkell, *M. elegans* looks near *M. busqueti*, but the umbilicus is never so wide and the *busqueti*-like whorl section, as illustrated by Arkell

Table 16: Measurements of *M. intermedius* Arkell.

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 177 304 - VD82.357	82	?60	35	0.42	22.8	0.27	18	0.21	0.65
UCBL-FSL 177 338 - VD82.357	39	n	21	0.53	19.7	0.50	3.9	0.10	0.93
	29		16	0.55	12.2	0.55	3.6	0.12	0.76
UCBL-FSL 177 339 - VD82.357	35	n	19	0.54	17	0.48	4.7	0.13	0.89

Table 17: Measurements of *M. elegans* Arkell.

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 177 309 - VD82.357	70	n	36	0.51	26	0.37	10.7	0.15	0.72
UCBL-FSL 177 310 - VD82.357	50	n	26	0.52	22.8	0.45	7	0.14	0.87
UCBL-FSL 177 308 - VD82.357	49	n	24.8	0.50	--	--	7.5	0.15	--
UCBL-FSL 177 307 - VD82.357	47	n	23	0.48	--	--	7.7	0.16	--
UCBL-FSL 177 334 - VD82.357	39	n	20	0.51	21	0.53	5	0.128	1.05
UCBL-FSL 177 335 - VD82.357	37	n	20	0.54	21	0.56	4.7	0.12	1.05
UCBL-FSL 177 345 - VD82.357	36	n	20	0.55	21	0.58	3	0.08	1.05
UCBL-FSL 177 357 - VD82.484B	33	n	17.5	0.53	22	0.66	6	0.18	1.25

(1952, fig. 9) is limited to the inner whorls changing soon to a quite different morphology. Innermost whorls are difficult to separate from those of *M. intermedius*. They are separated on the base of the W/H ratio greater than 1.00.

**Distribution:** Dhurma Fm, D5 unit. *Shaqrā' Quadrangle*: VD82.484B (UCBL-FSL 177 355-361), Jurayfah South, about 25°28' N; VD82.357 (UCBL-FSL 177 307-313, 334-337, 345, 346), Jurayfah, 25°30' to 38' N.

**Age:** Lower Bathonian, Clydocromphalus Zone; equivalent of the upper part of the Zigzag zone, Macrescens Subzone and Aurigerus Zone, Recinctus Subzone in NW Europe well established in the Nevers area (Énay *et al.*, 2001) and in Morocco (Du Dresnay, 1974, 1979; Du Dresnay *et al.*, 1985; Énay *et al.*, 1987b).

#### *Micromphalites busqueti* (de Grossouvre, 1918)

Pl. XXV, figs 1-2; Tab. 18

1918. *Ammonites busqueti* de Grossouvre, p. 412, pl. 14, fig. 2a, b (holotype lost).
1951. *Micromphalites busqueti* (de Grossouvre).— Arkell, p. 46, text-fig. 9/1a, b (Type figures after de Grossouvre).
- non 1952. *Ammonites* cf. *busqueti* de Grossouvre.— Arkell, p. 284 (pars), pl. 27, figs 1a, b, 2 a-c;
1952. *Ammonites* cf. *busqueti* de Grossouvre.— Arkell, p. 284, pl. 27, figs 3a, b, 4a, b, 5a, b, 6.
1952. *Micromphalites vertebralis* Arkell, p. 286, pl. 28, fig. 11a, b.
1986. *Micromphalites busqueti* (de Grossouvre).— Énay *et al.*, p. 33 (tab. 1).
1986. *Micromphalites vertebralis* Arkell.— Énay *et al.*, p. 33 (tab. 1).
- 1987a. *Micromphalites busqueti* (de Grossouvre).— Énay *et al.*, p. 36.
- 1987a. *Micromphalites busqueti* (de Grossouvre).— Énay *et al.*, p. 35.
2001. *Micromphalites busqueti* (de Grossouvre).— Énay *et al.*, p. 513, fig. 3, pl. 2, figs 8-9 (fig. 3 and pl. 7, fig. 7 = designated as neotype).
2001. *Micromphalites vertebralis* Arkell.— Énay *et al.*, p. 514.
- ? 2015. *Micromphalites pustuliferus* (Douvillé).— Abdelhady & Fursich, fig. 13/R.

2020. *Micromphalites (Micromphalites) busqueti* (de Grossouvre), Jaffrè *et al.*, p. 63, fiche 26 Bat. (refiguration from Énay *et al.*, 2001, fig. 3 and pl. 2, fig. 7a, b).

**Material:** A single specimen of large size, but wholly septate and four nuclei from the Jurayfah *Micromphalites* clay in Arkell (1952), seven specimens from pink limestone, of which five not well-preserved cf.-specimens and two fragments with questionable determinations (*M. gr. busqueti*).

**Description:** As already published the holotype must be considered lost and a neotype has been designated in Énay *et al.* (2001). The most characteristic feature is the strong circum-umbilical bulge with incipiently tuberculate primary ribs arising from the umbilical edge that overhangs a narrow and deep, crater-like umbilicus. Coarse and blunt ribs at mid-side, bifurcated or simple, the secondaries stronger, curved forward at the periphery, on the sides of the well-marked keel. The neotype and the largest Saudi Arabian specimen (FSL 177 342), about of same size, do not show signs of uncoiling of the umbilical seam. But the holotype, a little larger, seems to show an incipient uncoiling.

**Discussion:** Arkell (1952) was obviously embarrassed by the Early Bathonian age of *M. busqueti* in the type-locality and he was still struggling to accept the occurrence of *M. busqueti* in the Zigzag Zone of St Benin d'Azy, later quoted as an "alleged occurrence" by Arkell (1956, p. 63). The opinion of Arkell *et al.* (1957, p. 291) was still confuse: *Micromphalites* is given from the Lower and Middle Bathonian but *Clydomphalites* from the Lower Bathonian. Currently there is no longer doubt that the Arabian species of *Micromphalites* are Early Bathonian in age. *M. vertebralis* Arkell is a thick-whorled variant of the species. Although the studied material is relatively scarce, it shows certain variability. Thus the umbilicus of the specimen selected as a neotype is more open than it is in the holotype or the largest specimen in Pl. XXV, fig. 1; as well as the thickness of the whorl section, more or less strong at the same diameter or more or less early or late during growth.

**Distribution:** Dhurma Fm, D5 unit. *Wadi al Rayn Quadrangle*: VD80. 608 (UCBL-FSL 177 297, 298), lonely place north of Wadi al Hawtah about 23°35' N. VD80.448 (UCBL-FSL 177 285), Khashm al Jufayr, 23°58' N; *Darmā' Quadrangle*: JMA82.308 (UCBL-FSL 177 293, 294); JMA82.312 (UCBL-FSL 177 366), Graben south of Khashm Hisyan, about 24°35' N; *Shaqrā' Quadrangle*: VD82.654 (UCBL-FSL 177 284), lonely place north of Khashm Turab, 25°05' N; VD82.635 (UCBL-FSL 177 296), Al Lughf, 25°10' N; VD82.357 (UCBL-FSL 177 340-344), Jurayfah, 25°30' to 38' N.

**Age:** Lower Bathonian, Clydocromphalus Zone; equivalent of the upper part of the Zigzag zone, Macrescens Subzone and Aurigerus Zone, Recinctus Subzone in NW Europe well established in the Nevers area (Énay *et al.*, 2001) and in Morocco (Du Dresnay, 1974, 1979; Du Dresnay *et al.*, 1985; Énay *et al.*, 1987b).

***Micromphalites pustuliferus* (de Grossouvre, 1918)**

Pl. XXV, fig. 5; Tab. 19

1918. *Stringoceras pustuliferum* de Grossouvre, p. 412, pl. 14, fig. 2a, b (holotype lost).  
 1951. *Micromphalites pustuliferus* (de Grossouvre).– Arkell, p. 46, text-fig. 9a-c.  
 1952. *Micromphalites pustuliferus* (de Grossouvre).– Arkell, p. 285, pl. 28, fig. 1.  
 1979. *Micromphalites pustuliferus* (de Grossouvre).– Mangold, p. 272, fig. 2.

1986. *Micromphalites pustuliferus* (de Grossouvre).– Énay *et al.*, p. 33 (tab. 1).

1987a. *Micromphalites pustuliferus* (de Grossouvre).– Énay *et al.*, p. 36.

? 2004. *Micromphalites* aff. *pustuliferus* (de Grossouvre).– Schlogl & Rakus, p. 454, figs 4-6.

non 2015. *Micromphalites pustuliferus* (Douvillé) (sic).– Abdelhady & Fursich, fig. 13R.

**Material:** A single small, wholly septate specimen, fairly well-preserved.

**Description:** Fairly evolute coiling, wider in the umbilical edge; strong inner and outer tubercles, the inner row overhanging the steep umbilical wall, 15 outer tubercles, the ribs joining the tubercles not well-preserved; tabulate, keeled venter.

**Discussion:** Among the *Micromphalites* of the Early Bathonian, *M. pustuliferus* represents an extreme morphology, by its strong and coarse ornamentation, in contrast to the forms of the subgenus *Clydomphalites*.

**Distribution:** Dhurma Fm, unit D5. *Darmā' Quadrangle*: JMA82.197 (UCBL-FSL 177 300), Khashm adh Dhibi, 24°14' N.

**Age:** Lower Bathonian, Clydocromphalus Zone; equivalent of the upper part of the Zigzag zone, Macrescens Subzone and Aurigerus Zone, Recinctus Subzone in NW Europe well established in the Nevers area (Énay *et al.*, 2001), Morocco (Du Dresnay, 1974, 1979; Du Dresnay *et al.*, 1985; Énay *et al.*, 1987b), and Spain (Mangold, 1979).

Table 18: Measurements of *M. busqueti* (de Grossouvre) and *M. vertebralis* Arkell.

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 177 342 - VD82.357	54	n	27	0.50	30	0.55	11.5	0.21	1.10
	40	-	18	0.45	28.5	0.71	10	0.25	1.58
	c 30	-	12	0.40	24	0.80	8	0.27	2.00
UCBL-FSL 177 343 - VD82.357	23	n	10	0.43	1	0.65	5	0.21	1.5
	18		8	0.44	12.5	0.69	4.5	0.25	1.56
UCBL-FSL 177 340 - VD82.357	36	n	19	0.52	21	0.58	4.7	0.13	1.10
UCBL-FSL 177 341 - VD82.357	35	n	17	0.48	18	0.51	5	0.14	1.05
<i>M. busqueti</i> (de Gross.), 1918, p. 412, pl. 14, fig. 2a, 2b, holotype.	63	?	33	0.52	28	0.44	7.5	0.12	0.84
<i>M. busqueti</i> (de Gross.), neotype. Énay <i>et al.</i> , 2001, p. 514.	48.4	n	25	0.51	—	—	11.5	0.23	—
	42		20.5	0.49	c 24	0.57	10	0.24	1.17
	36		17.6	0.48	—	—	9.6	0.26	—
<i>M. busqueti</i> (de Gross.) Énay <i>et al.</i> , 2001, p. 514	32.5	n	15	0.46	15	0.46	8	0.25	1.00
	23		11	0.48	12	0.52	7	0.30	1.09
<i>M. vertebralis</i> Arkell, holotype (SM. F 10797)	15	n	—	—	12	0.80	—	—	—

Table 19: Measurements of *M. pustuliferus* (de Grossouvre).

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 177 300 - JMA82.197	38	n	16	0.42	17	0.45	17	0.45	1.06
	29		12.4	0.42	14	0.48	9	0.31	1.12

***Micromphalites* nov. sp. B**

Pl. XXV, fig. 3

1986. *Micromphalites* n. sp. 3, Énay *et al.*, p. 33 (tab. 1).1987a. *Micromphalites* n. sp. 3, Énay *et al.*, p. 36.

**Material:** A single specimen of large size (116 mm in diameter), wholly septate with the four or five last septa approximated and the corresponding innermost whorls (21 mm in diameter), the middle whorls missing.

**Description:** Innermost whorls involute with narrow umbilicus and thick whorl section, subquadrate-shouldered, venter keeled. On the most part of the whorl ribs only on shoulders, and just at the end of the preserved whorl bifurcating from a tubercle on the umbilical edge; all these ribs prorsiradiate towards the venter. The large outermost whorl fairly evolute, without umbilical bulges, high and compressed whorl section, with narrower and more rounded venter, well-defined carina. Coarse ribbing arising from elongate tubercles, bifurcating, trifurcating or polyfurcating, with some intercalatories; these ribs projected forward on shoulders. Partial fading of the ribbing on the last quarter whorl by weathering.

**Discussion:** It is surely a new species, but the only one known specimen is not suitable for its characterization. The resemblance to *M. (Jordaniceras) jordanicus* Bandel & Zeiss (1987) is only apparent and does not withstand comparison with the holotype (plaster cast, UCBL-FSL 179 996). Concerning the Jordanian species, proposal of a new subgenus based on a single specimen was not justified (Énay *et al.*, 2001, p. 507). *M. jordanicus* differs by its larger umbilicus, more square-shouldered venter and stronger tubercles.

**Distribution:** Dhurma Fm, unit D5. *Wadi al Mulayh Quadrangle*: JMA80.567 (UCBL-FSL 177 280), Khashm Munyyiyiyah, 22°11' N.

**Age:** Lower Bathonian, Clydocromphalus Zone; equivalent of the upper part of the Zigzag zone, Macrescens Subzone and Aurigerus Zone, Recinctus Subzone in NW Europe well established in the Nevers area (Énay *et al.*, 2001), in Morocco (Du Dresnay, 1974, 1979; Du Dresnay *et al.*, 1985; Énay *et al.*, 1987b) and in Spain (Mangold, 1979).

Genus *Pseudomicromphalites* Collignon, 1966

**Type species:** *Pseudomicromphalites kuntzi* Collignon; by original designation

**Remarks:** The inclusion of *Pseudomicromphalites* in the Clydoniceratinae subfamily was formerly adopted by Collignon (1958). While underlining the difficulty of relating its new genus to one or the other genera which are part of the subfamily, Collignon insisted on the characters shared with *Dhrumaites* (inflated whorl section, lanceolate-acute venter) and *Micromphalites* (suture line). On the other hand, the costulation is described as recalling that of *Micromphalites*, while the type species has some phlycticeratin ribbing style, bidichotome branching but without the tubercles (see Schweigert & Dietze, 1998). Considering that the genus *Phlycticerat* eventually reaches its greatest distribution in the middle Callovian (Jason zone) before apparently disappearing without descendants after the onset of the Upper Callovian (Athleta zone, Trezeense subzone; Schweigert & Dietze, 1998, p. 4), it would be tempting to interpret *Pseudomicromphalites* as an Arabo-Madagascan branch of the Phlycticeratines. However, when compared with the species of *Phlycticerat*, of varying origins and ages, as illustrated by Schweigert & Dietze (1998), especially the shape of the section, does not agree with this assumption. *Pseudomicromphalites* is considered here as an original Arabo-Madagascan branch of Clydoniceratinae.

***Pseudomicromphalites kuntzi* Collignon, 1966**

Pl. XXV, fig. 6; Tab. 20

1963a. *Dhrumaites* n. sp. Collignon, p. 149.

1964. New genus, unnamed, Collignon, p. 45.

1966. *Pseudomicromphalites Kuntzi* Collignon, p. 22, pl. 7, fig. 2, 2a, 2b.1985. *Pseudomicromphalites kuntzi* Collignon.– Énay & Mangold, p. 645.1986. *Pseudomicromphalites kuntzi* Collignon.– Énay *et al.*, pp. 33 (tab. 1), 39, 47.1987. *Pseudomicromphalites kuntzi* Collignon.– Énay *et al.*, pp. 36 (tab. 1), 40, 44.1994. *Pseudomicromphalites kuntzi* Collignon.– Énay & Mangold, p. 171.

**Material:** A well-preserved but incomplete, wholly septate specimen (FSL 1777 187); two small fragments determined as cf. *kuntzi*.

**Description:** Oxyconic involute shell, with acute venter, the greater thickness on the umbilical edge, umbilicus narrow; primary ribs emerging from the umbilical edge, bifurcated as soon they emerge or at mid-side and again

Table 20: Measurements of *Pseudomicromphalites kuntzi* Collignon.

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 177 187 – VD82.489	c 50 44	n	-- 24	-- 0.54	-- 13	-- 0.29	-- 3	-- 0.06	-- 0.54
Holotype, Collignon, 1966, pl. 7, fig. 2, 2a, 2b.	33	n	19	0.58	13	0.39	2	0.06	0.68

near the ventral margin, the external ribs stronger than the primaries and secondaries; septal suture not visible.

**Discussion:** The Saudi Arabian specimen is larger than the holotype and the ribbing is well marked up to the end. The only difference concerns the thickness not so large than it is in the holotype that could be correlated to the younger age of the Saudi Arabian specimens.

**Distribution:** Dhurma Fm, unit D7, upper part (Hisyan Member). *Darmā' Quadrangle:* JMA82.425 (éb.) (FSL 177 216), lonely place north of Wadi al Jufayr, 24°05' N; *Shaqrā' Quadrangle:* VD82.509 (FSL 177 175), Khashm Abu al Hayyal, 25°22' N; VD82.489 (FSL 177 187), Jurayfah, 25°30' to 38' N.

**Age:** Middle Callovian, Ogivalis Zone, Kuntzi Horizon. An early Middle Callovian age has been previously assumed by Énay *et al.* (1986, 1987, 2009) and Énay & Mangold (1985, 1994). The present species is considered late Early Callovian in Madagascar, but in Saudi Arabia is associated with species of *Grossouvria*, *Rollierites* and *Erymnoceras* by which it seems to be a little younger.

Genus *Dhrumaites* Arkell, 1952

**Type species:** *Dhrumaites cardioceratoides* Arkell, 1952; by original designation

***Dhrumaites cardioceratoides* Arkell, 1952**

Pl. XXVI, figs 1-2; Tab. 21

- non 1963. *Dhrumaites* (nov. sp.) Collignon, p. 149 (= *Pseudomicromphalites kuntzi*).
1964. New genus, unnamed, Collignon, p. 45.
1970. *Dhrumaites cardioceratoides* Arkell.– Imlay, p. D11, pl. 1, figs 13-15; pl. 3, fig. 8; pl. 4.
1986. *Dhrumaites cardioceratoides* Arkell.– Énay *et al.*, p. 33 (tab. 1).
1987. *Dhrumaites cardioceratoides* Arkell.– Énay *et al.*, p. 36 (tab. 1).
1994. *Dhrumaites cardioceratoides* Arkell.– Énay & Mangold, p. 170.

**Material:** Thirteen more or less well-preserved specimens, some of large size (greater diameter 290 mm) but still wholly septate, and about twelve fragments or small pieces strongly weathered and specifically undeterminable (*Dhrumaites* sp.).

**Description:** Large oxyconic involute shell, lanceolate acute venter and compressed whorl section, the greater thickness at about mid-flank, involute coiling and narrow umbilicus, sloping umbilical wall. The largest specimen

(FSL 177 232) shows traces of ribs at the beginning of the last whorl (200-220 mm in diameter) but it is not possible to decide if fading or weathering was responsible for the absence of ribs on the outer whorl. None of them shows well developed external ribs as they are exposed in Arkell, 1952, fig. 8). Ribbing is better preserved on the smaller specimens (e.g. FSL 172 241 and 242). They display on the whorl-sides straight distant, feeble and blunt ribs, fading out when approaching the venter. Another specimen from the upper part of the unit D5 or base of the unit D6 displays sinuous to falcoid ribs projected forward on approaching the venter.

**Discussion:** On the basis of the ornamentation and especially the suture line, particularly the second lateral lobe, Arkell (1952, 1956) claims that the genus is an oxycone form derived from *Micromphalites*, homoeomorph of *Clydoniceras*, but it actually would be a parallel development rather than being directly related to it. At the same time, he points out several points in common with *Clydoniceras*. “Degeneration” with simplification of the suture-line is a common feature of all Arabic forms adapted to shallow environments and it is difficult to decide whether certain characters indicate a true relationship with other forms with similar features or are only adaptive without any phyletic significance. If we ignore the ornamentation and the suture line, by their very similar morphology, *D. cardioceratoides* and *R. avus* could represent the same adaptive response in very close environmental conditions (back-barrier for unit D3 and barrier for unit D6).

**Distribution:** Dhurma Fm, unit D5 (uppermost beds, but not *in situ* and from the overlying D6 unit). *Wadi ar Rayn Quadrangle:* VD80.559 (FSL 177 301), Khashm Birk 23°18' N. – Dhurma Fm D6 unit. *Wadi ar Rayn Quadrangle:* VD80.587 (UCBL-FSL 177 231, 233, 235, 237, 238a-b) and VD.80.588 (UCBL-FSL 177 232, 236), Khashm al Majulah 23°48' N; *Darmā' Quadrangle:* JMA82.198 (UCBL-FSL177 241) and JMA82.320 (UCBL-FSL 177 234, 242), Wadi al Jufayr, 24°05' N. *Shaqrā' Quadrangle:* VD82.596 (177 239), Khashm Turab, 25°03' N.

*Dhrumaites* sp. (and dubious specimens or fragments): Dhurma Fm, D5/D6 units boundary. *Darmā' Quadrangle:* JMA82.396 (UCBL-FSL 177 244), lonely place at the same latitude as Wadi al Jufayr section, 24°05' N. - D6 unit. *Wadi ar Rayn Quadrangle:* VD80.612 (UCBL-FSL 177 240 a-c), lonely place north of Wadi al Hawtah, about 23°35'N; *Shaqrā' Quadrangle:* VD82.332 (? 177 246a-

Table 21: Measurements of *Dhrumaites cardioceratoides* Arkell.

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 177 232 – VD80. 588	c 290	n	160	0.55	61	0.21	28	0.09	0.38
UCBL-FSL 177 241 – VD80.198	c 135	n	72	0.53	37	0.27	11	0.08	0.51
UCBL-FSL 177 242 – VD80.320	127	n	75	0.59	35	0.27	7.5	0.05	0.46

c), lonely place south of Khashm Turab, 25°03' N.; VD82.596 (177 239a-c), Khashm Turab, 25°03' N.

**Age:** Middle or, more probably, Late Bathonian, *Cardioceratoides* Zone. *Dhruhaites* is unknown outside Saudi Arabia and unsuitable for dating. This age is deduced from (i) the overlying position above Early Bathonian *Clydocromphalus* Zone (unit D5), (ii) the assumed discontinuity between units D5 and D6 interpreted as a downlap surface connected to the prograding siliciclastic body (known as “delta”) and (iii) the units D6-D7 being interpreted as the transgressive systems track onlapping the deltaic wedge.

Superfamily Stephanoceratoidea Neumayr, 1875  
[*nom. transl.* J. P. Smith, 1913, p. 661, *ex*  
Stephanoceratidae Neumayr, 1875, p. 905]  
[= Stepheocerataceae Buckman, 1919a, p. xvi, as  
Stepheocerataceae].

Family Stephanoceratidae Neumayr, 1875  
[*nom. correct.* Fischer, 1882, p. 393, *pro*  
Stephanoceratinen Neumayr, 1875, p. 905, vernacular  
name, validated by ICZN Direction 14, 1955b, p. 466]  
[= Stepheoceratidae Buckman, 1898, p. 450,  
table 2, obj.]

Subfamily Stephanoceratinae Neumayr, 1875  
[*nom. transl.* Buckman, 1887, p. 14, *ex*  
Stephanoceratidae Neumayr, 1875, p. 905] [=  
Stemmatoceratidae Mascke, 1907, p. 23; =  
Normannitinae Westermann, 1954, p. 124; = Sturaniinae  
Parnes, 1985, p. 29]

**Remarks:** The subfamily is represented by very few specimens and only two genera are sufficiently well represented by specimens suitable for description. A small number of fragments with evolute coiling are attributable to *Stephanoceras* s.l.

Genus *Stephanoceras* Waagen, 1869

**Type species:** *Ammonites humphriesianus* J. de C. Sowerby, 1825; SD by Buckman, (1898, p. 454), ICZN Opinion 324, 1955a, p. 231, see Arkell, 1951, p. 226  
[= *Stepheoceras* Buckman, 1898, p. 454, obj.; = *Stephoceras* Rollier, 1909, pp. 613, 616, obj., misspelling of *Stepheoceras*]

Subgenus *Stemmatoceras* Mascke, 1907

**Type species:** *Ammonites humphriesianus coronatus* Quenstedt, 1886; by original designation; *non* *Ammonites coronatus* Bruguière, 1789 in 1789-1792, p. 43 (*Erymnoceras*, Perisphinctoidea); = *Stephanoceras frechi* Renz, 1913, p. 684, *nom. nov. pro* *Ammonites humphriesianus coronatus* Quenstedt, 1886 in 1882-1888, p. 539; [= *Gibbistephanus* Buckman, 1928, pl. 780; = *Pavicerias* Gauthier, Rioult, & Trévisan, 1996, p. 35]

***Stephanoceras (Stemmatoceras) aff. frechi*  
(Renz, 1913)**

1886. *Ammonites Humphriesianus coronatus*, Quenstedt, p. 539, pl. 66, fig. 11.  
1913. *Stephanoceras frechi* Renz, p. 684, *nom. nov. pro* *A. humphriesianus coronatus* Quenstedt (1886, p. 539).  
1932. *Stemmatoceras coronatum* Quenstedt, emend. Weisert, p. 159, pl. 18, figs 1, 4.  
1939. *Cadomites quenstedti* Roché, p. 205.  
1985. *Stephanoceras frechi* Renz.– Schlegelmilch, p. 77, pl. 27, fig. 6.  
1986. *Stephanoceras aff. quenstedti* Roché.– Énay *et al.*, p. 33 (tab. 1).  
1987a. *Stephanoceras aff. quenstedti* Roché.– Énay *et al.*, p. 35 (tab. 1).

**Material:** One body chamber three-quarter-whorl long, the inner whorls missing, and only one side well-preserved. D: 89 mm; dph: 67; at d = 85 mm: 88 (0,32); c 50 (0,58); 35 (0,41); 1,78.

**Description:** Moderately involute shell, whorl-section depressed, rounded umbilical wall and umbilical edge, primary ribs emerging from the umbilical seam divide at strong tubercles into bundles of three or more prorsiradiate secondary ribs with some secondaries that pass radially across the venter.

**Discussion:** The change of name of the Saudi Arabian specimen only results from the fact that Roché was unaware of Renz's 1913 paper and the name proposed by Roché was preoccupied. The Saudi Arabian specimen is very similar to Quenstedt's type of the species as figured in Weisert (1932, pl. 18, fig. 4), but it fits better with the second figured specimen (*ibid.*, fig. 1). Especially the whorl-section is not so high and the umbilicus more open than in Quenstedt's type specimen.

**Distribution:** Dhurma Fm, upper D2 Unit (Dhibi Limestone). *Durma Quadrangle*: JMA82.280 (UCBL-FSL 178 226), Wadi al Hisyan, 24°45' N.

**Age:** Lowest Upper Bajocian, Runcinatum Zone. According to the association with European elements in Sinai and Northern Africa, Upper Bajocian age, Niortense Zone (Arkell & Lucas, 1953; Du Dresnay, 1964a; Du Dresnay *et al.*, 1985; Énay *et al.*, 1987b; Énay & Mangold, 1994).

Genus *Normannites* Munier-Chalmas, 1892 [m]

**Type species:** *Normannites orbigny* Buckman, 1908, p. 146; SD, ICZN Opinion 309, 1954d, p. 347 [= *Itinsaites* McLearn, 1927, p. 73; = ?*Germanites* Schindewolf, 1929, p. 57; = *Parallites* Westermann, 1954, p. 205; = *Platystomites* Westermann, 1954, p. 218; = *Dettermanites* Imlay, 1961, p. 471]

***Normannites aff. braikenridgii* (Sowerby, 1818) [m]  
Pl. VIII, figs 9-11; Tab. 22**

1818. *Ammonites Braikenridgii* Sowerby, p. 187, pl. 182.

1913. *Otoites Braikenridgii* Sowerby.– Buckman, p. 71 (holotype).
1923. *Normannites Braikenridgii* Sowerby.– Fallot & Blanchet, pl. 13, fig. 3.
1952. *Normannites* cf. *braikenridgii* Sowerby.– Arkell, 1951, p. 309, pl. 30, fig. 3a, b.
1954. *Normannites (Normannites) braikenridgii braikenridgii* Sowerby.– Westermann, p. 164, pl. 9, figs 1-3; text-figs 50, 51, 57.
1954. *Normannites (Normannites) braikenridgii ventriplanus*, Westermann, p. 168, pl. 9, fig. 4-7; text-figs 50, 51.
1986. *Normannites* cf. *braikenridgii* Sowerby.– Énay *et al.*, p. 33 (tab. 1).
1986. *Normannites* cf. *braikenridgii ventriplanus* Westermann.– Énay *et al.*, pl. 2, figs 6, 7.
- 1987a. *Normannites* cf. *braikenridgii* Sowerby.– Énay *et al.*, p. 34 (tab. 1).
- 1987a. *Normannites* cf. *braikenridgii ventriplanus* Westermann.– Énay *et al.*, pl. 2, figs 6, 7.

**Material:** Two small specimens; one with the aperture preserved, other well-preserved.

**Description:** The largest specimen is not complete but agrees closely with the holotype refigured by Westermann (1954, pl. 9, fig. 1a-c), also with the form distinguished as *N. b. ventriplanus* (Westermann, 1954, pl. 9, fig. 4a-c). Evolute coiling with rounded to moderately depressed whorl-section; strong primary ribs bifurcate at mid-side into secondaries with small, subdued tubercles at point of bifurcation, and some intercalatories; the secondaries and the intercalatories cross the venter.

**Discussion:** The best preserved, small specimen with body chamber bears large lappets in the mouth border, severely constricting the aperture; it is ascribed to the species as a dwarf form.

**Distribution:** Dhurma Fm, lowermost unit D2. *Wadi ar Rayn Quadrangle*: VD80.564 (UCBL-FSL 178 287) and VD.80.590 (UCBL-FSL 178 290), Wadi Birk, 23°12' N; VD80.546 (UCBL-FSL 178 253-255), Khashm al Hamra, 23°30' N; *Darmā' Quadrangle*: JMA82.166 (UCBL-FSL 178 269), Khashm adh Dhibi, 24°14' N; *Shaqrā' Quadrangle*: ? VD82.628 (UCBL-FSL 177 439, 440, 834), South of Jurayfah, about 25°22' N/45° 20' E.

**Age:** Upper Lower Bajocian, Glabrum Zone. The associated fauna with dominant *Dorsetensia* of the *liostraca* group favours an age in the upper part of the Lower Bajocian, Humphriesianum Zone, Romani Subzone and ?Humphriesianum Subzone owing to the occurrence of few *Teloceras* [m].

Genus *Teloceras* Mascke, 1907

**Type species:** *Ammonites blagdeni* J. Sowerby, 1818; by original designation [= *Epalxites* Mascke, 1907, p. 23]

***Teloceras* aff. *lepsiusi* (Gillet, 1937) [m]**

Pl. VIII, fig. 12; Tab. 23

1875. *Ammonites Braikenridgii* Sowerby.– Lepsius, p. 60, pl. 2, fig. 7.
1937. *Cadomites Lepsiusi* Gillet, p. 87, pl. 5, fig. 6.
1954. *Epalxites lepsiusi* (Gillet).– Westermann, p. 307; text-fig. 124a, 131; pl. 29, figs 2, 3.

**Material:** Sixty-six well-preserved and small specimens (the largest is 37 mm in diameter), including microconchs and probably full-grown specimens but suture line not visible and peristome scarcely preserved. The only with the aperture preserved is 23 mm in diameter. All microconchs.

**Description:** Small-sized shell, fairly evolute, wide and deep umbilicus, flat sides and venter nearly flat, highly depressed and trapezoidal whorl section. Distant primary ribs divide at large ventrolateral tubercles in 2-5 secondary ribs which cross unchanged the venter. Strongly ribbed up to the adult peristome, which bears large lappets (UCBL-FSL 178 288). Peristome not totally preserved in the largest full-grown specimen (UCBL-FSL 178 325) which shows change in the ribbing and the basal part of the lappet.

**Discussion:** Our specimens show a large spectrum of morphologies, from sparsely and coarsely to finer and densely ribbed forms. Size and ribbing style agree closely with the specimens figured as *E. lepsiusi* (Westermann, 1954, pl. 29, figs 2, 3).

Table 22: Measurements of *Normannites* sp. aff. *braikenridgii*.

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
UCBL-FSL 178 290 - VD80.590	45	?	17.7	0.39	21.6	0.48	16	0.35	1.22
	37	-	14	0.37	17.4	0.47	13.8	0.38	1.24
	28		10	0.35	13	0.46	10.9	0.39	1.30
UCBL-FSL 178 269 - JMA82.166	31	?	12.5	0.40	14.6	0.48	11.5	0.38	1.16

Table 23: Measurements of *Teloceras* aff. *lepsiusi* (m).

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 178 325 - VD82-92	37	?	12	0.32	14.5	0.39	16	0.43	1.20
UCBL-FSL 178 288 - VD82-92	23	?	9	0.39	10.8	0.46	9.7	0.42	1.20

**Distribution:** Dhurma Fm, lowermost unit D2. *Wadi ar Rayn Quadrangle*: VD80.590 (UCBL-FSL 178 274) Wadi Birk, 23°12' N; *Shaqrā' Quadrangle*: VD82.92 (UCBL-FSL 178 288, 325-350, 376-412, 432-435), south of Jurayfah, about 25°22' N/40°20' E.

**Age:** Upper Lower Bajocian, Glabrum Zone. The associated fauna with dominant *Dorsetensia* of the *liostraca* group favours age in the upper part of the Lower Bajocian, Humphriesianum Zone, Romani Subzone and ?Humphriesianum Subzone owing to the occurrence of few *Teloceras* [m].

Subfamily Ermoceratinae Howarth, 2017

**Remarks:** The subfamily is known to have a geographical distribution restricted to the Arabian Peninsula, Egypt (Sinai), Jordan and NAfrica (WAlgeria, Morocco), directly connected with the extent of restricted epicontinental environments to which the included genera were adapted. Arkell (1952) defined the subgenera *Telermoceras* and *Kosmermoceras* which were recently considered genera (Énay & Mangold, 1996; Howarth, 2017). After some nomenclatural revision of the first description by Douvillé (1916) of the material from Jebel Maghara (Sinai, Egypt), the genus included five species. When additional material from Saudi Arabia became available, Arkell (1952) introduced other seven species. But in the study of Douvillé (1916), Arkell (1952) overlooked: (i) that Douvillé (1916) clearly distinguished two successive faunas occurring in two different lithostratigraphic units, the basal Black Limestones with *E. coronatoides*, *E. deserti*, and *E. elegans* ("Main *Ermoceras* Fauna" in Énay *et al.*, 1986, 1987a; Énay & Mangold, 1994), and the upper Yellow Limestones with *E. mogharensis* and *E. inerme*; these have been confirmed by Imlay (1970), Énay *et al.* (1986, 1987a) and Énay & Mangold (1994). Furthermore, a third, new and older Ermoceratid fauna was identified as "*the first Ermoceras (primitive) fauna*" by Énay *et al.* (1986, 1987a). (ii) the observations made by Douvillé (1916) on the dimorphism within the genus *Ermoceras* (dimorphism as a whole was not considered by Arkell). Énay & Mangold (1996) brought new data on ermoceratines dimorphism but the question is far to be solved. Save *E. elegans* and *E. inerme*, identified as "mâle" (i.e. microconch) by Douvillé and whose holotypes are nearly complete adult specimens, the other ten species described by Douvillé (1916) and Arkell (1952) are based on inner whorls. From this latter the identification is problematic since fully-grown specimens (250-300 mm in diameter) show significant changes in shape and ornament during growth.

Genus *Eoermoceras* nov.

**Type species:** *Eoermoceras glabrum* nov. sp. (described below)

**Origin of the name:** From the Greek: *eōs* = dawn with the meaning the first, the earlier (Ermoceratids).

**Diagnosis:** Large-sized primitive ermoceratid with involute coiling and angulate-shaped outer whorl, distinct from other ermoceratid genera by lacking of a smooth band or ventral groove.

**Remarks:** The new name applies to the two new species, *E. glabrum* n. sp. and *E. angulatidomus* n. sp. as well as two other possibly new species, from lower unit D1 identified as "*the first Ermoceras (primitive) fauna*" (Énay *et al.*, 1986, 1987a). Although a true ventral groove is missing, assignment to the Ermoceratids is not dubious. They are earlier off-shoots probably not directly connected with the younger and classic species of the genus and a new genus seems necessary.

#### *Eoermoceras glabrum* n. sp. [M]

Pl. XI, figs 1, 2; Tab. 24

1987. *Ermoceras* n. sp. 1, Énay *et al.*, p. 34, tab. 1.

1987. *Ermoceras* n. sp. 2 pars, Énay *et al.*, p. 34, tab. 1.

1994. "*Ermoceras primitifs*" nov., Énay & Mangold, p. 168.

**Material:** Fifty specimens or fragments, more or less well-preserved, coming from eight different places on Wadi ar Rayn and Darmā' quadrangles.

**Type specimens:** Holotype, the wholly septate specimen that well exposes the inner whorls figured here Pl. XI, fig. 1a-c (UCBL-FSL 178 190). Paratypes 1 and 2, the specimens UCBL-FSL 178 199 and UCBL-FSL 178 150 (Pl. XI, fig. 2).

**Origin of the name:** From the Latin: *glabrus*, *a*, *um* = smooth.

**Description:** Species of large size, the first paratype (UCBL-FSL 178 199) still septate at D = 210 mm and a part of a specimen larger than the paratype is also still septate (UCBL-FSL 178 211). Involute coiling, whorl section high and compressed, oval shaped in the inner and middle whorls, the venter narrow and rounded, progressively narrower and angular-shaped, the umbilical edge surrounding the umbilical wall high and vertical. Radial bifurcated ribs arise near the umbilical edge, intercalatory simple ribs, slightly thickened on the ventral part of the side and crossing the venter without any smooth band or ventral groove. Ribs fade before the end of the phragmocone; the last septate whorl is totally smooth; whorl section increasingly more compressed with acute venter, but with no true carina.

**Discussion:** *E. glabrum* n. sp. and *E. angulatidomus* n. sp. display the common feature of angular-shaped outer whorl, but the inner whorls are quite different and the two species are well differentiated. Among the Upper Bajocian Ermoceratids, the closest species are *T. deserti* and *K. magnificum*, especially considering the material collected in the BRGM field work, establishing that these are species of large size. When specimens of the same sizes are compared, *K. magnificum* is more compressed up to the end of growth and never shows the angular-shaped whorl section of *E. glabrum* n. sp.

Table 24: Measurements of *E. glabrum* n. sp. and *E. angulatidomus* n. sp.

Specimen number	Dm/D	Ph	Wh		Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
<i>E. glabrum</i> n. sp. Holotype UCBL-FSL 178 190 - JMA82.372	c160	n	75		0.46	-	-	33	0.20	-
	131		61		0.46	-	-	20	0.15	-
	97		46		0.47	34	0.35	19	0.19	0.74
<i>E. glabrum</i> n. sp. Paratype 1 UCBL-FSL 178 199 – JMA82.372	210	200	-			-	-	-	-	-
	180		84			0.46	-	35	0.19	-
	152		71			0.46	-	27	0.17	-
	115		58			0.50	0.37	-	-	0.75
<i>E. glabrum</i> n. sp. Paratype 2 UCBL-FSL 178 150 - JMA82.540	195	n	-		-	-	-	-	-	-
	146		70		0.47	-	-	30	0.19	-
<i>P. angulatidomus</i> n. sp. Holotype UCBL-FSL 178 210 -VD80.540	250	235	100		0.40	-	-	76	0.30	-
	190		75		0.39	-	-	60	0.31	-
	145		55		0.38	-	-	54	0.37	-
	115		37		0.32	71	0.61	36	0.31	1.91
<i>E. angulatidomus</i> n. sp. Paratype UCBL-FSL 178 202 - JMA82.372	c 102	n	42		0.40	-	-	37	0.36	-

**Distribution:** Dhurma Fm, lower unit D2. *Wadi ar Rayn Quadrangle:* VD80.540 (UCBL-FSL 178 150-169, 173-176, 203), lonely place between Khashm al Hamra (23°30' N) and Wadi al Hawtah (23°32' N) about 23°31' N; VD80.546 (UCBL-FSL 178 204, 211), Khashm al Hamra 23°30' N; VD80.567 (UCBL-FSL 178 177, 186, 208, 209), lonely place north of Faridat Balum, 23°52' N. *Darmā' Quadrangle:* JMA82.166 (UCBL-FSL 178 187-189) and JMA82.167 (UCBL-FSL 178 213), Khashm ADH Dhibi 24°14' N; JMA82.289 (UCBL-FSL 178 182-185), north of Khashm adh Dhibi about 24°19' N; JMA82.372 (UCBL-FSL 178 181, 190, 199-202, 212, 214, 215), lonely place north of Khashm adh Dhibi, about 24°22' N.

*Eoermoceras* cf. *glabrum* n. sp.: *Shaqrā' Quadrangle:* VD82.92 (UCBL-FSL 178 414-417) and VD82.628 (UCBL-FSL 178 442), South of Jurayfah, about 25°22' N.

**Age:** Upper Lower Bajocian, Glabrum Zone. The associated fauna with dominant *Dorsetensia* of the *liostraca* group favours age in the upper part of the Lower Bajocian, Humphriesianum Zone, Romani Subzone and ?Humphriesianum Subzone owing to the occurrence of few *Teloceras* (m).

***Eoermoceras angulatidomus* n. sp. [M]**

Pl. X, figs 1, 2; Tab. 24

1987. *Ermoceras* n. sp. 2 (pars), Énay *et al.*, p. 34, tab. 1.

1987. *Ermoceras* n. sp. 5, Énay *et al.*, p. 34, tab. 1, p. 38.

1994. "*Ermoceras primitifs*" nov., Énay & Mangold, p. 168.

**Material:** Three specimens from two different places, VD80.540 (UCBL-FSL 178 202, 210) and JMA82.272 (UCBL-FSL 178 191).

**Type specimens:** Holotype, the adult nearly complete specimen figured here Pl. X, fig. 1a, b (UCBL-FSL 178 210). Paratype, the specimen figured in Pl. X, fig. 2 (UCBL-FSL 178 202).

**Origin of the name:** From the Latin: *angulatus*, a, um = angular and *domus* = house, habitation for body chamber.

**Description:** Coiling fairly involute, whorl section depressed, clearly wider than high (W/H = 1.91), narrow, deep, crater-like umbilicus surrounded by large nodes or tubercles, the umbilical wall high and vertical with well-marked umbilical edge, broad and angular or roof-shaped ventral area. On inner and middle whorls, blunt bifurcated ribs, emerging from periumbilical tubercles, and simple intercalated ribs, all crossing the ventral area without any change. Ribbing is rapidly fading before the end of the septate whorls completely smooth as well as the living chamber, and increasing of the angular or roof-shaped morphology of the ventral area leading to a well-defined carina.

**Discussion:** The roof-shaped ventral area with a ventral carina of the living chamber well distinguishes *E. angulatidomus* n. sp. from *E. glabrum* n. sp. Among the younger ermoceratid species, the closest is *Telermoceras coronatoides* Douvillé. Save the missing ventral groove and the roof-shaped ventral area, the inner whorls of these two species match closely. Differences are more striking in the adult stage as they were illustrated concerning *T. coronatoides* by Énay & Mangold (1996, p. 794, figs 1, 2).

**Distribution:** Dhurma Fm, lower unit D2. *Wadi ar Rayn Quadrangle:* VD80.540 (UCBL-FSL 178 202, 210), lonely place between Khashm al Hamra (23°30' N) and Wadi al Hawtah (23°32' N) about 23°31' N. *Darmā' Quadrangle:* JMA82.372 (UCBL-FSL 178 191), lonely place north of Khashm adh Dhibi, about 24°22' N.

**Age:** Upper Lower Bajocian, Glabrum Zone. The associated fauna with dominant *Dorsetensia* of the *liostraca* group favours age in the upper part of the Lower Bajocian, Humphriesianum Zone, Romani Subzone and ?Humphriesianum Subzone owing to the occurrence of few *Teloceras* [m].

## Undetermined "primitive" Ermoceratids

These are small-sized, incomplete specimens, from small outcrops in the Jurayfah area (VD82.92 and 93, and VD82.628), far south of the localities which yielded the first ermoceratid fauna on the Wadi ar Rayn (VD80) and Darmā' (JMA82) quadrangles. The associated fauna includes several species of *Dorsetensia* dominated by *D. liostraca* and there is no doubt that the fauna belongs to the *Dorsetensia* and *E. glabrum* Fauna. This statement is supported by (i) the venter without any smooth band or ventral groove and (ii) the only ones enough well-preserved specimens are determined as *T. cf. glabrum* n. sp. (UCBL-FSL 178 414-417, 442). Other Ermoceratids are described below.

*Eoermoceras* nov. sp. A  
Tab. 25

**Material:** Five specimens, four fragments and inner whorls (FSL 178 257-260) and a larger specimen, not well-preserved and wholly septate (FSL 178 413) from the same locality (VD82.92).

**Description:** Slow coiling and very depressed whorl section (W/H = 2) resulting in wide and deep, crater-like umbilicus. Ribs arising from the umbilical wall, umbilical tubercles well visible on the inner whorls in the umbilicus, each with three or four secondaries crossing the venter without any smooth band or ventral groove.

**Discussion:** The specimen was first ascribed to *T. cf. coronatoides*. The missing ventral groove is the only reason why it is not assigned to *Telermoceras* but to the new genus *Eoermoceras*. New material is required for confirming assignment.

**Distribution:** Dhurma Fm, lower unit D2. *Shaqrā'* *Quadrangle*: VD82.92 (UCBL-FSL 178 257-260, 413), south of Jurayfah, about 25°22' N/40° 20' E.

**Age:** Upper Lower Bajocian, Glabrum Zone. The associated fauna with dominant *Dorsetensia* of the *liostraca* group favours age in the upper part of the Lower Bajocian, Humphriesianum Zone. A little younger in the Jurayfah area (VD82.92) owing to the occurrence of *Teloceras* [m].

Table 25: Measurements of *Eoermoceras* nov. sp. A.

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 178413 – VD86.92	66 61	n	- 20.5	- 0.33	- 41	- 0.67	- 29.4	- 0.48	- 2

Table 26: Measurements of *Eoermoceras* nov. sp. B.

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 178 352– VD82.92	40	n	15	0.375	20	0.50	16	0.40	1.33

*Eoermoceras* nov. sp. B  
Pl. VIII, figs 7, 8; Tab. 26

**Material:** Twenty-nine small specimens from the locality VD82.92, all septate. Other specimen which could be part of the living chamber from VD82.628.

**Description:** Moderate coiling and depressed whorl section, umbilicus wide and deep, venter fairly rounded, band steep umbilical wall with primary ribs emerging into a row of umbilical tubercles on the umbilical edge; secondaries born of tubercles and intercalatory ribs crossing the venter without any smooth band or groove. The fragmentary body chamber agrees well with the description above save it seems a little more depressed. The measured specimen FSL 178 352 fits well with the inner whorls imprint of the larger specimen.

**Discussion:** *Eoermoceras* nov. sp. B. is a well-characterized species quite apart from *E. nov. sp. A*. Among the species of the second (principal) *Ermoceras* fauna, the closest is *T. splendens* Arkell but the more evolute coiling and wide umbilicus distinguish the new species.

**Distribution:** Dhurma Fm, lower unit D2. *Shaqrā'* *Quadrangle*: VD82.92 (UCBL-FSL 178 351-375 and 418-421) and VD82.628 (UCBL-FSL 178 441), south of Jurayfah, about 25°22' N/45° 20' E.

**Age:** Upper Lower Bajocian, Glabrum Zone. The associated fauna with dominant *Dorsetensia* of the *liostraca* group favours age in the upper part of the Lower Bajocian, Humphriesianum Zone, Romani Subzone and ?Humphriesianum Subzone owing to the occurrence of few *Teloceras* (m).

Genus *Ermoceras* H. Douvillé, 1916

**Type species:** *Ermoceras mogharensis* Douvillé, 1916; by original designation

*Ermoceras mogharensis* H. Douvillé, 1916 [M]  
Pl. XIX, fig. 5

1916. *Ermoceras mogharensis* H. Douvillé, p. 19, pl. 2, figs 5-9.  
non 1952. *Ermoceras* (*Ermoceras*) aff. *mogharensis* H. Douvillé.– Arkell, p. 275, pl. 20, figs 3, 10.

- ? 1963b. *Ermoceras* sp. nov. aff. *mogharensis* (Douvillé).– Du Dresnay, p. 889.
- ? 1964b. *Ermoceras* sp. nov. aff. *mogharensis* (Douvillé).– Du Dresnay, p. 4756.
- ? 1964. *Ermoceras* cf. *mogharensis* (Douvillé).– Lorenchet de Montjamont, p. 122.
- ? 1974. *Ermoceras* cf. *mogharensis* (Douvillé).– Du Dresnay, p. 149.
1986. *Ermoceras* gr. *mogharensis* Douvillé.– Énay *et al.*, pp. 33 (tab. 1), 36, 42, 44.
- 1987a. *Ermoceras* gr. *mogharensis* Douvillé.– Énay *et al.*, pp. 35 (tab. 1), 38, 41 (tab. 2), 43.
- 1987b. *Ermoceras mogharensis* Douvillé.– Énay *et al.*, p. 108.
- non 1994. *Ermoceras* gr./cf. *mogharensis* Douvillé.– Alméras *et al.*, p. 223, pl. 3, fig. 9.
1996. *Ermoceras mogharensis* Douvillé.– Énay & Mangold, pp. 792-793.
- ? 2003. *Ermoceras mogharensis* Douvillé.– Khalil, pl. 4, figs 17-19.
2015. *Ermoceras mogharensis* Énay *et al.*, 2011, figs 4/4 and 5a-b.
2015. *Thamboceras mirium* (sic!) Douvillé.– Abdelhady & Fursich, fig. 13/G-H.
2017. *Ermoceras mogharensis* Douvillé.– Howarth, 2017, p. 25, fig. 19/a-e (holotype and paratype).

**Material:** Nine incomplete or young specimens badly preserved.

**Description:** The largest specimens (UCBL-FSL 178 807 and 817) are part of a whorl a little larger than the holotype. Although weathered it shows the typical ribbing style, unchanged across the venter. Juvenile specimens display bullate primary ribs branching from a lateral tubercle, and sheaves of prorsiradiate secondary ribs interrupted by a deep mid-ventral groove.

**Discussion:** As noticed by Énay & Mangold (1996), Douvillé (1916) suggested that *E. inerme* was the microconch (i.e. male) of *E. mogharensis* based on the fact that they occur in the same beds. However, this is not confirmed by the new material from which, otherwise, we describe what we think is the macroconch of *E. inerme* (see below). Until now the microconch of *E. mogharensis* remains unknown.

**Distribution:** Dhurma Fm, lowest D3 Unit. *Darmā' Quadrangle*: JMA82.347 (UCBL-FSL 177 829, 830), Wadi al Jufayr, 24°05' N; JMA82.186 (UCBL-FSL 178 823), Khashm adh Dhibi, 24°14' N; JMA82.294, 296, 297, 298 (UCBL-FSL 177 807, 808, 817-819, 828, 829), lonely place north of Khashm adh Dhibi, about 24°16' N.

**Age:** Upper Bajocian, Mogharensis Zone. *E. mogharensis* was selected (Énay *et al.*, 1986, 1987a; Énay & Mangold, 1994) as the index species of the Mogharensis Zone, the fauna of the lowest unit D3. The rich faunal association from the Sinai (Douvillé, 1916; Arkell, 1952), of which *Spiroceras annulatum* occurs in the fauna of Arabia (Imlay, 1970; Énay *et al.*, 1986, 1987a), dates the base of the unit D3 in the middle part of the upper Bajocian

Garantiana Zone (Arkell & Lucas, 1953; Du Dresnay, 1964; Énay *et al.*, 1986, 1987a; Énay & Mangold, 1984, 1994).

Genus *Telermoceras* Arkell, 1952

**Type species:** *Coeloceras coronatoides* H. Douvillé, 1916; by original designation

***Telermoceras coronatoides* (Douvillé, 1916) [M]**

Pl. XII, fig. 2; Pl. XIII, figs 1-3; Tab. 27

1916. *Coeloceras coronatoides* H. Douvillé, p. 24, pl. 1, figs 3-5.
1952. *Ermoceras (Telermoceras) coronatoides* H. Douvillé.– Arkell, p. 273, pl. 21, figs 1, 3-7, 12; text-fig. 7.
- ? 1952. *Teloceras* cf. *labrum* Buckman.– Arkell, p. 271.
1961. *Erymnoceras coronatum* (d'Orbigny).– Colo, p. 185.
- 1963b. *Telermoceras coronatoides* (Douvillé).– Du Dresnay, p. 889.
1964. *Telermoceras coronatoides* (Douvillé).– Du Dresnay & Kuntz, p. 211.
1964. *Telermoceras coronatoides* (Douvillé).– Benzaquen, p. 191.
- 1964b. *Telermoceras coronatoides* (Douvillé).– Du Dresnay, pp. 4755-4756.
1965. *Telermoceras coronatoides* (Douvillé).– Du Dresnay, p. 238.
1974. *Telermoceras coronatoides* (Douvillé).– Du Dresnay, p. 149.
- 1986a. *Ermoceras coronatoides* Douvillé.– Énay *et al.*, p. 33 (tab. 1).
- 1987a. *Ermoceras coronatoides* Douvillé.– Énay *et al.*, p. 35 (tab. 1).
1996. *Telermoceras* cf. *coronatoides* H. Douvillé.– Énay & Mangold, pp. 794-796, figs 1-3.

**Material:** Twenty-five wholly septate specimens, three of them of large size (UCBL-FSL 178 078, 079, 080).

**Description:** Large evolute macroconchs with crater-like umbilicus, whorl section thick and depressed, vertical high umbilical wall and rounded venter; large umbilical nodes or tubercles from which arise coarse, prorsiradiate secondary ribs; narrow and prominent mid-ventral groove on inner and middle whorl disappearing on the outer whorl. Not any specimen with the body chamber preserved, probably as described in the Moroccan Middle Atlas (Énay & Mangold, 1996).

**Discussion:** *T. coronatiforme* Arkell is close to *T. coronatoides*. According to Arkell (1952) *T. coronatiforme* differs by a much narrower and somewhat more arched venter and coarser and more distant secondary ribs. However, Douvillé (1916) and Arkell (1952) had at their disposal only few small specimens (nuclei), but with more material at hand these features are found to be expression of intraspecific variability. The question is put in a different way when we have at our disposal incomplete and still septate specimens of *T. coronatoides* but of larger size as UCBL-FSL 178 078 (VD80.400), 178 079 (VD80.537) and 178 080 (JMA80.80). The size

Table 27: Measurements of *Telermoceras coronatoides* (Douvillé, 1916).

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 178 079 – VD80.511	190	n	C 55	0.29	120	0.63	74	0.38	2.18
UCBL-FSL 178 080– VD80.593	c 150	n	-	-	-	-	-	-	-
	148	-	49	0.33	76	0.51	59	0.39	1.55
	140	-	31	0.28	-	-	40	0.36	-
	92	-	33	0.35	48	0.52	35	0.38	1.45
UCBL-FSL 178 078 – VD80.400	147	n	49	0.33	89	0.60	50	0.34	1.80
UCBL-FSL 178 089 – JMA80.80	55	?	19	0.34	36	0.65	24	0.43	1.89
Holotype: Douvillé, 1916, pl. 1, fig. 3-5. UCBL-EM 1800	95	?	33	0.34	58	0.61	33	0.34	1.75

is smaller than the specimen from the Moroccan Middle Atlas which is fully grown and complete with half a whorl of body chamber and the aperture at  $D = 190$  mm (Énay & Mangold, 1996, fig. 1a, b). The specimens are very depressed in the outer whorl ( $1.45 < W/H < 2.18$ ). On the contrary, the single large size specimen of *T. coronatiforme* ( $D = 179$  mm), with half a whorl of the living chamber preserved, shows an earlier decrease of the whorl thickness on the outer whorl ( $W/H$  from 1.16 at  $D = 131$  mm to 1.01 at  $D = 179$  mm), the whorl-section quadrate rounded, with fairly parallel or slightly rounded sides and venter.

*T. coronatoides* and *coronatiforme* are evidently two macroconchs. Thus the only microconch described until yet and assigned to *T. cf. coronatoides* by Énay & Mangold (1996, fig. 3a-b) could also correspond to *T. coronatiforme*. Unfortunately, among the relatively abundant material from Saudi Arabia there are no microconchs.

**Distribution:** Dhurma Fm, upper unit D2 (Dhibi Limestone. *Wadi al Mulayh Quadrangle:* JMA80.80 (UCBL-FSL 178 045, 082-086, 089, 106 107) and 80/2 (UCBL-FSL 178 116), As Sitarah Khashm Ushayrah  $22^{\circ}38'$  N; JMA80.553/1 (UCBL-FSL 178 118) and JMA80.555 (UCBL-FSL 178 108-110), between As Sitarah and Fara'id al Ahmar about  $22^{\circ}31'$  N. *Wadi ar Rayn Quadrangle:* VD80.400 (UCBL-FSL 178 077, 078), Khashm al Hadafiyah,  $23^{\circ}05'$  N; VD80.511 (UCBL-FSL 178 112), Wadi Birk,  $23^{\circ}12'$  N; VD80.537 (UCBL-FSL 178 079), North of Khashm Birk,  $23^{\circ}18'$  N; VD80.544 (UCBL-FSL 178 103-105), lonely place north of Wadi al Hawtah, about  $28^{\circ}39'$  N; VD80.593 (UCBL-FSL 178 080), Wadi Birk,  $23^{\circ}12'$  N; *Shaqrā' Quadrangle:* VD82.651 (UCBL-FSL 178 867-870) and 651A (UCBL-FSL 178 924-934), South of Jurayfah South, about  $25^{\circ}22'$  N.

**Age:** Lower Upper Bajocian, Runcinatum Zone. In Saudi Arabia, save *Thamboceras* another Arabian endemic genus, and a few Stephanoceratids or Perisphinctids, *Ermoceras* is the only ammonite present in the upper unit D2. Forms of open marine environment known with *Ermoceras* in Sinai and occurrence of the genus together

with European elements in North Africa, indicate an Upper Bajocian age, Niortense Zone (Arkell & Lucas, 1953; Du Dresnay, 1964b; Du Dresnay *et al.*, 1985; Énay *et al.*, 1987b; Énay & Mangold, 1994).

#### *Telermoceras coronatiforme* (Arkell, 1952) (M)

Pl. XII, fig. 1; Tab. 28

1952. *Ermoceras (Telermoceras) coronatiforme* Arkell, p. 274, pl. 19, fig. 2.  
 1964b. *Ermoceras coronatiforme* Arkell.– Du Dresnay, p. 4755.  
 1986. *Ermoceras coronatiforme* Arkell.– Énay *et al.*, p. 33.  
 1987a. *Ermoceras coronatiforme* Arkell.– Énay *et al.*, p. 35 (tab. 1).  
 ? 2003. *Ermoceras coronatiforme* Arkell.– Khalil, pl. 3, figs 3-5.

**Material:** Twenty-six wholly-septate specimens; one nearly complete fully grown specimen with half a whorl of the body chamber (UCBL-FSL 178 081).

**Description:** The species resembles *T. coronatoides* save the narrower arched venter and coarser and distant secondary ribs of the inner whorls. Specimens of larger size, especially UCBL-FSL 178 081, with half a whorl of the living chamber preserved at 179 mm in diameter, show smooth outer whorl with decrease of the whorl thickness ( $W/H$  from 1.16 at  $D = 131$  mm to 1.01 at  $D = 179$  mm). Adult whorl-section subquadrangular, with fairly parallel or slightly rounded sides and venter. Thus, the species is quite apart from *T. coronatoides*.

**Discussion:** Discussion of the species of Arkell (1952) above, under *T. coronatoides*.

**Distribution:** Dhurma Fm, upper unit D2 (Dhibi Limestone). *Wadi al Mulayh Quadrangle:* JMA80.80 (UCBL-FSL 178 087, 088, 090, 091) and JMA80.80/0 (UCBL-FSL 178 117), As Sitarah Khashm Ushayrah  $22^{\circ}38'$  N. *Wadi ar Rayn Quadrangle:* VD80.400 (UCBL-FSL 178 078), Khashm al Hadafiyah,  $23^{\circ}05'$  N; VD80.507 (UCBL-FSL 178 102), VD80.509 (UCBL-FSL 178 111), VD80.510 (UCBL-FSL 178 081), VD80.521 (178 113), VD80.565/1 (UCBL-FSL 178 073), VD80.565/2 (UCBL-FSL 178 074), VD80.565/3 (UCBL-FSL 178 072, 075),

VD80.593 (UCBL-FSL 178 099-101) and VD80.594 (178 061), Wadi Birk, 23°12' N; VD80.532 (UCBL-FSL 178 071), Faridat Balum, 24°42' N; *Darmā' Quadrangle*: JMA82.409 (UCBL-FSL 178 092-098), lonely place at the same latitude as Awsat graben, 24°38' N.

**Age:** Lower Upper Bajocian, Runcinatum Zone. According to the association with European elements in Sinai and Northern Africa, Upper Bajocian age, Niortense Zone (Arkell & Lucas, 1953; Du Dresnay, 1964b; Du Dresnay *et al.*, 1985; Énay *et al.*, 1987b; Énay & Mangold, 1994).

***Telemoceras n. sp. A***

Pl. XIII, fig. 4

1986. *Ermoceras* sp. 3, Énay *et al.*, p. 33 (tab. 1).

1987a. *Ermoceras* sp. 3, Énay *et al.*, p. 35 (tab. 1).

**Material:** A single specimen, half-whorl preserved, with the very beginning of the living chamber.

**Description:** Fairly evolute coiling, rounded and well-defined umbilical wall, whorl section depressed with a broad and arched venter; short umbilical ribs on the umbilical wall arising from sharp tubercles on the umbilical edge, from which branch three or four secondaries, with more or less numerous intercalatories terminating at a prominent midventral groove.

**Discussion:** Owing to the short primary ribs terminated by a tubercle and the dense and fine secondary ribbing, this specimen closely resembles *T. deserti*, but the whorl section brings it closer to *Telemoceras coronatoides-coronatiforme* group with broad and depressed section and arched ventral region.

**Distribution:** Dhurma Fm, upper unit D2 (Dhibi Limestone). *Wadi al Mulayh Quadrangle*: JMA80.80 (UCBL-FSL 178 119), As Sitarah Khashm Ushayrah, 22°38' N.

**Age:** Lower Upper Bajocian, Runcinatum Zone. According to the association with European elements in Sinai and Northern Africa, Upper Bajocian age, Niortense Zone (Arkell & Lucas, 1953; Du Dresnay, 1964b; Du Dresnay *et al.*, 1985; Énay *et al.*, 1987b; Énay & Mangold, 1994).

***Telemoceras splendens* Arkell, 1952 [M]**

Pl. XIV, figs 1, 2; Tab. 29

1952. *Ermoceras (Telemoceras) splendens* Arkell, p. 274, pl. 23, figs 1, 2, 8; pl. 30, fig. 6; text-fig. 7.

1964b. *Ermoceras splendens* Arkell.– Du Dresnay, p. 4755.

1986. *Ermoceras splendens* Arkell.– Énay *et al.*, p. 33 (tab. 1).

1987a. *Ermoceras splendens* Arkell.– Énay *et al.*, p. 35 (tab. 1).

? 2003. *Ermoceras splendens* Arkell.– Khalil, pl. 3, figs 9-11.

**Material:** Thirty-six specimens (twenty-four fragmentary) from VD82 A and VD82.651A, south of Jurayfah, Shaqrā' Quadrangle, probably from the same beds as in the type locality (Arkell, 1952 “purple reds beds”). Twelve large specimens of which one (UCBL-FSL 178 050) could be dissected, allowing description from the inner whorls up to the adult stage.

**Description:** The inner whorls of the specimens from the Jurayfah area (“purple red beds”) match the type specimens (Arkell, 1952, pl. 23, figs 1, 2, 8). Rounded whorl section, slightly depressed, deep umbilicus, the side and umbilical wall rounded; rounded primary ribs on the umbilical wall, ending in a tubercle, strong and sharp, triplicate secondary ribs, ending on the prominent ventral groove. New large specimens show the adult stages of the species. Middle whorls with ogival whorl section, rounded umbilical edge; the tubercles progressively less prominent and the umbilical wall first vertical, then overhanging. These features are remarked on the outer

Table 28: Measurements of *Telemoceras coronatiforme* Arkell, 1952.

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 178 081 – VD80.510	179	c 145	63	0.35	85	0.44	64	0.35	1.01
	131		49	0.37	57	0.43	50	0.38	1.16
	100		34	0.34	49	0.49	38	0.38	1.44
UCBL-FSL 178 087 – JMA80.80	76	n	27	0.35	46	0.60	27	0.35	1.00
UCBL-FSL 178 088 – JMA80.80	69	?	26	0.37	40	0.58	25	0.36	1.53

Table 29: Measurements of *Telemoceras splendens* Arkell, 1952.

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 178 076– JMA82.409	135	n	80	0.45	82	0.46	43	0.24	1.02
	134	-	60	0.44	70	0.52	39	0.29	1.16
UCBL-FSL 178 048 – JMA80.80	135	n	67	0.49	-	-	29	0.21	-
	75	-	35	0.46	44	0.58	18	0.24	1.25
UCBL-FSL 178 050– JMA80.553/1	100	n	45	0.45	-	-	23	0.23	-

whorl, including the end of the septate whorls and part of the body chamber (UCBL-FSL 178 050), more acute whorl section with obsolete ventral groove, the ribs fading, first on the internal part, then on the whole side.

**Discussion:** The specimen from Sinai referred by Arkell (1952) does not seem to belong to the species.

**Distribution:** Dhurma Fm, upper unit D2 (Dhibi Limestone). *Wadi al Mulayh Quadrangle:* JMA80.80 (UCBL-FSL 178 026, 048, 049, 057, 058), As Sitarah Khashm Ushayrah, 22°38' N; JMA80.553/1 (UCBL-FSL 178 050, 053-056, 135 and 36 with doubt), between As Sitarah and Fara'id al Ahmar, about 22°31' N. *Wadi ar Rayn Quadrangle:* VD80.511 (UCBL-FSL 178 052), Wadi Birk, 23°12' N. *Darmā' Quadrangle:* JMA82.409 (UCBL-FSL 178 051, 076), lonely place at the same latitude as the Graben Awsat, about 24°38' N. *Shaqrā' Quadrangle:* VD82.478A (UCBL-FSL 177 945-953) and 478B (UCBL-FSL 177 876), Jurayfah South, about 25°22' N; VD82.651A (177 910-923), south of Jurayfah South, about 25°22' N.

**Age:** Lower Upper Bajocian, Runcinatum Zone. According to the association with European elements in Sinai and Northern Africa, Upper Bajocian age, Niortense Zone (Arkell & Lucas, 1953; Du Dresnay, 1964b; Du Dresnay *et al.*, 1985; Énay *et al.*, 1987b; Énay & Mangold, 1994).

***Telermoceras deserti* (Douvillé, 1916)**

Pl. XV, figs 1-2; Tab. 30

- v 1916. *Ermoceras deserti* Douvillé, p. 17, pl. 2, fig. 2a-c. 1964b. *Ermoceras deserti* Arkell.– Du Dresnay, p. 4755.  
1965. *Ermoceras deserti* Arkell.– Du Dresnay, p. 288.  
1974. *Ermoceras deserti* (Douvillé).– Du Dresnay, p. 149.  
1986. *Ermoceras deserti* Douvillé.– Énay *et al.*, p. 33.  
1987a. *Ermoceras deserti* Douvillé.– Énay *et al.*, p. 35 (tab. 1).

**Material:** Nine incomplete specimens, most of them wholly septate, save FSL 178 065 with part of the body chamber less than half a whorl long, probably juvenile.

**Description:** Inner whorls not visible; outer whorl section compressed, ogival-shaped, the greater whorl thickness low on the side, umbilical edge rounded; prominent and coarse primary ribs the ending part strengthened like a small tubercle at mid-height of the side and branching in three or four prorsiradiate secondaries with some intercalatories, all of the same strength.

**Discussion:** This species was curiously considered as intermediate between *T. coronatoides* and *T. deserti* by Arkell (1952, p. 273). In our opinion *T. splendens* is more similar to *T. deserti* and we wondered whether the two species were not conspecific, but complete adult specimens are needed for further analysis. In the present state of knowledge *T. deserti* differs from *T. splendens* in the denser and finer ribbing and somewhat weaker tubercles. Until the complete adult form of *T. deserti* is known, it cannot be excluded that it would be the microconch of *T. splendens*.

**Distribution:** Dhurma Fm, upper unit D2 (Dhibi Limestone). *Wadi al Mulayh Quadrangle:* JMA80.553 (UCBL-FSL 178 067), JMA80.553/1 (UCBL-FSL 178 062) and JMA80.553/2 (UCBL-FSL 178 068), lonely place between As Sitarah and Fara'id al Ahmar, about 22°31' N; JMA80.80 (UCBL-FSL 178 064, 065) and JMA80.80/0 (UCBL-FSL 178 069, 070), As Sitarah Khashm Ushayrah, 22°38' N. *Wadi ar Rayn Quadrangle:* VD80.593 (UCBL-FSL 178 063) et VD80.594 (UCBL-FSL 178 061), Wadi Birk, 23°12' N. *Darmā' Quadrangle:* JMA82.409 (UCBL-FSL 178 066), lonely place at the same latitude as the Graben Awsat, about 24°38' N.

**Age:** Lower Upper Bajocian, Runcinatum Zone. According to the association with European elements in Sinai and Northern Africa, Upper Bajocian age, Niortense Zone (Arkell & Lucas, 1953; Du Dresnay, 1964b; Du Dresnay *et al.*, 1985; Énay *et al.*, 1987b; Énay & Mangold, 1994).

***Telermoceras reineckeoides* Arkell, 1952 [M?]**

1952. *Ermoceras (Telermoceras) reineckeoides* Arkell, p. 274, pl. 20, figs 8, 9; text-fig. 7.  
1986. *Ermoceras reineckeoides* Arkell.– Énay *et al.*, p. 33.  
1987a. *Ermoceras reineckeoides* Arkell.– Énay *et al.*, p. 35 (tab. 1).

**Material:** Two fragmentary and poorly preserved specimens.

**Description and remarks:** Although fragmentary the two specimens match the original description of Arkell (1952).

**Distribution:** Dhurma Fm, upper unit D2 (Dhibi Limestone). *Wadi ar Rayn Quadrangle:* VD80.592 (UCBL-FSL 178 059), Wadi Birk 23°12' N; *Darmā' Quadrangle:* JMA82.169 (UCBL-FSL 178 060), north of Khashm adh Dhibi.

Table 30: Measurements of *Telermoceras deserti* (Douvillé, 1916).

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 178 065 – JMA80.80	77	?	34	0.44	35	0.45	25	0.32	1.02
UCBL-FSL 178 067– JMA80.553	59 45	n -	30 22	0.50 0.48	29 23	0.49 0.51	11 9	0.18 0.20	0.96 1.04
Holotype: Douvillé, 1916, p. 17, pl. 2, fig. 2a-c. UCBL-EM 1804.	97	n	40	0.41	39	0.40	25	0.25	0.97

**Age:** Lower Upper Bajocian, Runcinatum Zone. According to the association with European elements in Sinai and Northern Africa, Upper Bajocian age, Niortense Zone (Arkell & Lucas, 1953; Du Dresnay, 1964b; Du Dresnay *et al.*, 1985; Énay *et al.*, 1987b; Énay & Mangold, 1994).

Genus *Kosmermoceras* Arkell, 1952a

**Type species:** *Ermoceras* (*Kosmermoceras*) *runcinatum*; by original description

***Kosmermoceras runcinatum* Arkell, 1952 [M & ?m]**

Pl. XVIII, figs 1-2; Pl. XIX, figs 1-3; Tab. 31

1952. *Ermoceras* (*Kosmermoceras*) *runcinatum* Arkell, p. 276, pl. 20, fig. 2 (non fig. 1); pl. 21, figs 8-10; pl. 22, figs 8-11; text-fig. 7.
1953. *Ermoceras* (*Kosmermoceras*) *runcinatum* Arkell.– Arkell & Lucas, p. 2258.
- 1963c. *Ermoceras* aff. *runcinatum* Arkell.– Du Dresnay, p. 2873.
1974. *Ermoceras* cf. *runcinatum* Arkell.– Du Dresnay, p. 149.
1986. *Ermoceras runcinatum* Arkell.– Énay *et al.*, pp. 33, 42.
- 1987a. *Ermoceras runcinatum* Arkell.– Énay *et al.*, p. 35 (tab. 1).
- 1987b. *Ermoceras runcinatum* Arkell.– Énay *et al.*, p. 108.
- 1987b. *Ermoceras* n. sp. aff. *elegans* Douvillé.– Énay *et al.*, p. 108.
1994. *Ermoceras runcinatum* Arkell.– Énay & Mangold, p. 169.
1994. *Ermoceras runcinatum* Arkell.– Alméras *et al.*, p. 225, fig. 4, pl. 3, fig. 4.
1994. *Ermoceras magnificum* Arkell.– Alméras *et al.*, p. 225, fig. 4 and p. 232, fig. 8.
1996. *Ermoceras* (*Kosmermoceras*) n. sp. aff. *elegans* Douvillé.– Énay & Mangold, pp. 169, fig. 9a, b.
1996. *Ermoceras* (*Kosmermoceras*) n. sp. aff. *elegans* Douvillé.– Énay & Mangold, p. 169, fig. 6-8a, b.
- 1999b. *Ermoceras runcinatum* Arkell.– Galacz, pp. 607, 608, text-fig. 2.

**Material:** Forty-three fragments and three more or less complete specimens.

**Description:** Middle-sized form with high and compressed whorl section, high and rounded umbilical edge, the largest thickness just below the middle of the flank. Sharp and dense ribbing with prorsiradiate primaries ending in sharp tubercles at about third part of the side, fading on middle and outer whorls; sharp secondaries emerge from the tubercles with a gentle backward swing, changing on the outer whorl of the large

complete specimens to broad flat-ended ribs. Narrow and tabulate venter with wide, deep furrow. Towards the end of the last whorl the ventral furrow disappears, the ribs cross the venter without changing and display a more flexuous style. These features suggest the specimens are adults. Body chamber about half a whorl long (e. g. UCBL-FSL 178 031).

**Discussion:** We doubt about the conspecificity of some of the specimens described by Arkell (1952), especially that figured in the fig. 1 of his pl. 20. Although the relative smaller size of our specimens they are macroconchs. Two possible microconchs (UCBL-FSL 178 997, 998) are in the studied material, but too poorly preserved for being illustrated. Microconchs have also been recorded in Morocco and/or Algeria (the frontier between these two countries is contested and not defined) where better preserved specimens come from. These specimens were first supposed to be a new species (*K. aff. elegans* in Énay *et al.*, 1987b), but latter they have been considered as the probable microconch of *E. runcinatum* (Énay & Mangold, 1996, p. 796).

**Distribution:** Dhurma Fm, upper unit D2 [Dhibi Limestone. *Wadi al Mulayh Quadrangle*: JMA80.80 (UCBL-FSL 178 027, 031, 032, 034-037, 042)], As Sitarah Khashm Ushayrah, 22°38' N; JMA80.186 (UCBL-FSL 178 038), Fara'id al Ahmar, about 22°27' N; JMA80.519 (UCBL-FSL 178 039), Jabal Fahhamah, 22°07' N. *Wadi ar Rayn Quadrangle*: VD80.510 (UCBL-FSL 178 028, 040), Wadi Birk, 23°12' N; VD80.544 (UCBL-FSL 178 033), lonely place north of Wadi al Hawtah, about 23°39' N; VD80.567 (UCBL-FSL 178 041), Khashm al Jufayr, 23°58' N; VD80.594 (UCBL-FSL 178 030) and VD80.595 (UCBL-FSL 178 019), Wadi Birk, 23°12' N. *Darmā' Quadrangle*: JMA82.280 (UCBL-FSL 178 029), Wadi al Hisyan, 24°45' N. *Shaqrā' Quadrangle*: VD82.478 (UCBL-FSL 178 901-903), VD82.478A (UCBL-FSL 877-880, 895-898, 935-944) and VD82.478B (UCBL-FSL 177 904-908), Jurayfah South, 25° 30' N; VD82.651 and 651A (UCBL-FSL 177 871-875, 892-894), south of Jurayfah South about 25°40' N.

**Age:** Lower Upper Bajocian, Runcinatum Zone. According to the association with European elements in Sinai and Northern Africa, Upper Bajocian age, Niortense Zone (Arkell & Lucas, 1953; Du Dresnay, 1964; Énay *et al.*, 1987b; Énay & Mangold, 1994).

Table 31: Measurements of *K. runcinatum* Arkell

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 178 031 – JMA80.80	145	c 100	65	0.46	42	0.29	29	0.20	0.64
UCBL-FSL 178 032– JMA80.80	97	n	48	0.49	34	0.35	17	0.18	0.71
UCBL-FSL 177 877– VD82.478A	38	n	20.5	0.54	18	0.47	6	0.16	0.88

***Kosmocereras magnificum* Arkell, 1952 (M & m)**

Pl. XV, fig. 4; Pl. XVI, fig. 1, 2; Pl. XVII, fig. 1, 2;  
Tab. 32

1952. *Ermoceras* (*Kosmocereras*) *magnificum* Arkell, p. 275, pl. 22, figs 1-4.  
 ? 1952. *Ermoceras* (*Kosmocereras*) *aulacostephanus* Arkell, p. 276, pl. 22, fig. 7.  
 1964. *Ermoceras* (*Kosmocereras*) aff. *magnificum* Arkell.– Du Dresnay & Kuntz, p. 211.  
 1965. *Ermoceras* aff. *magnificum* Arkell.– Du Dresnay, p. 238.  
 1973. *Ermoceras magnificum* Arkell.– Bassoulet, p. 2631.  
 1986. *Ermoceras magnificum* Arkell.– Énay *et al.*, p. 33 (tab. 1).  
 1987a. *Ermoceras magnificum* Arkell.– Énay *et al.*, p. 35 (tab. 1).  
 non 1994. *Ermoceras runcinatum* Arkell.– Alméras *et al.*, p. 225, fig. 4, pl. 3, fig. 4.  
 1994. *Ermoceras magnificum* Arkell.– Alméras *et al.*, p. 225, fig. 4 and p. 232, fig. 8.

**Material:** Forty-four specimens including twenty-four more or less complete and well-preserved macroconchs, some with large part of the body chamber, mostly from the locality JMA80.80; two supposed microconchs and fragmentary cf. specimens.

**Description:** The holotype consists of only inner whorls unable to provide a complete characterization of the species. The largest specimen (UCBL-FSL 177 969) is the body chamber of a macroconch; it is more than half a whorl long, conspicuously uncoiled, exceeding the 250 mm in diameter.

The specimens are involute with narrow umbilicus, vertical umbilical wall, and compressed whorl section. The venter is narrow with a well-marked ventral furrow on the inner and middle whorls, disappearing towards the adult stage. On the inner and middle whorls, the ribbing is

composed of well-marked rectiradiate primaries (stronger than in the holotype); irregularly branched secondaries, ending along the ventral furrow. Ribbing fading on the outer whorl, the primary ribs as soon as the end of the septate whorls, latter the secondaries, first on the inner half, then on the whole whorl-sides totally smooth. Well-preserved large specimens show clearly uncoiling of the body chamber and overhanging umbilical edge.

The studied material allows to distinguish between thicker and more compressed phragmocones. This variation covaries with the ribbing style, denser and finer in the compressed forms, coarser in the thicker ones.

**Discussion:** Two small (40-45 mm in diameter) and badly preserved specimens (UCBL-FSL 177 997, 998) could represent the microconch. They are not suitable for being described, but they fit well with the holotype of *K. aulacostephanus* Arkell (1952, pl. 22, fig. 7). Another and best preserved specimen (UCBL-FSL 177 881) found together poorly preserved *K. cf. magnificum*, matches closely the holotype, save the smaller size (D = 28 mm) and the more compressed whorl section. Arkell (1952) well noticed that the holotype comes nearest of the Arabian material to the Sinai *Ermoceras inerme* Douvillé, an undoubted microconch (cf. Énay & Mangold, 1996, p. 797, fig. 10a, b; Howarth, 2017, p. 25, fig. 19, 2e, f). Thus, there is good evidences that *K. aulacostephanus* is the microconch counterpart of the macroconch *K. magnificum*, thus parts of a same species.

**Distribution:** Dhurma Fm, upper unit D2 (Dhibi Limestone). *Wadi al Mulayh Quadrangle:* JMA80.80 (UCBL-FSL 177 965-970, 974, 978-984, 986, 988, 990, 996, 178 042, 123) et JMA80.80/1 (UCBL-FSL 177 971, 975-977, 178 000, 001), between As Sitarah Khashm Ushayrah, 22°38' N; JMA80.553 (UCBL-FSL 177 987), between As Sitarah and Fara'id al Ahmar, about 22°31' N. *Wadi ar Rayn Quadrangle:* VD80.510

Table 32: Measurements of *K. magnificum* Arkell.

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 968 – JMA80.80	225	205	116	0.52	-	-	33	0.15	
UCBL-FSL 978 – JMA80.80	187	n	100	0.53	-	-	23	0.12	-
	145		73	0.50	-	-	20	0.14	-
	132		69	0.52	46	0.35	20	0.15	0.67
UCBL-FSL 985 – JMA82.409	220/230	140	-	-	-	-	-	-	-
	160	-	79	0.49	-	-	31	0.19	-
UCBL-FSL 971– JMA80.80/1	123	n	60	0.49	c 37	0.30	21	0.17	0.62
	94	-	42	0.45	34	0.36	19	0.20	0.81
UCBL-FSL 979 – JMA80.80	110	n	58	0.53	-	-	22	0.20	-
UCBL-FSL 986 – JMA80.80	c 205	c 200	-	-	-	-	-	-	-
	105	-	51	0.49	c 35	0.33	c 18	0.17	0.69
UCBL-FSL 989 – JMA80.80/1	89	n	41	0.46	-	-	16	0.18	-
UCBL-FSL 996 – JMA80.80	86	?	43	0.50	-	-	17	0.20	-
UCBL-FSL 981 – JMA80.80	84	n	41	0.49	-	-	15	0.18	-
UCBL-FSL 991 – VD80.510	70	n	36	0.51	-	-	10	0.14	-

(UCBL-FSL 177 991, 997-999), Wadi Birk, 23°12' N; VD.80.533 (UCBL-FSL 177 973), lonely place north of Faridat Balum, 23°42' N. *Darmā' Quadrangle*: JMA82.402 (UCBL-FSL 177 972) and JMA82.409 (UCBL-FSL 177 985, 992-995), lonely place at the same latitude as graben Awsat 24°38' N. *Shaqrā' Quadrangle*: VD82.478 (UCBL-FSL 177 899), VD82.478A (UCBL-FSL 177 895-898) and VD82.478B (UCBL-FSL 177 881), Jurayfah South, about 25° 22' N.

**Age:** Lower Upper Bajocian, Runcinatum Zone. According to the association with European elements in Sinai and Northern Africa, Upper Bajocian age, Niortense Zone (Arkell & Lucas, 1953; Du Dresnay, 1964b; Du Dresnay *et al.*, 1985; Énay *et al.*, 1987b; Énay & Mangold, 1994).

***Kosmermoceras elegans* H. Douvillé, 1916 [m]**

Pl. XVII, figs 3-5; Tab. 33

1916. *Ermoceras elegans* H. Douvillé, p. 18, pl. 2, figs 3, 4

1952. *Ermoceras (Kosmermoceras) elegans* H. Douvillé.– Arkell, p. 275, pl. 22, figs 1-4.

1981. *Ermoceras* sp. cf. *E. (Kosmermoceras) runcinatum* Arkell.– Parnes, p. 49, pl. 9, figs 5-7.

1986. *Ermoceras elegans* H. Douvillé.– Énay *et al.*, p. 33 (tab. 1).

1987a. *Ermoceras elegans* H. Douvillé.– Énay *et al.*, p. 35 (tab. 1).

1996. *Ermoceras (Kosmermoceras) elegans* H. Douvillé.– Énay & Mangold, pp. 794-796, figs 4-5.

non 1996. *Ermoceras (Kosmermoceras)* n. sp. aff. *elegans* Douvillé.– Énay & Mangold, p. 169, figs 6a, b, 7a, b, 8a, b, and 9a, b.

2017. *Kosmermoceras elegans* H. Douvillé.– Howarth, p. 25, fig. 19/2c, d (specimen figured in Énay & Mangold, 1996, fig. 4a, b).

**Material:** Thirty nine specimens (not more than 40 as stated in Énay & Mangold, 1996), the major part (20) from a single locality in the Wadi al Mulayh Quadrangle (JMA80.80), many with the change of the ribbing indicating the adult stage and most likely the proximity of the not preserved aperture.

**Description:** The studied collection shows a large variability of adult size as indicated by the ribbing. The size of such subcomplete specimens vary up to twofold

of the smaller one, the 54 mm in diameter holotype. This latter is small-sized with thick section and coarse ribbing, like the specimen figured in Énay & Mangold (1996, fig. 5a, b). The largest specimen reaches about 110 mm in diameter (UCBL-FSL 178 010); it is compressed with dense and fine ribbing.

Whorl section rectangular and compressed, the side slightly convex, steep umbilical wall and well-defined umbilical edge. The species is well characterized by its ribbing style, flexuous primaries, first prorsiradiate when emerging from the umbilical edge, then rectiradiate and divided into three secondary ribs, which curve forwards on the external part of the side and end at the prominent ventral groove.

**Discussion:** Continuation up to the end of the prominent ventral groove associated with the change to a more flexuous ribbing style prove that the specimens are full-grown. *K. elegans* was considered as microconch by Douvillé (1916) who even claimed “*it could be the male of Ermoceras deserti*” as Énay & Mangold (1996) recalled, but Howarth (2017, p. 25), about the large-sized specimen already figured by Énay & Mangold, wrote “*macroconch or microconch uncertain*”. The possibility that *K. elegans* would be the microconch of several macroconch species such as *K. deserti* and *splendens* cannot be set aside (Énay & Mangold, 1996), so the generic position would be changed from *Kosmermoceras* to *Telermoceras*. Considering the great variability of the size, associated with a difference in whorl-section thickness and the ribbing, another possibility is a dimorphism of size alone with similar plain adult mouth borders in both dimorphs.

**Distribution:** Dhurma Fm, upper D2 Unit (Dhibi Limestone). *Wadi al Mulayh Quadrangle*: JMA80.80 (UCBL-FSL 178 002-009, 017, 021-023, 046, 096) and JMA80.80/1 (UCBL-FSL 178 010-016, 018), As Sitarah Khashm Ushayrah, 22°38' N; JMA80.553 (UCBL-FSL 178 024), between As Sitarah and Fara'id al Ahmar, about 22°31' N. *Wadi ar Rayn Quadrangle*: VD80.522 (UCBL-FSL 178 025) and VD80.595 (UCBL-FSL 178 020), Wadi Birk, 24°12' N. *Shaqrā' Quadrangle*: VD82.478A (UCBL-FSL 177 839-843, 883-885), Jurayfah South, about 25° 22' N; VD82.651A (UCBL-FSL 177 844-849), South of Jurayfah South, about 25°22' N.

Table 33: Measurements of *Kosmermoceras elegans* Douvillé, 1916.

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 178 010 – JMA80.80/1	100 74	65 -	43 37	0.43 0.50	25 23	0.25 0.31	25 14	0.25 0.19	0.58 0.62
UCBL-FSL 178 002 – JMA80.80/1	85 64	54 -	43 32	0.50 0.50	24 23	0.28 0.35	14.5 12	0.22 0.18	0.55 0.71
UCBL-FSL 178 003 – JMA80.80/1	82	54	38	0.46	23	0.28	17	0.20	0.42
UCBL-FSL 178 018 – JMA80.80/1	65	54	35	0.53	c 24	0.37	10	0.15	0.68
Holotype: Douvillé, 1916, p. 18, pl. 2, fig. 3, 4. UCBL-EM 1803	54	?	24	0.44	21	0.38	13	0.24	0.87

**Age:** Lower Upper Bajocian, Runcinatum Zone. According to the association with European elements in Sinai and Northern Africa, Upper Bajocian age, Niortense Zone (Arkell & Lucas, 1953; Du Dresnay, 1964b; Du Dresnay *et al.*, 1985; Énay *et al.*, 1987b; Énay & Mangold, 1994).

***Kosmocereras inerme* (Douvillé, 1916) [M? & m]**

Pl. XIX, figs 6-8

- v 1916. *Ermoceras inerme* Douvillé, p. 20, pl. 2, fig. 10; text-fig. 8.  
 1986. *Ermoceras inerme* H. Douvillé.– Énay *et al.*, p. 33.  
 1987a. *Ermoceras inerme* H. Douvillé.– Énay *et al.*, p. 35 (tab. 1).  
 1987a. *Ermoceras* (*Kosmocereras*) sp. Énay *et al.*, p. 35 (tab. 1).  
 1996. *Ermoceras* (? *Kosmocereras*) *inerme* Douvillé.– Énay & Mangold, 1996, p. 797, fig. 10a, b.  
 2017. *Ermoceras* (? *Kosmocereras*) *inerme* Douvillé.– Howarth, p. 25, fig. 19/2e, f.

**Material:** A single poorly preserved but complete microconch (UCBL-FSL 177 810) with lappets, and eleven fragmentary, wholly septate specimens which are supposed to belong to the macroconch counterpart of the microconch described by Douvillé.

**Description:** *Microconch.* Small-sized (maximum D = 30.8 mm), involute, whorl section compressed, narrow umbilicus, ribbing preserved only on the ventral part of the side with dense prorsiradiate ribs ending on the ventral furrow deep and well-marked until the end; aperture with lappet at mid-height of the side, long and spatulate.

*Macroconch?* The largest and wholly septate specimen, more than 110 mm in diameter. Other large-size, involute form, with compressed and high whorl section, flat-sided whorls and narrow, tabulate venter with a prominent mid-ventral groove.

Some small specimens from the Jurayfah area (VD82.478A and 651) and upper unit D2 (Runcinatum Zone), geologically older than the previous studied specimens, differ by the finer and denser ribbing, the small-size, the lack of ventral groove probably due to a slight compression, but two larger ones with dense and fine ribbing show a well-marked ventral groove.

**Discussion:** The lappeted microconch (UCBL-FSL 177 810) closely resembles the holotype, better preserved but with the aperture missing. In J. Moghara *K. inerme* was found in the same beds (Yellow Limestones) as *E. mogharensis* and was assumed by Douvillé (1916) to be probably the microconch of *E. mogharensis*. The new specimens described in this work as being the possible

macroconch may be better paired with the microconch *E. inerme*. So the microconch counterpart of *E. mogharensis* is still unknown.

**Distribution:** Dhurma Fm, upper unit D2. *Darmā' Quadrangle:* JMA82.186 (UCBL-FSL 177 822, 824), Khashm adh Dhibi, 24°14' N; *Shaqrā' Quadrangle:* VD82.478A (UCBL FSL 178 861, 862), Jurayfah South; VD82.651 (UCBL-FSL 177 863-866), south of Jurayfah South, about 25°40' N. – lowest D3 unit. *Wadi ar Rayn Quadrangle:* VD80.547 (UCBL-FSL 177 838), south of Khashm al Jufayr, 23°58' N; *Darmā' Quadrangle:* JMA82.294 [UCBL-FSL 177 791, 810 (m), 825, 826], lonely place north of Khashm adh Dhibi, 24°14' N.

**Note about the specimen UCBL-FSL 177863:** It is assigned to the upper part of the unit D2 by the BRGM and it is actually associated with species of the upper unit D2 (Runcinatum Zone), in the same beds with ferruginous oolites. According to the BRGM also, the basal part of the unit D3 and the *Ermoceras* gr. *mogharensis* and *Spiroceras* fauna is not known north of the reference section (see above). From these data, several possible explanations are possible: (i) a condensed level with mixed faunas from the upper unit D2 (Runcinatum Zone) and from lowest unit D3 (Mogharensis Zone), or (ii) these forms occur at different levels within the oolitic beds, but they were not divided when collected, or (iii) the range of *K. inerme* encompass both the Runcinatum and Mogharensis zones.

**Age:** Upper Bajocian, Runcinatum and Mogharensis Zone (see above) according to the association with European elements in Sinai and Northern Africa, Upper Bajocian age, Garantiana Zone (Arkell & Lucas, 1953; Du Dresnay, 1964b; Imlay, 1970; Énay *et al.*, 1987b; Énay & Mangold, 1994).

***Kosmocereras?* n. sp. A**

Pl. XIII, fig. 4 ; Tab. 34

1986. *Ermoceras* n. sp. Énay *et al.*, p. 33 (tab. 1).  
 1987a. *Ermoceras* sp. Énay *et al.*, p. 35 (tab. 1).

**Material:** One small well-preserved specimen.

**Description:** Involute coiling, trapezoidal whorl section as high as thick, the greater thickness at the umbilical edge with seven strong umbilical tubercles and rounded umbilical wall; three secondaries by tubercles and a few intercalatories, first and briefly prorsiradiate, then clearly rursiradiate ending in a small tubercle on the sides of the well-defined ventral furrow.

**Discussion:** This species resembles *T. reineckeoides*, but differs by the whorl section and involution. *K. runcinatum*

Table 34: Measurements of *Kosmocereras?* n. sp. A.

Specimen number	Dm/D	Ph	Wh	Wh/D	Wb	Wb/D	Ud	Ud/D	Wb/Wh
UCBL-FSL 178 136 - JMA82.409	51	?	25	0.49	25	0.49	10	0.196	1.00

is probably the closest species. Our isolated specimen could correspond to an extreme variant of *K. runcinatum*.

**Distribution:** Dhurma Fm, upper unit D2 (Dhibi Limestone). *Darmā' Quadrangle*: JMA82.409 (UCBL-FSL 178 136), lonely place at the same latitude as the Graben Awsat, about 24°38' N.

**Age:** Lower Upper Bajocian, Runcinatum Zone. According to the association with European elements in Sinai and Northern Africa, Upper Bajocian age, Niortense Zone (Arkell & Lucas, 1953; Du Dresnay, 1964b; Énay *et al.*, 1987b; Énay & Mangold, 1994).

Subfamily Cadomitinae Westermann, 1956

Genus *Cadomites* Munier-Chalmas, 1892

**Type species:** *Ammonites deslongchampsii* d'Orbigny, 1846; ICZN Opinion 324 (1955a, pp. 230, 236) [= *Polyplectites* Mascke, 1907, p. 23; = *Polystephanus* Buckman, 1922, pl. 311, *non* Brandt, 1835, p. 12 (Coelenterata); = *Stegeostephanus* Buckman, 1922, pl. 312]

#### *Cadomites* gr. *daubenyi* (Gemmellaro, 1873)

1877. *Stephanoceras Daubenyi* Gemmellaro, p. 67 (pars), pl. 4, figs 3, 5 (not fig. 4 and pl. 4b, fig. 12 = *C. galaczi* Pavia).
1882. *Stephanoceras Daubenyi* Gemmellaro, p. 141 (pars), pl. 19, figs 3, 5 (not fig. 4 and pl. 20, fig. 1 = *C. galaczi* Pavia).
1964. *Cadomites daubenyi* Gemmellaro.– Wendt, p. 130 (non pl. 21, fig. 1 = *C. galaczi* Pavia).
1986. *Cadomites* sp. Énay *et al.*, p. 33 (tab. 1).
- 1987a. *Cadomites* sp. Énay *et al.*, p. 34 (tab. 1).
2002. *Cadomites daubenyi* (Gemmellaro, 1877).– Pavia in Pavia & Cresta, p. 236, figs 161-163.

**Material:** Wholly septate nucleus (about 50 mm in diameter), not well-preserved.

**Description:** The most diagnostic features are the deep umbilicus and subpentagonal whorl-section, the umbilical area rounded with obtuse mid-side angularity, together with the maximum width and a row of small and numerous tubercles where dense primary ribs divide into sheaves of fine and radiate secondaries crossing the venter without interruption.

**Discussion:** The description above is consistent with that of the two syntypes reviewed by Pavia (in Pavia & Cresta, 2002) much better preserved. A closely related

species is *C. galaczi* Pavia (in Pavia & Cresta, 2002, 240, figs 164, 165) based on some of the forms attributed to *C. daubenyi* by Gemmellaro (1877, 1882), which according to Pavia (2002) differs from *C. daubenyi* by the regularly arched venter, the umbilicus steeper and the costulation more spaced. These are difficult to highlight on the Saudi material because of insufficient preservation.

**Distribution:** Dhurma Fm, upper unit D2 (Dhibi Limestone). *Darmā' Quadrangle*: JMA82.509 (UCBL-FSL 178 302), Wdi Birk, 23°12' N.

**Age:** Lower Upper Bajocian, Runcinatum Zone. According to the association with European elements in Sinai and Northern Africa, Upper Bajocian age, Niortense Zone (Arkell & Lucas, 1953; Du Dresnay, 1964b; Énay *et al.*, 1987b; Énay & Mangold, 1994).

Family Sphaeroceratidae Buckman, 1920

Subfamily Mayaitinae Spath, 1928

[*nom. transl.* Westermann, 1964, p. 130, *ex* Mayaitidae Spath, 1928, pp. 165, 222] [= Grayiceratidae Spath, 1925, p. 145 (*nom. dub.*), ICZN Opinion 471, 1957, p. 203]

Genus *Paryphoceras* Spath, 1928

**Type species:** *Paryphoceras badiense*; by original designation

#### *Paryphoceras* sp.

Pl. XXXVI, fig. 1; Pl. XXXVII, fig. 3; Tab. 35

1986. New genus and species Énay *et al.*, p. 33 (tab. 1).
- 1987a. New genus and species Énay *et al.*, p. 36 (tab. 1).

**Material:** One well-preserved specimen, nearly complete from the unit H2 (UCBL-FSL 177 035); and with doubt, according to the stratigraphic position (unit H1), two pieces of outer whorls (UCBL-FSL 177 037 and 038) and casts of small fragments (UCBL-FSL 177 039-044).

**Description:** The specimen is probably fully grown, but the suture lines are not visible and the aperture is not preserved. Fairly involute planulate shell, the relative umbilical diameter increases regularly during growth with correlative decrease of the relative whorl height; the larger width of the outer whorl compared to middle whorls is the result of changes in the rib sharpness. Whorl-section first high and compressed, flat side and rounded venter, umbilical wall high and overhanging the umbilical seam and the preceding whorl, then

Table 35: Measurements of *Paryphoceras* sp.

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
UCBL-FSL 177 035 - VD80.325	290	?	99	0.34	–	–	100	0.34	–
	235		95	0.40	89	0.37	68	0.29	0.93
	160		74	0.46	50	0.31	33	0.21	0.67
	85		44	0.51	30	0.35	17	0.20	0.70

progressively rounded on the outer whorl. Ornamentation not preserved on the inner and middle whorls but is well-preserved in the outer whorl with well-marked prominent complete simple ribs; secondary not observable.

**Discussion:** During the early study this specimen was tentatively compared to the large perisphinctids of the middle Oxfordian-lower Kimmeridgian, especially the macroconchs of *Orthosphinctes* (i.e. *Lithacosphinctes*), resembling the so-called “*Subdiscosphinctes*” in Hantzpergue (1989) whose coiling is fairly involute. For instance, *S. orbignyi* Hantzpergue and *S. castroi* (Choffat), here referred to *Lithacosphinctes* according to Atrops (1982). But the more involute coiling, particularly of the inner whorls, lead us to reject this hypothesis. In any case the specimen studied can not be really identified with any known *Orthosphinctes* macroconch. Despite the insufficient preservation, assignation to the Mayaitinae seems to be the best choice. However, it is hard to decide the genus to which it could belong. Firstly because “*dimorphism probably occurs, but has been little investigated*” (Howarth, 2017, p. 54). On the other hand, the two best candidates to which assign our specimen, *Paryphoceras* and *Dhosaites*, described by Spath (1928), Collignon (1959a, b), and Alberti *et al.* (2015) are microconchs. *Paryphoceras* is considered preliminary.

**Distribution:** Hanifa Fm, unit H1 (upper part). *Wadi ar Rayn Quadrangle*: VD80.319 (UCBL-FSL 177 037-044), Ulayyah, 23°54' N - unit H2. *Wadi ar Rayn Quadrangle*: VD80.325 (UCBL-FSL 177 035), Ulayyah, 23°54' N.

**Age:** Middle-Late Oxfordian. In the Indo-Madagascan Province *Paryphoceras* ranges from the Middle Oxfordian (Plicatilis Zone) to the Lower Kimmeridgian (Platynota-Hypselocyclum Zones). Our specimens is assumed to occur in the Upper Oxfordian, Planula Zone.

Superfamily Spiroceratoidea Hyatt, 1900

[*nom. transl.* Arkell, 1950, p. 359, *ex Spiroceratidae* Hyatt, 1900, p. 584]

Family Spiroceratidae Hyatt, 1900

Subfamily Spiroceratinae Hyatt, 1900

[*nom. transl.* Spath, 1933, p. 681, *ex Spiroceratidae* Hyatt, 1900, p. 584]

Genus *Spiroceras* Quenstedt, 1856

**Type species:** *Spiroceras bifurcatum* Hyatt, 1900; by subsequent monotypy by Hyatt, 1900, p. 584 (ICZN Code, 1999, Article 69.3).

***Spiroceras annulatum* (Deshayes, 1831)**

Pl. XIX, fig. 9

1970. *Spiroceras annulatum* (Deshayes).– Imlay, p. D11, pl. 1, figs 7-8.  
 1978. *Spiroceras annulatum* (Deshayes).– Dietl, p. 40 (*cum* synonymy).  
 1986. *Spiroceras annulatum* (Deshayes).– Énay *et al.*, p. 33 (tab. 1); pl. 4, fig. 5a, b.

1987a. *Spiroceras annulatum* (Deshayes). – Énay *et al.*, p. 35 (tab. 1); pl. 4, fig. 5a, b.

**Material:** Seven incomplete specimens, more or less well-preserved.

**Description:** The best preserved specimen is part of the body chamber, probably not fully grown, according to Dietl (1978) unrolled in the form of a space spiral. The ribbing is regular and shows only at the edges of the ventral band a node-like thickening.

**Discussion:** The species was published erroneously (see Dietl, 1978, p. 40) as *Ancyloceras tenue* d'Orbigny by Douvillé (1916, p. 40, pl. 3, figs 12-14) from the fossil-rich Yellow Beds (Couches jaunes) with *Ermoceras mogharensense*, well above the Black Limestones (Calcaires noirs).

**Distribution:** Dhurma Fm, lowest unit D3. *Darmā' Quadrangle*: JMA82.347 (UCBL-FSL 177 829, 830), Wadi al Jufayr, 24°05' N; JMA82.294, 296, 297 (UCBL-FSL 177 812 (Pl. XIX, fig. 9), 813-815, 832), lonely place north of Khashm adh Dhibi, about 24°16' N.

**Age:** Lower Upper Bajocian, Mogharensense Zone. The rich faunal association from the Sinai (Douvillé, 1916; Arkell, 1952) with *Spiroceras annulatum*, dates the base of the unit D3 and the Mogharensense Zone in the middle part of the upper Bajocian Garantiana Zone (Arkell & Lucas, 1953; Du Dresnay, 1964b; Énay *et al.*, 1986, 1987a; Énay & Mangold, 1984, 1994).

Superfamily Perisphinctoidea Steinmann, 1890

[*nom. transl.* Wedekind, 1918, p. 103, *ex Perisphinctinae* Steinmann in Steinmann & Döderlein, 1890, p. 441]

Family Perisphinctidae Steinmann, 1890

[*nom. transl.* Hyatt, 1900, p. 580, *ex Perisphinctinae* Steinmann in Steinmann & Döderlein, 1890, p. 441]

Subfamily Perisphinctinae Arkell, 1950

[*Leptosphinctinae* Arkell, 1950, p. 363] [= *Bigotitinae* Westermann, 1956, p. 271]

Genus *Leptosphinctes* Buckman, 1920

**Type species:** *L. leptus*; by original designation [= *Kubanoceras* Kakhadzé & Zesashvili, 1955, p. 707 (also Kakhadzé & Zesashvili, 1956, p. 31); = *Cleistosphinctes* Arkell *et al.*, 1957, p. 314, *non* Arkell & Lucas, 1953, p. 2258, *nec* Arkell, 1956, pp. 32, 77, 176, 264, 363, both *nom. nud.* and invalid under ICZN Code, 1999, Article 13.1; = *Oxysphinctes* Beznosov in Beznosov & Mikhaylova, 1981, p. 54; = *Bajocisphinctes* (*Obsoletosphinctes*) Beznosov in Beznosov & Mikhaylova, 1981, p. 54; = *Otiosphinctes* Beznosov, 1982, p. 130 (*Otiosphinctes* Beznosov in Beznosov & Mikhaylova, 1979, pp. 6-7, *nom. nud.*), *nom. nov. pro Praebigotites* (*Otiosphinctes*) Beznosov in Beznosov & Mikhaylova, 1981, p. 51, *non Otiosphinctes* Buckman, 1926, pl. 649)]

***Leptosphinctes aff. umbilicatus* Galacz, 2012 [m]**

Pl. XVI, fig. 3

- aff. 1973. *Leptosphinctes (Cleistosphinctes)* nov. sp. indet. Pavia, p. 134, pl. 27, fig. 5.  
 aff. 2012. *Leptosphinctes (Cleistosphinctes) umbilicatus* nov. sp., Galacz, p. 291, fig. 6 (5-7).

**Material:** An incomplete wholly septate specimen, 39 mm in diameter.

**Description:** Evolute, whorl-section compressed, the side flat and parallel, the venter rounded; dense radial ribs bifurcate high on the whorl side, the secondaries of equal strength passing across the rounded venter, more than 30 primary ribs and three deep constrictions on the outer half whorl.

**Discussion:** According to Galacz (2012), *L. umbilicatus* differs from other *Cleistosphinctes* by its very evolute coiling and dense ribbing which are exactly the main features of the Arabian specimen.

**Distribution:** Dhurma Fm, upper unit D2 (ferruginous oolitic limestone). *Shaqrā Quadrangle*: VD82.651A (UCBL-FSL 178 891), South of Jurayfah South.

**Age:** Lower Upper Bajocian, Runcinatum Zone. According to the association with European elements in Sinai and Northern Africa, Upper Bajocian age, Niortense Zone (Arkell & Lucas, 1953; Du Dresnay, 1964b; Du Dresnay *et al.*, 1985; Énay *et al.*, 1987b; Énay & Mangold, 1994). This is the range of *L. umbilicatus* in western Europe.

Subfamily Zigzagiceratinae Buckman, 1920

[*nom. transl.* Arkell, 1950, p. 363, *ex* Zigzagiceratidae Buckman, 1920, p. 30] [= *Pseudoperisphinctinae* Schindewolf, 1925; *nom. correct.* Arkell, 1950, p. 363, footnote 24, *ex* *Pseudoperisphinctidae* Schindewolf, 1925, p. 319]

Genus *Procerites* Siemiradzki, 1898

**Type species:** *Procerites schloenbachi* Grossouvre, 1906; SD ICZN Opinion 301, 1954a, p. 251. [= *Siemiradzki* Hyatt, 1900, p. 582; *Zigzagites* Buckman, 1922, pl. 301; *Parkinsonites* Buckman, 1922, pl. 302; *Phaulozigzag* Buckman, 1926, pl. 643; *Euprocerites* Wetzel, 1950, p. 76. (Howarth in Énay & Howarth, 2019).

***Procerites* sp. A**

1986. *Procerites* gr. *costulatosus* Buckman.– Énay *et al.*, *pars.*, p. 33 (tab. 1).  
 1987a. *Procerites* gr. *costulatosus* Buckman.– Énay *et al.*, *pars.*, p. 35 (tab. 1).

**Material:** One wholly septate and badly preserved specimen from the same locality and section as *Procerites* sp. gr. *intersertus* (Buckman).

**Description:** Discoidal with the whorl height growing faster than the wide, and fairly involute coiling.

**Discussion:** Only one of the two specimens (FSL 177 638) could, as formerly done in Énay *et al.* (1986, 1987a), be assigned to *P. costulatosus* (see Buckman, 1923, pl. 386, figs 1, 2), but it is too poorly preserved for a definite assignment. The few characters preserved correspond well to those of *P. costulatosus*. This latter is the type species of the genus *Phanerosphinctes* Buckman (1923) that Énay & Howarth (2019) assumed, but with doubts, to be a junior synonym of *Vermisphinctes* Buckman (1920). The species is assigned to *Procerites* by Rioult *et al.* (1997).

**Distribution:** Middle Dhurma Fm, unit D3. *Sulayyimah Quadrangle*: VD81.277 (UCBL-FSL 177 638) South of Khashm Abu al Jiwār, 21°51' N.

**Age:** Uppermost Bajocian, Planus Zone. Previously dated as Bathonian (Arkell, 1952; Imlay, 1970; Lewy, 1983; Gill *et al.*, 1985) but revised as Uppermost Bajocian, Parkinsoni Zone (Du Dresnay, 1964b; Du Dresnay *et al.*, 1985; Énay *et al.*, 1986, 1987b; Énay & Mangold, 1994), Bomfordi subzone (Rioult *et al.*, 1997).

***Procerites* gr. *intersertus* (Buckman, 1923)**

Tab. 36

- 1923b. *Lobosphinctes intersertus* n. sp. – Buckman, pl. 447, figs 1, 2.  
 1986. *Procerites* gr. *costulatosus* Buckman.– Énay *et al.*, *pars.*, p. 33 (tab. 1).  
 1987a. *Procerites* gr. *costulatosus* Buckman.– Énay *et al.*, *pars.*, p. 35 (tab. 1).

**Material:** One specimen moderately well-preserved, from the same locality and section as *Procerites* sp. A.

**Description:** Fairly evolute coiling with a high and compressed whorl-section; dense, fine and prorsiradial ribbing with constrictions, all crossing the venter.

Table 36: Measurements of *Procerites* gr. *intersertus* (Buckman).

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
UCBL-FSL 177 637 - VD81.188/1	134	n	44	33	31	0.23	58	0.43	0.70
	108		36	0.33	17	0.16	44	0.40	0.50
	82		27	0.33	-	-	30	0.36	-
<i>Lobosphinctes intersertus</i> (Buck.)	142		32.5		31		41		
	91		31		33		39.5		

**Discussion:** The specimen shows close resemblance with *Procerites intersertus* (Buckman), but the ribbing is finer and weaker. This is the type species of *Lobosphinctes* Buckman, assumed by Énay & Howarth (2019) to be a junior synonym of *Bigotites* Nicolesco (1918). However, the species is assigned to *Procerites* by Rioult *et al.* (1997).

**Distribution:** Middle Dhurma Fm, unit D3. *Sulayyimah Quadrangle*: VD81.188/1 (UCBL-FSL 177 637), South of Khashm Abu al Jiwar, 21°51' N.

**Age:** Uppermost Bajocian, Planus Zone. Previously dated as Bathonian (Arkell, 1952; Imlay, 1970; Lewy, 1983; Gill *et al.*, 1985) but revised as Uppermost Bajocian, Parkinsoni Zone (Du Dresnay, 1964; Énay *et al.*, 1986, 1987b; Du Dresnay *et al.*, 1985; Énay & Mangold, 1994), Bomfordi subzone (Rioult *et al.* in Cariou & Hantzpergue, 1997).

Genus *Metazigzagiceras* Fernández-López & Pavia, 2013

**Type species:** *Metazigzagiceras subarabicum* Fernández-López & Pavia, 2014; by original designation.

***Metazigzagiceras subarabicum* Fernández-López & Pavia, 2013 [m]**

Pl. XVIII, fig. 3; Tab. 37

1986. *Zigzagiceras (Franchia)* sp. – Énay *et al.*, p. 33 (tab. 1).

1987a. *Zigzagiceras (Franchia)* sp. – Énay *et al.*, p. 35 (tab. 1), 41, 43.

1994. *Zigzagiceras (Franchia)* sp. – Énay & Mangold, p. 170.

2010. *Franchia* sp. – Énay & Mangold, fig. 2.

2014. *Metazigzagiceras subarabicum* n. sp. – Fernández-López & Pavia, p. 734, figs 8, 19 [online from 2013; see references].

**Material:** The holotype.

**Description:** Large microconch, expected to surpass 100 mm in diameter with the phragmocone; a zigzag-stage composed of prorsidiate to subradiate, blunt sigmoid ribs reinforced in the upper flank (12 to 17 per half a whorl) but of variable strength and spacing. Outer whorl with the primaries fading (may be weathered) towards the venter. Relatively simple suture line, with broad lateral lobe.

**Discussion:** The species (still represented by the holotype only) is probably derived from *Franchia*. It was characterized by Fernández-López & Pavia (2014) by its large size, depressed whorl-section and evolute coiling. It seems to be a species endemic to the Ethiopian province.

**Distribution:** Middle Dhurma Fm, top of unit D3.

*Durma Quadrangle*: JMA82.285 (UCBL-FSL 177 639), Wadi al Hisyan, 24°45' N.

**Age:** Lower Bathonian, Tuwaiquensis Zone. As a whole, the age of the unit D3 is Late Bajocian, Planus Zone of the Arabian Province (more or less equivalent with the Parkinsoni Zone), save the uppermost beds which have been dated as Lowermost Bathonian, Tuwaiquensis Zone on the basis of the occurrence of this species as “*Zigzagiceras (Franchia)*” sp. (Énay *et al.*, 1987a, tables 1, 2; Énay & Mangold, 1994), correlated with the Parvum and Convergens subzones of the Submediterranean and NW European provinces (Énay *et al.*, 2007; Alméras *et al.*, 2010).

Subfamily Grossouvrinae Spath, 1930

[Grossouvrinae Spath, 1930, p. 36; retained under Article 40.1, ICZN Code, 1999] [= Siemiradzkiinae

Westermann, 1958, p. 75; = Gracilisphinctinae Beznosov, 1982, p. 54]

Genus *Choffatia* Siemiradzki, 1898

**Type species:** *Perisphinctes cobra* Waagen, 1875, p. 174; SD Buckman, 1920, p. 29 [= *Grossouvrina* Siemiradzki, 1898 in 1898-1899, p. 76; SD Buckman, 1920, p. 28; = *Poculisphinctes* Buckman, 1920, pl. 185; = ?*Trinisphinctes* Buckman, 1922, pl. 332; = *Klematosphinctes* Buckman, 1922, pl. 333; = ?*Cutchisphinctes* Spath, 1931, pp. 283, 285]

***Choffatia aff. kontkiewiczzi kontkiewiczzi* (Siemiradzki, 1894) [m]**

aff. 1970. *Choffatia kontkiewiczzi* (Siemiradzki 1894).– Mangold, figs 135-136; pl. 8, figs 3-5 (cum synonymy).

1986. *Grossouvrina kontkiewiczzi* (Siemiradzki).– Énay *et al.*, p. 33 (tab. 1).

1987a. *Grossouvrina kontkiewiczzi* (Siemiradzki).– Énay *et al.*, p. 36 (tab. 1).

**Material:** One specimen, wholly? septate (30 mm in diameter) and two fragments.

**Description:** Evolute coiling, rounded whorl-section and convex sides; dense and spaced ribs on the inner whorls, the furcation points not visible; outer whorl irregularly ribbed, with radial primary ribs with parabolic ribs and nodes responsible for the irregular character of the ribbing.

**Distribution:** Upper Dhurma Fm, unit D7, upper part (Hisyan Member). *Wadi ar Rayn Quadrangle*: VD80.520 (UCBL-FSL 177 170), lonely place between Khashm Hadafiyah and Wadfi al Hawtah, around 23°18'N;

Table 37: Measurements of *Metazigzagiceras subarabicum* Fernández-López & Pavia.

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
UCBL-FSL 177 639 - JMA82.285	c100	C92	25	0.25	25	0.25	60	0.60	1.00

*Durma Quadrangle*: JMA82.207 (UCBL-FSL 177 214), Khashm adh Dhibi, 24°14' N.

**Age**: Lower Middle Callovian, Ogivalis Zone, Kuntzi Horizon. A lower Middle Callovian age has been assumed previously by Énay *et al.* (1986, 1987, 2009) and Énay & Mangold (1985, 1994). The equivalence of the Ogivalis Zone with the Coronatum Zone of W Europe was established from the more diversified successions of Israel (Gill *et al.*, 1985). The Kuntzi horizon occupies the lower part of the zone.

Subfamily Kinkeliniceratinae Krishna & Ojha, 1996  
[= Sivajiceratinae Dutta & Bardhan, 2016, p. 25]

**Remarks**: The subfamily is represented by whorl fragments and specimens, too small to be determined beyond the genus level, assigned to the Subaustral genera *Obtusicoelites* or *Kinkeliniceras*. Previously included in the Proplanulitinae, they are almost certainly unrelated and conform to a provincial assemblage, the Kinkeliniceratinae. This latter is restricted to the South Tethyan Indo-Ethiopian Province (Énay & Howarth, 2019, p. 28). Small specimens show two types of preservation, internal calcareous or pyritic casts. The suture lines are not preserved in the former and it is not possible to know if they are the inner whorls of larger specimens or juveniles. There is no doubt about the pyritized specimens formerly believed juveniles (Énay *et al.*, 1986 and 1987a, pl. 6, figs 5-8). The most likely interpretation is that given by Ziegler (1967, p. 460) for juvenile Aulacostephanids from the Kimmeridge Clay of Dorset (England). It is a spat of dead juveniles on or in the immediate vicinity of the nesting site of adults normally inhabiting the deeper environments off the Arabian platform, what they visited only during the spawning-season.

Genus *Kinkeliniceras* Buckman, 1921

**Type species**: *Proplanulites kinkelini* Dacqué, 1910; by original designation

***Kinkeliniceras* (or *Sivajiceras*?) sp.**

Pl. XXVIII, fig. 2

1986. *Kinkeliniceras*. – Énay & Mangold, p. 645.

1986. Proplanulitidae (cf. *Kinkeliniceras*) indét. – Énay *et al.*, p. 33 (tab. 1), pl. 6, fig. 4.

1987a. Proplanulitidae (cf. *Kinkeliniceras*) indét. – Énay *et al.*, p. 36 (tab. 1), pl. 6, fig. 4.

**Material**: Five fragmentary specimens and ten small specimens.

**Description**: Involute to moderately evolute, whorl section oval to circular, compressed; primary ribs strong, simple or bifurcate on middle to high whorl side with intercalated secondary ribs.

**Discussion**: More involute and compressed than *Obtusicoelites*, and ribbing generally weaker.

**Distribution**: Upper Dhurma Fm, unit D7, upper part (Hisyan Member). *Shaqrā' Quadrangle*: VD82.607 and 608 (UCBL-FSL 177 167, 168, 171-173, 184/1-8, 185/1-5, 188-192) Khashm Turab, 25°03' N.

**Age**: Middle Callovian, Ogivalis Zone, Kuntzi Horizon. A lower Middle Callovian age has been assumed previously by Énay *et al.* (1986, 1987, 2009) and Énay & Mangold (1985, 1994). The equivalence of the Ogivalis Zone with the Coronatum Zone of W Europe was established from the more diversified successions of Israel (Gill *et al.*, 1985). The Kuntzi horizon occupies the lower part of the zone.

Genus *Obtusicoelites* Buckman, 1921

**Type species**: *Perisphinctes obtusicoelita* Waagen, 1875; by original designation [= *Hubertoceras* Spath, 1930, p. 35]

**Remarks**: The genus had never been cited from Saudi Arabia before Énay *et al.* (1986, 1987a) as cf.-*Obtusicoelites*. Indeed, the forms studied by these latter authors are represented by nuclei or complete juvenile specimens. These are again described and figured here. However, the genus is now represented by rare specimens which have reached the adulthood and are well-preserved, but difficult or impossible to attribute to any of the species previously described.

***Obtusicoelites gigas* nov. sp. [M]**

Pl. XXVII, fig. 1; Tab. 38

? 1985. *Erymnoceras* (?) cf. *philbyi* Arkell. – Gill *et al.*, p. 725, pl. 2, fig. 2; pl. 5, fig. 2.

1986. *Pachyerymnoceras* sp. 5. – Énay *et al.*, p. 33 (tab. 1).

1987a. *Pachyerymnoceras* sp. 5. – Énay *et al.*, p. 36 (tab. 1).

**Material**: A single large specimen, well-preserved.

**Holotype**: The adult complete specimen figured in Pl. XXVII, fig. 1a-c (UCBL-FSL 177 205).

**Origin of the name**: From the Latin *gigas*, *gigantis* = one of the Giants (mythology), which refers to its large size.

Table 38: Measurements of *Obtusicoelites gigas* nov. sp.

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
UCBL-FSL 177 205 - JMA83.199	247	175	101	0.40	88	0.35	101	0.40	0.87
	204	-	75	0.37	87	0.42	70	0.34	1.14
	160	-	60	0.37	-	-	57	0.35	

**Description:** The holotype is a fully grown specimen, with complete body chamber, the aperture poorly preserved. The body chamber is longer than three quarters of a whorl. The size is larger (247 mm in diameter) than in any other known species of *Obtusicosites*.

Moderately evolute; whorl section circular and rounded, first slightly depressed, then more compressed and higher than thick, but still wide; body chamber contracted; vertical, high umbilical wall with well-defined umbilical edge; broad rounded venter. Ornamentation: coarse and bold primary ribs, strengthened or bullate arising from the umbilical edge, bifurcating in the middle of the flank, and strengthened in the body chamber, but weakening near the aperture; secondary ribs fade in the upper flank of the body chamber, leaving a broad smooth ventral area.

Suture well-preserved, well frilled, first saddle very broad and lateral lobe showing a broad and trifurcate ending.

**Discussion:** Already quite apart from the other species of *Obtusicosites* by its large size, *O. gigas* is also distinguished by its general morphology and the costulation of the outer whorl. In the inner whorls only observable the thick periumbilical base of the primary ribs.

The body chamber considered by Gill *et al.* (1985) as a possible *E. philbyi* is insufficiently preserved to be firmly included in the new species. However, the size (237 mm in diameter) is similar to that of the holotype and the costulation is quite similar; on the other hand the whorl section is more inflates.

**Distribution:** Upper Dhurma Fm, unit D7, upper part (Hisyan Member. *Buraydah Quadrangle*: JMA83.199 (UCBL-FSL 177 205), Al Liqa, 26°26' N.

**Age:** Middle Callovian, Ogivalis Zone, Kuntzi horizon. A lower Middle Callovian age has been assumed previously by Énay *et al.* (1986, 1987, 2009) and Énay & Mangold (1985, 1994). The equivalence of the Ogivalis Zone with the Coronatum Zone of W Europe was established from the more diversified successions of Israel (Gill *et al.*, 1985). The Kuntzi horizon is in the lower part of the zone.

***Obtusicosites* gr. *devi/ushas* Spath, 1931**

Pl. XXVIII, fig. 1; Tab. 39

gr. 1931. *Obtusicosites devi* Spath, p. 301, pl. 52, figs 2, 5; pl. 54, fig. 1; pl. 55, fig. 4; pl. 58, fig. 7; pl. 62, fig. 3; pl. 65, fig. 3

gr. 1931. *Obtusicosites ushas* Spath, p. 302, pl. 52, fig. 6; pl. 53, fig. 1; pl. 56, fig. 1; pl. 57, figs 3, 7; pl. 63, fig. 6.

**Material:** A single large incomplete specimen with a short part of the body chamber; traces on the outer whorl show that the body chamber was about three quarters of whorl long and the adult size would be 240-250 mm in diameter.

**Description:** Moderately evolute; stout but compressed whorl section, broad venter and high, vertical umbilical wall, the umbilical edge rounded. Primary ribs simple or bifurcate, thickened on the umbilical margin, with intercalatory ribs and long, blunt secondary ribs crossing the venter, but fading on the living chamber.

**Discussion:** None of the species in the literature is comparable with the present specimen. The closest species could be *O. ushas* Spath (1931, pl. 56, fig. 1), but the holotype consist of only inner whorls, 110 mm in diameter. The differences in size and growth stage make the comparisons to be tentative. The coiling and the style of the ribbing are comparable, but the ornamentation of *O. ushas* is coarser. With *O. devi*, the clearest difference is the more involute coiling in comparison with the holotype of the new species.

**Distribution:** Upper Dhurma Fm, unit D7, upper part (Hisyan Member). *Buraydah Quadrangle*: JMA83.195 (UCBL-FSL 177 204), Al Liqa, 26°26' N.

**Age:** Middle Callovian, Ogivalis Zone, Kuntzi horizon. A lower Middle Callovian age has been assumed previously by Énay *et al.* (1986, 1987, 2009) and Énay & Mangold (1985, 1994). The equivalence of the Ogivalis Zone with the Coronatum Zone of W Europe was established from the more diversified successions of Israel (Gill *et al.*, 1985). The Kuntzi horizon occupies the lower part of the zone.

***Obtusicosites* sp.**

Pl. XXVII, figs 2-5

1986. *Obtusicosites* Énay & Mangold, p. 645.

1986. Proplanulitidae (cf. *Obtusicosites*) indét.– Énay *et al.*, p. 33 (tab. 1), pl. 6, figs 5-8.

1987a. Proplanulitidae (cf. *Obtusicosites*) indét.– Énay *et al.*, p. 36 (tab. 1), pl. 6, figs 5-8.

**Material:** Nine calcareous casts and ten pyritized specimens, small-sized (maximum diameter 35 mm) with the body chamber preserved.

Table 39: Measurements of *Obtusicosites* gr. *devi/ushas* Spath.

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
UCBL-FSL 177 204 - JMA83.199	206 170	c 177 -	72 65	0.35 0.38	66 -	0.31 -	75 56	0.36 0.32	0.90 -
<i>O. devi</i> Spath, 1931, pl. 55, fig. 4	127	?		0.38		0.34		0.37	
<i>O. ushas</i> Spath, 1931, holotype, pl. 56, fig. 1 (nucleus)	115	n		0.37		0.37		0.41	

**Description:** Moderately involute; whorl section rounded to slightly compressed; coarse primary ribs, simple or bifurcate on middle to high whorl side, and intercalatory secondary ribs.

**Discussion:** Pyritized specimens are surely juvenile with nearly complete body chamber half to three quarters of whorl long, with simple earliest sutures.

**Distribution:** Upper Dhurma Fm, unit D7, upper part (Hisyan member). *Shaqrā' Quadrangle:* VD82.607 and 608 (UCBL-FSL 177 176, 179-183), Khashm Turab, 25°03' N; VD82.509 (UCBL-FSL 177 193-196, 197/1-10), Khashm Aba al Hayyah, 25°2' N; *Buraydah Quadrangle:* JMA83.195 (UCBL-FSL 177 212), Al Liqa, 26°26' N.

**Age:** Middle Callovian, Ogivalis Zone, Kuntzi Horizon. A lower Middle Callovian age has been assumed previously by Énay & Mangold (1985, 1994) and Énay *et al.* (1986, 1987, 2009). The equivalence of the Ogivalis Zone with the Coronatum Zone of W Europe was established from the more diversified successions of Israel (Gill *et al.*, 1985). The Kuntzi horizon occupies the lower part of the zone.

#### Family Tullitidae Buckman, 1921

[= Morrisiceratidae Westermann, 1956, p. 262; = Bullatimorphitinae Callomon, Dietl, & Niederhöfer, 1992, p. 40]

#### Genus *Tulites* Buckman, 1921

**Type species:** *Tulites tula* Buckman, 1922, pl. 269, by original designation

[Subjective synonyms *Tulophorites*, *Madarites* Buckman, 1921, p. 45; *Pleurophorites* Buckman, 1921, p. 46; *Sphaeromorphites* Buckman, 1921, p. 49; *Trollicerat* Torrens, 1971, p. 136, *nom. nov. pro Krumbeckia* Arkell, 1951a, p. 10, obj., *non* Diener, 1915]

**Remarks:** Described for the first time as *Tulites* by Arkell (1952) the forms of Saudi Arabia present several peculiarities. First, according to Arkell (1952, p. 298) “*in Arabia there is an inversion of the faunas with respect to the overlying Micromphalites*”. In fact, in Europe only the type species of *Micromphalites* is known, everywhere below the main level of *Tulites*. Second, because in Europe the *Tulites* and *Micromphalites* characterize the Middle Bathonian, the Arabian forms have also been dated as Middle Bathonian (Arkell, 1952, p. 297; 1956, p. 299). However, recent work on the fauna and biostratigraphy of the Jurassic in Saudi Arabia (Énay *et al.*, 1986, 1987a; Énay & Mangold, 1985, 1994) and on new Arabian *Micromphalites* in France (dated Early Bathonian by Énay *et al.*, 2001), led to date the *Tulites* from Saudi Arabia (and also the *Micromphalites*) as Lower Bathonian. These elements raise the question of (i) whether these forms specific to Saudi Arabia are related or not to the forms found in Europe, (ii) and even if they should be placed in the genus *Tulites*.

Thus, *T. tuwaiqensis* Arkell from Sicily was described by Galacz (1999a, b) as “*Tulites*”. Galacz (1999b) concluded that “*The best approach is to regard as a group of specialized Ermoceras, which shows homoeomorphic similarity to tullitids, with a loss of the ventral groove*”, [thus correcting the error of the first publication (1999a) – quoted also in Zaton, 2007 – which refers to the erymoceratids, a group of Pachyceratidae with no ventral furrow and Late Bathonian-Late Callovian age]. In our preliminary publications (Énay *et al.*, 1986, 1987a; Énay & Mangold, 1985, 1994), while highlighting the differences with European species, we followed Arkell (1952, 1956) and we still think that the forms of Saudi Arabia are true *Tulites*, not homeomorphs (see Mangold & Gygi, 1997, p. 506).

On the one hand, the last known *Ermoceras*, in the lowest levels of unit D3, are much older than the first *Tulites* of the overlying unit D4. In addition, the species of the lower D3 unit, *E. mogharensis* as well as *K. inerme*, are far removed from the *Tulites*. The cadiconic *Telemoceras*, morphologically closest to *Tulites*, are not known beyond the D2 unit. On the other hand, the new material shows that these forms of Saudi Arabia share quite a few characters in common with the *Tulites* of Europe.

- Most specimens are all incomplete and the size is surely larger; a few specimens reach dimensions comparable to those of European forms, diameter of 100 mm for a specimen attributed to *T. tuwaiqensis* (FSL 177 370) and up to 127 mm for a specimen too poorly preserved for specific determination (FSL 177 385 bis).
- Fading of the ornamentation in the transition zone between the septate whorls and the body chamber.
- Cadicone coiling of the inner whorls with a wide and deep umbilicus, crater-like, bounded by a vertical umbilical wall; eccentric coiling of the outer whorl and contracted body chamber.

In conclusion, the creation of a new genus does not seem justified, as much by the data of the stratigraphy as by that of the morphology, and the belonging to the genus *Tulites* is not in doubt, but so far no form microconch of the Arabian *Tulites* could not be identified. This does not call into question the probable origin of Tullitidae from Perisphinctidae (*Zigzagiceratinae*), rather than Sphaeroceratidae, based on perisphinctid-like inner whorls. But remains to know the relations between the Arabian and European *Tulites*. The presence of an isolated form in western Sicily (Galacz, 1999a, b) suggests a history comparable to that of the *Micromphalites* which, from their Bathonian Arabian ancestor, dispersed both, on the one hand to Madagascar and India, on the other hand to W Europe (via Tunisia, Morocco and Spain). It is to be hoped and waited for the discovery in Europe of larger populations of Arabian *Tulites*, such as those of the *Micromphalites* of Nièvre (Énay *et al.*, 2001). In this hypothesis, the Middle Bathonian explosion would translate into a greater success of the Arabian *Tulites* than

the *Micromphalites* at the origin of the only type species of the genus, *M. micromphalus*.

***Tulites tuwaiqensis* Arkell, 1952**

Pl. XXIII, figs 6-8; Tab. 40

1952. *Tulites tuwaiqensis* n. sp. – Arkell, p. 284, pl. 25, fig. 3a-c.  
 1986. *Tulites tuwaiqensis* Arkell.– Énay *et al.*, p. 33 (tab. 1).  
 1987a. *Tulites tuwaiqensis* Arkell.– Énay *et al.*, p. 35 (tab. 1).  
 1994. *Tulites tuwaiqensis* Arkell.– Énay & Mangold, p. 170.  
 1999a. “*Tulites*” *tuwaiqensis* Arkell.– Galacz, p. 160, pl. 2, fig. 1.  
 1999b. “*Tulites*” *tuwaiqensis* Arkell.– Galacz, pp. 608, 609, text-fig 3a-c.

**Material:** Four more or less well-preserved specimens at different growth stages, some with part of the body chamber (one half whorl portion in the largest).

**Description:** The mid-sized specimens (FSL 177 371, 395, 400) with part of the body chamber are similar to the holotype.

Tubercles in the umbilical edge; ribbing fading out soon; some specimens preserve growth-lines. Larger specimens have high compressed body chamber, with the flanks converging to the rounded venter.

**Discussion:** *T. tuwaiqensis* is well distinguished from *T. arabicus* when the inner whorls are considered, the former with the whorl section less depressed and the umbilical edge less sharp. Complete specimens of *T. arabicus* for comparison are unknown but in those

with part of the body chamber preserved the ontogenic development is the same, the outer whorl rapidly compressed and contracted, and the ribbing fading out rapidly.

**Distribution:** Dhurma Fm, unit D4. *Durma Quadrangle*: JMA82.191 (UCBL-FSL 177 399), Khashm adh Dhi’bī; *Shaqrā’ Quadrangle*: VD82.482 UCBL-FSL 177 395) and 482B (UCBL-FSL 177 408), Jurayfah South; VD82.354 A (UCBL-FSL 177 400), and B (UCBL-FSL 177 370, 371), lonely place between Jurayfah South and Jurayfah, 25°30’ N to 38’ N.

**Age:** Lower Bathonian, Tuwaiqensis Zone. The equivalence with the lower part of the Zigzag zone, Early Bathonian, in Europe is deduced from its position between the Planus Zone (*Thambites* and *Rebouliceras avus* Assemblage) of the late Bajocian and Clydocromphalus Zone (*Micromphalites* Fauna) well dated from the Lower Bathonian.

***Tulites arabicus* Arkell, 1952**

Pl. XXIII, figs 1-3; Tab. 41

1952. *Tulites arabicus* Arkell, p. 283, pl. 25, figs 5-7.  
 1986. *Tulites arabicus* Arkell.– Énay *et al.*, p. 33 (tab. 1).  
 1987a. *Tulites arabicus* Arkell.– Énay *et al.*, p. 35 (tab. 1).

**Material:** Thirty-three specimens and fragments more or less well-preserved, at different growth stages, some with part of the body chamber.

**Description:** In the best preserved specimen (FSL

Table 40: Measurements of *T. tuwaiqensis* Arkell.

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
Holotype: Arkell, 1952, pl. 25, fig. 3	68	?	25	0.36	22	0.32	26	0.38	0.88
UCBL-FSL 177 370 - VD82.354A	100	?	--	--	--	---	--	--	--
	92		34	0.37	--	--	33	0.36	--
UCBL-FSL 177 371 - VD82.354A	60	C 41	24	0.40	--	--	20	0.33	--
	47		19	0.40	20	0.42	16	0.34	1.05
	38		15	0.39	--	--	13	0.34	--

Table 41: Measurements of *T. arabicus* Arkell.

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
UCBL-FSL 177399 – JMA82.191	77	?	30	0.38	--	--	27	0.35	--
	47		21	0.44	28	0.59	18	0.38	1.33
UCBL-FSL 177 372 – VD82.354A (slightly crushed)	59	?	23	0.38	25	0.42	18	0.30	1.08
	39		17	0.43	24	0.61	--	--	--
UCBL-FSL 177 402 – VD82.354A (best preserved specimen)	51	?	17.5	0.34	37	0.72	17.5	0.34	2.1
	46		15	0.32	39	0.84	18	0.39	2.6
UCBL-FSL177 409 – JMA83-236 (slightly distorted)	31	?	9	0.29	21	0.67	11.7	0.37	2.33
UCBL-FSL 177 403 – VD82.354A	22	?	6	0.27	14.5	0.65	9	0.40	2.41
	12		5	0.41	8	0.66	5	0.41	1.66

177 402), 51 mm in diameter, the transition zone where the ribbing fades out and the whorl-section contracts is missing. Traces of a completely missing whorl are preserved on the side opposite from the figured one and the final diameter would reach up to 100 mm or more.

Cadicone inner whorls, with deep crater-like umbilicus and tuberculate umbilical edge, broad venter and depressed whorl-section. Inconspicuous bifurcated ribs arise from the umbilical tubercles and cross the venter, then disappear onwards at the time that the whorl contracts. Less well-preserved specimens show part of the outer whorl and body chamber high and compressed, with convergent sides and rounded venter. The specimen FSL 177 408 is a portion of body chamber with the mouth border partly preserved, simple and preceded by a constriction; it is probably a juvenile specimen.

**Discussion:** As pointed out by W. J. Arkell (1952, p. 284), the inner whorls quite distinctly distinguish *T. arabicus* and *T. tuwaiqensis*, but the separation of the two species is also clear from the adult whorls. In the few forms with a part the body chamber preserved, this is always higher, more compressed, and much more involute, leaving hardly visible the row of tubercles of the inner whorls.

**Distribution:** Dhurma Fm, D4 Unit. *Wadi al Mulayh Quadrangle:* JMA80.328 (UCBL-FSL 177 397), Jabal Shimrakh, 22°10' N; JMA80.558 (UCBL-FSL 177 396), lonely place between J. Shimrakh, 22°10' N and K. Munayyifiyah, 22°11' N; *Darmā' Quadrangle:* JMA82.191 (UCBL-FSL 177 399), Khashm adh Dhibi, 24°14' N; *Shaqrā' Quadrangle:* VD82.629 (UCBL-FSL 177 387-389/2) and 631 (UCBL-FSL 177 401), Al Lughf, 25°10' N; VD82.482 (UCBL-FSL 177 402-407), and 482B (UCBL-FSL 177 398), Jurayfah South; VD82.354 A (UCBL-FSL 177 372-386, 410), lonely place between Jurayfah South and Jurayfah, 25°30' N to 38' N; *Buraydah Quadrangle:* JMA83.236 (UCBL-FSL 177 409), Nafud al Mazhur, 26°55' N.

**Age:** Lower Bathonian, Tuwaiqensis Zone. The time-equivalence with the lower part of the Zigzag zone, Early Bathonian, in Europe is deduced from its position between the Planus Zone (*Thambites* and *Rebouliceras avus* Assemblage) of Late Bajocian age and Clydocromphalus Zone (*Micromphalites* Fauna) well dated from the Lower Bathonian.

### *Tulites erymnoides* Arkell, 1952

Pl. XXIII, figs 4-5; Tab. 42

1952. *Tulites erymnoides* n. sp. – Arkell, p. 284 pl. 25, figs 1, 4.

1986. *Tulites erymnoides* Arkell.– Énay *et al.*, p. 33 (tab. 1).

1987a. *Tulites erymnoides* Arkell.– Énay *et al.*, p. 35 (tab. 1).

**Material:** Four specimens, three nuclei and a large fragment.

**Description:** The small septate specimen (FSL 177 390) and the large fragment with traces of a missing whorl (FSL 177 391) match the description given by Arkell (1952). The ribbing style, stronger, sharper and more persistent than in other Arabian species.

**Distribution:** Dhurma Fm, D4 Unit. *Shaqrā' Quadrangle:* VD82.482 (UCBL-FSL 177 390, 391) and 482B (UCBL-FSL 177 392, 393), Jurayfah South.

**Age:** Lower Bathonian, Tuwaiqensis Zone. The time-equivalence with the lower part of the Zigzag zone, Early Bathonian, in Europe is deduced from its position between the Planus Zone (*Thambites* and *Rebouliceras avus* Assemblage) of Late Bajocian age and Clydocromphalus Zone (*Micromphalites* Fauna) well dated from the Lower Bathonian.

### *Tulites* n. sp. A

Pl. XXIII, fig. 9

**Material:** Two small specimens from the same locality, one suitable for description, the second strongly distorted.

**Description:** Small-sized and involute, whorl-section fairly depressed, with arched venter, crater-like umbilicus deep and narrow; a row of well-marked tubercles surrounding the umbilical edge wherefrom arise two coarse ribs, first prorsiradiate, then radially oriented and crossing the arched venter.

**Discussion:** *Tulites* n. sp. A shows resemblance with *T. erymnoides*, but this displays more evolute inner whorls as suggested by the specimens figured in Arkell (1952, pl. 25, fig. 4) and herein (Pl. XXIII, fig. 5). These two specimens like those of *Saudisphinctes arabicus* n.gen. n.sp. come from a very high position in the unit D4 and it is supposed that the corresponding horizon exists only in this locality and are missing in the other sites studied.

Table 42: Measurements of *T. erymnoides* Arkell.

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
UCBL-FSL 177 390 – VD82.482	29 6	?	9.5 6	0.32 0.30	12.5 9.5	0.43 0.41	12 10	0.41 0.50	1.31 1.58
Holotype. Arkell, 1952, pl. 25, fig. 1a, b. SM. F10764	55	?	19	0.34	23	(0.41)	23	(0.41)	1.21
Syntype. Arkell, 1952, pl. 25, fig. 4a, b. SM. F10767	27	?	8	0.29	19	0.70	13	0.48	2.37

**Distribution:** Dhurma Fm, unit D4, uppermost part. *Shaqrā' Quadrangle*: VD82.632 (UCBL-FSL 177 424, 425), Al Lughf, 25°10' N.

**Age:** Lower Bathonian, Tuwaiqensis Zone. The time-equivalence with the lower part of the Zigzag zone, Early Bathonian, in Europe is deduced from its position between the Planus Zone (*Thambites* and *Rebouliceras avus* Assemblage) of Late Bajocian age and Clydocromphalus Zone (*Micromphalites* Fauna) well dated from the Lower Bathonian.

Family *incertae sedis*  
Subfamily *incertae sedis*

Genus *Saudicostites* nov.

**Type species:** *Saudicostites arabicus* nov. sp.

**Origin of name:** from Saudi the name of the country where the type specimen was found, and from Latin *costa*, *costae* = rib (s).

**Diagnosis:** Involute shell with high compressed whorl section, resembling pseudocosmocerotins but with no small ventral tubercles.

**Remarks:** *S. arabicus* and the only other associated species, *Tulites* n. sp. A, were found in high layers within the unit D4 assumed that the corresponding horizon occurs only in this locality, missing in the other localities studied. However, being situated stratigraphically between the *Planus* fauna below and the *Micromphalites* Fauna above, this level is well dated as Lower Bathonian. The most recent review of the Lower Bathonian perisphinctid genera and families (Énay & Howarth, 2019) do not include a genus or family that could comprise the new genus.

***Saudicostites arabicus* nov. sp. (m)**

Pl. XXII; fig. 5; Tab. 43

1986. New genus and species.—Énay *et al.*, p. 33 (tab. 1).

1987a. New genus and species.—Énay *et al.*, pp. 35 (tab. 1), 39.

**Holotype:** The specimen figured in Pl. XXII, fig. 5a-b (UCBL-FSL 177 418).

**Origin of name:** From the Latin *arabicus*, *a*, *um*: Arabian.

**Material:** Six specimens; only the holotype (35 mm in diameter) is well-preserved.

**Description:** Involute shell with the whorl section high and compressed, the maximum thickness at mid-flank, narrow and rounded venter; dense and prominent ribbing with bifurcate primary ribs and a few simple; the dorsal

part weakened, the secondary ribs more prominent on the ventral margin, projected forwards and forming a chevron on the venter.

**Discussion:** No published genera of Early Bathonian age matches with *S. arabicus* n. gen. n. sp. By its involute coiling and the type of ribbing, the closest morphology is *Sokurella galaczi* Mitta, 2004, in particular the microconch and the inner whorls of the macroconch. Other similar form is the juvenile form of *Pseudocosmoceras michalskii* (Borissjak, in Mitta, 2004, pl. 4, figs 3a, b, 4), but these are Pseudocosmocerotinae of which the microconchs and the inner whorls of the macroconch are characterized by either a well-pronounced ventral band or a tabulate venter bordered by small tubercles (Énay & Howarth, 2019, p. 18), whereas in *S. arabicus* the secondary ribs are reinforced in the ventral region. This significant difference excludes *S. arabicus* n. gen. n. sp. from the subfamily Pseudocosmocerotinae.

**Distribution:** Dhurma Fm, unit D4, uppermost part. *Shaqrā' Quadrangle*: VD82.632 (UCBL-FSL 177 418-423), Al Lughf, 25°10' N.

**Age:** Lower Bathonian, Tuwaiqensis Zone. The time-equivalence with the lower part of the Zigzag zone, Early Bathonian, in Europe is deduced from its position between the Planus Zone (*Thambites* and *Rebouliceras avus* Assemblage) of Late Bajocian age and Clydocromphalus Zone (*Micromphalites* Fauna) well dated from the Lower Bathonian.

Family Pachyceratidae Buckman, 1918  
[= Erymnoceratidae Breistroffer, 1947]

Genus *Erymnoceras* Hyatt, 1900  
Subgenus *Erymnoceras* Hyatt, 1900

**Type species:** *Ammonites coronatus* Bruguière, 1789; by original designation

[= *Doliolumites* Breistroffer, 1947, p. 101; *Rollierites* Jeannot, 1951, p. 124]

**Remarks:** The genus is known only from the unit D7 of the Dhurma Fm and there are very few specimens, mainly nuclei.

***Erymnoceras (Erymnoceras) cf. coronatum***  
**(d'Orbigny, 1845)**

Tab. 44

cf. 1848. *Ammonites coronatus* Bruguière.—d'Orbigny, p. 465; pl. 168, figs 1-8; pl. 169, figs 1-4.

cf. 1994. *Erymnoceras coronatum* (Bruguière).—Fischer *et al.*, p. 150, pl. 62, fig. 3a-c; pl. 63, figs 1a-b, 2, 3a-b.

Table. 43: Measurements of *Saudicostites arabicus* nov. sp.

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
UCBL-FSL 177 418 - VD82.632	35	? 26	14	0.40	15	0.42	9	0.35	1.07

**Material:** Three specimens, two septate whorl fragments, and poorly preserved inner whorls.

**Description:** The largest specimen, only 102 mm in diameter and wholly septate, shows cadicone and coronatiform shell-shape, strongly depressed whorl section, nearly twice wider than high, with deep and relatively wide umbilicus. Ribbing made up of coarse primary ribs falsely tuberculate, irregularly trifurcate or bifurcate.

**Distribution:** Dhurma Fm, unit D7 (Hisyan). *Durma Quadrangle:* JMA82.402 (UCBL-FSL 177 220), lonely place north of Wadi al Jufayr, 24°05' N; *Buraydah Quadrangle:* JMA83.199 (UCBL-FSL 177 206, 222), Al Liqa, 26°26' N.

**Age:** Middle Callovian, Ogivalis Zone. An Early Middle Callovian age has been assumed previously by Énay *et al.* (1986, 1987, 2009) and Énay & Mangold (1985, 1994). The time-equivalence of the Ogivalis Zone with the Coronatum Zone of W Europe was established from the more diversified successions of Israel (Gill *et al.*, 1985).

***Erymnoceras (Erymnoceras) nov. sp. A [m]***

Pl. XXVIII, fig. 3; Tab. 45

1986. *Erymnoceras* cf. *schloenbachi* Roman in Jeannet.–Énay *et al.*, p. 33 (tab. 1), pl. 6, fig. 2a-c.

1987a. *Erymnoceras* cf. *schloenbachi* Roman in Jeannet.–Énay *et al.*, p. 36 (tab. 1), pl. 6, fig. 2a-c.

**Material:** One small specimen partially crushed with less than a quarter whorl of the body chamber.

**Description:** Involute, inner whorls fairly depressed, the sides and venter rounded, vertical umbilical wall and angular umbilical edge, probably with but very small tubercles, not well-preserved, and blunt (? secondary) ribs prorsiradiate onto the venter. Following the crushed part of the shell, about a quarter whorl long, the beginning

of the body chamber shows drastic changes. The whorl-section becomes strongly depressed and arched, the ribbing with short and slightly tuberculate primary ribs from which arise three secondary ribs, crossing the venter with no changes.

**Discussion:** Contrary to Énay *et al.* (1986, 1987a) this specimen does not belong to *Erymnoceras* cf. *schloenbachi* as interpreted by Jeannet (1951). Only the inner whorls recall this latter. The drastic changes in the whorl-section and the ribbing of the body chamber suggest that the present specimens is a microconch, but currently does not match entirely any known species.

**Distribution:** Dhurma Fm, unit D7 (Hisyan). *Buraydah Quadrangle:* JMA83.199 (UCBL-FSL 177 223), Al Liqa, 26°26' N.

**Age:** Middle Callovian, Ogivalis Zone. An Early Middle Callovian age has been assumed previously by Énay *et al.* (1986, 1987, 2009) and Énay & Mangold (1985, 1994). The time-equivalence of the Ogivalis Zone with the Coronatum Zone of W Europe was established from the more diversified successions of Israel (Gill *et al.*, 1985).

***Erymnoceras (Erymnoceras) cf. schloenbachi***  
**(Roman, 1930)**

Pl. XXVIII, fig. 4; Tab. 46

cf. 1930. *Stepheoceras schloenbachi* Roman, p. 173, pl. 13, fig. 6 (lectotype designated by Arkell, 1952).

? 1952. *Pachyceras* cf. *schloenbachi* Roman.–Arkell, p. 291, pl. 30, fig. 1.

1986. *Erymnoceras* cf. *schloenbachi* Arkell non Roman.–Énay *et al.*, p. 33 (tab. 1).

1987a. *Erymnoceras* cf. *schloenbachi* Arkell non Roman.–Énay *et al.*, p. 36 (tab. 1).

**Material:** A single small-sized and wholly septate specimen, 55 mm in diameter.

Table 44: Measurements of *Erymnoceras (E.)* cf. *coronatum* (d'Orbigny).

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
UCBL-FSL 177 206 - JMA83.199	102	n	38	0.37	51	0.50	36	0.35	1.34
Neotype M.N.H.N. Paris, coll. d'Orbigny 3185A-2.	205	?	66.5	0.32	-	-	118	0.35	-
	183		64.2	0.35	126	0.69	80	0.39	1.96
	166		60	0.36	114	0.68	66	0.36	1.90
M.N.H.N. Paris, coll. d'Orbigny 3176A-1.	56	?	20.5	0.36	45	0.80	21.2	0.38	2.19
	51		18	0.35	43.2	0.84	19.5	0.38	2.40

Table 45: Measurements of *Erymnoceras (E.)* n. sp. A [m].

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
UCBL-FSL 177 223 - JMA83.199	45	42.5	20	0.44	31	0.68	14	0.31	1.55
	35		c 15	0.42	18	0.51	11	0.31	1.2
	25		12.5	0.50	15	0.60	6.5	0.26	1.2

Table 46: Measurements of *Erymnoceras* (*Erymnoceras*) cf. *schloenbachi* (Roman, 1930).

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
UCBL-FSL 177 229 - JMA83.199	5	n	21	0.47	18	0.40	14	0.31	0.86
	33		16	0.48	14.5	0.44	7	0.21	0.90
	23		11	0.48	11	0.48	c 5	0.21	1.00
Holotype: Roman, 1930, pl. 13, fig. 6. UCBL-FSL 11 650	45	?	20.07	0.45	20	0.44	10.55	0.23	0.97
	25		11.6	0.46	11.5	0.46	6.5	0.26	0.99

**Description:** Fairly compressed, planulate shell, whorl-section high, the maximum thickness on the rounded umbilical edge, the sides slightly convergent, the venter rounded, short primary ribs not tuberculate or strengthened, from which secondaries emerge, the branching being not well-preserved, projected and stronger ventrally, crossing the ventral area without any change.

**Discussion:** The specimen figured by Roman (1930), called “unique” by its author, is thus the holotype by monotypy (ICZN, 1999, articles 68.3 and 73.1.2) of *Stepheoceras schloenbachi*. The designation of a lectotype by Arkell (1952) was not necessary. Roman assumed that his new species is close to the “Schloenbach type” (1865, pl. 31, fig. 1a-c) figured as *Ammonites ajax* d’Orbigny (1850), but considered by Roman as distinct from *A. ajax* d’Orbigny created without figuration. This mention is worth designation of the specimen of Schloenbach as lectotype of *A. ajax* Schloenbach, not d’Orbigny.

Roman followed therefore the proposition of R. Douvillé (1912), who had already stated that the Schloenbach’s *Ammonites ajax*, “latter figured in *Prodrome’s* publication”, “becomes by the very nature of things the type of the species”. He advocated the disregarding of the species of d’Orbigny, not figured, for the benefit of *Ammonites ajax* Schloenbach, proposal falling within the framework of inversion of precedence (ICZN, 199, articles 29.9.1 and 2); thus, *Ammonites ajax* d’Orbigny would become a *nomen oblitum* and *Ammonites ajax* Schloenbach a *nomen protectum*. The situation was complicated by Thevenin (1925), showing (pl. 35, figs 12-13 and 14-15) “two samples from d’Orbigny collection, No. 3160 A, from Mamers (Sarthe)”, close to that figured by Schloenbach, especially that in figs 14-15. The latter specimen is only quoted by Jeannet (1950), author of the most complete study on the Callovian *Erymnoceras*, who mentions *E. ajax* (d’Orbigny) and *E. schloenbachi* (Roman), without ever mentioning *E. ajax* (Schloenbach), nor the comments and the position adopted by Douvillé and followed by Roman. *E. schloenbachi* (Roman) seems close to *E. ajax* (Schloenbach) as Roman assumed, save it is more involute and the ribbing is weaker. Coiling distinguishes also the Roman species from *E. ajax* (d’Orbigny), the primaries not so obvious in the former resulting probably from weathering. Both *Ammonites ajax* species are very close, the specimen of Schloenbach

being distinguished by its stronger ribbing, perhaps increased in the drawing.

**Distribution:** Dhurma Fm, unit D7 (Hisyan). *Buraydah Quadrangle*: JMA83.199 (UCBL-FSL 177 229), Al Liqa, 26°26’ N.

**Age:** Middle Callovian, Ogivalis Zone. An Early Middle Callovian age has been assumed previously by Énay *et al.* (1986, 1987, 2009) and Énay & Mangold (1985, 1994). The time-equivalence of the Ogivalis Zone with the Coronatum Zone of W Europe was established from the more diversified successions of Israel (Gill *et al.*, 1985).

Genus *Pachyerymnoceras* Breistroffer, 1947

**Type species:** *Pachyceras jarryi* Douvillé, 1912; by original designation

**Remarks:** *Pachyerymnoceras* is the genus most frequent among the representatives of Pachyceratidae with original forms sometimes confused with *Pachyceras* (Lewy, 1983; Gill *et al.*, 1985). In a first examination of these faunas (Énay & Mangold, 1994) we have underlined the existence of characters specific to each of the faunas known along the western southern margin of the Tethys, in W Algeria (Mangold, 1988), in Tunisia (unpublished), Sinai and Israel (Lewy, 1983; Gill *et al.*, 1985; unpublished new collection from G. Moghara by R. Énay and C. Mangold). Especially those from N Africa opposed to more homogeneous Arabian and Israelian forms. This new examination leads to a more nuanced position that is based on the confrontation between the material of Arabia and that of Israel.

Dimorphism within *Pachyerymnoceras* is a rather problematic issue. Lewy (1983) refers to dimorphism only in his discussions of forms figured by other authors and often in the form of “microconch” or “macroconch”, which seems to question the true existence of dimorphism. Even more, his descriptions do not allow us to know the state of development achieved by the specimens described or figured, whether they are nuclei, juveniles, or fully-grown adults. On the other hand, the reference to the existence of dimorphs is constant in the descriptions by Gill *et al.* (1985), without bringing all the desirable clarity to the *Pachyerymnoceras* fauna in Israel.

***Pachyerymnoceras cf. philbyi* Arkell, 1952 [m]**

Tab. 47

1952. *Erymnoceras philbyi* n. sp. – Arkell, p. 290, pl. 29, figs 1 (holotype), 2, 3.
1958. *Erymnoceras* aff. *dorothea* Spath.– Hudson, p. 418.
- non 1970. *Erymnoceras* cf. *E. philbyi* Arkell.– Imlay, p. D12, pl. 2, figs 12, 13.
- non 1975. *Erymnoceras* (?) cf. *philbyi* (Arkell).– Gill & Tintant, p. 104.
1983. *Pachyerymnoceras philbyi* (Arkell).– Lewy, p. 24, pl. 2, fig. 2; pl. 3, fig. 10.
- non 1983. *Pachyerymnoceras philbyi* (Arkell).– Lewy, p. 24, pl. 2, fig. 7 (= Imlay, 1970, pl. 2, fig. 12).
- non 1985. *Erymnoceras* (?) cf. *philbyi* (Arkell).– Gill *et al.*, p. 725, pl. 2, fig. 2; pl. 5, fig. 2.
1986. *Pachyerymnoceras* n. sp. – Énay *et al.*, p. 33 (tab. 1).
- 1987a. *Pachyerymnoceras* n. sp. – Énay *et al.*, p. 36 (tab. 1).
- non 2015. *Erymnoceras philbyi* Arkell.– Abelhady & Fürsich, fig. 14/O-P.

**Material:** One incomplete microconch with part of the body chamber without the aperture, not well-preserved and slightly distorted.

**Description:** The fragment of the body chamber a quarter-whorl long suggests that it is an adult microconch. Although slightly distorted the septate whorls with a depressed whorl-section and the tuberculate umbilical edge resemble *P. philbyi*. The fragment of the body chamber shows a whorl-section barely wider than high, the venter is smooth and rounded and carries five forwardly projected strong ribs. These features lead us to consider this specimen as the possible microconch of *P. philbyi*.

**Distribution:** Dhurma Fm, unit D7 (Hisyan). *Darmā'*

**Quadrangle:** JMA82.231 (UCBL-FSL 177 210), lonely place north of Khashm Hisyan, 23°45' N.

**Age:** Middle Callovian, Ogivalis Zone. An Early Middle Callovian age has been assumed previously by Énay *et al.* (1986, 1987, 2009) and Énay & Mangold (1985, 1994). The time-equivalence of the Ogivalis Zone with the Coronatum Zone of W Europe was established from the more diversified successions of Israel (Gill *et al.*, 1985).

***Pachyerymnoceras* nov. sp.?**

Pl. XXX, fig. 2; Tab. 48

1986. *Pachyerymnoceras* cf. *levantinense* Lewy.– Énay *et al.*, p. 33 (tab. 1), pl. 6, fig. 1a-c.

1987a. *Pachyerymnoceras* cf. *levantinense* Lewy.– Énay *et al.*, p. 36 (tab. 1), pl. 6, fig. 1a-c.

**Material:** Five well-preserved, wholly septate small-sized specimens, the largest 48 mm in diameter.

**Description:** Involute cadicone shell, whorl-section depressed and coronate, the width twice the whorl high and deep, rounded, roof-shaped venter, crater-like umbilicus, with tuberculate umbilical edge and vertical umbilical wall, strong ribs branching from tubercles into two secondaries.

**Discussion:** Formerly compared with *P. levantinense*, these small-sized specimens are excluded here for they differ by the much thicker and depressed whorl-section, with a deep and vertical umbilical wall. Since the middle and adult whorls are missing, it is not possible to propose a definite determination.

These specimens also resemble *Pachyerymnoceras jarryi*, especially the inner whorls (Douvillé, 1912, pl. 7 figs 4, 4a, 7-8) with the whorl-section also very depressed, but the microconch form recently illustrated by Charpy

Table 47: Measurements of *Pachyerymnoceras cf. philbyi* and *P. philbyi* Arkell. \*From Arkell (1952, pl. 29, fig. 1a).

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
UCBL-FSL 177 210 - JMA82.231	105	75	28	0.26	(30)	(0.30)	50	0.48	1.07
Possible microconch	66		28	0.42	33	0.50)	28	0.42	1.17
Holotype: Arkell, 1952, pl. 29, fig. 1a, b (M)	165	c 115	53	0.32	-	-	70	0.42	1.27
	150	-	54*	0.36	69*	0.46	55*	0.37	1.15
	70	-	32*	0.46	37*	0.53	24*	0.35	

Table 48: Measurements of *Pachyerymnoceras* nov. sp.?

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
UCBL-FSL 177 228 - JMA82.199	48	n	18	0.37	40	0.83	19	0.39	2.2
	32		12	0.37	27.5	0.85	12	0.36	2.29
UCBL-FSL 177 225 - JMA82.199	31	n	12	0.38	-	-	11.5	0.36	-
	25		9	0.36	21	0.84	9	0.36	2.33
UCBL-FSL 177 226 - JMA82.199	24	n	9	0.38	18	0.75	8.5	0.35	2
	19		7	0.37	14.5	0.76	7.5	0.40	2.07

& Thierry (1977, pl. 5, fig. 2a-c, neotype and fig. 3a-c) shows a section at least noticeably depressed and more arched. The largest (but distorted) specimen (UCBL-FSL 177 202) is wholly septate at about 82 mm in diameter, suggesting that it would be the macroconch.

**Distribution:** Dhurma Fm, unit D7 (Hisyan). *Shaqrā' Quadrangle*: VD82.640 (UCBL-FSL 177 198), lonely place north of Khashm Turab about 25°20' N; *Buraydah Quadrangle*: JMA82.185 (UCBL-FSL 177 230), south of Az Zilfi, 26°12' N; JMA83.199 (UCBL-FSL 177 225-228), Al Liqa, 26°26' N; dubious specimens: JMA83.280 (UCBL-FSL 177 202, 203), Az Zilfi, 26°17' N.

**Age:** Middle Callovian, Ogivalis Zone. An Early Middle Callovian age has been assumed previously by Énay *et al.* (1986, 1987, 2009) and Énay & Mangold (1985, 1994). The time-equivalence of the Ogivalis Zone with the Coronatum Zone of W Europe was established from the more diversified successions of Israel (Gill *et al.*, 1985).

***Pachyerymnoceras arabicum* n. sp. [M]**

Pl. XXIX, fig. 1; Tab. 49

1986. *Pachyerymnoceras* n. sp. 4.– Énay *et al.*, p. 33 (tab. 1).  
1987a. *Pachyerymnoceras* n. sp. 4.– Énay *et al.*, p. 36 (tab. 1).  
2009. *Pachyerymnoceras* sp. – Énay *et al.*, p. 25, photo 7.

**Holotype:** The specimen figured in Pl. XXIX, fig. 1a-c (UCBL-FSL 177 159).

**Origin of name:** From the Latin *arabicus*, *a*, *um*: Arabian, Arabic.

**Material:** The holotype, a nearly complete well-preserved macroconch without the aperture and one fragment third a whorl long of the body chamber.

**Description:** Medium-sized, evolute and regular coiling; whorl section wider than high, depressed, contracted just

before reaching the aperture; deep crater-like umbilicus with tuberculate umbilical edge, vertical and smooth umbilical wall. Strong ribs branching from tubercles into 2 or 3 secondaries. Last adult whorl with non-tuberculate and strong, swollen ribs, ventrally inflated and projected forwards on the final part of the body chamber.

**Discussion:** *P. arabicum* n. sp. shows general resemblance with *P. philbyi* and similar slow and regular coiling, by which we long hesitated before adding a new species. But the whorl section remains depressed nearly up to the end of the body chamber in contrast to *P. philbyi*, whose section, depressed in the inner whorls, early becomes more rounded. Furthermore, the slightly eccentric coiling of the outer whorl is lacking. Finally, the ribs, more often trifurcate than bifurcate in *P. philbyi*, are exceptionally trifurcate in *P. arabicum*. All these elements lead us to the establishment of a new species.

**Distribution:** Tuwaiq Mountain Limestone Fm, unit T1. *Shaqrā' Quadrangle*: VD82.618 (UCBL-FSL 177 159) and VD82.617 (UCBL-FSL 177 161), Khashm Turab, 25°03' N.

**Age:** Middle Callovian, Ogivalis Zone. An Early Middle Callovian age has been assumed previously by Énay *et al.* (1986, 1987, 2009) and Énay & Mangold (1985, 1994). The time-equivalence of the Ogivalis Zone with the Coronatum Zone of W Europe was established from the more diversified successions of Israel (Gill *et al.*, 1985).

***Pachyerymnoceras* cf. *praecox* Mangold, 1988 [M]**

Pl. XXX, fig. 1; Tab. 50

1986. *Pachyerymnoceras* n. sp. 3.– Énay *et al.*, p. 33 (tab. 1).  
1987a. *Pachyerymnoceras* n. sp. 3.– Énay *et al.*, p. 36 (tab. 1).

Table 49: Measurements of *Pachyerymnoceras arabicum* n. sp. compare with *P. philbyi* (Arkell). \*From Arkell (1952, pl. 29, fig. 1a).

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
UCBL-FSL 177 159 - VD82.618 (M)	190	120	67	0.35	71	0.37	70	0.36	1.05
	150	-	52	0.34	78.5	0.52	53	0.35	1.50
	120	-	44	0.36	68	0.56	41	0.34	1.55
<i>P. philbyi</i> Arkell, 1952, holotype, pl. 29, fig. 1a, b (M.)	165	c 115	53	0.32	-	-	70	0.42	1.27
	150		54*	0.36	69*	0.46	55*	0.37	1.15
	70		32*	0.46	37*	0.53	24*	0.35	

Table 50: Measurements of *Pachyerymnoceras* cf. *praecox* Mangold [M].

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
UCBL-FSL 177 146a - JMA82.346	c 250	180	-	-	-	-	-	-	-
	195		76.5	0.39	-	-	62	0.31	-
Allotype: Mangold, 1988, pl. 1, fig. 2 (M) – UCBL-FSL 83 844.	132	116	55	0.42	-	-	40.5	0.31	-
	116		50	0.43	-	-	36	0.31	-
	100		41.5	0.42	-	-	28	0.28	-

cf. 1988. *Pachyerymnoceras praecox* n. sp. – Mangold, p. 575, text-fig. 6/1-2 ; pl. 1, figs 1-2.

**Material:** Two specimens. One nearly complete with three quarters of body chamber whorl but with no aperture. The other, rather well-preserved with a quarter of whorl of body chamber.

**Description:** Large size, fairly involute, large and shallow umbilicus with high vertical wall and rounded shoulder. Tubercles radially elongated on the outer whorl; outer whorl-section compressed and ogival; ribbing visible only in the body chamber as radially elongated primaries and three or more secondaries.

**Discussion:** Save its larger size (D = 250 versus 132 mm in *P. praecox*) the Saudi Arabian specimens are close to *P. praecox* Mangold from W Algeria. Other differences are the shorter primary ribs and the occurrence of intercalatories. *P. praecox* would be a little older than the present material according to Mangold (lower part of the Coronatum Zone, Villanyensis Subzone) what could explain these differences.

**Distribution:** Tuwaiq mountain limestone Fm, unit T1. *Durma Quadrangle:* JMA82.232; (UCBL-FSL 177 160), lonely place between Wadi Hanifa, 24°50' N and Khashm Turab, 25°03' N, about 24°56' N. – unit T2. *Durma Quadrangle:* JMA82.346 (UCBL-FSL 177 146a and b), Graben Missah, 24°16' N.

**Age:** Middle Callovian, Ogivalis Zone. An Early Middle Callovian age has been assumed previously by Énay *et al.* (1986, 1987, 2009) and Énay & Mangold (1985, 1994). The time-equivalence of the Ogivalis Zone with the Coronatum Zone of W Europe was established from the more diversified successions of Israel (Gill *et al.*, 1985).

***Pachyerymnoceras cf. kmerense* Mangold, 1988 [M]**

Tab. 51

1986. *Pachyerymnoceras* n. sp. 1.– Énay *et al.*, p. 33 (tab. 1).

1987a. *Pachyerymnoceras* n. sp. 1.– Énay *et al.*, p. 36 (tab. 1).

cf. 1988. *Pachyerymnoceras kmerense* Mangold, p. 578, text-fig. 6/3-4, 8-10; pl. 1, fig. 3; pl. 4, fig. 2.

**Material:** One specimen, poorly preserved, with

incomplete body chamber and the inner whorls partly preserved.

**Description:** Fairly involute, whorl section first depressed then more compressed and ogival-shaped; inner whorls coronate with tuberculate umbilical edge, strong bifurcate ribbing changing to long primary ribs on the body chamber; the secondaries crossing the venter with no change, then progressive thickening towards the non preserved aperture.

**Discussion:** The preservation of the only known specimen is not good enough to allow a definite identification. It was first compared to *P. levantinense* Lewy, but the size as well as the changes during growth of the whorl section, ornamentation, and size are in better agreement with the Algerian *P. kmerense*.

**Distribution:** Tuwaiq mountain limestone Fm, unit T1 (scree, ? from unit T2). *Durma Quadrangle:* JMA82.397 éb; (UCBL-FSL 177 129), Wadi al Jufayr, 24°55' N.

**Age:** Middle Callovian, Ogivalis Zone. An Early Middle Callovian age has been assumed previously by Énay *et al.* (1986, 1987, 2009) and Énay & Mangold (1985, 1994). The time-equivalence of the Ogivalis Zone with the Coronatum Zone of W Europe was established from the more diversified successions of Israel (Gill *et al.*, 1985).

***Pachyerymnoceras cf. maghareense* (Lewy, 1983) [M]**

Pl. XXXI, figs 1, 2; Tab. 52

1983. *Pachyceras maghareense* n. sp. – Lewy, p. 29, text-fig. 5B; pl. 6, fig. 12.

**Material:** A nearly complete specimen, with the body chamber partially preserved. A possible microconch, incomplete with one half whorl long of the body chamber.

**Description:** In both specimens only the outer whorl is preserved, hampering a definite identification. The largest specimen is involute with compressed whorl section, first ogival with acute venter, then more inflated and wide, rounded venter in the adult stage; strong, blunt prorsiradiate ribs, simple or bifurcate, forming chevrons but weakened on the venter, weak or absent on the umbilical part of the side on the body chamber.

The other specimen, possibly microconch, exhibits only the body chamber; whorl section compressed, lanceolate

Table 51: Measurements of *Pachyerymnoceras cf. kmerense* Mangold (M).

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
UCBL-FSL 177 129 - JMA82.397	157	c 102	58	0.36	50	0.31	50	0.31	0.86
Holotype: Mangold, 1988, pl. 4, fig. 2 (m) UCBL-FSL 83 866.	137	80	47	0.34	43	0.31	54	0.39	0.91
	100		36	0.36	40	0.40	44	0.44	1.11
	80		29	0.36	39	0.49	29	0.36	1.34
Allotype: Mangold, 1988, pl. 4, fig. 2 (M) - UCBL-FSL 83 873.	161	110	55	0.34	56.5	0.33	56	0.35	1.03
	140		60	0.43	52	0.37	30	-	0.87
	110		42	0.38	44	0.40	-	-	1.05



First, thick and depressed, angular whorl section on the inner whorls, then changing progressively to ogival with acute venter, and ending with more compressed quadratic rounded body chamber. Ribbing composed of short primary ribs, bulbous but non-tuberculate near the umbilical edge, bifurcate at mid-side, first crossing the angular venter, then ending on the ventrolateral region. The body chamber is feebly ribbed with simple, blunt prorsiradiate ribs fading on the final part; about one half whorl long, aperture not preserved.

**Discussion:** *P. magnum* n. sp. resembles *P. robustum* Lewy. The developmental stage reached by the holotype of this latter (Lewy, 1983, p. 31, pl. 5, fig. 5; pl. 6, fig. 1) is not specified, but it fits perfectly with the inner whorls of the new species, except the secondary ribs much more projected forwards on the venter. No fully grown specimens of *P. robustum* are known, leaving the adult morphology unknown.

**Distribution:** Tuwaiq Mountain limestone Fm, unit T3, basal part. *Shaqrā' Quadrangle*: VD82.1 (UCBL-FSL 177 083, 084, 088) and VD82.38 (UCBL-FSL 177 090, 091), Khashm Aba al Hayyal, 25°22' N - Al Asa'ad collection (UCBL-FSL 177 098, 103, 104, 107, 109, 114, 117-122, 124-127), Al Mu'ayshibah, 25°34' N.

**Age:** Late Callovian, Solidum Zone. A Late Callovian age has been assumed with doubts by Énay & Mangold (1985) and Énay *et al.* (1986, 1987a). Latter (Énay & Mangold, 1984; Énay *et al.*, 2009) ascertained this age as well as the time-equivalence of the Athleta Zone of W Europe from the more diversified successions of Israel (Gill *et al.*, 1985).

#### *Pachyerymnoceras cf. spathi* (Lewy, 1983) [M]

- cf. 1983. *Pachyceras spathi* n. sp. – Lewy, p. 28, text-fig. 4G; pl. 5, figs 2-4.  
 1986. *Pachyerymnoceras* sp. 6 (*pars*). – Énay *et al.*, p. 33 (tab. 1).  
 1987a. *Pachyerymnoceras* sp. 6 (*pars*). – Énay *et al.*, p. 36 (tab. 1).  
 1985. *Pachyceras (Pachyceras) lalandeanum* (d'Orbigny). – Gill *et al.*, p. 731, fig. 5D, pl. 4, fig. 1 and pl. 7, fig. 1; ?pl. 6, fig. 1a, b.

**Material:** Fragment of a septate whorl.

**Remarks:** The material collected by Dr Al-Asa'ad includes a fragment of a septate whorls with a clearly lanceolate whorl section. It corresponds quite well to the end of the septate part of the holotype of *P. spathi* between 130 and 160 mm in diameter. But it could also be considered as a variant of *P. magnum* with a whorl-section more clearly lanceolate than in the typical form.

**Distribution:** Tuwaiq Mountain limestone Fm, unit T3, basal part. *Shaqrā' Quadrangle*: Al Asa'ad collection (UCBL-FSL 177 099), Al Mu'ayshibah, 25°34' N.

**Age:** Late Callovian, Solidum Zone. A Late Callovian age has been assumed with doubts by Énay & Mangold (1985) and Énay *et al.* (1986, 1987a). Latter (Énay &

Mangold, 1984; Énay *et al.*, 2009) ascertained this age as well as the time-equivalence of the Athleta Zone of W Europe from the more diversified successions of Israel (Gill *et al.*, 1985).

#### Undetermined microconch *Pachyerymnoceras*

Unlike the many macroconchs described above, the microconchs are scarce in the collection of Dr Al-Asa'ad. Besides the two specimens described with their supposed macroconchs, there remain four microconch specimens whose macroconch counterparts are still unknown. They are small specimens (below 70-80 mm in diameter) – much smaller and with quite different morphology compared to the macroconchs described above. The situation is different from that in Western Algeria where the species described by Mangold (1988) show only a size dimorphism.

The specimens described below come from the Tuwaiq Mountain Limestone Fm, unit T3 and the same locality, Al-Mu'ayshibah area, NW of Riyadh, about 25°34' N.

- *Pachyerymnoceras* sp. A. (Pl. XXX, fig. 3; UCBL-FSL 177 101). Well-preserved but slightly crushed dorso-ventrally outer whorl. Small (63 mm in diameter), whorl-section depressed, coronate with tuberculate umbilical edge, strong bifurcate ribbing, the secondaries branching from tuberculate primary ribs, projected forwards. This specimen is close to the specimen figured as *Erymnoceras (Pachyerymnoceras) cf. jarryi* (Douvillé) by Imlay (1970, pl. 2, figs 1, 2), identified by Zeiss with *P. imlayi* Zeiss (1974, pl. 37, figs 5, 8, 9).
- *Pachyerymnoceras* sp. B. (Pl. XXX, fig. 4; UCBL-FSL 177 110). Well-preserved, body chamber half a whorl long, 66 mm in diameter; inner whorl with depressed whorls, coronate and tuberculate umbilical edge, changing on the body chamber to compressed whorl-section. Short primary ribs divided from small tubercles at the umbilical margin into bundles of prorsiradiate secondary ribs that cross the venter radially.
- *Pachyerymnoceras* sp. C. (UCBL-FSL 177 106). One nearly complete specimen. Body chamber three quarters of a whorl long, slight uncoiled, 71 mm in diameter.
- *Pachyerymnoceras* sp. D. (UCBL-FSL 177 085). Fragment of body chamber, half a whorl long, 69 mm in diameter; short primary ribs divided from small tubercles at the umbilical margin into bundles of prorsiradiate secondary ribs that cross the venter radially; first with depressed arched whorl-section, then strongly contracted.

Genus *Kurnubiella* Gill, Thierry & Tintant, 1985

[M & m]

**Type species:** *Kurnubiella ogivalis* Gill, Thierry & Tintant, 1985; by original designation

**Remarks:** The new genus was based on microconchs from the upper Zohar Fm, southern Israel (Kurnub Anticline or Makhtesh Hatira) of Middle Callovian age, according Gill *et al.* (1985). These forms were dated as Late Callovian by Lewy (1983) who described the first specimens under the boreal-subboreal genera *Lamberticeras*, “*Quenstedtoceras*” and “*Prorsiceras*”. These statements will be discussed latter.

Recently Énay & Howarth (2019), in a review of the faunas of Saudi Arabia, identified some well-preserved, complete and fully grown specimens as the macroconch of *Kurnubiella*. These were unpublished, so the species *Pachyerymnoceras levantinense* Lewy, with *Pachyerymnoceras*-like inner whorls and compressed *Pachyceras*-like body chamber, has been considered the macroconch of *Kurnubiella*. Latter, a new and more elaborate study of this material has shown that this association is erroneous. On the one hand, the forms of Saudi Arabia attributed to *P. levantinense* Lewy have coronate inner whorls with a depressed whorl-section. On the other hand, these specimens constitute a different and new species, *K. fallax* (described below), which could be the true *Kurnubiella* macroconch.

The first microconch *Kurnubiella* were described by Lewy (1983) as cardioceratids (“*Quenstedtoceras*”, *Lamberticeras* and *Prorsiceras*), thus assuming Late Callovian age of the corresponding beds (top of the Zohar Fm). To *Kurnubiella hatirae* (Lewy) Gill *et al.* (1985) added *Kurnubiella ogivalis* (type species of the genus), *Kurnubiella compressa*, and *Kurnubiella* n. sp. A. From the associated fauna these latter authors established a Middle Callovian age (= Coronatum zone of Western Europe). Two of these forms, *K. hatirae* and *K. ogivalis*, are well characterized by their type specimens, in contrast to *K. compressa*. The holotype of this latter, an adult, is hardly convincing, any more than the other cotypes, nuclei or juveniles very different from the holotype.

***Kurnubiella ogivalis* Gill, Thierry & Tintant, 1985 [m]**

Pl. XXXIV, fig. 3, 4; Tab. 54

1970. *Rollierites?* cf. *tenue* Rollier.– Imlay, p. 13, pl. 1, figs 16, 17.  
 1975. Pachyceratidae gen. et sp. nov. – Gill & Tintant, p. 104.  
 1983. cf. “*Quenstedtoceras*” sp. – Lewy, p. 32, pl. 7, fig. 7; text-fig. 6D.  
 1985. *Kurnubiella ogivalis* n. sp. – Gill, Thierry & Tintant, p. 726, text-fig. 6; pl. 5, fig. 4 (?non 3).  
 1986. *Kurnubiella* cf. and gr. *hatirae* (Lewy).– Énay *et al.*, p. 33 (tab. 1), pl. 6, fig. 3.  
 1987a. *Kurnubiella* cf. and gr. *hatirae* (Lewy).– Énay *et al.*, p. 36 (tab. 1), pl. 6, fig. 3.  
 1994. *Kurnubiella ogivalis* (Lewy).– Énay & Mangold, p. 171.  
 2019. *Kurnubiella ogivalis* (Lewy).– Énay & Howarth, p. 73, fig. 57/2a-b.

**Material:** Two complete, crushed specimens of which one with one whorl of body chamber; plus six fragmentary specimens.

**Description:** Small shell, fairly evolute, with ogival but slightly compressed whorl section and acute venter; coarse primary ribs raised from near the umbilical edge and bifurcating at about mid-flank with some prorsiradiate secondaries, all projected at the periphery and V-shaped on the venter.

**Discussion:** The only one complete and well-preserved specimen, already figured in Énay *et al.* (1986, 1987a), from the Tuwaiq Mountain Limestone Fm, unit T2, is less well-preserved as the holotype. Crushing is probably responsible for the more compressed whorl-section. Some uncrushed fragments display the thick and rounded ventral area.

**Distribution:** Upper Dhurma Fm, unit D7, upper part (Hisyan Member). *Durma Quadrangle:* JMA82.213 (UCBL-FSL 177 218), Khashm adh Dhibi, 22°14' N; *Shaqrā' Quadrangle:* JMA83.403 (UCBL-FSL 177 215), lonely place north of Wadi al Jufayr, 24°05' N. – Tuwaiq Mountain Limestone, Fm, unit T1. *Shaqrā' Quadrangle:* VD82.617 (UCBL-FSL 177 163), Khashm Turab,

Table 54: Measurements of *Kurnubiella ogivalis* Gill, Thierry & Tintant.

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
UCBL-FSL 177 218 - JMA82.213	51	29	16	0.31	11	0.21	20	0.39	0.68
UCBL-FSL 177 141 - JMA82.34	28	?	9	0.32	-	-	13	0.46	-
Holotype: Gill <i>et al.</i> , 1985, p. 727. pl. 5. fig. 4 (n° 47)	36		12	0.33	9.5	26.5	15	0.42	0.78
	27		9.6	0.35	9.4	34	11	0.41	0.98
	20		7.2	0.36	8	40	8	0.40	1.11
Cotype: Gill <i>et al.</i> , 1985, p. 727 (n° 54)	41		13	0.32	11.8	0.29	16	0.39	0.90
	28		10	0.36	9.5	0.34	11	0.40	0.95
	16		5.5	0.40	7	0.44	6.5	0.40	1.28
Cotype: Gill <i>et al.</i> , 1985, p. 727 (n° 55)	36		13	0.36	11.3	0.29	-	-	0.79
	26		10	0.36	10	0.36	-	-	1.0
	18		7	0.40	8	0.46	-	-	1.14

25°03' N; Tuwaiq Mountain Limestone, Fm, unit T2. *Durma Quadrangle*: JMA82.34 (UCBL-FSL 177 140-142), Khashm Hisyan, 24°45' N; *Shaqrā' Quadrangle*: VD82. 621 (UCBL-FSL 177 152, 154), Khashm Turab, 25°03' N.

**Age:** Middle Callovian, Ogivalis Zone. An early Middle Callovian age has been assumed previously by Énay *et al.* (1986, 1987a, 2009) and Énay & Mangold (1985, 1994). The time-equivalence of the Ogivalis Zone with the Coronatum Zone of W Europe was established from the more diversified successions of Israel (Gill *et al.*, 1985).

***Kurnubiella cf. hatirae* (Lewy), 1983 [m]**

1983. "*Prorsiceras*" *hatirae* n. sp. – Lewy, p. 33, pl. 6, figs 7-11.  
 1986. *Kurnubiella hatirae* (Lewy).– Énay *et al.*, p. 33 (tab. 1).  
 non 1987a. *Kurnubiella cf. and gr. hatirae* (Lewy).– Énay *et al.*, p. 36 (tab. 1).  
 1994. *Kurnubiella hatirae* (Lewy).– Énay & Mangold, p. 171.  
 2019. *Kurnubiella hatirae* (Lewy).– Énay & Howarth, p. 73, fig. 57/2c-d.

**Material:** Two specimens, one of which distorted and dubious.

**Description:** The only well-preserved specimen is small (18.6 mm in diameter), but displays the same aspect and ribbing ontogeny that the holotype (23 mm in diameter), particularly the single ribs strongly projected forward.

**Discussion:** The specimen is considered dwarfish, doing that the comparison of its dimensional parameters with those of the holotype have little meaning.

**Distribution:** Tuwaiq Mountain Limestone, Fm, unit T2. *Durma Quadrangle*: JMA82.34 (UCBL-FSL 177 139) and 34bis (UCBL-FSL 177 200), Khashm Hisyan, 24°45' N.

**Age:** Middle Callovian, Ogivalis Zone. An early Middle Callovian age has been assumed previously by Énay *et al.* (1986, 1987, 2009) and Énay & Mangold (1985,

1994). The time-equivalence of the Ogivalis Zone with the Coronatum Zone of W Europe was established from the more diversified successions of Israel (Gill *et al.*, 1985).

***Kurnubiella cf. compressa* Gill, Thierry & Tintant, 1985 [m]**

1975. Pachyceratidé, gen. et sp. nov. – Gill & Tintant, p. 104.  
 1983. cf. *Lamberticeras henrici* (R. Douvillé).– Lewy p. 32, pl. 7, figs 1-6.  
 cf. 1985. *Kurnubiella compressa* n. sp. – Gill, Thierry & Tintant, 1985, p. 729, pl. 5, figs 5-7.

**Material:** An incomplete phragmocone 19 mm in diameter.

**Description and remarks:** As previously stated (see above genus *Kurnubiella*) the specimens figured by Lewy (1983) are the better illustration of the species. The Saudi Arabian specimen are very similar to the inner whorls figured by Lewy (1983, pl. 7, figs 1, 2).

**Distribution:** Tuwaiq Mountain Limestone, Fm, unit T2. *Shaqrā' Quadrangle*: VD82.621 (UCBL-FSL 177 153), Khashm Turab, 25°03' N.

**Age:** Middle Callovian, Ogivalis Zone. An early Middle Callovian age has been assumed previously by Énay *et al.* (1986, 1987a, 2009) and Énay & Mangold (1985, 1994). The time-equivalence of the Ogivalis Zone with the Coronatum Zone of W Europe was established from the more diversified successions of Israel (Gill *et al.*, 1985).

***Kurnubiella fallax* n. sp. [M]**

Pl. XXXIV, figs 1-2; Pl. XXXV, fig. 1; Tab. 55

- ? 1985. *Kurnubiella ogivalis* n. sp. – Gill *et al.*, p. 726, pl. 5, fig. 3.  
 ? 1985. *Pachyceras (Pachyceras) cf. schloenbachi* Arkell, non Roman. – Gill *et al.*, pl. 4, fig. 2a-b.  
 1986. *Pachyerymnoceras* n. sp. 1. – Énay *et al.*, p. 33 (tab. 1).  
 1987a. *Pachyerymnoceras* n. sp. 1. – Énay *et al.*, p. 35 (tab. 1).

Table 55: Measurements of *Kurnubiella fallax* n. sp. and *Pachyerymnoceras levantinense* Lewy. \* From Lewy (1983, pl. 3, figs 1-3).

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
UCBL-FSL 177 129 - JMA82.397	157	c102	58	0.64	50	0.31	50	0.31	0.86
UCBL-FSL 177 130 - JMA82.397	139	109	53	0.38	34	0.24	c42	0.30	0.64
UCBL-FSL 177 131 - VD82.621	134	79	49	0.36	32.5	0.24	45	0.33	0.66
	110	-	44	0.40	32	0.29	31	0.28	0.72
	78	-	35	0.44	31	0.39	-	-	-
UCBL-FSL 177 132 - VD82.621	131	80	47	0.35	34	0.26	40	0.30	0.72
	112	-	49	0.43	31	0.27	27	0.27	0.63
	80	-	37	0.46	25	0.31	18	0.22	0.67
<i>P. levantinense</i> Lewy. Holotype. Lewy, 1983, p. 3, fig. 1-3 (n° 1207)	107	?	36	0.33	40	0.37	37	0.34	1.11
	83	-	34	0.40	41	0.49	26	0.31	1.20
	60	-	22	0.36	45	0.75	19	0.21	2.04

**Type specimens:** Holotype is the specimen figured in Pl. XXXIV, fig. 1a-b (UCBL-FSL 177 131). Paratype is the specimen figured in Pl. XXXV, fig. 1a-b (UCBL-FSL 178 132).

**Origin of name:** From the Latin *fallax, acis*: deceiving, by reference to its deceptive appearance that led to confuse it with *P. levantinense* Lewy.

**Material:** Three specimens well-preserved and more or less complete (UCBL-FSL 177 130 -132). Other two less well-preserved are doubtful UCBL-FSL 177 207, 208).

**Description:** Outer whorl (adult stage) well-preserved, inner whorls poorly preserved. Shell fairly evolute, the umbilical width increasing relatively during growth with slight uncoiling of the end of the outer whorl. Whorl-section compressed, rounded-quadrate. Blunt primary ribs emerge from the umbilical edge, dividing into three-four secondary ribs a little below the middle of the flank; these are succeeded by spaced bifurcated or single ribs thicken ventrally on the last quarter whorl and approaching the aperture (simple and flexuous).

**Discussion:** First identified with *P. levantinense* Lewy, *K. fallax* differs from the Israeli species. Although not preserved the inner whorls seem to have not had the depressed and coronatiform whorl-section of *P. levantinense*. They are probably represented by an incomplete specimen (UCBL-FSL 177 201) from the same place as the two adults. This specimens is involute with compressed whorl section and continuous proverses ribs on the ventral area, it fits well with the end of the septate whorls and the beginning of the body chamber of the adults, except that the rib density is higher. Another small fragment (UCBL-FSL 177 095) fits better but it would have been found in the T3 unit (VD81.144, Sulayyimah Quadrangle, Khashm al Mukassar, 21°36' N.) where it is the only *Kurnubiella* recorded.

It is possible that the specimen attributed to *K. ogivalis* by Gill *et al.* (1985, pl. 5, fig. 3), which differs from the holotype by its more involute coiling, may correspond to the inner whorls of *K. fallax*; and probably also the inner whorls assigned to *Pachyceras* (*Pachyceras*) cf. *schloenbachi* (Roman) by Gill *et al.* (1985, pl. 4, fig. 2a, b).

Thus, the new species cannot be assigned to *Pachyerymnoceras* and the need for a new genus does not seem to be necessary. The solution adopted herein agrees with that of Énay & Howarth (2019).

**Distribution:** Upper Dhurma Fm, unit D7, upper part (Hisyan Member). *Buraydah Quadrangle*: JMA83.280 (UCBL-FSL 177 201, 207, 208), Az Zilfi, 26°10' N. - Tuwaiq Mountain Limestone, Fm, unit T2. *Durma Quadrangle*: JMA82.397 (UCBL-FSL 177 130), Wadi al Jufayr, 24°05' N; *Shaqrā' Quadrangle*: VD82.621 (UCBL-FSL 177 131, 132), Khashm Turab, 25°03' N. - Tuwaiq Mountain Limestone, Fm, unit T3. *Sulayyimah Quadrangle*: VD81.144 (UCBL-FSL 177 095), Khashm al Mukassar, 21°36' N.

**Age:** Middle Callovian, Ogivalis Zone. An early Middle Callovian age has been assumed previously by Énay *et*

*al.* (1986, 1987a, 2009) and Énay & Mangold (1985, 1994). The time-equivalence of the Ogivalis Zone with the Coronatum Zone of W Europe was established from the more diversified successions of Israel (Gill *et al.*, 1985).

Genus *Pachyceras* Bayle, 1878

**Type species:** *Ammonites lalandeanus* d'Orbigny, 1848; by original designation

[= *Lalandeites* Breistroffer, 1947, p. 101, obj.]

**Remarks:** Occurrence of western European species of *Pachyceras* (*P. lalandeanum* and *P. schloenbachi* sensu Arkell] in the Middle East has been assumed first by Arkell (1952), then and with more conviction by Lewy (1983) and Gill *et al.* (1985). These identifications seem to be the result of a confusion with forms of *Pachyerymnoceras* presenting during their growth a whorl section with acute or even lanceolate venter. But, there remains at least one specimen for which there is still some doubt that the genus would be rare but really present.

#### *Pachyceras?* sp.

A wholly septate specimen, 70 mm in diameter, weathered. Involute with high compressed whorl section and acute venter; non-tuberculate umbilical edge and prorsiradiate ribs crossing the venter, but branching not visible. Upper Dhurma Fm, unit D7, upper part (Hisyan Member). *Buraydah Quadrangle*: JMA83.199**é**b. (UCBL-FSL 177 229), Al Liqa, 26°26' N.

Family Aspidoceratidae Zittel, 1895

**Remarks:** Aspidoceratids are a well-defined offshoot from the Perisphinctidae and as soon as appeared they developed very distinctive features. A complete review of these was recently published (Parent *et al.*, 2020) and used to raise the Aspidoceratidae to the taxonomic rank of superfamily, the Aspidoceratoidea. It is permissible to wonder whether these features justify such a change, but this aspect will not be discussed in this work because the aspidoceratids occupy a very small place in the whole of the studied fauna. The change of taxonomic rank of the Aspidoceratidae results in the change of taxonomic rank of lower-ranking taxa and the proposal of new subfamilies (i.e. Epipeltoceratinae Callomon in Donovan & others, 1981, and Gregoryceratinae Parent *et al.*, 2020). These are not affected, thus will not be used in this work which retains the classification of Énay & Howarth (2019).

Subfamily Peltoceratinae Spath, 1924

[*nom. transl.* Schindewolf, 1925, p. 320, *ex*

Peltoceratidae, Spath, 1924, p. 18]

Genus *Peltoceras* Waagen, 1871

Subgenus *Peltoceras* Waagen, 1871

**Type species:** *Ammonites athleta* Phillips, 1829; SD by Schindewolf (1925, p. 321)  
[= *Rursiceras* Buckman, 1919]

***Peltoceras (Peltoceras) cf. trifidum (Quenstedt, 1887)***  
[m]

Pl. XXXV, fig. 3

1887. *Ammonites athleta trifidus*.– Quenstedt, p. 781, pl. 88, figs 1, 5, 9.  
1931. *Peltoceras trifidum* (Quenstedt).– Spath, p. 562, pl. 110, fig. 5a, b.  
1937. *Peltoceras trifidum* (Quenstedt).– Prieser, p. 28, pl. 2, fig. 7.  
1951. *Peltoceras trifidum* (Quenstedt).– Jeannet, p. 167, pl. 72, fig. 4; pl. 73, figs 1-4, text-figs 394-396.  
1975. *Peltoceras trifidum* (Quenstedt).– Gill & Tintant, p. 104, 105.  
1983. *Peltoceras trifidum* (Quenstedt).– Lewy, p. 37, pl. 7, figs 16-21.  
1985. *Peltoceras* aff. *trifidum* (Quenstedt).– Gill, Thierry & Tintant, p. 741, pl. 5, fig. 8.  
1994. *Peltoceras trifidum* (Quenstedt).– Énay & Mangold, p. 171.

**Material:** One small specimen, less than a quarter whorl long.

**Description:** Shell with a compressed and subquadrate whorl section with eight ribs, simple or bifurcate, curving backwards on the ventral margin, the secondaries crossing the venter.

**Distribution:** Tuwaiq Mountain limestone Fm, unit T3, basal part. *Shaqra' Quadrangle*: Al Asa'ad collection (UCBL-FSL 177 105), Al Mu'ayshibah, 25°34' N.

**Age:** Late Callovian, Solidum Zone. A Late Callovian age has been assumed with some doubt by Énay & Mangold (1985) and Énay *et al.* (1986, 1987a). Latter (Énay *et al.*, 2009) ascertained this age as well as the close time-equivalence of the Solidum Zone with the Athleta Zone of W Europe from the more diversified successions of Israel (Gill *et al.*, 1985).

***Peltoceras (Peltoceras) solidum* Spath, 1931 [M]**

Pl. XXXV, fig. 2

1931. *Peltoceras solidum* n. sp. – Spath, p. 568, pl. 108, fig. 2.  
1975. *Peltoceras* aff. *antiquum* Loczy.– Gill & Tintant, pp. 104, 105.  
1983. “*Paraspidoceras*” sp. – Lewy, p. 39, pl. 8, fig. 7; text-fig. 6E.  
1985. *Peltoceras (Peltoceras?) pachygaster* n. sp. – Gill, Thierry & Tintant, p. 738, fig. 7, pl. 8, figs 1-2, 4.  
1994. *Peltoceras solidum* Spath.– Énay & Mangold, p. 171.

**Material:** One specimen, about a quarter whorl long of the body chamber.

**Description:** The body chamber fragment has retained five large spaced tubercles placed very high on the side, the umbilical wall smooth and very sloping inwards,

without umbilical edge. The upper edge of the tubercles prolonging the enlarged ventral region, results in a subtrapezoidal whorl-section, with a gently rounded ventral area and ribs joining the opposite tubercles. The dorsal side of the flank is very sloping without umbilical rim and a high, convex, umbilical slope.

**Discussion:** The whorl-section is the only figure given by Lewy (1983, fig. 6E) of the specimen he assigned to “*Paraspidoceras*” sp. This specimens matches perfectly the present specimen. Gill *et al.* (1985, pl. 8, figs 1, 2, 4) have figured a very similar form for which a new name, *P. (P.) pachygaster*, was proposed, but which does not seem fundamentally different from *P. solidum*. The only difference would be the ribs extending into large tubercles to the umbilical seam that can enter into the intraspecific variability.

**Distribution:** Tuwaiq Mountain limestone Fm, unit T3, basal part. *Shaqra' Quadrangle*: Al Asa'ad collection (UCBL-FSL 177 096), Al Mu'ayshibah, 25°34' N.

**Age:** Late Callovian, Solidum Zone.

Subfamily Euaspidoceratinae Spath, 1931

[= Epipeltoceratinae Callomon in Donovan *et al.*, 1981, p. 149]

Genus *Euaspidoceras* Spath, 1931

Subgenus *Euaspidoceras* Spath, 1931

**Type species:** *Ammonites perarmatus* J. Sowerby, 1822; by original designation

[= *Neaspidoceras* Spath, 1931, p. 59; *Arcaspidoceras* Jeannet, 1951, p. 224; *Mirospinctes* Schindewolf, 1926, p. 501]

***Euaspidoceras (Euaspidoceras) cf. catena* (Sowerby, 1825) [M]**

Pl. XXXVII, figs 1-2

1940. *Aspidoceras (Euaspidoceras) catena* (Sowerby).– Arkell, p. 199, pl. 42, figs 1-6; pl. 43, figs 2-3, text-fig. 70 (cum synonymy).  
1986. *Euaspidoceras* gr. *catena-perarmatum* (Sowerby).– Énay *et al.*, p. 33 (tab. 1), pl. 6, figs 9-10.  
1987a. *Euaspidoceras* gr. *catena-perarmatum* (Sowerby).– Énay *et al.*, p. 36 (tab. 1), pl. 6, figs 9-10.

**Material:** Thirty seven more or less well-preserved fragmentary specimens. The largest specimen available (UCBL-FSL 177 062), with less than a quarter-whorl of the body chamber and the last suture-line preserved, is part of a complete specimen probably over 300-400 mm in diameter.

**Description:** The fairly evolute coiling of the shell and the rather slow whorl increasing in size can be deduced from the largest whorl fragment. Whorl-section quadrate, venter gently rounded. Two rows of prominent tubercles connected by short ribs, the outer stronger; the inner row at some distance of the umbilical edge, slightly radially elongated, the outer row prominent and pyramidal slightly elongated in the direction of coiling.

**Discussion:** *E. catena* and *E. perarmatum* are very close by which in former studies we had not decided a definite classification of the present material. Arkell (1940) discussed the two species at length and summarized the characters that distinguish them. But for this it is necessary to have material for the ontogeny to be followed, since the conclusion of Arkell (1940, p. 195) is that on the outer whorl, convergence makes the two species barely distinguishable. However, the position of the internal tubercles close to the umbilical seam, the more compressed whorl section, the thickness hardly equal to the height at the ribs, also the adult size point to *E. catena*.

**Distribution:** Hanifa Fm, unit H1, upper part (Ulayyah Member). *Wadi ar Rayn Quadrangle:* VD80.319 (UCBL-FSL 177 045), Ulayyah, 23°54' N; *Durma Quadrangle:* JMA82.51 (UCBL-FSL 177 051), Khashm Hisyan, 24°45' N; JMA82.276 (UCBL-FSL 177 046-049), Khashm al Qaddiyah, 24°31' N; JMA82.318 (UCBL-FSL 177 051a-c), lonely place north of Khashm al Qaddiyah, 24°37' N; JMA82.334 (UCBL-FSL 177 052); *Shaqrā' Quadrangle:* VD82. 644A (UCBL-FSL 177 054-080), Khashm Turab, 25°03' N. – Al-Asa'ad's collection (UCBL-FSL 177 081, 082), Al-Mu'ayshibah area, NW of Ryadh, about 25°34' N.

**Age:** Middle Oxfordian, *catena* Horizon. The acme of *E. catena* is slightly earlier than that of *E. perarmatum*, but they have a common vertical range within the Plicatilis zone. *Euaspidoceras perarmatum* was once used as a zonal index in Europe later replaced by *Arisphinctes plicatilis*. However, the *catena* Horizon lies in the Plicatilis Zone.

Family Ataxioceratidae Buckman, 1921

Subfamily Ataxioceratinae Buckman, 1921

[*nom. transl.* Arkell, 1950, p. 363, *ex* Ataxioceratidae Buckman, 1921] [= Idoceratinae Spath, 1924; = Gravesiinae Fischer & Zeiss, 1987]

**Remarks:** According to Schweigert & Kuschel (2017a, b) who argue, based on the type species, that microconchs have lost their lappets, the Idoceratinae should be separated from the Atraxioceratinae.

Based on few fragments of the aptychus, “*different from that of ataxioceratids*”, Scherzinger *et al.* (2006) separate the Gravessinae from the Ataxioceratinae, but as *incertae sedis*.

Genus *Orthosphinctes* Schindewolf, 1925

**Type species:** *Ammonites tiziani* Oppel, 1863; by original designation

*Orthosphinctes (Orthosphinctes) sp. [m]*

Tab. 56

**Material:** A fairly well-preserved cast and the plastic cast of an imprint.

**Description:** Small, evolute platyconic shell, with rounded to slightly compressed whorl section; fine, moderately radial primary ribs bifurcate in middle flank, with some simple ribs; all passing across the rounded venter; 2-4 deep, prorsiradiate constrictions per whorl. Probably a microconch, but the aperture is not preserved.

**Discussion:** The above description justifies assignment of these two specimens to *Orthosphinctes*, but their conservation is not good enough for a more precise determination.

**Distribution:** Jubaila Fm, lower unit J1. *Wadi al Mulay Quadrangle:* JMA80.560/2 (UCBL-FSL 177 006, 007), lonely place north of As Sitarah, about 22°37' N.

**Age:** The lower part (unit J1) of the Jubaila Fm is tentatively dated as Early Kimmeridgian by the assemblage with *Alienispinctes cavellieri*.

Genus *Alienispinctes* nov.

**Type species:** *Alienispinctes cavellieri* nov. sp. (described below).

**Origin of the name:** From the latin *alienus*, *a*, *um* = foreign.

**Diagnosis:** Dimorphic. Moderately involute planulate shell. Macroconch with prorsiradiate bifurcate primary ribs, intercalatory ribs common; microconch with more quadratic whorl section, flat venter and the secondary ribs more projected forwards on the shoulder.

**Remarks:** During field work of the BRGM team and the authors, the Jubaila Fm yielded a number of specimens of “*Perispinctes jubailensis*” larger than those studied by Arkell (1952). But of the about thirty specimens collected (not counting fragmentary casts), and despite being mentioned in the published lists in the preliminary works (Énay *et al.*, 1986, 1987a; Énay & Mangold, 1985, 1994), no new specimens that ammonite have been found. A single small fragment could be approximated to the “*Perispinctes jubailensis*”, which suggests an involute coiling with a high and compressed whorl section, rectiradiate and bifurcate primary ribs and very few, free ending intercalatories, sometimes joined to the primary up to the end.

Table 56: Measurements of *Orthosphinctes* sp.

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
UCBL-FSL 177 007 - JMA80.560/2	54	?	18	0.33	15	0.27	23	0.42	0.83

Most of these fragmentary casts and/or crushed impressions of large perisphinctid suggest more evolute platycone shells, with a thick, ogival whorl section, slightly prorsiradiate, bifurcated primary ribs, and intercalatory ribs sometimes joined to the secondaries forming polyschizotome bundles resembling "*Lithacoceras*" *mombassanum* Scott (1943, pl. 14, figs 1, 2).

More interesting is a set of small-sized specimens the aperture which are interpreted as microconch forms. Indeed, the casts from the Jubaila Fm never show the suture, thus to interpret the degree of development achieved by each individual one must rely only on the development of the ornamentation. This form is close to if not identical to that figured as *Perisphinctes* aff. *jubailensis* by Arkell (1952, pl. 30, fig. 2). A well-preserved specimen and several whorl fragments represent the corresponding macroconch of this new species.

***Alieniphinctes cavellieri* nov. sp.**

Fig. 9/1-4; Tab. 57

1952. *Perisphinctes* aff. *jubailensis* n. sp. – Arkell, 1952, p. 292, pl. 30, fig. 2a, b (*non* pl. 29, fig. 5a, b).  
 1986. *Perisphinctes jubailensis* Arkell.– Énay *et al.*, p. 33 (tab. 1), *non* Arkell, 1952.  
 1986. *Perisphinctes* n. sp. 1 and 2 (*pars*).– Énay *et al.*, p. 33 (tab. 1).  
 1987a. *Perisphinctes jubailensis* Arkell.– Énay *et al.*, pp. 36 (tab. 1), 39.  
 1987a. *Perisphinctes* n. sp. 1 and 2 (*pars*).– Énay *et al.*, p. 36 (tab. 1).

**Material:** Eight more or less complete specimens with no aperture, including macro- and microconchs, quite well-preserved, but more or less crushed, and four fragmentary casts and impressions.

**Type specimens:** Holotype, the supposed macroconch in Fig. 10, 1a-b (UCBL-FSL 177 018). Allotype, the supposed microconch in Fig. 10, 2a-b (UCBL-FSL 177 026).

**Origin of the name:** The species is dedicated to C. Cavellier, formerly Chief of the Geological Department of the BRGM/SGN (Bureau de Recherches

Géologiques et Minières/Service Géologique National), who gave us the opportunity to visit the Jurassic outcrops of Saudi Arabia and study their ammonite faunas.

**Type locality:** Durma Quadrangle, Nissah graben, 24°16' N.

**Type Horizon:** Jubaila Fm, lower unit J1; Early Kimmeridgian, Cavellieri Zone.

**Description:** *Macroconch.* Inner whorls are not preserved in the holotype; from the microconch described below they are supposed to have quadratic or trapezoidal whorl section. Outer whorl moderately involute, laterally compressed, planulate; high whorl section, maximum thickness on the umbilical edge, flat side and rounded venter, rounded umbilical wall. Bold prorsiradiate primary ribs bifurcate on middle-side, and intercalatory ribs common, projected forwards on the shoulders and forming a chevron on the venter; occasional constrictions. *Microconch* differs by its well-defined umbilical wall and strengthening of the umbilical part of the ribs, more quadratic whorl-section and flat venter, the secondary ribs are more projected forwards on the shoulders.

**Discussion:** Only the small specimen figured by Arkell (1952, pl. 30, fig. 2) belongs to the new species and corresponds to the microconch. The inner whorls of the microconch, especially by the well-defined ventral chevron, recall "*Perisphinctes*" *singularis* Wegele (1929, p. 53, pl. 2, fig. 7), but the furcation points of the primary ribs located high on the side is enough to make the difference.

**Distribution:** Jubaila Fm, lower unit J1. *Wadi al Mulay Quadrangle:* JMA80.171 (UCBL-FSL 177 004), Al Hamr Wasit, 22°26' N; JMA80.295 (UCBL-FSL 177 005), As Sitarah, 22°36' N; *Wadi ar Rayn Quadrangle:* VD80.613 (UCBL-FSL 177 026), lonely place south of Al Hariq about 23°21' N; VD80.569 (UCBL-FSL 177 033), Al Hariq, 23°30' N; *Durma Quadrangle:* JMA82.409 (UCBL-FSL 177 018), Graben Nissah, 24°16' N; JMA82.277 (UCBL-FSL 177 017), lonely place at the same latitude as Khashl al Qaddiyah, 24°31' N; and plaster cast (UCBL-FSL 177 034) of the inner whorls of a specimen in Jeddah University from "Riyadh-Wadi Hanifa area"; *Shaqrā' Quadrangle:* VD82.658 (UCBL-FSL 177 031), Khashm Raghbah, 25°10' N.

Table 57: Measurements of *Alieniphinctes cavellieri* n. gen. n. sp.

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
UCBL-FSL 177 018 holotype. (M) - JMA82.409.	76	?	-	-	-	-	-	-	-
	66		26	0.39	21	0.31	25	0.37	0.80
	55		20	0.36	16	0.29	-	-	0.80
	45		15.5	0.34	15	0.33	-	-	0.96
UCBL-FSL 177 017 (M) (strongly crushed) - JMA82.277	64	?	22	0.34	-	-	27	0.42	-
	52		18	0.34	crushed	-	22	0.42	-
	40		13	0.32	-	-	14.5	0.36	-
UCBL-FSL 177 026. paratype. (m) - VD80.613	50	?	17.5	0.35	-	-	21	0.42	-
	40		16	0.40	13.5	0.33	17	0.42	0.84

**Age:** Both the genus and the species being new, they do not provide an age to the Jubaila Fm, unit J1, which is tentatively dated as Early Kimmeridgian.

Genus and species noves indet.

Fig. 9/5a-c; Tab. 58

1986. *Perisphinctes* n. sp. 1, 3, 5 (*pars*).– Énay *et al.*, p. 33 (tab. 1).

1987a. *Perisphinctes* n. sp. 1, 3, 5 (*pars*).– Énay *et al.*, p. 36 (tab. 1).

**Material:** Six specimens, of which two are fairly well-preserved and nearly complete (UCBL-FSL 177 027), and half a whorl specimen (FSL 177 023) with the plastic cast from imprints of the missing part; four not well-preserved or fragmentary casts.

**Description:** Moderately evolute planulate shell, the whorl height increasing fairly quick; high compressed whorl section, the sides converging to the rounded venter, the maximum thickness on the umbilical edge. Thick, prorsiradiate primary ribs, bifurcating at mid-side, and intercalatories more or less connected to the branched primary, especially when associated with the deep constrictions (3-4 per whorl), well-marked in some specimen (FSL 177 023, 0.027), less obvious in other one (FSL 177 009); the secondary ribs curving slightly forwards across the venter. Probably a microconch but the aperture is not preserved.

**Discussion:** The individuals considered to be the most representative (UCBL-FSL 177 027 and 023) are somewhat similar to *Ardescia* illustrated by Atrops (1982). Other specimens display a more regular (or *Orthosphinctes*-like) ribbing or are not well-preserved. The former were tentatively assigned to *Ardescia desmoides debelmasi*, the end-form of the species, in which “no parabolic formation was observed” (Atrops, 1982, p. 84), but the number of primary ribs in our specimens is constantly increasing (23 to 28 primaries at D = 27 to 58 mm). Then, we considered the Saudi Arabian form close to species with variable rib curve not clearly stabilized on a defined type (Atrops, 1982, p. 97), that is to say of *Orthosphinctes* s. st. (ascending), or of *Ardescia*-type (descending), such as *O. (A.) schaireri* Atrops and *O. (A.) perayensis* Atrops. But these ammonites show several distinctive features: slower and more evolute

coiling, denser and finer ornamentation with parabolae on the inner whorls and the beginning of the body chamber. Thus, the studied ammonites show significant differences with respect to the ataxioceratids compared, such as the more prominent and coarser primary ribs, the lower number of primary ribs per whorl, and the lower position of the furcation point, as well as the probable absence of parabolae.

These are the reasons why we think this is a new species, but it is very difficult to decide which genus it should be assigned to. The “probable absence of parabolae” suggests to *Orthosphinctes*, but their insufficient preservation hampers to realize whether they are present or not on the innermost whorls. Better preserved material is needed. However, it cannot be included in *Aliensphinctes* nov. gen. because: the whorl height grows faster and the coiling is less tight than in *Aliensphinctes*, the whorl section is clearly quadrate and thicker ventrally. Thus, the choice was made not to name this species while waiting for more material.

**Distribution:** Jubaila Fm, lower unit J1. *Wadi al Mulay Quarangle*: JMA80-560 (UCBL-FSL 177 008) and 560/1 (UCBL-FSL 177 023), lonely place north of As Sitarah, about 22°37' N; *Wadi ar Rayn Quadrangle*: VD80.614 (UCBL-FSL 177 027), lonely place south of Al Hariq, about 23°21' N. *Durma Quadrangle*: JMA82.63 (UCBL-FSL 177 009) and 73 (UCBL-FSL 177 012) Wadi Hanifa, 24°50' N; *Shaqrā' Quadrangle*: VD82.658 (UCBL-FSL 177 031), Khashm Raghbah, 25°10' N.

**Age:** Despite the uncertainty of the determination, genus and species noves indet. could date the lower part (unit J1) of the Jubaila Fm as Early Kimmeridgian.

### PART III – PALAEOENVIRONMENTAL AND PALAEOBIOGEOGRAPHICAL SETTING OF THE ARABIAN AMMONITE FAUNAS

There are at least 16 successive ammonite faunas that have been identified in the Jurassic series of central Saudi Arabia, in a time interval that ranges from the Early Toarcian to the Early Kimmeridgian. All of them have the same characteristics, on the one hand a discontinuous succession over time, each fauna being separated from the others by levels devoid of ammonites. On the other hand a more or less extensive spatial distribution

Table 58: Measurements of genus and species noves indet.

Specimen number	Dm/D	Ph	H	H/D	W	W/D	U	U/D	W/H
UCBL-FSL 177 027 - VD80.614	58	?	19	0.32	11.5	0.19	26	0.44	0.60
	45		14	0.31	13	0.28	C 15	0.33	0.92
	35		14	0.3&	11	0.31	11	0.31	0.78
UCBL-FSL 177 023 - JMA80.560/1	c 58	?	-	-	-	-	-	-	-
	48		14	0.29	13	0.27	22	0.45	0.92
UCBL-FSL 177 009 - JMA82.63	67	?	20	0.30	-	-	35	0.52	-

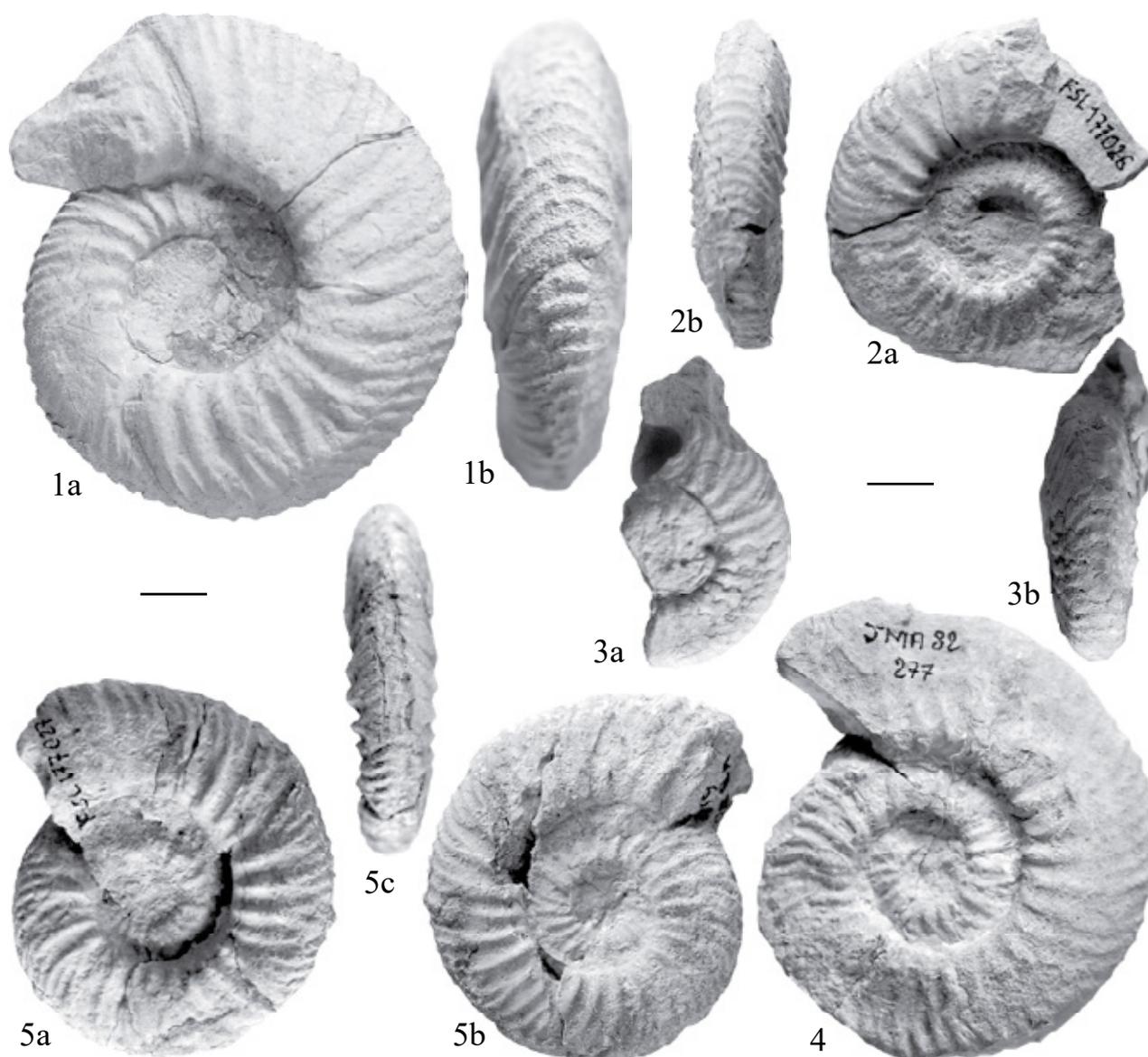


Fig. 9: *Alienisphinctes cavelleri* n. gen. n. sp. and genus and sp. nov. indet. Scale bar 10 mm.

1. *Alienisphinctes cavelleri* n. gen., n. sp. Holotype. Subcomplete macroconch, the aperture not preserved (UCBL-FSL 177 018), lateral (1a) and ventral (1b) views. Jubaila Fm, lower unit J1, Early Kimmeridgian, Cavelleri Zone. Durma Quadrangle: JMA82.409, Nissah graben 24°16' N.

2. *Alienisphinctes cavelleri* n. gen., n. sp. Paratype, supposed microconch (UCBL-FSL 177 026), lateral (2a) and ventral (2b) views. Jubaila Fm, lower unit J1, Early Kimmeridgian, Cavelleri Zone. VD80.613 lonely place south of Al Hariq about 23°21' N.

3. *Alienisphinctes cavelleri* n. gen., n. sp. Half a whorl long fragment of a microconch with part of the body chamber (UCBL-FSL 177 017), lateral (3a) and ventral (3b) views. Jubaila Fm, lower unit J1, Early Kimmeridgian, Cavelleri Zone. JMA82.277, lonely place at the same latitude as Khashl al Qaddiyah, 24°31' N.

4. *Alienisphinctes cavelleri* n. gen., n. sp. Nearly complete, but crushed specimen (UCBL-FSL 177 017), lateral view. Jubaila Fm, lower unit J1, Early Kimmeridgian, Cavelleri Zone. JMA82.277, lonely place at the same latitude as Khashl al Qaddiyah, 24°31' N.

5. Genus and sp. nov. indet. Nearly complete specimen (UCBL-FSL 177 027), lateral (5a, b) and ventral (5c) views. Jubaila Fm, lower unit J1, Early Kimmeridgian, Cavelleri Zone. Wadi ar Rayn Quadrangle: VD80.614 lonely place south of Al Hariq, about 23°21' N.

according to the fauna. Thus, these successive faunas all represent transitory episodic colonizations in relation to the regional palaeoenvironmental dynamics. The composition of each fauna and the presence of external elements of northwestern European affinities together with the autochthonous (Arabian) or sub-indigenous (Arab-Indo-Madagascan) forms are also to be taken into consideration.

## 5. AMMONITE FAUNAL EXTENSIONS AND ENVIRONMENTAL CONTROL

A detailed review of the faunas has been given in the first part of this work. Two large periods of extension of the ammonite faunas can be distinguished (or succeeded each other) during the Jurassic, which themselves are formed of several subsets (Figs 7 and 11). These changes in the geographic distribution of successive faunas are accompanied by significant variations in their generic and/or specific diversity (Fig. 10 and Tab. 59).

### 5.1. The first period of faunal extension (Early Toarcian – Early Bathonian)

This first expansion period is recorded from the Middle Marrat to the Middle Dhurma, unit D5 and has ten distinct successive faunas. The distribution of faunas, first limited to only part of the Wadi ar Rayn (northern part) and Durma (southern part) quadrangles extended in stages both towards the south (Wadi al Mulayh and Sulayyimah quadrangles) and to the north (Shaqrā and even Buraydah quadrangles). This period of large faunal expansion is interrupted at the basal part of the unit D3 by a singular event, the Late Bajocian *Ermoceras mogharensis* and *Spiroceras annulatum* event, which allows two sub-periods to be distinguished. Another singular event is the Late Bathonian *Cardioceratoides* fauna of the unit D6 which ends this first period.

#### 5.1.1. First sub-period (Early Toarcian – Early Late Bajocian)

Six faunas are concerned, the extent of which is regularly increasing both southwards and northwards. The largest extent between 22°02' N (Jabal Fahhamah, Wadi al Mulayh Quadrangle) and 25°30' N (Jurayfah, Shaqrā Quadrangle) of the Late Bajocian fauna (Runcinatum / Subfurcatum Zone) of the unit D2, upper part (Dhibli Limestone).

*Bouleiceras* and *Nejdia* faunas. The first *Bouleiceras* (Lower Toarcian) and *Nejdia* (Middle Toarcian) faunas are mostly present in the Wadi ar Rayn Quadrangle with a northwards extension in the Durma Quadrangle, limited

for the first (*Protogrammoceras madagascariense* only present), more widely for the second. The two faunas consist only of Arab-Madagascan forms.

*Sonninia arabica* and *Pseudoshirbuirnia stephani* faunas. The overlying lower Bajocian *Arabica* fauna and *Stephani* faunas show roughly the same extent as those of the Toarcian, even smaller compared to the *Nejdia* fauna. The *Arabica* fauna is known mainly in the Durma Quadrangle with limited extent on the Wadi ar Rayn Quadrangle. Its contents is also mainly of Arab-Madagascan forms, with the exception of *Hyperlioceras* gr. *discites*, known in the only section-type (Khashm adh Dhibi), which perhaps occupies a different and slightly older level. In contrast, the *Stephani* fauna is mainly present on the Wadi ar Rayn Quadrangle and only one site in the Durma Quadrangle, and only northwestern European elements are present.

*Eoermoceras glabrum* fauna. A change occurs with the upper lower Bajocian *Glabrum* fauna (*Glabrum* Zone/Humphriesianum Zone, Romani and Humphriesianum subzones), whose extent is well established from the reference section (Khashm adh Dhibi) in the Durma Quadrangle and southward over most of the Wadi ar Rayn Quadrangle (as far as Wadi Birk, 23°12' N.) The *Glabrum* fauna associates autochthonous forms, especially the first *Ermoceratids* (*Eoermoceras* nov. gen.) and northwestern European forms, including the genus *Dorsetensia*, present in many sites and abundant in number of specimens. *Eoermoceras* nov. gen. is present but not so well characterized in the sites of the Shaqrā Quadrangle (Jurayfah, 25°30' N), very far northwards and without intermediate site from Khashm adh Dhibi (24°14' N). It is precisely the presence of many *Dorsetensia*, which justifies the attribution of these localities to the *Glabrum* fauna. Thus the *Glabrum* fauna is the first fauna with such a large extent.

*Kosmermoceras runcinatum* fauna. Confirmation of this broad extension of the faunas during the Bajocian is confirmed by the *Runcinatum* fauna of the lower part of the Upper Bajocian fauna (*Runcinatum*/Subfurcatum Zone). This wide extension of the fauna is supported by the numerous fossiliferous sites in the Dhibi Limestone or equivalents, particularly towards the south in the Wadi ar Rayn and Wadi al Mulayh quadrangles, but also northwards (Durma and Shaqrā quadrangles). This is the level of the main *Ermoceras* fauna (*Telermoceras* and *Kosmermoceras*) which is largely dominant, both in number of species and in number of specimens, associated in a locality with *Thamboceras*, another autochthonous genus. The northwest European forms (*Stemmatoceras* and *Cadomites*) are represented by only two specimens, which have no apparent significance. This fauna illustrates the largest extension of ammonite faunas.

***Ermoceras mogharensense* and *Spiroceras annulatum* event (Late Bajocian Mogharensense Zone/Gargantia Zone):** This event is inscribed in the basal beds of the unit D3 with a fauna composed by few species. Besides the two characteristic species, only one other, *K. inerme*, already present in the underlying *K. runcinatum* fauna. Moreover, this fauna has a limited extension in latitude, essentially the Durma Quadrangle and the northern part of the Wadi ar Rayn Quadrangle. Thus, the situation is identical to those already examined for the Lower Toarcian (Middle and Upper Marrat) and Lower Bajocian (Lower Dhurma Fm, unit D1) faunas.

### 5.1.2. Second sub-period (Late Bajocian – Early Bathonian)

This is a repetition of the pattern already seen for the first sub-period, except that only 3 faunas (and not 6) are involved, the extent of which is regularly increasing both southwards and northwards, the largest extent between 22°02' N (Jabal Fahhamah, Wadi al Mulayh Quadrangle) with the unit D5 and the *Clydocromphalus* Fauna (Clydocromphalus Zone/Zigzag Zone, Macresens Subzone and Aurigerus Zone, Yeovilensis subzone) and 26°55' N (Nafud al Mazhur, Buraydah Quadrangle) with the unit D4 and the *Tuwaiqensis* Fauna (Tuwaiqensis Zone/Zigzag Zone).

*Thambites planus* fauna. Except that it has not been identified in most of the Durma Quadrangle, save its northern part (Wadi al Hisyan), its extension is very similar to that of the *Kosmormoceras runcinatum* fauna, and even more extended to the south in the Sulayyimah Quadrangle. The great number of specimens in most collection sites contrasts with low generic and specific diversity: three indigenous genera, *Thambites*, “*Reboulliceras*” and *Pseudoclydoniceras*, each with a single dominant species. The other elements are limited to two badly preserved specimens of *Procerites*.

*Tulites tuwaiqensis* fauna. This fauna has not been identified in most of the Durma Quadrangle, except in the typical locality (Khashm adh Dhibi). It is well represented between Khashm Hadafiyah (23°05' N) and Khashm Furaytah (25°42' N), in the quadrangles Wadi ar Rayn, Durma and Shaqrā, two isolated localities in the south (Jabal Shimrakh, 22°10' N.) in the Wadi al Mulayh Quadrangle and north (Nafud al Mazhur, 26°55' N) in the Buraydah Quadrangle. This distribution makes of this fauna most widely extended (nearly 5° in latitude). The faunal content is almost entirely made up of autochthonous elements, *Tulites* is dominant, *Saudisphinctes* nov. gen., and (from the top of the unit D3) *Metazigzagiceras subarabicum* (close to the *Franchia* Northwest European affinity and Early Bathonian age).

*Micromphalites clydocromphalus* fauna. This is other of the faunas with widest extension, especially towards the south, in the Wadi al Mulayh and Sulayyimah quadrangles, where the *Micromphalites* beds support the detrital body of the Wadi ad Dawasir “delta”. Northwards the fauna does not exceed Jurayfah south (25°30' N), on the Shaqrā Quadrangle. The fauna is monogeneric and dominated by the various species of *Micromphalites* associated with rare *Pseudoclydoniceras* sp. Not any northwestern European genus.

**Late Bathonian *dhrumaites cardioceratoides* event:** The unit D6 and the *Dhrumaites cardioceratoides* fauna have a singular situation (position) in the Jurassic series and there are two major reasons for distinguishing them from older or more recent faunas. First, stratigraphically the contact with the underlying unit corresponds to the only non-deposition surface of large extent at the top of the unit D5, probably associated with a gap of the Middle Bathonian and perhaps also a part of the Lower Bathonian. Then, the lower part (Hisyan Member) of the overlying unit D7 has not yielded ammonites, the first ones appearing in the upper part (Atash Member) of the unit D7 and its exact age remains uncertain. The other reason is that *D. cardioceratoides*, the only species present is not known outside Arabia, thus it does not convey any age by itself, and the Middle Bathonian dating rests mainly on brachiopods.

## 5.2. The second period of faunal extension (Middle Callovian – Early Kimmeridgian)

Six faunas are involved that can be organized into two distinct sets by the common characters of the assemblages belonging to each of them, but none of these faunas extended as widely as the faunas of the first period. The first brings together the *Ogivalis* fauna (Ogivalis Zone/Coronatum Zone) and the *Solidum* fauna (Solidum Zone/Athleta Zone) of the Upper Dhurma Fm, upper part of the unit D7 (= Hisyan member) and Tuwaiq Mountain Limestone Fm, units T1-T3. The second includes the *Catena* fauna (Catena Horizon/Plicatilis Zone) of the Hanifa formation and the *Cavelieri* fauna (Cavelieri Zone/Platynota Zone) of the lower member (T1 unit) of the Jubaila Fm.

### 5.2.1. Middle and Upper Callovian faunal extensions

The palaeogeographic framework has been completely modified with the setting-up on the southern margin of the detrital body of Wadi ad Dawasir “delta”. So the units of the succession D7 to T3 are transgressive and overlap the clastic deltaic body. The unit D7 contrasts with the impoverished and endemic not very characteristic fauna of the unit D6 and shows a progressive trend towards open marine environments.

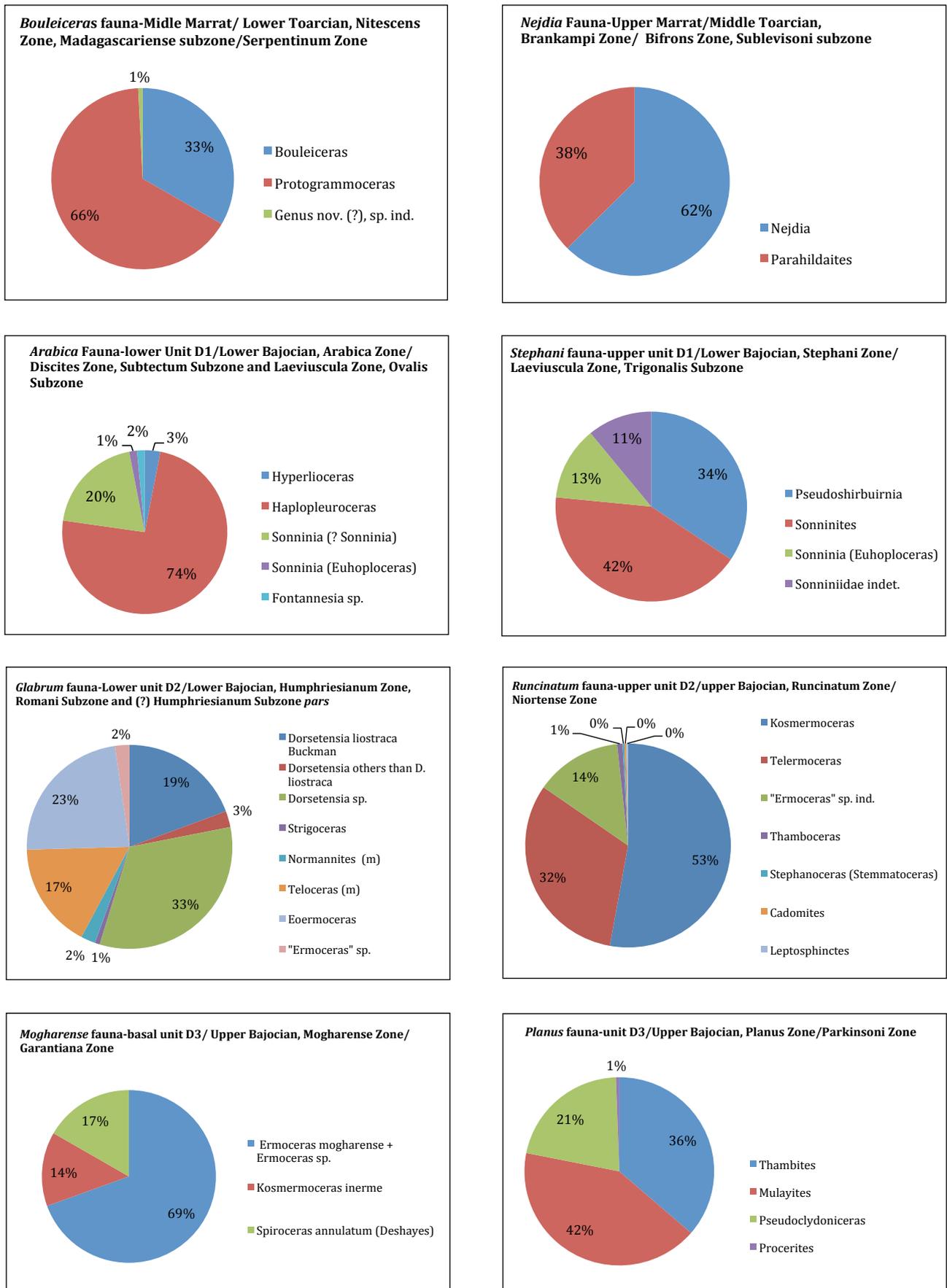


Fig. 10: Ammonite genera composition of successive Jurassic faunas of Central Saudi Arabia. Explained in the text.

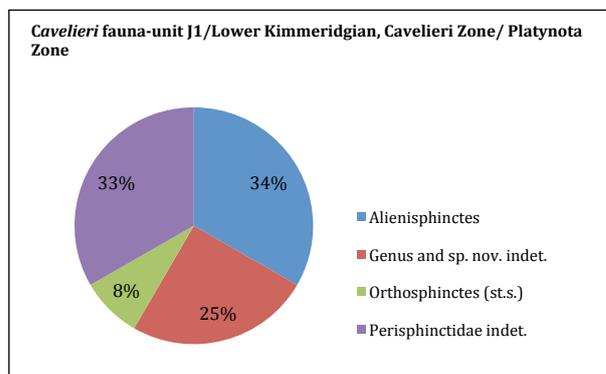
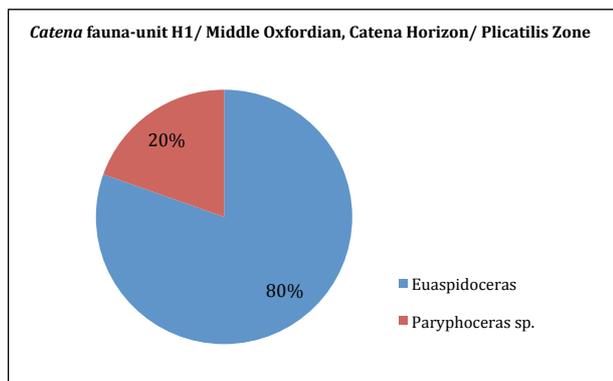
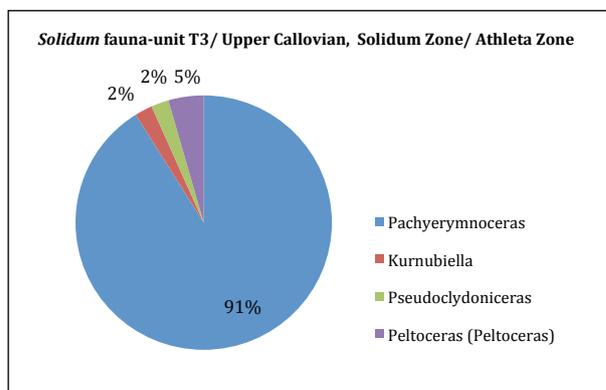
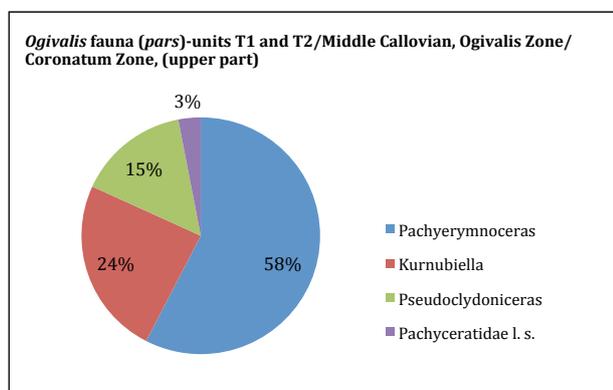
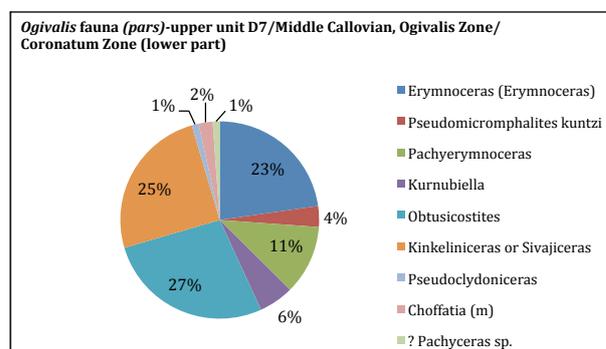
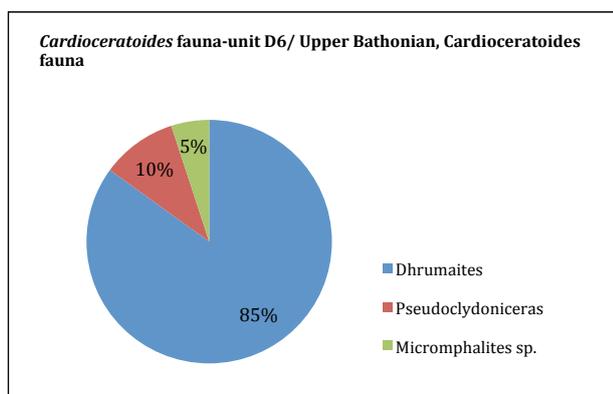
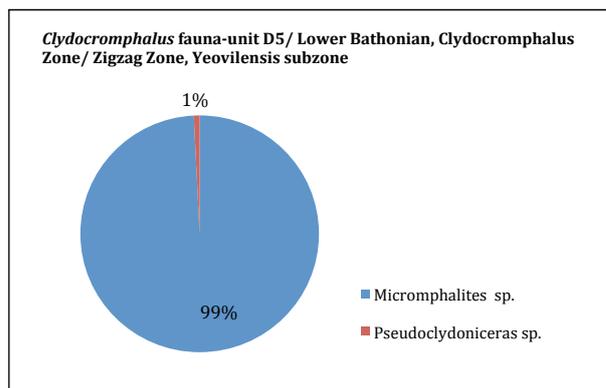
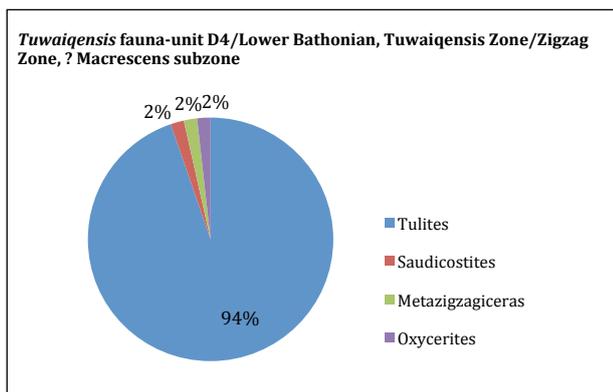


Fig. 10: Continued

Table 59: Generic and specific content of the successive faunal assemblages, with the total number of specimens for each quadrangle, the total number of studied specimens and the percent of Arabian-Indian-Madagascan (1) and Western European (2) taxa; ww = world wide; ? unknown affinities.

FORMATIONS	UNITS	Lower/Upper	GENERIC AND SPECIFIC CONTENT OF THE SUCCESSIVE FAUNAL ASSEMBLAGES 1 : Arabo-Indo-Madagascan and/or 2: Western European taxa; ww: Worldwide; ? Unknown affinities						QUADRANGLES						ARABO-INDO MADAGASCAN (1) / W.EUROPEAN (2) TAXA	
									BURAYDAH	SHAQRĀ	DARMĀ	WADI ar RAYN	WADI al MULAYH	SULAYYIMAH	TOTAL NUMBERS	Nb
MARRAT	MM	Middle	1	<i>Bouleiceras cf. nitescens</i> Thévenin						1	1	129	85	65.89%		
				<i>Bouleiceras elegans</i> Arkell						17	17					
				<i>Bouleiceras arabicum</i> Arkell						4	4					
	<i>Bouleiceras cf. rochi</i> Collignon						1	1								
	<i>Bouleiceras</i> sp.						62	62								
	2	<i>Protogrammoceras madagascariense</i> (Thévenin)						1	21	22	43	33.33%				
<i>Protogrammoceras</i> sp.						21	21									
?	Genus nov. (?), sp. ind.						1		1	1	0.77%					
UM	Upper	1	<i>Parahildaites sanderi</i> (Arkell)							26	184	184	100%			
			<i>Parahildaites</i> sp.							23						
			<i>Nejdia brankampi</i> Arkell							91						
			<i>Nejdia</i> sp.							23						
							1	1								
LOWER DHRUMA	Unit DI	Lower	1	<i>Sonninia</i> (? <i>Sonninia</i> ) <i>arabica</i> (Arkell)						48	1	103	55	53.39%		
				<i>Sonninia</i> ( <i>Euhoploceras</i> ) <i>turbator</i> nov. sp.						1						
		<i>Sonninia</i> ( <i>Euhoploceras</i> ) <i>crassicostae</i> nov. sp.						2	3	5						
		2	<i>Hyperlioceras</i> sp. gr. <i>discites</i> (Waagen)							36	36	40	38.83%			
	<i>Haplopleuroceras</i> cf. <i>mundum</i> Buckman							2	2							
								1	1							
	Upper	2	<i>Sonninia</i> (? <i>Sonninia</i> ) sp.							2	64	49	76.56%			
			<i>Sonninia</i> ( <i>Euhoploceras</i> ) sp.							7						
							7	7								
WW	2	<i>Pseudoshirburnia stephani</i> (Buckman)							1	21	15	23.43%				
		<i>Sonninites albidus</i> Buckman							27	27						
							8	8								
							7	7								

FORMATIONS	UNITS	Lower/Upper	GENERIC AND SPECIFIC CONTENT OF THE SUCCESSIVE FAUNAL ASSEMBLAGES 1 : Arabo-Indo-Madagascan and/or 2: Western European taxa; ww: Worldwide; ? Unknown affinities	QUADRANGLES						TOTAL NUMBERS	ARABO-INDO MADAGASCAN (1) / W.EUROPEAN (2) TAXA		
				BURAYDAH	SHAQRĀ	DARMĀ	WADI ar RAYN	WADI al MULAYH	SULAYYIMAH		Nb	Per-centage	
LOWER DHRUMA	Unit D2	Lower	1	<i>Eoermoceras glabrum</i> n. sp.			17	31			48	100	26.10%
			<i>Eoermoceras</i> sp. cf. <i>glabrum</i> n. sp		5				5				
			<i>Eoermoceras angulatidomus</i> n. sp.			1	2		3				
			<i>Eoermoceras</i> nov. sp. A		5				5				
			<i>Eoermoceras</i> nov. sp. B		30				30				
			" <i>Ermoceras</i> " sp. ind.			7	2		9				
		2	<i>Dorsetensia liostraca tecta</i> Buckman		17	3	37			57	383	283	73.89%
		<i>Dorsetensia liostraca subtecta</i> Buckman		3	3	13		19					
		<i>Dorsetensia</i> cf. <i>deltafalcata</i> (Quenstedt)		5				5					
		<i>Dorsetensia</i> cf. <i>regrediens</i> (Haug)		4				4					
		<i>Dorsetensia</i> cf. <i>schlumbergeri</i> (Haug)				1		1					
		<i>Dorsetensia</i> sp. ind. (M)			3	79		82					
		<i>Dorsetensia</i> sp. ind. (m)				3		3					
		<i>Dorsetensia</i> sp. ind.		32		2		34					
		<i>Strigoceras</i> cf. <i>bessinum</i> Brasil		2				2					
		<i>Strigoceras</i> sp.		1				1					
		<i>Normannites</i> sp. aff. <i>braikenridgii</i> (Sowerby) (m)		3	1	5		9					
		<i>Teloceras</i> sp. aff. <i>lepsiusi</i> (Gillet)		65		1		66					
		1	<i>Thamboceras mirabile</i> Arkell		2			1	3	307	304	99.02%	
		<i>Thamboceras</i> sp.		1				1					
<i>Telermoceras coronatoides</i> (Douville)		15		7	13	35							
<i>Telermoceras coronatiforme</i> (Arkell)			7	14	5	26							
<i>Telermoceras</i> gr. <i>coronatoides</i> (Douv.) - <i>coronatiforme</i> (Arkell)				2	3	5							
<i>Telermoceras splendens</i> Arkell		24	2	11	1	38							
<i>Telermoceras deserti</i> (Douville)			1	2	7	10							
<i>Telermoceras reineckeoides</i> Arkell			1	1		2							
<i>Kosmermoceras runcinatum</i> Arkell		34	1	6	7	48							
<i>Kosmermoceras magnificum</i> Arkell		6	6	5	25	42							
<i>Kosmermoceras elegans</i> (Douville)		14		2	21	37							
<i>Kosmermoceras inerme</i> (Douville)		6	2			8							
? <i>Telermoceras</i> n. sp. A			1			1							
" <i>Ermoceras</i> " sp. ind.		18	5	14	11	48							
2	<i>Stephanoceras</i> ( <i>Stemmatoceras</i> ) aff. <i>frechi</i> (Renz)			1			1	3	0.98%				
<i>Cadomites</i> sp. gr. <i>daubenyi</i> (Gemmellaro)				1			1						
<i>Leptosphinctes</i> aff. <i>umbilicatus</i> Galacz		1					1						

FORMATIONS	UNITS	Lower/Upper	GENERIC AND SPECIFIC CONTENT OF THE SUCCESSIVE FAUNAL ASSEMBLAGES 1 : Arabo-Indo-Madagascan and/or 2: Western European taxa; ww: Worldwide; ? Unknown affinities		QUADRANGLES						TOTAL NUMBERS	ARABO-INDO MADAGASCAN (1) / W.EUROPEAN (2) TAXA											
					BURAYDAH	SHAQRĀ	DARMĀ	WADI ar RAYN	WADI al MULAYH	SULAYYIMAH		Nb	Per-centage										
MIDDLE DHRUMA	Unit D3	Basal	1	<i>Ermoceras mogharensis</i> Douvillé <i>Kosmermoceras inerme</i> Douvillé “ <i>Ermoceras</i> ” sp. ind.			10 4 15	1			10 5 15	36	30	83.33%									
			2	<i>Spirocera annulatum</i> (Deshayes)			6				6				6	6	16.66%						
		Major part	1		<i>Thambites planus</i> Arkell <i>Thambites oxynotus</i> Arkell <i>Thambites</i> nov. sp. or sp. ind. <i>Mulayites avus</i> (Arkell) <i>Pseudoclydoniceras pseudodiscus</i> (Arkell) <i>Pseudoclydoniceras</i> sp.		1 6 12 1	5 3 5 9	30 2 13 13	29 10 37 24	41 1 82 27	106 1 21 149 73	354	352	99.43%								
				2		<i>Procerites</i> sp. A <i>Procerites</i> sp. gr. <i>intersertus</i> (Buckman)					1 1	1 1				1 1	2	0.56%					
					Unit D4	1	<i>Tulites tuwaiqensis</i> Arkell <i>Tulites arabicus</i> Arkell <i>Tulites erymnoides</i> Arkell <i>Tulites</i> n. sp. A <i>Tulites</i> sp. <i>Saudisphinctes arabicus</i> nov. sp. (m)	1 6	5 34 5 2 1	1 1 1		2					6 38 5 2 3 6	62	60	96.77%			
				2			<i>Megazigzagiceras subarabicum</i> F.-López & Pavia <i>Oxycerites</i> sp. aff. <i>fallax</i> (Guéranger)			1 1						1 1	1 1				2 3.22%		
	Unit D5	1					<i>Pseudoclydoniceras</i> sp. <i>Micromphalites clydocromphalus</i> Arkell <i>Micromphalites</i> nov. sp. A <i>Micromphalites</i> cf. <i>torrensi</i> Énay <i>Micromphalites intermedius</i> Arkell <i>Micromphalites elegans</i> Arkell <i>Micromphalites busqueti</i> (de Grossouvre) <i>Micromphalites pustuliferus</i> (Douvillé) <i>Micromphalites</i> nov. sp. B <i>Micromphalites</i> sp.		25 1 9 12 3 1 14	25 1 1 1 3 1	17 1 3 3 3					1 1 1 1	1 67 1 2 13 12 9 1 1 19				126	126	100%
			Unit D6	1			<i>Pseudoclydoniceras</i> sp. <i>Dhrumaites cardioceratoides</i> Arkell ? <i>Dhrumaites cardioceratoides</i> Arkell <i>Micromphalites</i> sp.		1 6 1	1 3	8			2 11 6 1	20	20	100%						

FORMATIONS	UNITS	Lower/Upper	QUADRANGLES							TOTAL NUMBERS	ARABO-INDO MADAGASCAN (1) / W.EUROPEAN (2) TAXA		
			BURAYDAH	SHAQRĀ	DARMĀ	WADI ar RAYN	WADI al MULAYH	SULAYYIMAH	Nb		Per-centage		
												GENERIC AND SPECIFIC CONTENT OF THE SUCCESSIVE FAUNAL ASSEMBLAGES 1 : Arabo-Indo-Madagascan and/or 2: Western European taxa; ww: Worldwide; ? Unknown affinities	
UPPER DHRUMA	Unit D7	Upper (Hisyan member)	1	<i>Pseudoclydoniceras</i> sp.			1				1	64	73.86%
				<i>Pseudomicromphalites kuntzi</i> and cf. <i>kuntzi</i> Collignon		2	1				3		
				<i>Kinkeliniceras</i> sp. or <i>Sivajiceras</i> sp.		22					22		
				<i>Obtusicosites gigas</i> nov. sp.	1						1		
				<i>Obtusicosites</i> gr. <i>O. devi</i> / <i>O. ushas</i> Spath	1						1		
				<i>Obtusicosites</i> sp.	1	21					22		
				<i>Pachyerymnoceras</i> cf. <i>philbyi</i> Arkell			1				1		
				<i>Pachyerymnoceras</i> nov. sp. ?	4	1	1				6		
				<i>Pachyerymnoceras</i> sp.	2	1					3		
				<i>Kurnubiella ogivalis</i> Gill, Thierry & Tintant		1	1				2		
			<i>Kurnubiella fallax</i> n. sp.	3						3			
			2	<i>Erymnoceras</i> ( <i>Erymnoceras</i> ) cf. <i>coronatum</i> (d'Orbigny)	3	1				4			
				<i>Erymnoceras</i> ( <i>Erymnoceras</i> ) cf. <i>schloenbachi</i> (Roman)	1					1			
				<i>Erymnoceras</i> ( <i>Erymnoceras</i> ) n. sp. A	1					1			
<i>Erymnoceras</i> ( <i>Erymnoceras</i> ) sp. ind.	3	10		1			14						
<i>Choffatia</i> sp. aff. <i>kontkiewiczzi</i> (Siemiradzki)				1	1		2						
? <i>Pachyceras</i> sp.	1						1						
TUWAIQ MOUNRAIN LIMESTONE	Unit T1	1	<i>Pachyerymnoceras</i> cf. <i>praecox</i> Mangold			1			1	12	12	100%	
			<i>Pachyerymnoceras arabicum</i> n. sp.		2				2				
			<i>Pachyerymnoceras</i> sp.		2		1	5	8				
			<i>Kurnubiella ogivalis</i> Gill, Thierry & Tintant		1				1				
	Unit T2	1	<i>Pseudoclydoniceras</i> sp.		1	4			5	28	25	89,28%	
			<i>Pachyerymnoceras</i> cf. <i>kmerense</i> Mangold			1			1				
			<i>Pachyerymnoceras</i> cf. <i>praecox</i> Mangold			1			1				
			<i>Pachyerymnoceras</i> sp.		1	3	2		6				
			<i>Kurnubiella ogivalis</i> Gill, Thierry & Tintant		3	3			6				
			<i>Kurnubiella</i> cf. <i>hatirae</i> (Lewy)			2			2				
?	<i>Pachyceratidae</i> l. s.			1			2		3	3	10.71%		

FORMATIONS	UNITS	Lower/Upper	GENERIC AND SPECIFIC CONTENT OF THE SUCCESSIVE FAUNAL ASSEMBLAGES 1 : Arabo-Indo-Madagascan and/or 2: Western European taxa; ww: Worldwide; ? Unknown affinities	QUADRANGLES						TOTAL NUMBERS	ARABO-INDO MADAGASCAN (1) / W.EUROPEAN (2) TAXA		
				BURAYDAH	SHAQRĀ	DARMĀ	WADI ar RAYN	WADI al MULAYH	SULAYYIMAH		Nb	Per-centage	
TUWAIQ MOUNRAIN LIMESTONE	Unit T3	1	<i>Pseudoclydoniceras</i> sp.		1					1	46	45	97.82%
			<i>Pachyerymnoceras</i> cf. <i>magharensis</i> (Lewy)		2					2			
			<i>Pachyerymnoceras magnum</i> n. sp.		21					21			
			<i>Pachyerymnoceras</i> cf. <i>spathi</i> (Lewy)		1					1			
			<i>Pachyerymnoceras</i> sp. A (m)		1					1			
			<i>Pachyerymnoceras</i> sp. B (m)		1					1			
			<i>Pachyerymnoceras</i> sp. C (m)		1					1			
			<i>Pachyerymnoceras</i> sp. D (m)		1					1			
			<i>Pachyerymnoceras</i> sp. (M)		11		1		1	13			
			<i>Pachyerymnoceras</i> sp. (m)		1					1			
<i>Kurnubiella</i> sp. (? inner whorls of <i>K. cf. fallax</i> n. sp.)						1	1						
<i>Peltoceras (Peltoceras) solidum</i> Spath		1					1						
2		<i>Peltoceras (Peltoceras) cf. trifidum</i> (Quenstedt)		1				1	1	2.17%			
HANIFA	H1	1	<i>Paryphoceras</i> sp.				9		9	46	9	20%	
		2	<i>Euaspidoceras (Euaspidoceras) cf. catena</i> (Sowerby)		29	7	1			37	37	80.43%	
	H2	2	<i>Paryphoceras</i> sp.				1		1	1	1	100%	
JUBAILA	Unit J1	1	<i>Aliensphinctes cavellieri</i> nov. gen. and sp.		1	3	2	2		8	24	16	66.66%
			<i>Perisphinctidae</i> indet.		1	4	2	1		8			
		2	? <i>Orthosphinctes (Orthosphinctes)</i> sp. ind. Genus and sp. nov. indet.		1	2	1	2		6			
Total by quadrangle and grand total.....				28	577	432	603	213	155	2.01			

**Kurnubiella ogivalis fauna:** Renewal and diversification of ammonite fauna occurs latter than brachiopod and nannoplankton faunas, in the upper part (Hisyan Member) of unit D7. From the outset the upper part (Hiyan member) of the unit D7 displays the largest extension of the *Kurnubiella ogivalis* fauna which mainly concerns the northern margin of the basin on the Durma, Shaqrā and Buraydah quadrangles. Southwards the only site with ammonite on the Wadi ar Rayn Quadrangle has yielded only one of the rare microconch *Choffatia* (= *Grossouvria*) known from Saudi Arabia. In the overlying units T1 and T2 of the Tuwaiq Mountain Limestone Fm the extension of the *K. ogivalis* fauna is more limited. This is observed especially in the unit T1 in very remote sites, to the north in the Durma and Shaqrā quadrangles, on both sides of their common limit (25° N in latitude), to the south in the Wadi al Mulayh Quadrangle (As

Sitarah, 22°36' N), but only with undetermined species of pachyceratids or *Pachyerymnoceras*. In unit T2 the *K. ogivalis* fauna is experiencing a new extension phase mainly on the Durma Quadrangle and the south of the Shaqrā Quadrangle. To the south a single section in the Wadi al Mulayh Quadrangle again with undetermined species of *Pachyerymnoceras*. Besides the above-mentioned *Choffatia*, other elements of affinity or of northwestern European origin are the very rare *Erymnoceras* securely known only in the unit D7, but missing in the Tuwaiq Mountain Limestone units T1 and T2. Most of the fauna consists of Indo-Madagascan forms (*Pseudomicromphalites*, *Kinkeliniceras*, *Obtusicosites*) forms, again present only in the D7 unit, and of indigenous (*Pachyerymnoceras*, *Kurnubiella*) from the units D7 to T2.

***Peltoceras solidum* fauna:** The unit T3 is indicated by a widespread distribution in the Sulayyimah, Wadi ar Rayn and Shaqrā quadrangles, but only the Shaqrā Quadrangle sites have yielded really significant faunas (VD82.1, 38 and 40; Al-Asa'ad collection). The fauna is dominated by indigenous species of *Pachyerymnoceras*, to which are added very rare *Peltoceras* of Indo-Madagascan (*P. solidum*) or NW European (*P. cf. trifidum*) origin. Again the most valuable localities are in the northern part, in the Shaqrā Quadrangle. Localities, in the Wadi ar Rayn and Sulayyimah quadrangles yielded undetermined species of *Pachyerymnoceras* except exposure VD81.144, (Wadi al Misyab, 21°50' N) with well-preserved inner whorls of *Kurnubiella* sp. or *K. aff. fallax* nov. sp. (UCBL-FSL 177 095).

### 5.2.2. Middle Oxfordian – Early Kimmeridgian faunal extensions

*Euaspidoceras catena* horizon. A well-defined fauna both stratigraphically and taxonomically, from the basal part (unit H1) of the Hanifa Fm, with an extension mainly in the Durma Quadrangle and adjacent parts of the neighboring Wadi ar Rayn and Shaqrā quadrangles and a single species of NW European origin. Localities of the unit H1 with *Euaspidoceras* fauna are considered here as belonging to a single horizon and a single episodic settlement during a brief interval of favorable conditions.

***Paryphoceras* sp. fauna:** The only known species from the unit H2 of the Hanifa Fm in a single locality in the Durma Quadrangle is undoubtedly of Indo-Madagascan affinity.

***Aliensphinctes cavellieri* fauna:** This is the last Jurassic faunal expansion in the lower part (unit J1) of the Jubaila Fm, with few well-distributed localities in the Wadi al Mulayh quadrangles, Wadi ar Rayn, Durma and the southern margin of the Shaqrā Quadrangle. Although described for the first time in this work *A. cavellieri* nov. gen. nov. sp. cannot be considered as an indigenous species. It belongs to the subfamily Ataxioceratinae, of the Submediterranean Province, like the other associated species, *Orthosphinctes* (or ?*Ardescia*) nov. sp., as well as "*Perisphinctes*" *jubailensis* Arkell of which no new specimens have been found.

### 5.3. Faunal succession and environmental evolution

The above review of the succession of fauna highlights an oscillation of the faunal expansions on either side of the central region, west of Ar Riyād, on the quadrangles Durma and Wadi ar Rayn (northern part) quadrangles. This is the easternmost sector and the furthest from the probable shores, therefore the sector where the reference sections are situated.

#### 5.3.1. Faunal extension of faunas and large vs limited faunal extensions

The periods of relatively large extensions correspond to the following faunas and units: *Glabrum* fauna and lower part of the unit D2, *Runcinatum* fauna (main *Ermoceras* fauna) and upper part of the unit D2 (Dhibi Limestone), *Planus* fauna and most of the unit D3, *Tuwaiqensis* and *Clydocromphalus* faunas, *Ogivalis* fauna (*pars*) and the upper part of the unit D7 (Hisyan Member) and the *Cavellieri* fauna and the lower part of Jubaila (J1).

The *Ogivalis* fauna (*pars*) and the units T1 and T2, as well as the *Solidum* fauna and the unit T3 are distinguished from the previous ones by the contrast between, on the one hand, the diversified faunas of the northern part (Durma and Shaqrā quadrangles) and, on the other hand, the insignificant faunas (*Pachyceratidae* sp. and *Pachyerymnoceras* sp. ind.) of the southern part (Wadi ar Mulayh and Wadi ar Rayn quadrangles), with the exception of locality VD81.144 (Sulayyimah Quadrangle, Khashm al Mukassar, 21°36' N) which yielded inner whorls of *Kurnubiella* aff. *fallax* nov. sp.

The periods of limited faunal expansion and the corresponding units are the *Bouleiceras* fauna of the Middle Marrat, the *Nejdia* fauna of the Upper Marrat, the *Arabica* and *Stephani* fauna of the unit D1 (lower and upper part), the *Mogharensis* fauna of the base of the unit D3 and the *Cardioceratoides* fauna of the unit D6.

#### 5.3.2. Environments, geodynamic process and faunal extension

These oscillations of the faunal extensions reflect fairly faithfully the fluctuations and the evolution of the environments according to Le Nindre *et al.* (1990) and Manivit *et al.* (1990). The types of environments accepted here (Fig. 12) are taken from Le Nindre in Le Nindre *et al.* (1990a, p. 42; 1990b) and Manivit *et al.* (1990). One of the difficulties in interpreting depositional environments is the coexistence of siliciclastic and carbonate platform deposits. Only the marine domain is concerned and the ecological conventions adopted associate terms based on the bathymetry (Peres, 1961; Conrad, 1969), supra, middle and infra-littoral (proximal, middle, distal), also those based on the influence of the tides, supra-, inter- and subtidal (internal marine domain), barrier, fore- and back-barrier (external marine domain). So, the five identified subtypes are: (i) infralittoral distal; (ii) mid- infralittoral, (including barrier, reefal complex; (iii) back-barrier, perireefal sands, flat-shaped oolitic body and protected, outer lagoon), (iv) proximal infralittoral (inner lagoon); middle littoral (intertidal) and (v) supra littoral (supratidal).

The first set of faunas with two subsets (*Nitescens-Runcinatum* faunas/Middle Marrat-unit D2 and *Mogharensis-Clydocromphalus* faunas/units D3-D5) to which can be attached to the *Cardioceratoides* fauna/unit

D6 corresponds quite well with the installation of the marine domain in two stages on the Arabian shelf. It is the result of active tectonic subsidence, especially during the Bajocian and Bathonian and the environments range from supralittoral to distal infralittoral. It was interrupted at the end of the Early Bathonian or even before, by a relative sea-level fall and the establishment of the deltaic platform of the Wadi ad Dawasir, south of latitude 22°, and dated as Early Bathonian (Énay *et al.*, 2007, 2009). The eustatic decline in the relative sea level of the Bathonian is well known in Western Europe where it is responsible for the closure of the Viking Corridor (Doré, 1991, 1992) between the Arctic basin and the Tethys, with the consequent isolation of the fauna from the Boreal Province. This isolation was finished after the rise in relative sea level and the wide eustatic transgression which began in the Late Bathonian, increased in the Callovian.

The second set of faunas [*Ogivalis-Kuntzi-Catena-Perarmatum* faunas/units D7 (Hisyan)-H1-(Hawtah)] with marine environments ranging from mid- to proximal infralittoral. Faunal expansion during the Middle and Late Callovian is linked to the acceleration of sedimentation rates and tectonic subsidence. After the absence of deposition of the early Late Callovian/Basal Oxfordian, subsidence decreased and sea-level rise was the main controlling factor of deposition.

## 6. PALAEOECOLOGICAL AND PALAEOBIOGEOGRAPHICAL ASPECTS OF THE ARABIAN AMMONITE FAUNAS (Figs 11-12)

These different aspects have been dealt with or even developed in previous papers, particularly on the occasion of the discoveries of forms of Arabian origin in Western Europe (Énay, 1993; Énay *et al.*, 1987b, 2001, 2002, 2012a, b). These include the monogeneric, even monospecific, or more or less widely diversified nature of the identified associations; also the endemic forms of the Arabian Province or, more broadly, the Arabo-Indo-Madagascan Province and their migration/expansion outside their domain of origin; and finally, the forms of Western European origin, alone or associated with the Arabian forms, and the features of these associations.

### 6.1. From monogeneric or monospecific to diversified faunas

Even in the central part where the succession is most complete, the sites with ammonites appear isolated within the Jurassic series. Each site represents a brief marine incursion in relation to the structural reactivation of the basin, subsidence and eustatic variations in the relative sea level. On a vast platform like the Arabian Platform, the slightest marine oscillations affect the

environments and associated fauna. In addition to their episodic character, recognized successive faunas show different compositions (Figs 10 to 12).

The extent of variations in the composition of the faunal associations is quite wide, from monospecific or monogeneric fauna to fairly diverse fauna associating taxa usually occurring in different provinces. On the one hand, the Arab domain, sometimes extended to the Arabo-Indo-Madagascan domain, on the other hand the domain of the Mediterranean Tethys.

The generic and specific content of successive faunal associations is exposed in Table 59, with the total number and by quadrangle, the number and percentage of Arab-Indo-Madagascan (1) and West European (2) taxa for each faunal association. Forms of uncertain affinities are counted separately, either as worldwide (ww) or with unknown affinities (?). Fig. 12 shows the spatial distribution of the successive ammonite faunas and relation with the palaeoenvironmental conditions and the Transgressive/Regressive (T/R) cycles and Maximum Flooding Surfaces (MFS). The generic compositions of each association and their changes during Jurassic time are illustrated by the frequency diagrams (pie charts) of the Figure 11. The changes in the composition of the associations between the Lower Toarcian and the Lower Kimmeridgian is well conveyed by Fig. 12 and percentages of the Arab-Indo-Madagascan and West-European taxa of the successive faunas.

#### 6.1.1. Monospecific and monogeneric faunas

The *Dhrumaites cardioceratoides* fauna (unit D6) and the *Catena* Horizon (lower unit H1) are the only monospecific fauna, but their meaning is very different. *Dhrumaites* is a strictly Arabic form and is not currently known outside of Arabia. The very few number of the collected specimens explains the relative high values of the associated genera. In contrast, *Euaspidoceras catena* is a fairly common and well-known form of the middle Oxfordian in Western Europe. The *Paryphoceras* sp. fauna of the upper member (unit H2) of the Hanifa Fm is not taken into consideration because it is known only in a single locality and by a single specimen.

Another type of association is more widely present, which corresponds to associations dominated by Arabic forms of a single genus. Here included are the two successive faunas in this order *Tuwaiqensis* (unit D4) and *Clydocromphalus* (unit D5) faunas that come up a lot of similarities.

The *Tuwaiqensis* fauna (unit D4) is largely dominated by the genus *Tulites* (84%) associated with a new Arabic form *Saudisphinctes arabicus* (12%), the rare species of European affinity representing only 4%.

The *Clydocromphalus* fauna (unit D5) is even more clearly monogeneric if the two species, *M. busqueti* and *M. torrensensis*, are included among the Arabic forms, which

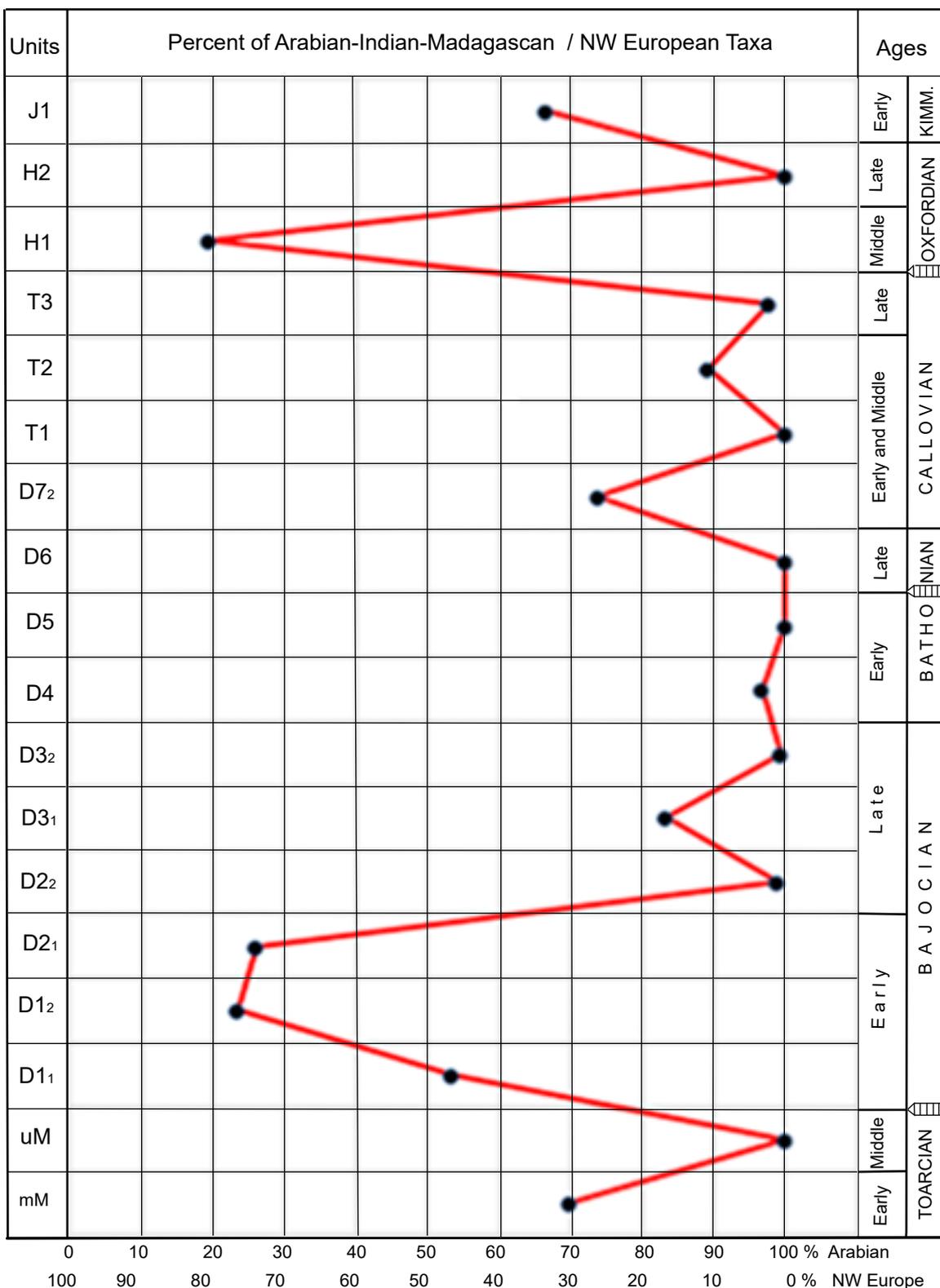


Fig. 11: Evolution of the percentage of Arabo-Indo-Madagascan and NW European taxa in the Jurassic ammonite faunas of Central Saudi Arabia. Subnumeration of the units (left column) indicate lower (1) and upper (2) parts of them.

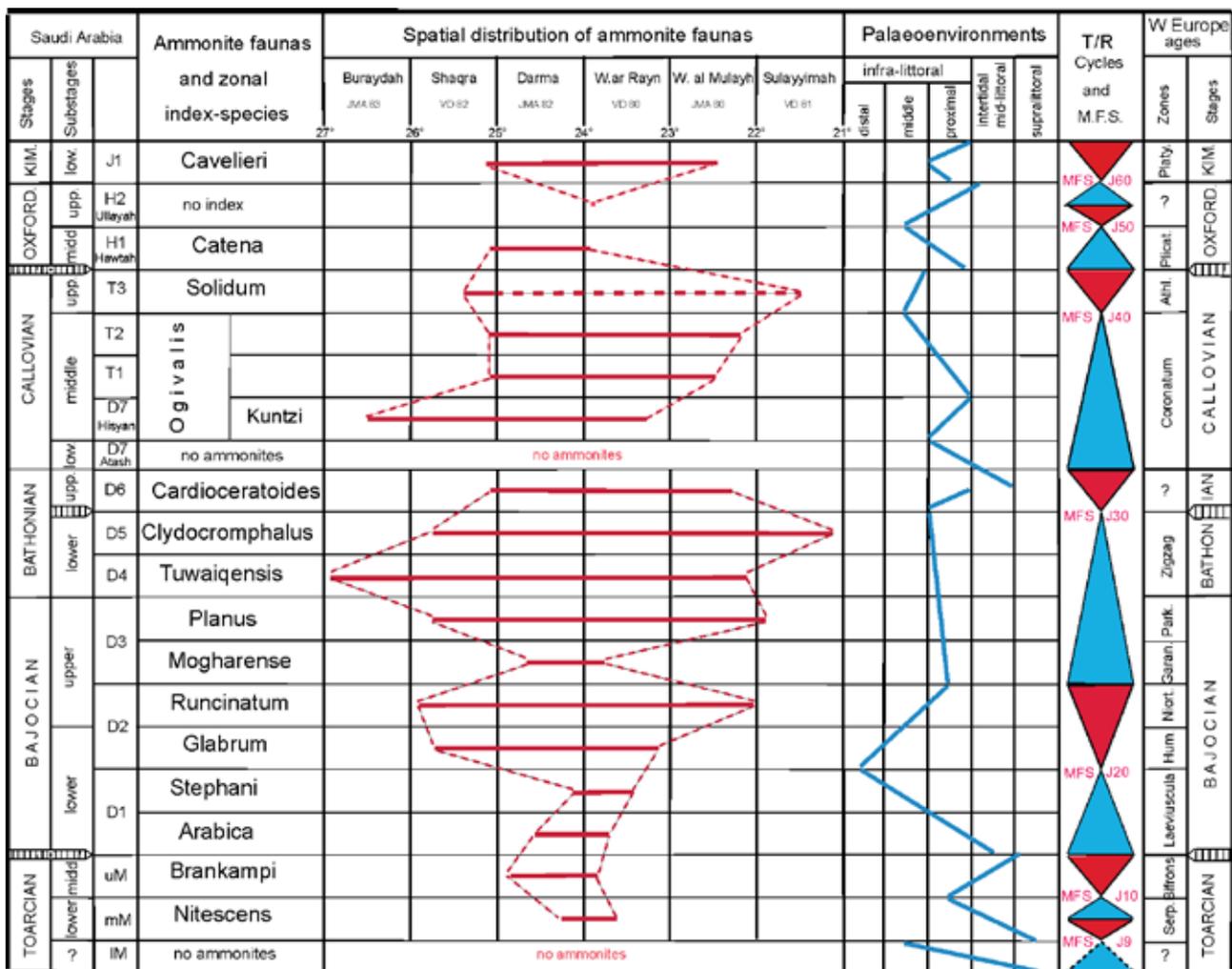


Fig. 12: Spatial distribution of the ammonite faunas, palaeoenvironmental conditions and sequence stratigraphy of the Jurassic in central Saudi Arabia. Palaeoenvironments based on Le Nindre (1990). Sequence stratigraphy based on Le Nindre (1990b), Sharland *et al.* (2001), Kadar *et al.* (2015), and Al-Mojed (2017).

by chance discoveries were first known (and described) in Western Europe, but surely of Arabian origin. Thus *Micromphalites* would represent 99% of the fauna, the only other associated species (*Pseudoclydoniceras* sp.) being an Arabic form.

### 6.1.2. More or less diversified faunas

The same contrast opposes the faunas dominated by the West European forms and those in which the Arabian forms are dominant.

The former type is well illustrated by the *Stephani* fauna (upper unit D1), whose the two characteristic forms, *Pseudoshirbuirnia stephani* and *Sonninites* aff. *albidus*, genera and species well known in Western Europe, represent 76% of the fauna. Their nearly exclusive presence (76%) testifies to a relatively deep environment. Another comparable situation is the *Glabrum* fauna

which, although the characteristic is a new genus and a species of Arabic affinity, it is dominated by the western European genera and species (75%), among which *Dorsetensia* (55%).

Concerning the Arabian dominated fauna, the *Runcinatum* fauna (upper unit D2) is certainly one of the most representative of these associations of which we can overlook the rare examples of genera and species known in Western Europe (*Stephanoceras*, *Cadomites*, *Leptosphinctes*, 3 specimens, 0.95%). *Thamboceras* (0.01%) being aside. The Ermoceratinae include 99.04% of species belonging to the different genera of this subfamily, all described from Egypt (Sinai) or Saudi Arabia, are largely dominant in response to the infra-littoral proximal environment to the limit of confinement. With the exception of the lower *Ogivalis* fauna (unit D7, upper member), in which the western European forms are quite numerous (26%), most of the *Ogivalis* fauna (units T1 and T2) and the *Solidum* fauna (unit T3) are

largely dominated by Arabian or Arab-Indo-Madagascan elements (T1: 100%, T2: 96.15% and T3: 95.5%, respectively)

## 6.2. Arabian endemic faunas, ecologic signification and migration outside the Arabian Province

The discontinuous nature of the succession of faunas and the oscillations of their extension described in the previous pages are directly linked to their dependence on environmental conditions. The endemic nature of the indigenous forms specific to the Arabian province results directly from their adaptation to the restrictive environmental conditions on very wide and very shallow platforms. Whatever the fauna considered, the Arabian faunas constantly show several common characteristics, monogeneric or monospecific assemblages, great intraspecific variability and constancy of the simple or simplified suture lines, whatever the shell morphology considered.

### 6.2.1. Intraspecific variability

That is one of the characteristics often mentioned for endemic faunas, linked to restrictive living environments. Among the studied faunas, the *Nejdia* fauna (Upper Marrat Fm), with a single species *N. brankampi*, is a first example. The intraspecific variability concerns first and foremost the pattern of the suture line, so much that *N. furnishi*, separated from *N. brankampi* by Arkell (1952) on the sole criteria of the enlargement of the first “accessory” lobe and the asymmetrical division of the adventive lobe seemed to us to be unfounded. As stated previously these seem to be related to the shape of the umbilical area and also probably the whorl section thickness which allow to distinguish “thick-whorled morphotype” opposite to the normal “compressed-whorled morphotype”. As a result of this the height of the ventral keel associated with a greater or lesser width and a more or less truncated inclination of the shoulders situated on either side, is also attributed to intraspecific variability.

Another example is the *Runcinatum* fauna (upper unit D2, Dhibi Limestone member) with two dominating genera, *Telermoceras* and *Kosmermoceras*. Unlike the type-specimens, incomplete nuclei, the present study is based on adult fully grown specimens, sometimes complete with the aperture. First, concerning *T. coronatoides* (Douvillé) and *T. coronatiforme* Arkell, intraspecific variability within a same population could explain the very few differences between these species. However, when we have still septate specimen but of larger size and still more half a whorl of the body chamber preserved, they are evidently two distinct macroconch species.

Then, Arkell considered *T. splendens* as intermediate between *T. coronatoides* and *T. deserti*, contrasting with our opinion that *T. splendens* is very close to *T. deserti*

wondering whether the two species are not conspecific. In the present state of knowledge, *T. deserti* could be a variant of *T. splendens* with denser and finer ribbing and less strong tubercles, but another possibility is it would be the microconch of *T. splendens*.

### 6.2.2. Constancy of the simple or simplified suture lines

This is a well-known characteristic of Arabian forms interpreted as an adaptive response to their habitat in shallow platform environments, with restrictive environmental conditions, at the tolerance limit for ammonites. This simplification of the suture line is present, to various degrees, in all the groups of ammonites, independently of their general shell shape, from the oxycones or suboxycones (*Nejdia*, *Thambites*, *Reboulliceras*, *Dhrumaites*, *Pseudoclydoniceras*), the cadicones and spherocones (*Eoermoceras*, *Telermoceras*, *Tulites*, *Pachyerymnoceras*) via the platycones-serpenticones (*Bouleiceras*, *Protogrammoceras*, *Parahildaites*, *Kosmermoceras*). The simplification of the septa can even affect forms of groups not exclusively Arabian, known mainly in Western Europe or with a worldwide distribution, but represented by forms adapted to the new environmental conditions specific to the Arab domain (ecological variants), such as the Sonniidae.

### 6.2.3. Migrations outside the Arabian Province

Although closely dependent on the shallow environments that have endured throughout the Jurassic (and beyond) many elements of the Arabian faunas are known outside the Arabian platform. A review of these Arabian forms recorded elsewhere that the Arabian Province has already been made by Rioult (1985), Énay (1993), Rioult & Chirat (1999) and Énay *et al.* (2012a, b). In summary (full references in Énay *et al.*, 2012b):

- During the Toarcian *Bouleiceras* is present in Spain (Betic and Iberian chains) and in Morocco (Middle Atlas Ranges); *Nejdia* in Spain and Italy.
- During the Bajocian, *Trimarginia* is recognized in Normandy, Spain, Sicily and Switzerland (here dated to the Bathonian by the associated fauna); *Ermoceras* in western Algeria and Morocco (Middle Atlas Ranges), also in Sicily; *Thambites* and *Mulayites* in western Algeria and Morocco.
- During the Bathonian, *Micromphalites* has been encountered in Morocco (Middle Atlas Ranges), Spain (Andalusia), France (Poitou, Nièvre and SE of France) and Slovakia; the *Tulites* of the Arabic type in Sicily; the presence of *Dhrumaites* in Morocco needs to be confirmed.
- During the Callovian, *Pseudoclydoniceras* is known in Poitou (Cariou *et al.*, 1989) and *Pachyerymnoceras* in Western Algeria and Southern Tunisia (Énay *et al.*, 2002).

Thus, the repeated appearances in Western Europe of these South Tethyan arrivals follow the same pattern throughout the Lower and Middle Jurassic. The route followed is first of all an expansion from East to West on the Northern African margin to the Ibero-Moorish Strait (Énay, 1980; Énay & Mangold, 1982), then, for those who reached Western Europe, either the “Atlantic” route via the Lusitanian facade to Normandy and England, invoked by Ager & Walley (1997) and Rioult (1985), or the more direct Ibero-Aquitaine route via Eastern Spain to Southern France.

These two variants of a same route of dispersal of elements of South Tethyan origin towards Western Europe are related to the regime of sea currents in the narrowed western part of Tethys associated with the absence of a wide opening on the eastern Pacific which will only be really active from the Oxfordian (Hispanic Corridor). Hence the existence in its narrowed western part of a current reflected towards the north in the direction of the North Atlantic passage (Viking Corridor of Doré, 1991, 1992), functional only temporarily until (before) the Callovian.

In the cessation of Arabian contributions to Western Europe after the Callovian, which coincides with the absence of more recent indigenous forms, other factors have certainly played a role. The widest opening from the Callovian of the Viking Corridor marked by the arrival of elements of subboreal origin within the sub-Mediterranean faunas which persist at least until the early Kimmeridgian, with alternating advances (Boreal spread of Arkell, 1956) and setbacks, associated with that of the Hispanic corridor at the location of the future central Atlantic and the wide opening of the Tethys towards the Pacific to the Oxfordian, are undoubtedly the first responsible, via the change in the regime of surface currents and the distribution of water masses with different characteristics (temperature, salinity, nutrients, among other).

Different possibilities of transport and dispersal of these arrivals are possible, between which it is not easy to decide for each of them, either by drifted shells, or arrival of living adult animals or passive dispersal by non-larval young during the brief stage of planktotrophic development. This last option is unavoidable whenever these Arabian immigrants had western European descendants, often known and described long before the Arabian forms from which they are issued (*Micromphalites*, *Pachyerymnoceras*, *Thamboceras*).

With the exception of *M. cf. clydocromphalus* discovered in Kutch (India) and wrongly dated from the Middle Bathonian (Pandey & Callomon, 1995), other species of *Micromphalites* (*M. golenkoi*, *M. hourcqui*, *M. saintoursi*) were described from Madagascar by Collignon (1958b) and assumed to be Late Bathonian (Hourcqi Zone). According to Mangold & Énay (2010) the Hourcqi Zone would start in the late Middle Bathonian (Bremeri Zone, Fortecostatum Subzone of the Submediterranean

Standard Scale), but the age would be mainly Late Bathonian. *M. aff. hourcqi* has been found also in Kachchh (India) by Jaitly & Singh (1984) and ascribed to the Middle Bathonian. These forms, different from those known in Europe, are undoubtedly the witnesses of an expansion or a migration towards the Indo-Madagascan Gulf, currently less documented than the expansion towards W Europe.

These periods of expansion of the Arabian faunas coincide with the periods of high sea level identified during the Early and the Middle Jurassic. The result is a broad development, especially along the Northern Africa margin, of shallow platforms with shallow medium environments favorable to Arabic forms, a determining factor for their expansion outside their area of origin.

### 6.3. Arrivals in the Arabian domain of western European and/or Indo-Madagascan taxa

In addition to episodic migrations outside their area of origin by Arabian forms, foreign elements entered the Arabian Province from two distinct origins.

#### 6.3.1 Arrivals of western European taxa

The taxa of NW European origin taxa in Saudi Arabia are known in several levels, two of which are particularly significant, but with very different characteristics.

The lower member of the Hanifa Fm, unit H1 yielded a single identifiable form, identical or very close to forms known from Western Europe, *Euspidoceras cf. catena* (Sowerby), but in sufficient number to define a true palaeontological horizon. This presence is in good agreement with the wide extension in Europe of the Submediterranean fauna which follows the expansion towards the south of the subboreal faunas in the Early Oxfordian (Boreal spread of Arkell, 1956).

On the contrary, the interval from the lower unit D1 up to the lower unit D2 (*Arabica*, *Stephani* and *Glabrum* faunas, Lower Bajocian) is distinguished by more abundant and more diversified NW European arrivals: 3 species (and 38.23% of the fauna) in the lower D1, dominated by a single form of the group of *Hypelioceras discites*, 2 species from Western Europe (*Pseudoshirburnia stephani* and *Sonninites aff. albidus*) representing 76.59% in the upper D1 and more than 10 species and 73.89% in the lower D2. The latter fauna is remarkable for the abundance of representatives of *Dorsetensia* (mainly *D. liostraca tecta* and *D. liostraca subtecta*, and *D. cf. deltafalcata*, *D. cf. regrediens*, *D. cf. schlumbergeri*), including macro- and microconchs, unlike *Teloceras*, whose only identified species (*T. aff. lepsiusi*) is known only by microconch specimens, like the less numerous *Normannites braikenridgei*. It is likely that these diversified faunas, at least for the

most abundant and, even more, those associating their two dimorphs, reflect a real settlement of these western European arrivals.

North-west European taxa are not altogether absent from other faunas dominated by native Arabian elements, but always with a reduced or very reduced number of specimens: thus in the upper unit D2 (*Stemmatoceras*, *Cadomites*, *Leptosphinctes*), the basal unit D3 (*Spiroceras annulatum*), the unit D3 (*Procerites*), the unit D4 (*Metazigzagiceras*, *Oxycerites*), the unit D7 (*Erymnoceras* cf. *coronatum*, *E.* cf. *schloenbachi*, *Choffatia* aff. *kontkiewiczzi*) and the unit T3 (*Peltoceras* cf. *trifidum*). However, in addition to their small number, the specimens collected are often poorly preserved, probably worn before being buried, therefore arrivals as drifted shells cannot be excluded.

### 6.3.2. Arrivals of Indo-Madagascan taxa

The *Bouleiceras* (Middle Marrat, Lower Toarcian) and *Nejdia* (Middle Marrat, Middle Toarcian) faunas are not further examined here; it is difficult to decide whether they are fundamentally Arabian or of Indo-Madagascan, with an migrations towards one or the other.

These arrivals of elements of true Indo-Madagascan origin are limited to the *Ogivalis* fauna and the upper part (Hisyan Member) of the unit D7 of the Middle Callovian, with *Pseudomicromphalites*, a Madagascan genus, *Kenkelinicerias* and *Obtusicostites* typically Indo-Madagascan as well, so 76.19% of the entire fauna. Besides a few large and well-preserved specimens and numerous nuclei, pyritized specimens already published as juveniles in earlier works (Énay *et al.*, 1986 and 1987a, pl. 6, figs 5-8) are juveniles on, or close to their breeding areas, the deeper environments off the Arabian Platform, which they frequented only during the spawning-season. Perhaps there is more than a coincidence with the fact, exposed in the previous pages, that it is also starting from Callovian that occurred the stop at the same time of the coming out of the Arabic forms in direction of Europe and arrivals in Arabia of forms of European origin. The reorganization of the surface marine currents system in the Tethys, following the opening of the Viking Corridor in Callovian time, followed by the wide communication with the Pacific by the Hispanic corridor to the Oxfordian is undoubtedly one of the major causes.

## 7. CONCLUSIONS

The study of ammonites is the missing centrepiece of the building started with the 1:250.000 map surveys of the Phanerozoic Rocks Program. The smaller scale of the land surveys involved the creation of a more precise and homogeneous lithostratigraphic framework which was extended outside the mapped territories, to all the

outcrops of the Jurassic formations of the Shaqra Group between latitudes 18° and 27° N, over about 1000 km.

It is the first time that such a complete and varied palaeontological documentation has been gathered: on the one hand, it covers almost all of the Jurassic outcrops of central Saudi Arabia and not only the central part, west of Riyadh (which yielded the richest fauna). On the other hand, none of the groups present has been neglected, among which the ammonites occupy a special place. These latter are the base of a biochronological scale specific to the Arabian Province, and for correlations with W Europe, more particularly, the zonation of Submediterranean Province.

This monograph shows a greater diversity of ammonite faunas than previously known (Douvillé, 1916; Arkell, 1952; Imlay, 1970). This greater diversity has been already noted (Énay *et al.*, 1986, 1987a; Énay & Mangold, 1985, 1994; Énay *et al.*, 2007, 2009), but is largely amplified with the study of all the forms collected (more than 2143 specimens, of which 2013 could be determined at least on generic level), ranging from the Early Toarcian up to the Early Kimmeridgian. These ammonites represent 14 families, of which 6 are largely dominant in the number of genera and species, 45 genera (including 3 new), 76 species (including 10 new) and 28 in open nomenclature. This greater diversity of ammonite faunas does not reduce the singular character of the faunas of the Arabian Platform including many genera endemic to the Middle East (Arabia, Sinai, Lebanon, Israel) and adjacent regions (Pakistan, Madagascar). Indeed, among these 14 families, 6 are distinguished by their relatively high specific diversity, often dominated by species of one or more genera:

- The dominant species are specific to the Arabian province: *Bouleiceras* and *Nejdia* among the Hildoceratidae of the Toarcian; *Thamboceras*, *Thambites*, *Pseudoclydoniceras* within Opelellidae from the Upper Bajocian and *Micromphalites* from the Lower Bathonian; the Ermoceratinae subfamily (*Eoermoceras* gen. nov., *Ermoceras*, *Telermoceras*, *Kosmermoceras*) among the Stephanoceratidae of the Bajocian; *Pachyerymnoceras* and *Kurnubiella* among the Callovian Pachyceratidae.
- Among the Sonniniidae, the new species specific to the Arabian domain co-exist with known forms in Western Europe (*Pseudoshirbuirnia* and *Sonninites*). The family Perisphinctidae is distinguished by a relatively high number of species (9) combining rare specimens, often poorly preserved, especially known or closely related forms of western European species (*Procerites*, *Choffatia*, *Metazigzagiceras*) and forms specific to the Indo-Madagascan domain (*Obtusicostites*, *Kinkelinicerias* / *Sivajiceras*).

In contrast, the 8 other families, remarkable because they are monogeneric, even monospecific, or paucigeneric, are separated into three groups:

- Families with genera and/or species specific to the Arabian Province, such as the Tullitidae (fauna and Tuwaiqensis Zone of the Lower Bathonian) whose species are all different from those known in Europe to the point that their belonging to a new genus could have been considered by Galácz (1999a, b).
- The families represented by genera especially recorded in Western Europe: Graphoceratidae and Hammatoceratidae (Arabica Zone, Lower Bajocian), Strigoceratidae (Glabrum Zone, lower Bajocian), Spiroceratidae (Mogharensis Zone, Upper Bajocian), Aspidoceratidae (Catena Horizon, Middle Oxfordian). The family of Ataxioceratidae being a little apart by its association of Western Europe forms (*Orthosphinctes*) and *Alienispinctes* nov. gen. supposed to be proper to the Arabian Province.
- Finally and quite apart, the family of Sphaeroceratidae represented by a single specimen of a genus of the Mayaitinae from the Indo-Madagascan Province (fauna with *Paryphoceras*) from the upper part (Hawtham Member) of the Hanifa Fm.

This interpenetration of forms of different biogeographical origins or affinities is the result, either of arrivals on the Arabic platform of taxa from Western Europe in the form of drifting shells (unique specimens, often incomplete and poorly preserved), or real settlers with populations of

adults (*Dorsetensia* of the fauna and Stephani Zone from the upper part of the unit D1, Lower Bajocian; *Teloceras* from the fauna and Glabrum Zone from the lower part of the unit D2, Upper Bajocian) or even juveniles [*Obtusicosites* sp. from the Kuntzi Horizon, fauna and Ogivalis Zone from the upper part (Hysian Member) of the unit D7, Middle Callovian].

The counterpart of these arrivals of forms of European origins or affinities is the coming out of their province of origin of several Arabian species, which reached Western Europe (France, Spain, Portugal, Italy) via Sicily, Tunisia, Algeria and Morocco, where they are associated with the Tethyan faunas of the Submediterranean Province. The review has already been made by Rioult (1985), Énay (1993), Rioult & Chirat (1999), Énay *et al.*, 2012a, b) and reproduced here. As well as the presence of forms of Western European origins or affinities within the native Arabian faunas, these contributions of Arabian forms within the Western European populations play an essential role for the correlations between the biochronological scales of the Arabian Province and Submediterranean one. Although their characteristic species are a form first known and described from Western Europe, *Micromphalites micromphalus* (Middle Bathonian) and *Pachyerymnoceras jarryi* (Upper Callovian) are the descendants of these Arab “migrants” that have taken root in their new field of extension.

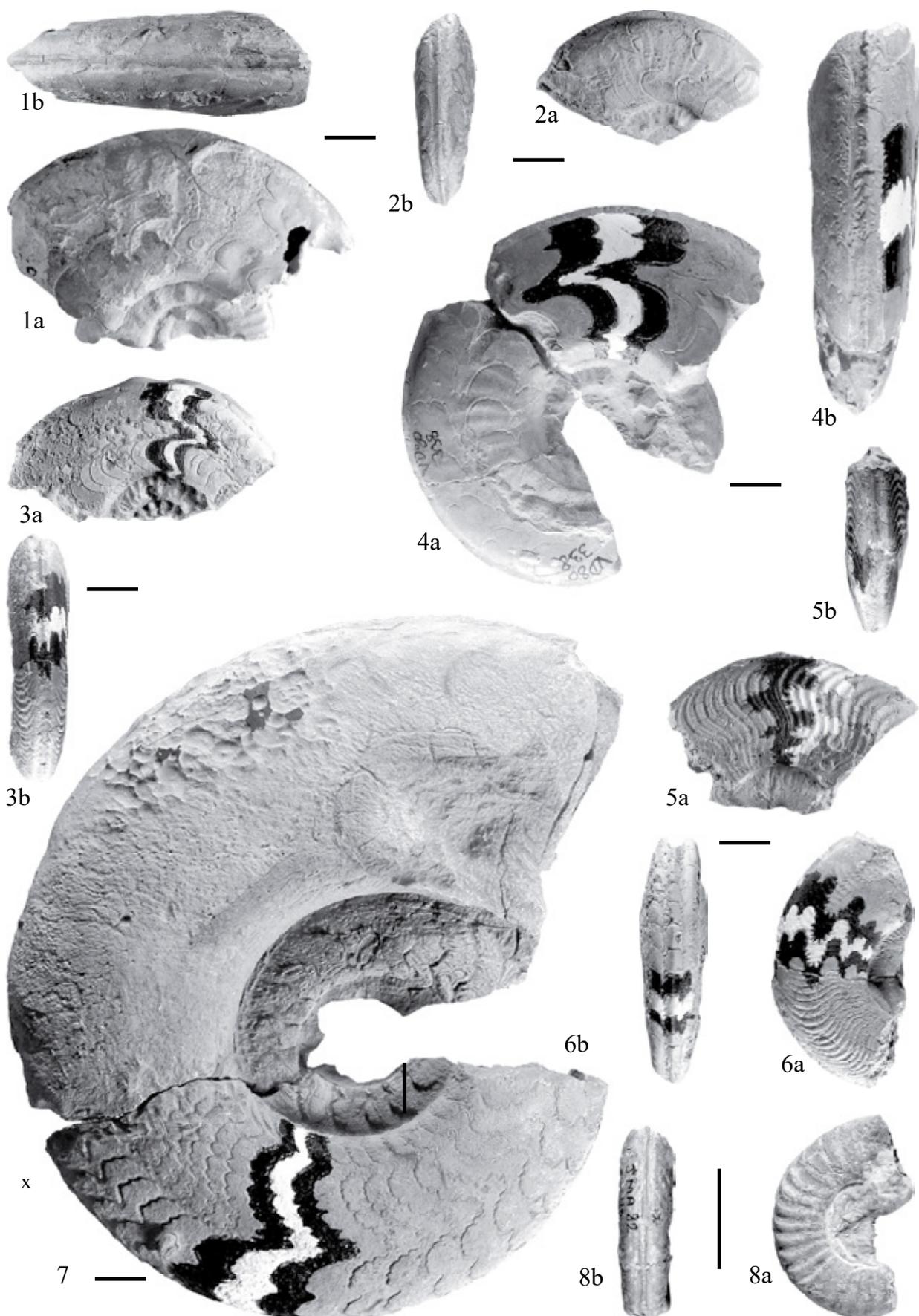
Thus the installation and expansion of successive ammonite faunas from the Lower Toarcian to the Lower Kimmeridgian on the Arabian Platform resulted from the

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In all figures the scale bars are 10 mm length.

#### Plate I

- Fig. 1a, b: *Bouleiceras arabicum* Arkell, incomplete specimen (UCBL-FSL 178 993), lateral (1a) and ventral (1b) views. Middle Marrat Fm. Lower Toarcian, Nitescens Zone. *Wadi ar Rayn Quadrangle*: VD80.338, Khashm al Jufayr, 23°58' N.
- Fig. 2: *Bouleiceras* cf. *rochi* Collignon, fragment a quarter whorl long (UCBL-FSL 178 989), lateral (2a) and ventral (2b) views. Middle Marrat Fm. Lower Toarcian, Nitescens Zone. *Wadi ar Rayn Quadrangle*: VD80.338, Khashm al Jufayr, 23° 58' N.
- Fig. 3a, b: *Bouleiceras nitescens* Thevenin, fragment about third a whorl long (UCBL-FSL 178 991), lateral (3a) and ventral (3b) views. Middle Marrat Fm. Lower Toarcian, Nitescens Zone. *Wadi ar Rayn Quadrangle*: Locality VD80.338, Khashm al Jufayr, 23°58' N.
- Fig. 4a, b: *Bouleiceras elegans* Arkell, well-preserved wholly septate specimen (UCBL-FSL 178 020), lateral (4a) and ventral (4b) views. Middle Marrat Fm. Lower Toarcian, Nitescens Zone. *Wadi ar Rayn Quadrangle*: VD80.338, Khashm al Jufayr, 23°58' N.
- Fig. 5: *Protogrammoceras madagascariense* (Thevenin), well-preserved whorl fragment (UCBL-FSL 178 949), lateral (5a) and ventral (5b) views. Middle Marrat Fm. Lower Toarcian, Nitescens Zone. *Wadi ar Rayn Quadrangle* VD80.338, Khashm al Jufayr, 23°58' N.
- Fig. 6: *Protogrammoceras madagascariense* (Thevenin), well-preserved half a whorl long (UCBLFSL 178 956), lateral (6a) and ventral (6b) views. Middle Marrat Fm. Lower Toarcian, Nitescens Zone. *Wadi ar Rayn Quadrangle*: VD80.338, Khashm al Jufayr, 23°58' N.
- Fig. 7: *Parahildaites sanderi* (Arkell), well-preserved specimen with a large part of the body chamber (UCBL-FSL 178 884) lateral view. Upper Marrat Fm. Middle Toarcian, Brankampi Zone. *Darmā' Quadrangle*: JMA82.419, lonely place South of Khashm Adh Dhibi, about 24°08' N (x indicates end of phragmocone).
- Fig. 8: *Haplopleuroceras* cf. *mundum* Buckman. Incomplete wholly septate specimen, half-whorl long, (UCBL-FSL 178 708-709), already figured by Énay *et al.* (1986, 1987a), lateral (8a) and ventral (8b) views. Lower Dhurma Fm, lower unit D1. Lower Bajocian, Arabica Zone. *Wadi ar Rayn Quadrangle*: VD80.525, Khashm al Majulah, 23°48' N.



concurrent action of several factors, the least obvious of which concerns the evolution of the Arabian forms themselves. If it is fairly obvious that there is a direct relationship between *Thamboceras* and *Thambites*, the relationship between the “primitive Ermoceras” (Énay *et al.*, 1986, 1987a) of the new genus *Eoermoceras* from the lower part of the unit D2 (fauna and Glabrum Zone) with the “true Ermoceras” (*Telermoceras*, *Kosmermoceras* and *Ermoceras*) from the upper part of the unit D2 (fauna and Runcinatum Zone) and from the basal part of the unit D3 (*Mogharensis* fauna and Mogharensis Zone) is not as certain. They could be two early off-shoots probably from the same ancestral form but not directly connected. More generally, except for brief periods of evolution on the spot, the origin of the forms specific to the Arabian Province has been sought outside their biogeographical domain in groups of forms known in more open marine environments. Their limited geographic location in shallow epicontinental environments suggests that they are the result of short-lived evolutionary burst in relative geographic isolation.

Thus, successive associations, discontinuous and variable in geographic distribution, are faunal changes resulting from ecological control. Indeed, the oscillations of the faunal extensions fairly faithfully reflect the fluctuations and the evolution of the environments according to Le Nindre *et al.* (1990a) and Manivit *et al.* (1990). These are under the control of several factors during the history of the basin, a high sedimentation rate for the transgressive deposits of the Toarcian, an active tectonic subsidence during the Bajocian-Bathonian, an acceleration of the sedimentation rate associated with active tectonic subsidence during the Middle and Upper Callovian, the rise in relative sea-level, a dominant factor in the Late Jurassic, period with not very active tectonic subsidence.

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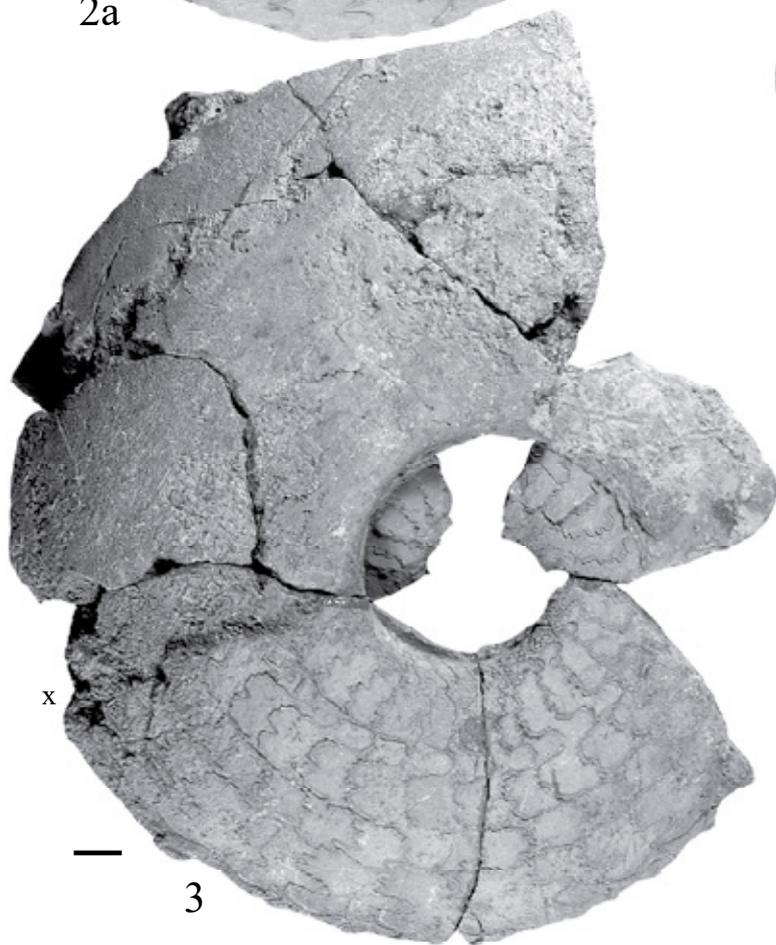
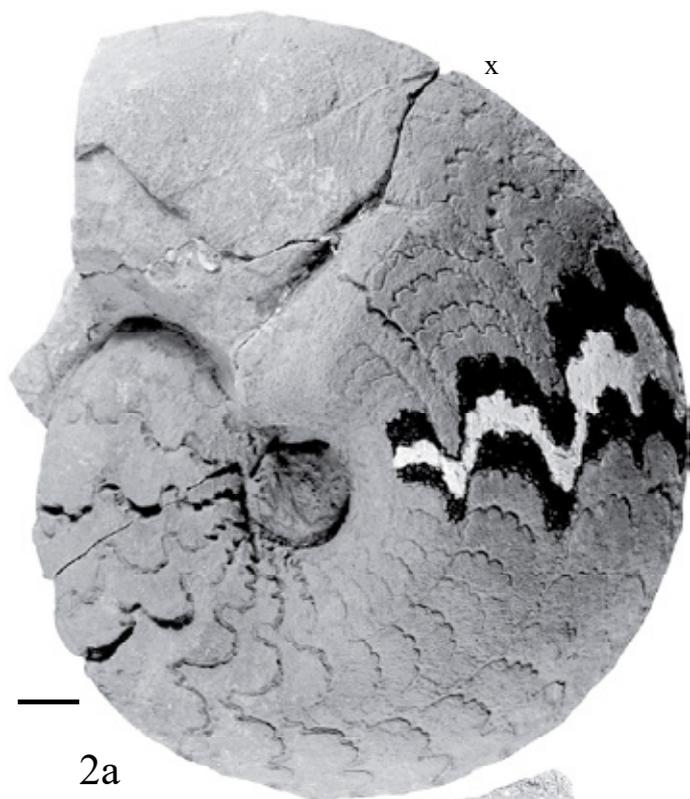
Excellency Ibrahim Ahmed Khabiri, then Vice Deputy / Minister of Mineral Resources of Saudi Arabia and Dr Mohamed Assad Tawfiq, then Chairman of Planning and Technical Supervision Committee of the DMMR are entitled to our warm thanks for the facilities granted to those who participated in the work in the field; and also by the authorization given to the publication of scientific results acquired from the material collected by the French BRGM field teams and during the three visits we made in the Saudi Arabia Jurassic outcrops. We are also indebted to the BRGM and especially C. Cavalier who gave us the opportunity to work on the samples from such an interesting and normally inaccessible region. During fulfilment of this work, we received the friendly help of many French or foreign colleagues, F. Cecca (†, Paris), R.B. Chandler (London), A. Galász (Budapest), S. Fernández-López (Madrid), V.V. Mitta (Moscow), J. Yin (Beijing), F. Venturi (Perugia) and L. Rulleau (Chasselay, France). They have always answered our requests, whether for publications or information on taxa for which we asked for their help. May they be warmly thanked. Many thanks also to H. Parent, editor (Rosario, Argentina) and to the reviewers A. Galász (Budapest) and G. Schweigert (Stuttgart). The poor command of the English language and the large number of spelling and language errors (and even more) required a heavy work of putting the manuscript back in shape for which they cannot be thanked enough. By the quality and the rigor of the work of formatting the final version carried out, Mrs. Corinne Charvet is entitled to my warmest thanks.

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#### Plate II

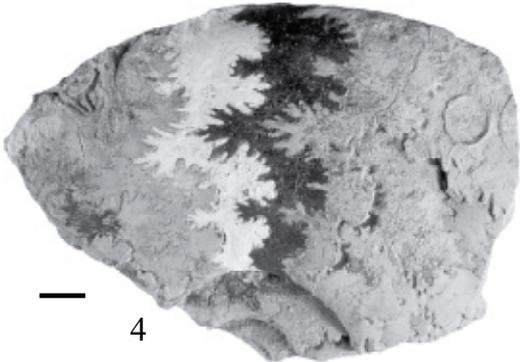
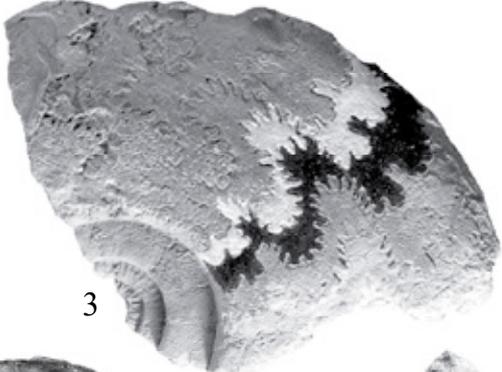
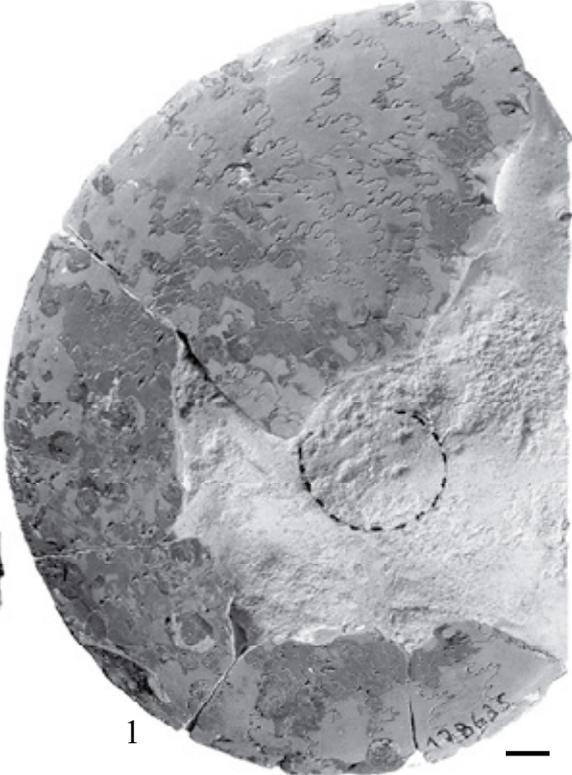
- Fig. 1: *Nejdia brankampi* Arkell. Morphotype with compressed whorl section (UCBL-FSL 178 833), lateral (1a) and ventral (1b) views. Upper Marrat Fm. Middle Toarcian, Brankampi Zone. *Darmā' Quadrangle*: JMA82.278, lonely place South of Wadi al Hisyan, 24°49' N.
- Fig. 2: *Nejdia brankampi* Arkell. Morphotype with thick whorl section (UCBL-FSL 178 739), lateral (2a) and ventral (2b) views. Upper Marrat Fm, Middle Toarcian, Brankampi Zone. *Darmā' Quadrangle*: JMA82.419, lonely place South of Khashm adh Dhibi, about 24°08' N (x indicates end of phragmocone).
- Fig. 3: *Nejdia brankampi* Arkell. The only preserved side of the largest known example with quarter whorl long body chamber (UCBL-FSL 178 749), Upper Marrat Fm. Middle Toarcian, Brankampi Zone. *Darmā' Quadrangle*: JMA82.278, lonely place south of Wadi al Hisyan, 24°49' N (x indicates end of phragmocone).



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## Plate III

- Fig. 1: *Hyperlioceras* sp. gr. *discites* (Waagen). Large wholly septate specimen (UCBL-FSL 178 635), lateral view. Lower Dhruma Fm, unit D1, basal part. Lower Bajocian, Arabica Zone. *Darm ' Quadrangle*: locality JMA82.120, Khashm adh Dhibi, 24 14' N.
- Fig. 2: *Sonninia* (? *Sonninia*) *arabica* (Arkell). Large wholly septate specimen (UCBL-FSL 178 684). 2a, lateral view and 2b, inner whorls. Lower Dhruma Fm, unit D1, basal part. Lower Bajocian, Arabica Zone. *Darm ' Quadrangle*: JMA82.289, lonely place North of Khashm adh Dhibi, about 24 7' N.
- Figs 3-4: *Sonninia* (? *Sonninia*) *arabica* (Arkell). Fragmentary, wholly septate (UCBL-FSL 178 700 and 701), lateral views, of which the one on fig. 3 looks near to Arkell's holotype (1952, pl. 19, fig. 10). Lower Dhruma Fm, unit D1, basal part. Lower Bajocian, Arabica Zone. *Darm ' Quadrangle*: JMA82.119 (178 700) and JMA82.119bis (178 701), Khashm adh Dhibi, 24 14' N.
- Fig. 5: *Sonninia* (? *Sonninia*) *arabica* (Arkell). Septate middle whorls of a larger specimen with the ribbing preserved (UCBL-FSL 178 661), lateral view. Lower Dhruma Fm, unit D1, basal part. Lower Bajocian, Arabica Zone. *Darm ' Quadrangle*: JMA82.119, Khashm adh Dhibi, 24 14' N.
- Fig. 6: ? *Sonninia* (? *Sonninia*) *arabica* (Arkell). Supposed microconch, nearly complete, the body chamber about a quarter whorl long, the aperture not preserved (UCBL-FSL 178 703), lateral (6a) and ventral (6b) views. Lower Dhruma Fm, unit D1, basal part, Lower Bajocian, Arabica Zone. *Darm ' Quadrangle*: JMA82.118 (UCBL-FSL 178 210, with doubt), JMA82.119, Khashm adh Dhibi, 24 14' N.



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## Plate IV

- Fig. 1: *Sonninia* (? *Sonninia*) *arabica* (Arkell). Wholly septate specimen with barely marked ribs (UCBL-FSL 178 687), lateral view. Lower Dhurma Fm, unit D1, basal part. Lower Bajocian, Arabica Zone. *Darmā' Quadrangle*: JMA82.289, lonely place North of Khashm adh Dhibi, about 24°7' N
- Fig. 2: *Sonninia* (*Euhoploceras*) *turbator* nov. sp. Nearly complete adult specimen with the beginning of the body chamber (UCBL-FSL 178 659). 2a, lateral view of the whole specimen; 2b, c lateral and ventral views of the inner whorls. Lower Dhurma Fm, unit D1, basal part, Lower Bajocian, Arabica Zone. *Darmā' Quadrangle*: locality JMA82.119bis Khashm adh Dhibi, 24°14' N (x indicates end of phragmocone).
- Fig. 3: *Fontannesia* sp. Wholly septate specimen (UCBL-FSL 178 698), lateral (3a) and ventral (3b) views. Lower Dhurma Fm, lower unit D1, Lower Bajocian, Arabica Zone. *Darmā' Quadrangle*: JMA82.289, lonely place North of Khashm adh Dhibi 24°14' N.

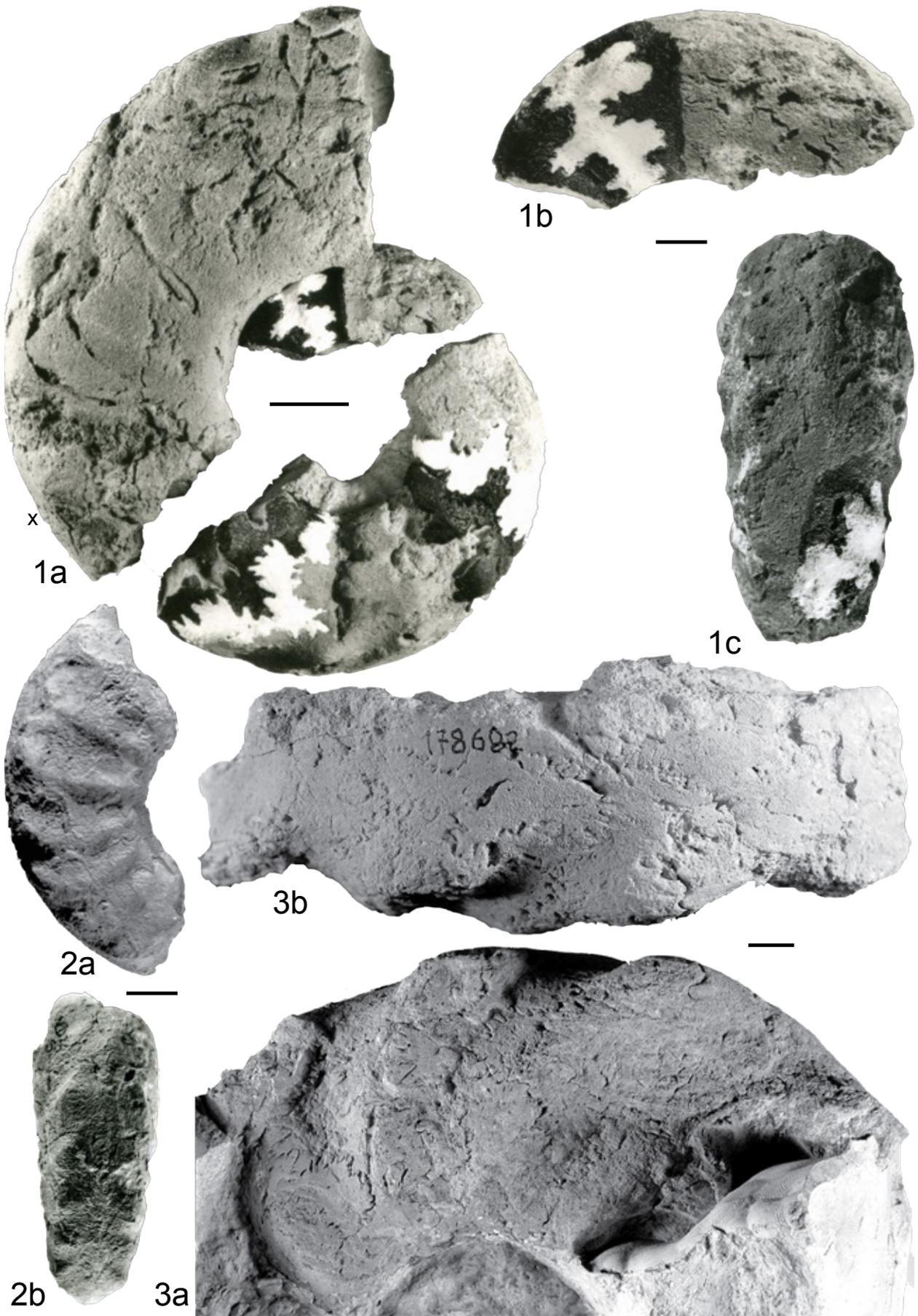


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## Plate V

Figs 1-3: *Sonninia (Euhoploceras) crassicosatae* nov. sp. Lower Dhruma Fm, unit D1, basal part, Arabica Zone.

1. Holotype, nearly complete specimen with a quarter whorl of the body chamber (UCBL-FSL 178 680); 1a, lateral view ; 1b, c, lateral and ventral views of part of the inner whorl. *Wadi ar Rayn Quadrangle*: VD80.525, Khashm al Majulah, 23°48' N. (x indicates end of phragmocone).
2. Better preserved inner whorls of another specimen (UCBL-FSL 178 673). Lateral (2a) and ventral (2b) views. *Darmā' Quadrangle*: JMA82.307, Graben South of Graben Awsat, about 24°32' N.
3. Still septate quarter whorl better preserved than the holotype, with badly preserved impression of the inner whorls (UCBL-FSL 178 682). Lateral (3a) and ventral (3b) views. *Wadi ar Rayn Quadrangle*: VD80.525, Khashm al Majulah, 23°48' N.



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## Plate VI

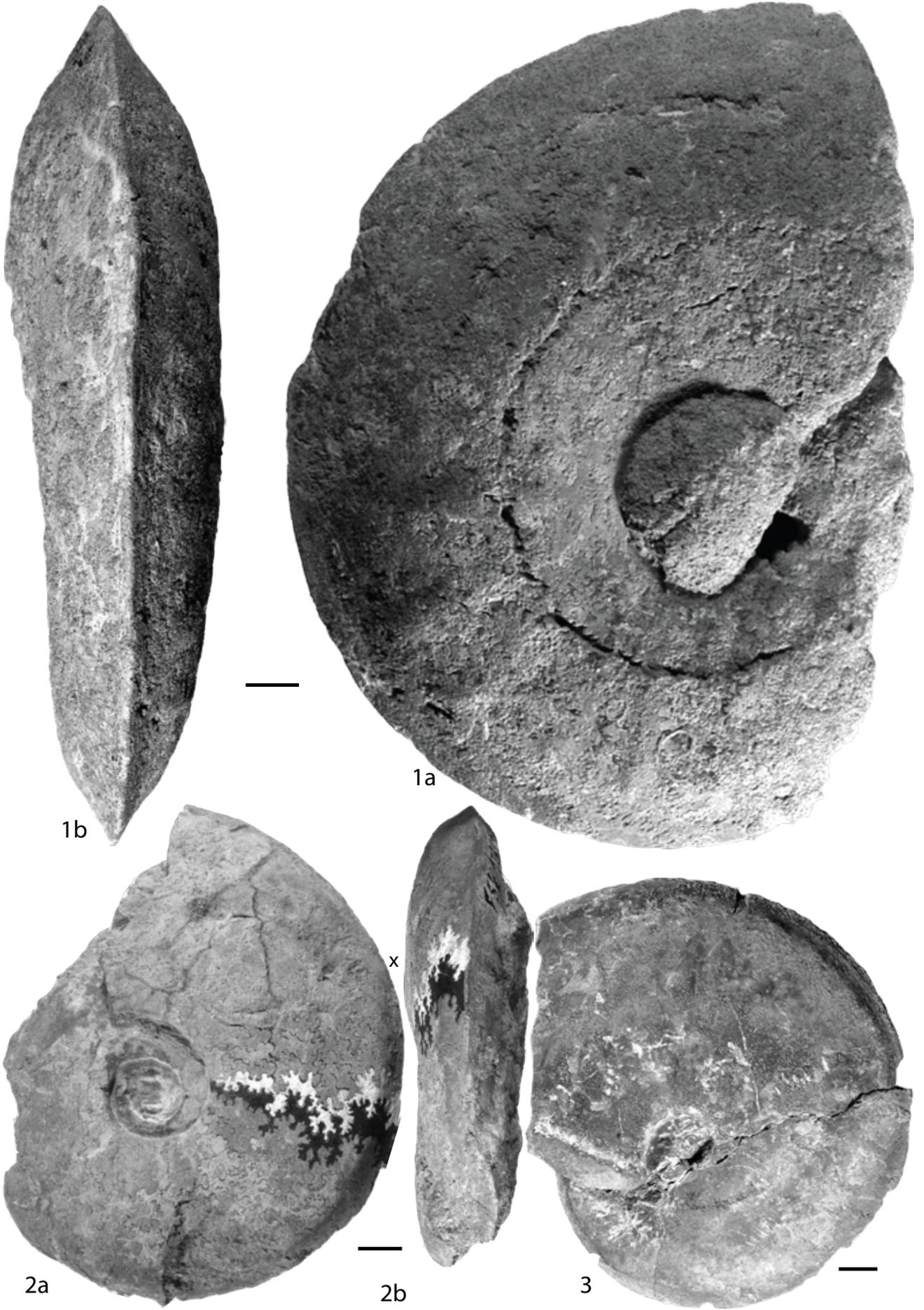
- Figs 1-3: *Sonninites* aff. *albidus* (Buckman). Lower Dhurma Fm, upper unit D1, Lower Bajocian, Stephani Zone. *Wadi ar Rayn Quadrangle*: VD80.527, Faridat Balum, 23°42' N (x indicates end of phragmocone).
1. Nearly complete macroconch (UCBL-FSL 178 577), lateral view.
  2. Nearly complete, small-sized macroconch (UCBL-FSL 178 69), lateral (2a) and ventral (2b) views.
  3. Supposed or possible microconch (UCBL-FSL 178 570), lateral (3a) and ventral (3b) views, together in the same piece of rock with FSL 178 569.



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## Plate VII

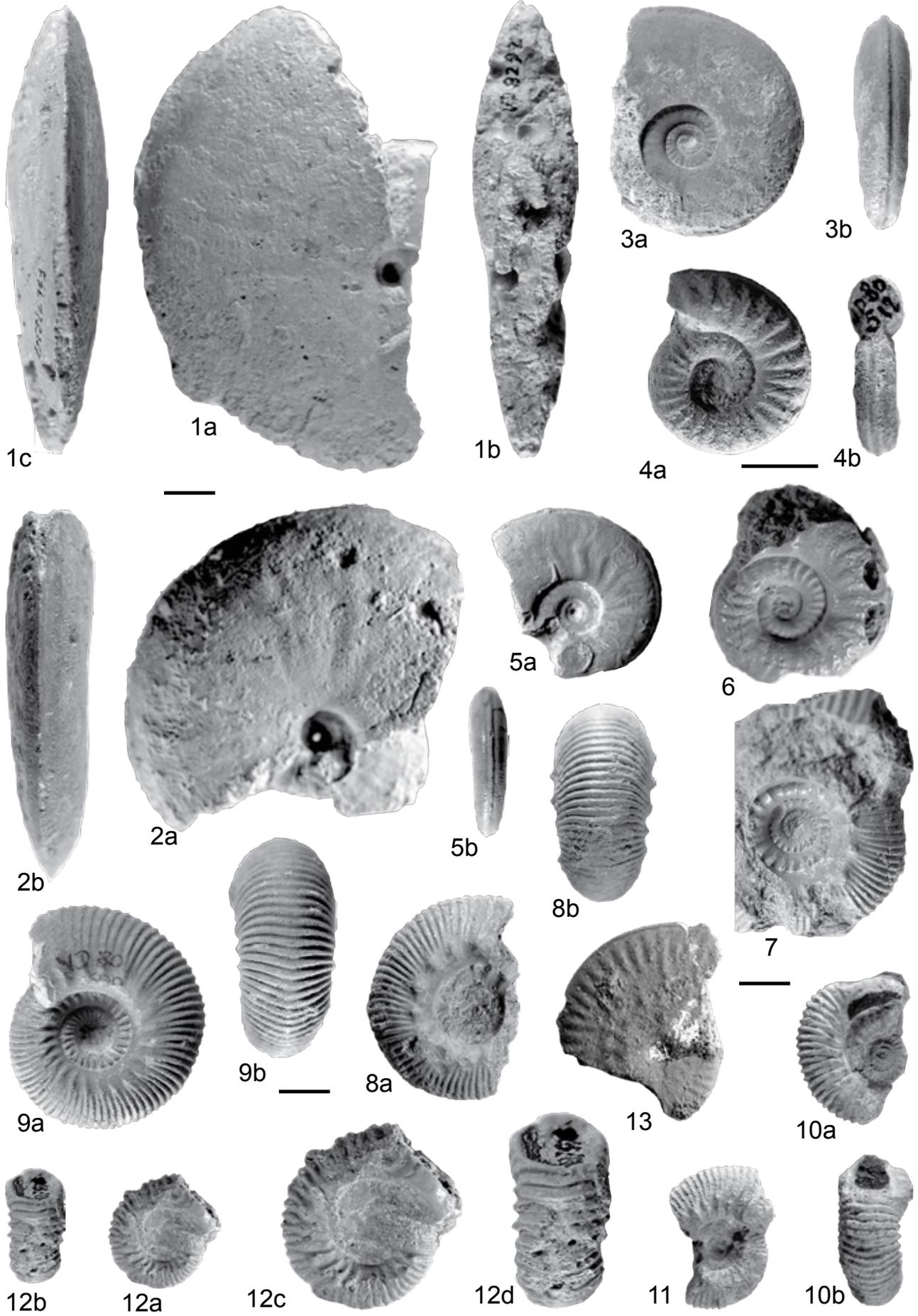
- Fig. 1: *Pseudoshirbuirnia stephani* (Buckman). Wholly septate specimen with the ribbing preserved (UCBL-FSL 178 620), lateral (1a) and ventral (1b) views. Lower Dhurma Fm, upper unit D1, Lower Bajocian, stephani Zone. *Wadi ar Rayn Quadrangle*: VD80.566, lonely place North of Faridat Balum, about 23°45' N.
- Fig. 2: *Dorsetensia liostraca tecta* Buckman. Adulte specimen with about a quarter whorl body chamber (UCBL-FSL 178 219), lateral (2a) and ventral (2b) views. Lower Dhurma Fm, Lower unit D2, Lower Bajocian, Glabrum Zone. *Darmā' Quadrangle*: JMA82.166, Khashm adh Dhibi, 24°14' N (x indicates end of phragmocone).
- Fig. 3: *Dorsetensia liostraca subsecta* Buckman. Immature specimen with part of the body chamber (UCBL-FSL 178 216), lateral view. Lower Dhurma Fm, Lower unit D2, Lower Bajocian, Glabrum Zone. *Darmā' Quadrangle*: JMA82.372, lonely place North of Khashm adh Dhibi about 24°22' N.



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## Plate VIII

- Fig. 1: *Dorsetensia liostraca tecta* Buckman. Wholly septate specimen with compressed and acute whorl section (UCBL-FSL 178 313), lateral (1a), whorls section (1b) and ventral (1c) views. Lower Dhurma Fm, Lower unit D2, Lower Bajocian, Glabrum Zone. *Shaqrā' Quadrangle*: VD82.92 lonely place (control hills) South of Jurayfah South about 25°22' N.
- Fig. 2: *Dorsetensia liostraca tecta* Buckman. Wholly septate specimen (UCBL-FSL 178 314), lateral (2a) and ventral (2b) views. Lower Dhurma Fm, Lower unit D2, Lower Bajocian, Glabrum Zone. *Shaqrā' Quadrangle*: VD82.92 lonely place (control hills) South of Jurayfah South, about 25°22' N.
- Fig. 3: *Dorsetensia liostraca subtectata* Buckman. Inner whorls with ribbing disappearing earlier (UCBL-FSL 178 252), lateral (3a) and ventral (3b) views. Lower Dhurma Fm, Lower unit D2, Lower Bajocian, Glabrum Zone. *Wadi ar Rayn Quadrangle*: VD80.590, lonely place North of Wadi Birk, 23°13' N.
- Fig. 4: *Dorsetensia* cf. *schlumbergeri* (Haug). Inner whorls or ? juvenile, no visible suture line (UCBL-FSL 178 289), lateral (4a) and ventral (4b) views, enlarged. Lower Dhurma Fm, Lower unit D2, Lower Bajocian, Glabrum Zone. *Wadi ar Rayn Quadrangle*: VD80.512 lonely place North of Wadi Birk about 23°14' N.
- Fig. 5: *Dorsetensia* cf. *deltafalcata* (Quenstedt). Well-preserved, small specimen (UCBL-FSL 178 422), lateral (5a) and ventral (5b) views. Lower Dhurma Fm, Lower unit D2, Lower Bajocian, Glabrum Zone. *Shaqrā' Quadrangle*: VD82.92 lonely place (control hills) South of Jurayfah South 25°40' N.
- Fig. 6: *Dorsetensia* cf. *regrediens* (Haug). Wholly septate, small specimen (UCBL-FSL 178 430), lateral view, enlarged. Lower Dhurma Fm, Lower unit D2, Lower Bajocian, Glabrum Zone. *Shaqrā' Quadrangle*: VD82.92, lonely place (control hills) South of Jurayfah South 25°40' N.
- Fig. 7: *Eoermoceras* n. sp. B. Wholly septate specimen (UCBL-FSL 178 351), lateral view. Lower Dhurma Fm, Lower unit D2, Lower Bajocian, Glabrum Zone. *Shaqrā' Quadrangle*: VD82.92, South of Jurayfah, about 25°22' N/45°20' E.
- Fig. 8: *Eoermoceras* n. sp. B. Half a specimen, wholly septate (UCBL-FSL 178 352), lateral (8a) and ventral (8b) views. Lower Dhurma Fm, Lower unit D2, Lower Bajocian, Glabrum Zone. *Shaqrā' Quadrangle*: VD82.92, South of Jurayfah, about 25°22' N/45°20' E.
- Fig. 9: *Normannites* aff. *braikenridgii* (Sowerby). Wholly septate specimen (UCBL-FSL 178 290), lateral (9a) and ventral (9b) views. Lower Dhurma Fm, Lower unit D2, Lower Bajocian, Glabrum Zone. *Wadi ar Rayn Quadrangle*: VD80.590 Wadi Birk, 23°12' N.
- Fig. 10: *Normannites* aff. *braikenridgii ventriplanus* Westermann. Small-sized but complete specimen with the lappets preserved (UCBL-FSL 178 287). Lower Dhurma Fm, Lower unit D2, Lower Bajocian, Glabrum Zone. *Wadi ar Rayn Quadrangle*: VD80.564, Wadi Birk, 23°12' N.
- Fig. 11: *Normannites* aff. *braikenridgii* (Sowerby) Small specimen, well-preserved but not complete (UCBL-FSL 178 269), lateral (11a) and ventral (11b) views Lower Dhurma Fm, Lower unit D2, Lower Bajocian, Glabrum Zone. *Darmā' Quadrangle*: JMA82.166, Khashm adh Dhibi, 24°14' N.
- Fig. 12: *Teloceras* aff. *lepsiusi* (Gillet). Small sized, complete microconch with the aperture preserved (UCBL-FSL 178 288), lateral (12a, c) and ventral (12b, d) views, natural size (12a, b) and enlarged (12c, d). Dhurma Fm, lowermost unit D2, Upper Lower Bajocian, Glabrum Zone. *Shaqrā' Quadrangle*: VD82.92, South of Jurayfah, about 25°22' N/40°20' E.
- Fig. 13: *Strigoceras* cf. *bessinum* Brasil. Stage of growth unknown, no visible suture line (UCBL-FSL 178 271), lateral view. Lower Dhurma Fm, Lower unit D2, Lower Bajocian, Glabrum Zone. *Shaqrā' Quadrangle*: VD82.93 lonely outcrops South of Jurayfah, about 25°22' N.



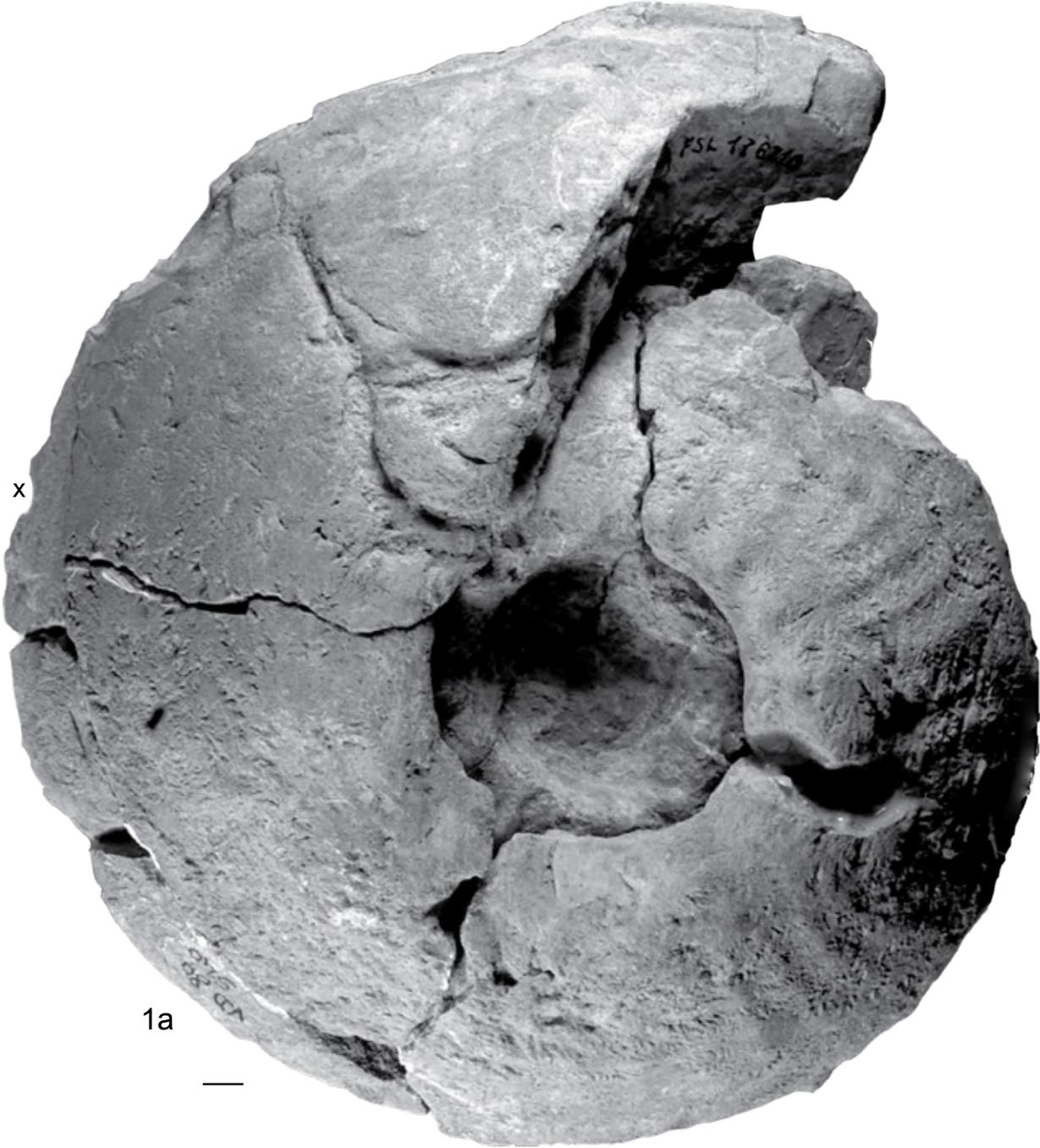
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## Plate IX

Fig. 1a, b: *Eoermoceras angulatidomus* nov. sp. Holotype, nearly complete adult specimen (UCBLFSL 178 210) lateral (1a) and ventral (1b) views. Dhurma Fm, lower unit D2, Upper Lower Bajocian, Glabrum Zone. *Wadi ar Rayn Quadrangle*: VD80.540, lonely place between Khashm al Hamra (23°30' N) and Wadi al Hawtah (23°32' N) about 23°31' N (x indicates end of phragmocone).



1b



1a

x

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## Plate X

- Fig. 1: *Eoermoceras angulatidomus* nov. sp. Holotype, inner whorls (UCBL-FSL 178 210), lateral (1a) and ventral (1b) views. Dhurma Fm, lower unit D2, Upper Lower Bajocian, Glabrum Zone. *Wadi ar Rayn Quadrangle*: VD80.540, lonely place between Khashm al Hamra (23°30' N) and Wadi al Hawtah (23°32' N) about 23°31' N.
- Fig. 2: *Eoermoceras angulatidomus* nov. sp. Paratype, inner whorls (UCBL-FSL 178 202), lateral view. Dhurma Fm, lower unit D2, Upper Lower Bajocian, Glabrum Zone. *Wadi ar Rayn Quadrangle*: VD80.540, lonely place between Khashm al Hamra (23°30' N) and Wadi al Hawtah (23°32' N) about 23°31' N.



2



1b

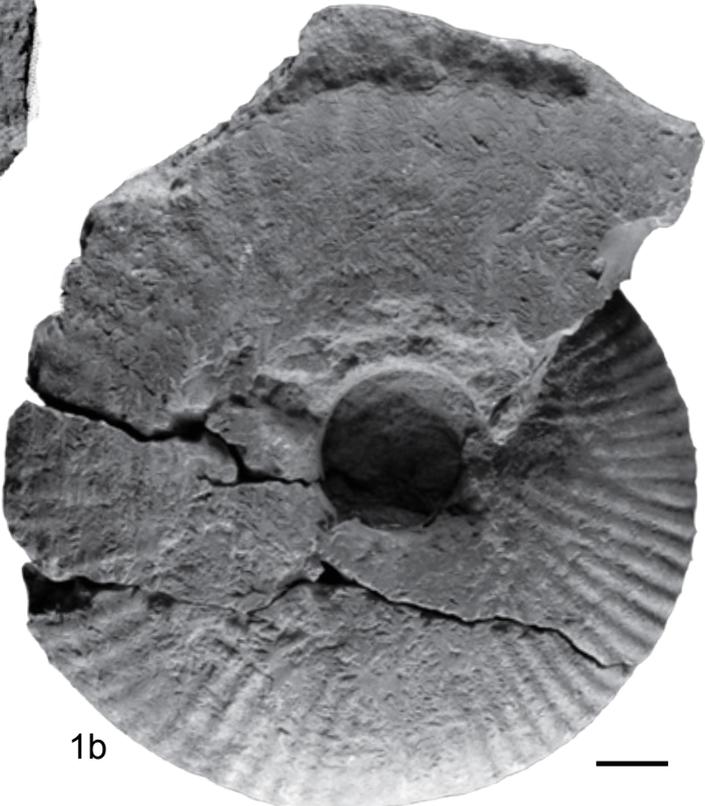
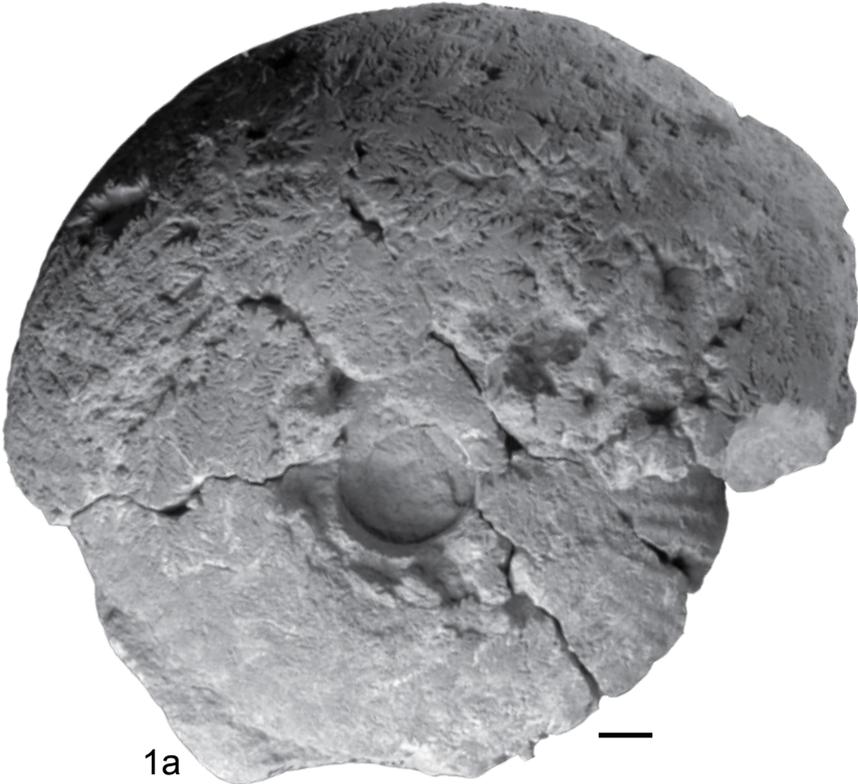


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## Plate XI

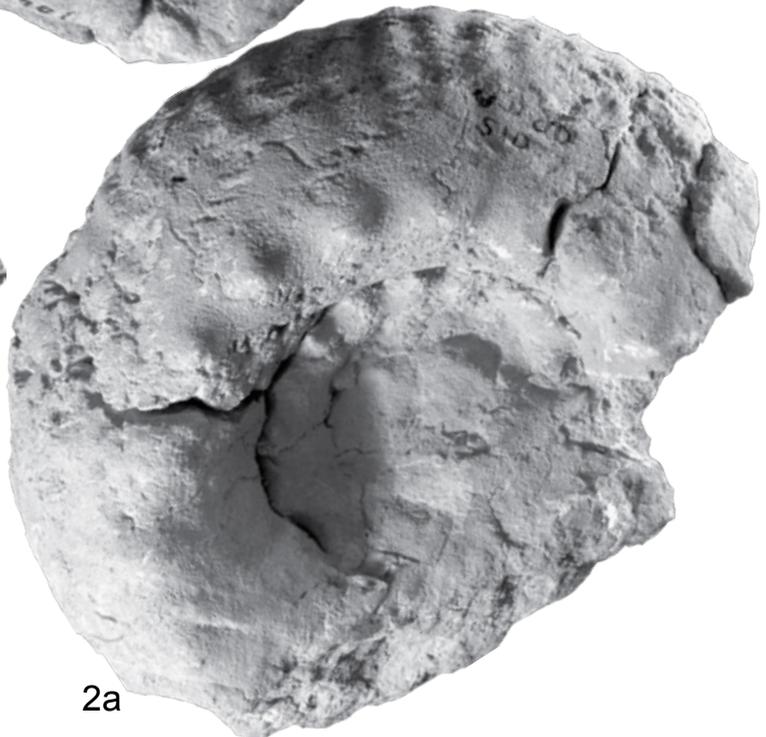
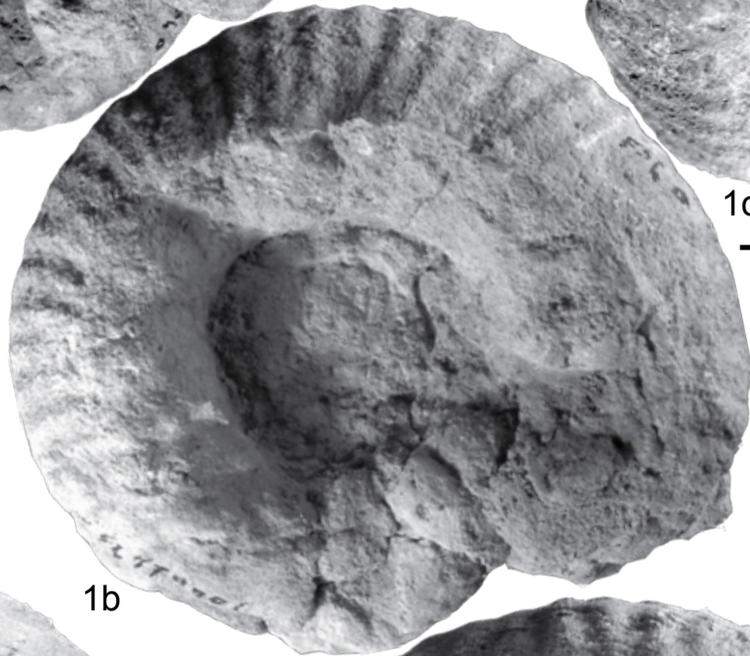
- Fig. 1a-c: *Eoermoceras glabrum* nov. sp. Holotype, wholly septate specimen (1a) that well exposes the inner whorls (1b, c) (UCBL-FSL 178 190). Dhurma Fm, lower unit D2, Upper Lower Bajocian, Glabrum Zone. *Darmā' Quadrangle*: JMA82.372, lonely place north of Khashm adh Dhibi, about 24°22' N.
- Fig. 2: *Eoermoceras glabrum* nov. sp. Paratype 2, wholly septate specimen (UCBL-FSL 178 150). Lateral view. Dhurma Fm, lower unit D2, Upper Lower Bajocian, Glabrum Zone. *Wadi ar Rayn Quadrangle*: VD80.540, lonely place between Khashm al Hamra (23°30' N) and Wadi al Hawtah (23°32' N) about 23°31' N.



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## Plate XII

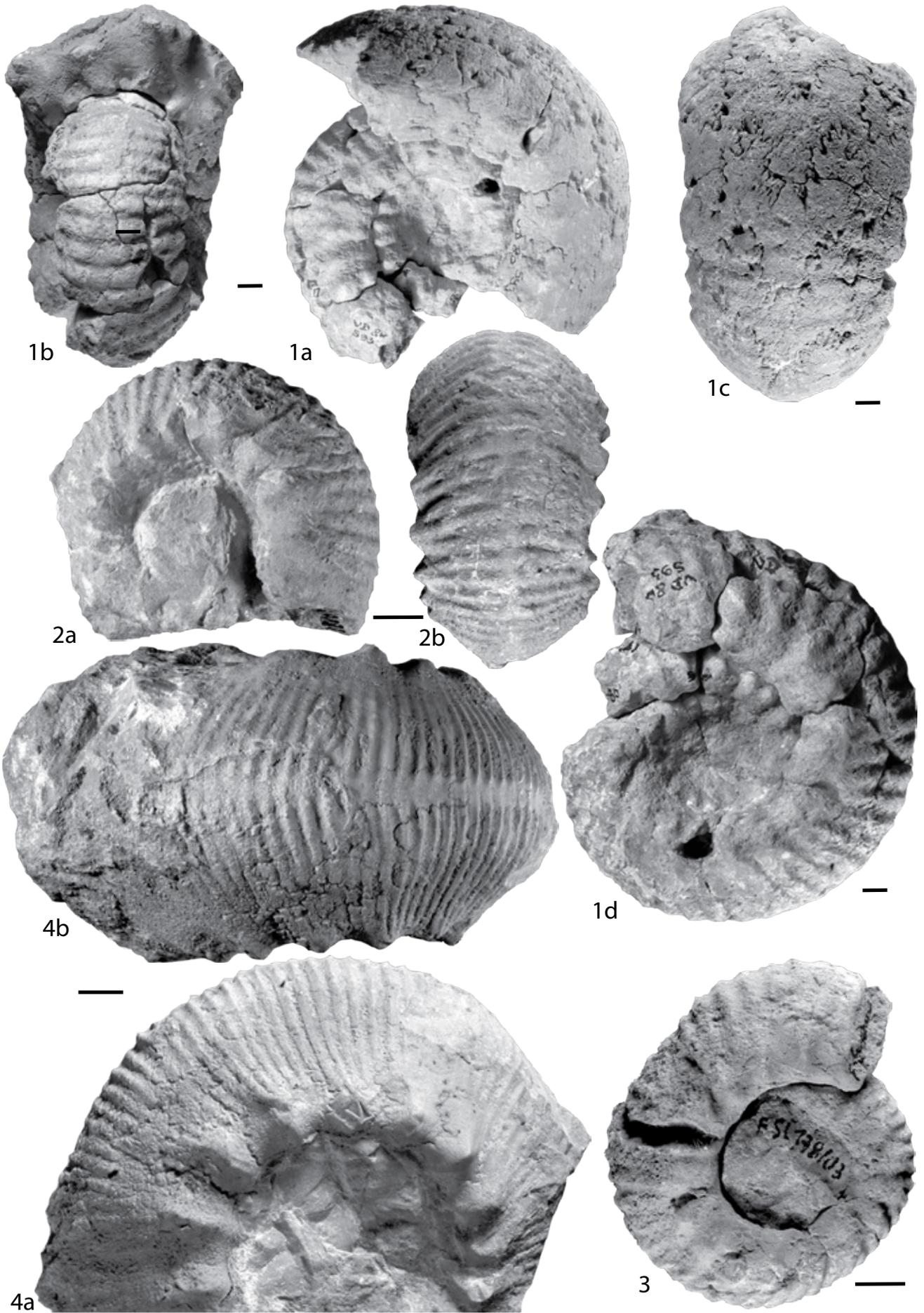
- Fig. 1: *Telemoceras coronatiforme* Arkell. Specimen with about half a whorl of the body chamber present (UCBL-FSL 178 081), poorly preserved, but which illustrates well the differences in the adult state with *T. coronatoides* (see fig. 2a, b). 1a, complete lateral view, 1b, c, inner whorls, lateral and ventral views. Dhurma Fm, upper D2 Unit (Dhibi Limestone), lowest Upper Bajocian, Runcinatum Zone. *Wadi ar Rayn Quadrangle*: VD80.510, Wadi Birk, 23°12' N.
- Fig. 2: *Telemoceras coronatoides* (Douvillé). Large-sized, wholly septate specimen (UCBL-FSL 178 079). Lateral (2a) and ventral (2b) views. Dhurma Fm, upper D2 Unit (Dhibi Limestone), Lowest Upper Bajocian, Runcinatum Zone. *Wadi ar Rayn Quadrangle*: VD80.537; North of Khashm Birk, 23°18' N.



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## Plate XIII

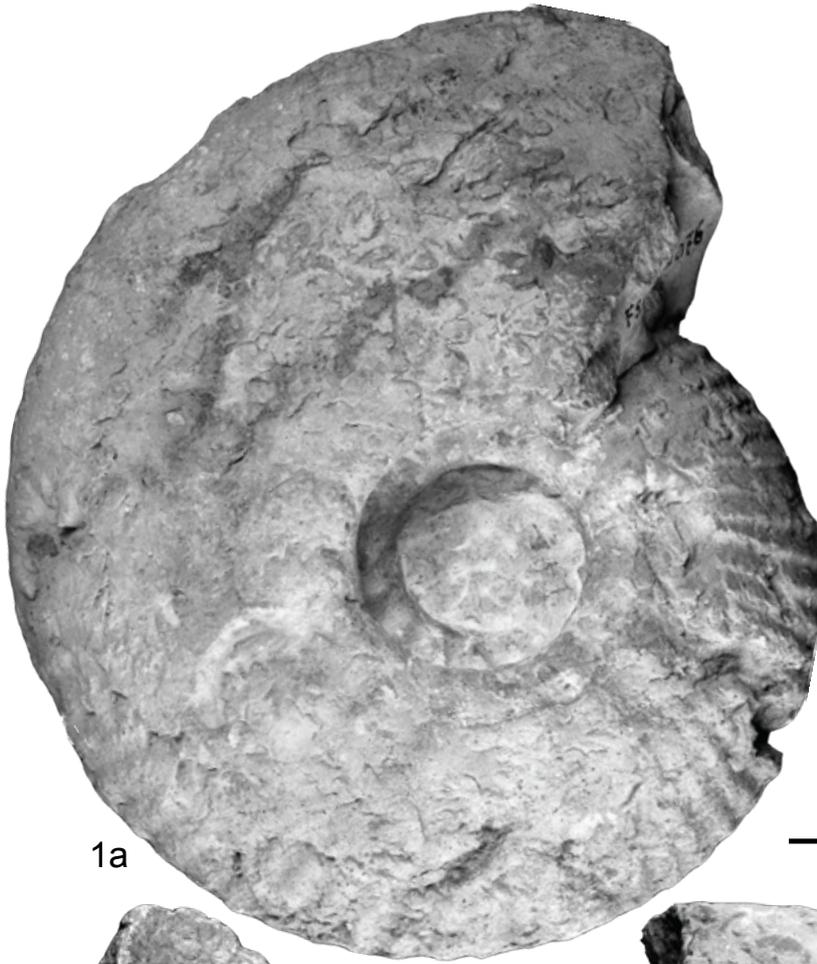
- Fig. 1: *Telermoceras coronatoides* (Douvillé). Large-sized, wholly septate specimen (UCBL-FSL 178 080). Two lateral views of the whole specimen (1a) and inner whorls (1d), and two ventral (1b, c) views illustrating the strongly depressed whorl-section. Dhurma Fm, upper D2 Unit (Dhibi Limestone), lowest Upper Bajocian, Runcinatum Zone. *Wadi ar Rayn Quadrangle*: VD80.593 Wadi Birk, 23°12' N (x indicates end of phragmocone).
- Fig. 2: *Telermoceras coronatoides* (Douvillé). Wholly septate specimen (UCBL-FSL 178 088), lateral (2a) and ventral (2b) views. Dhurma Fm, upper D2 Unit (Dhibi Limestone), lowest Upper Bajocian, Runcinatum Zone. *Wadi al Mulayh Quadrangle*: JMA80.80, As Sitarah Khashm Ushayrah, 22°38' N.
- Fig. 3: *Telermoceras coronatoides* (Douvillé). Wholly septate specimen (UCBL-FSL 178 103), lateral view. Dhurma Fm, upper D2 Unit (Dhibi Limestone), lowest Upper Bajocian, Runcinatum Zone. *Wadi ar Rayn Quadrangle*: VD80.544, lonely place North of Wadi al Hawtah, about 28°39' N.
- Fig. 4: *Telermoceras* n. sp. A. Half a whorl long and wholly septate specimen (UCBL-FSL 178 119). Lateral (4a) and ventral (4b) views. Dhurma Fm, upper D2 Unit (Dhibi Limestone), lowest Upper Bajocian, Runcinatum Zone). *Wadi al Mulayh Quadrangle*: JMA80.80, As Sitarah Khashm Ushayrah, 22°38' N.



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## Plate XIV

- Fig. 1: *Telermoceras splendens* Arkell. Wholly septate specimen (UCBL-FSL 178 076), lateral (1a) and ventral (1b) views. Dhurma Fm, upper D2 Unit (Dhibi Limestone), lowest Upper Bajocian, Runcinatum Zone. *Darmā' Quadrangle*: JMA82.409, lonely place at the same latitude as the Awsat graben about 24°38' N.
- Fig. 2: *Telermoceras splendens* Arkell. Wholly septate specimen (UCBL-FSL 178 048), lateral (2a) and ventral (2b) views. Dhurma Fm, upper D2 Unit (Dhibi Limestone), lowest Upper Bajocian, Runcinatum Zone. *Wadi al Mulayh Quadrangle*: JMA80.80, As Sitarah Khashm Ushayrah, 22°38' N.



1a



1b



2b

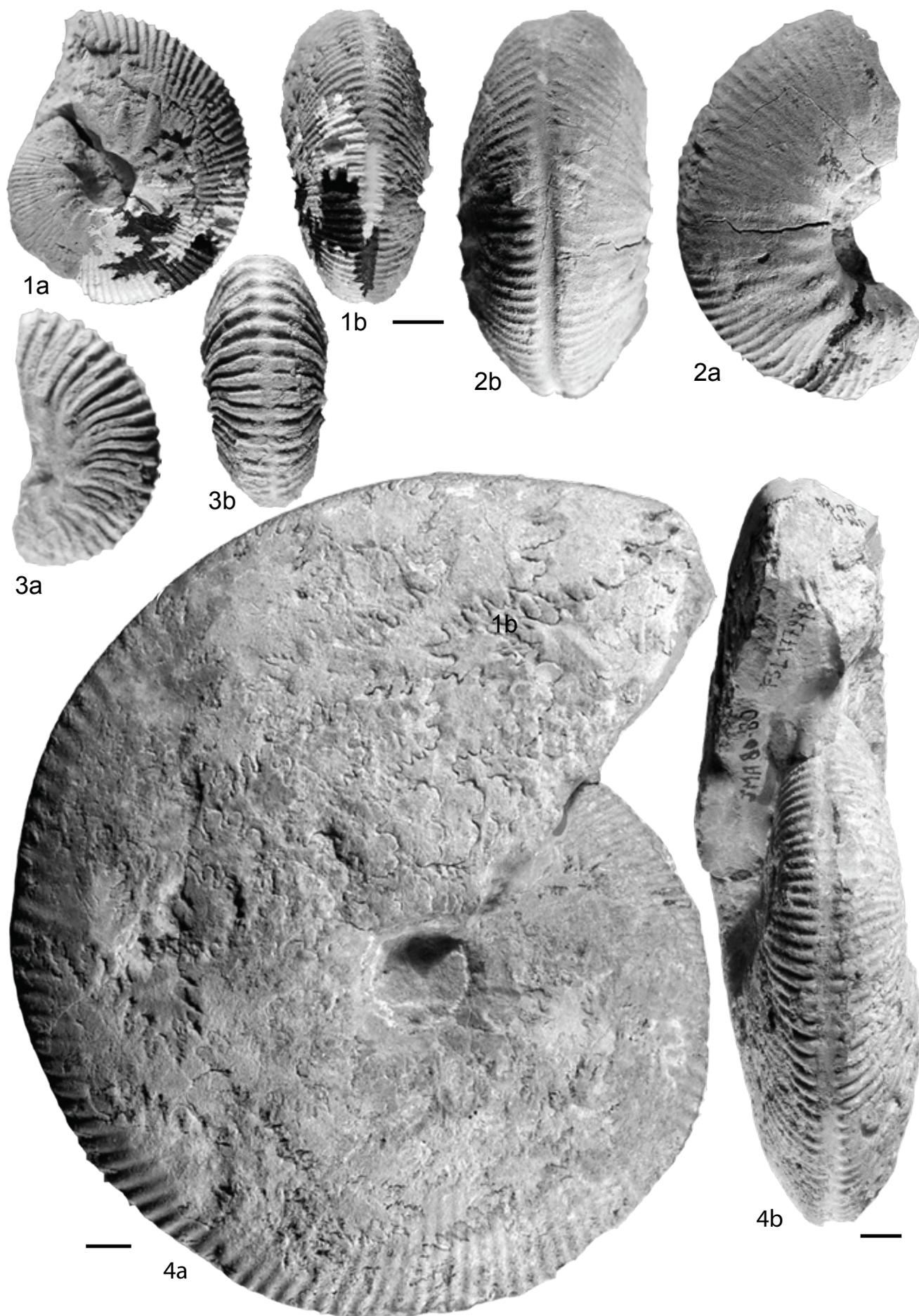


2a

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## Plate XV

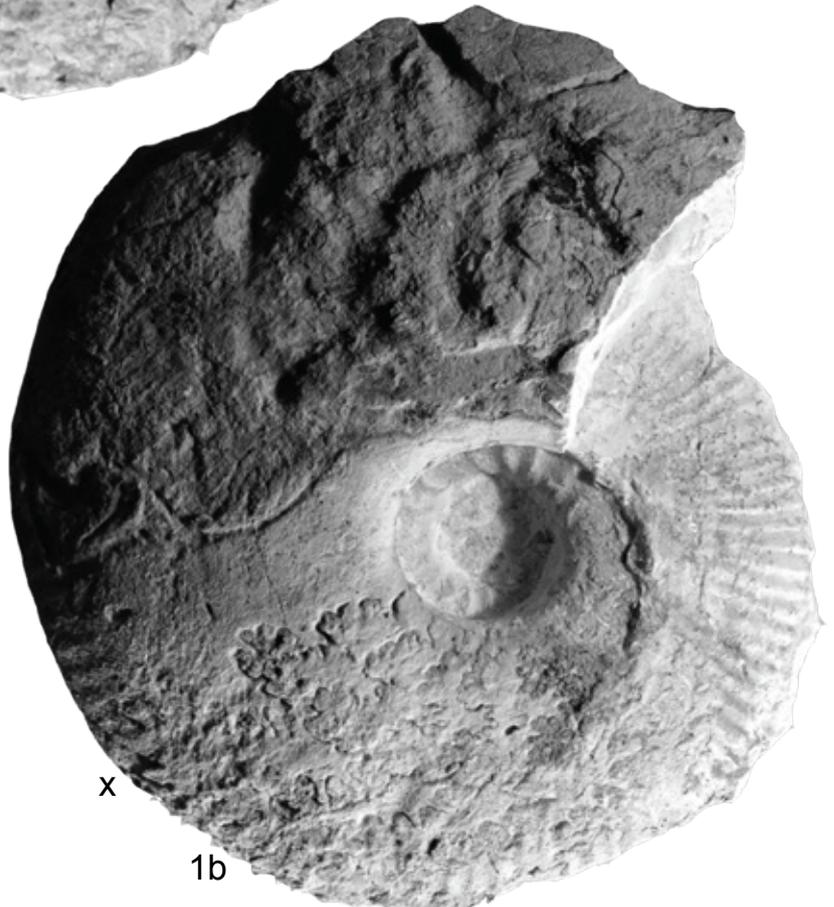
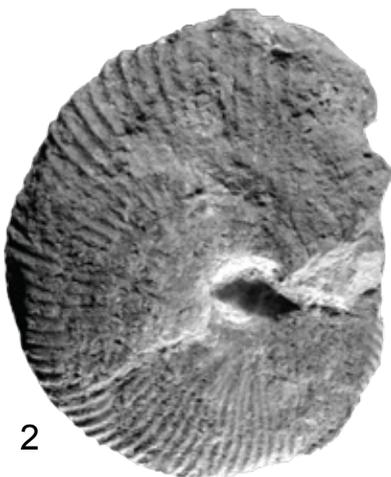
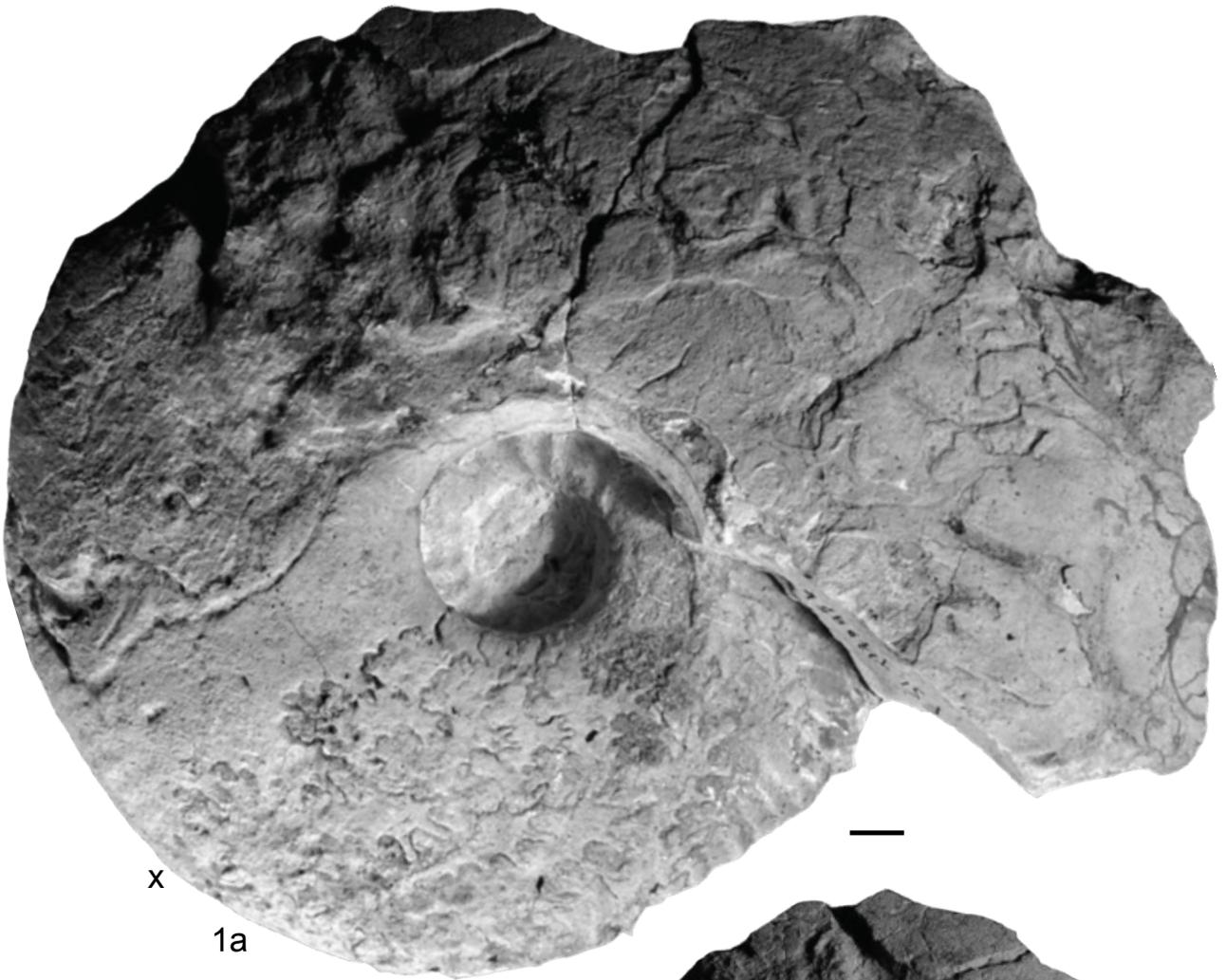
- Fig. 1: *Telermoceras deserti* (Douvillé). Wholly septate specimen (UCBL-FSL 178 067), lateral (1a) and ventral (1b) views. Dhurma Fm, upper D2 Unit (Dhibi Limestone), lowest Upper Bajocian, Runcinatum Zone. *Wadi al Mulayh Quadrangle*: JMA80.553, JMA80.553, lonely place between As Sitarah and Fara'id al Ahmar, about 22°31' N.
- Fig. 2: *Telermoceras deserti* (Douvillé). Wholly septate specimen (UCBL-FSL 178 065), lateral (2a) and ventral (2b) views. Dhurma Fm, upper D2 Unit (Dhibi Limestone), lowest Upper Bajocian, Runcinatum Zone. *Wadi al Mulayh Quadrangle*: JMA80.80, As Sitarah Khashm Ushayrah, 22°38' N.
- Fig. 3: *Kosmermoceras* n. sp. A. Half of a small, well-preserved specimen (UCBL-FSL 178 136), lateral (3a) and ventral (3b) views. Dhurma Fm, upper D2 Unit (Dhibi Limestone), lowest Upper Bajocian, Runcinatum Zone. *Darmā' Quadrangle*: JMA82.409 lonely place at the same latitude as the Graben Awsat, about 24°38' N.
- Fig. 4: *Kosmermoceras magnificum* Arkell. Wholly septate specimen with compressed whorl section (UCBL-FSL 177 978). Lateral (4a) and ventral (4b) views. Dhurma Fm, upper D2 Unit (Dhibi Limestone), lowest Upper Bajocian, Runcinatum Zone. *Wadi al Mulayh Quadrangle*: JMA80.80, As Sitarah Khashm Ushayrah, 22°38' N.



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## Plate XVI

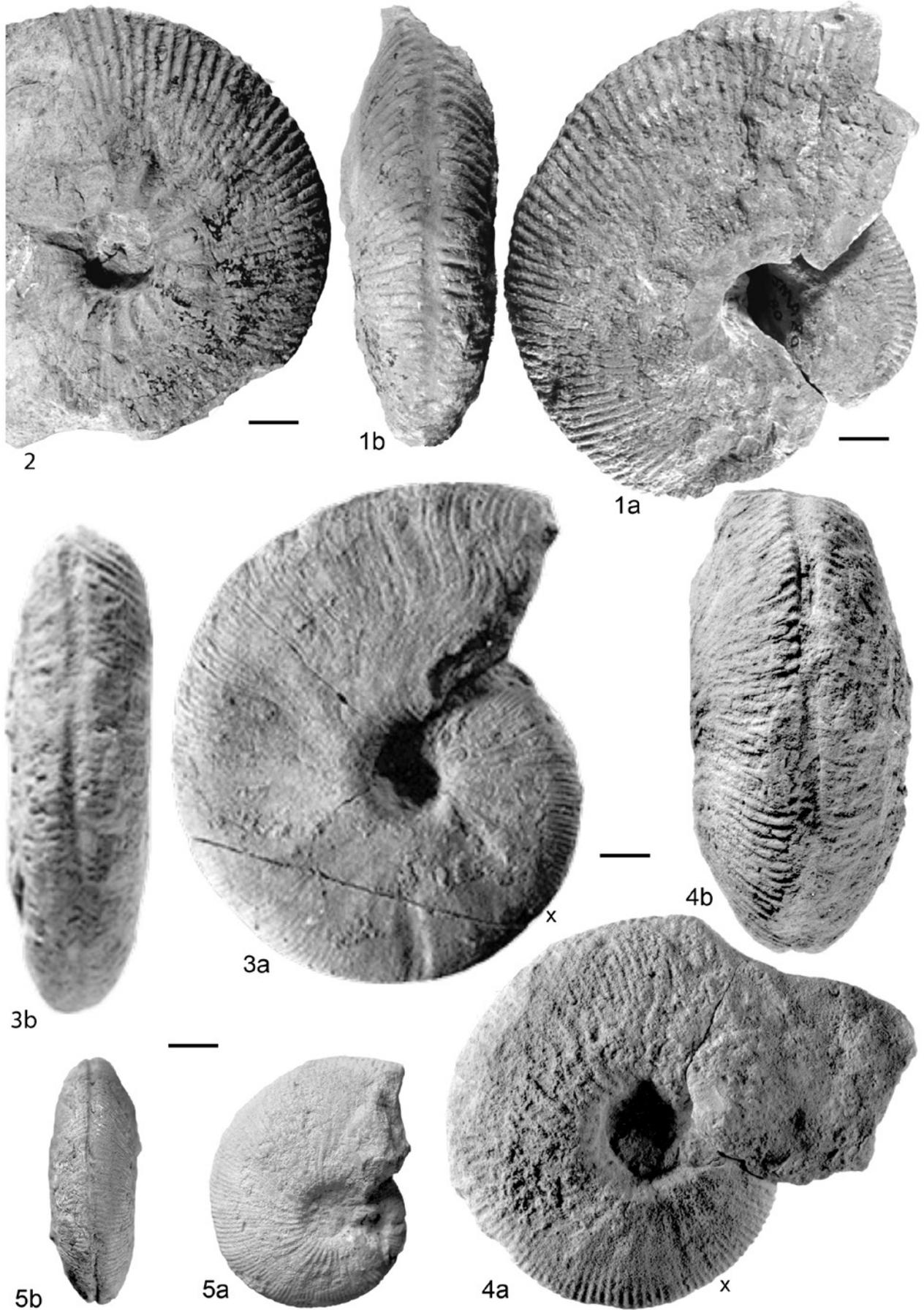
- Fig. 1: *Kosmermoceras magnificum* Arkell. Specimen with part of the body chamber three quarter long, strongly wathered (UCBL-FSL 177 985), complete lateral view (1a) and with part of the outer whorl removed (1b). Dhurma Fm, upper D2 Unit (Dhibi Limestone), lowest Upper Bajocian, Runcinatum Zone. *Darmā' Quadrangle*: JMA82.409, lonely place at the same latitude as graben Awsat 24°38' N (x indicates end of phragmocone).
- Fig. 2: *Kosmermoceras magnificum* Arkell. Wholly septate specimen (UCBL-FSL 177 991), lateral view. Dhurma Fm, upper D2 Unit (Dhibi Limestone), lowest Upper Bajocian, Runcinatum Zone. Wadi ar Rayn Quadrangle: VD80.510, Wadi Birk, 23°12' N.
- Fig. 3: *Leptosphinctes* aff. *umbilicatus* Galácz (m). Incomplete wholly septate specimen (UCBL-FSL 178 891), lateral view. Dhurma Fm, upper D2 Unit (ferruginous oolitic limestone), lowest Upper Bajocian, Runcinatum Zone. *Shaqrā' Quadrangle*: VD82.651A, South of Jurayfah.



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## Plate XVII

- Fig. 1: *Kosmermoceras magnificum* Arkell. Wholly septate nucleus (UCBL-FSL 177 989). Lateral (1a) and ventral (1b) views. Dhurma Fm, upper D2 Unit (Dhibi Limestone), lowest Upper Bajocian, Runcinatum Zone. *Wadi al Mulayh Quadrangle*: JMA80.80/1, As Sitarah Khashm Ushayrah, 22°38' N.
- Fig. 2: *Kosmermoceras magnificum* Arkell. Inner whorl of a large specimen with half a whorl long outer whorl and the very beginning of the body chamber at 200 mm in diameter (UCBL-FSL 177 986). Dhurma Fm, upper D2 Unit (Dhibi Limestone), lowest Upper Bajocian, Runcinatum Zone. *Wadi al Mulayh Quadrangle*: JMA80.80, As Sitarah Khashm Ushayrah, 22°38' N.
- Fig. 3: *Kosmermoceras elegans* (Douvillé). Well-preserved, nearly complete specimen, the aperture missing, with compressed whorl (UCBL-FSL 178 017). Lateral (3a) and ventral (3b) views. Upper D2 Unit (Dhibi Limestone), lowest Upper Bajocian, Runcinatum Zone. *Wadi al Mulayh Quadrangle*: JMA80.80/1 As Sitarah Khashm Ushayrah, 22°38' N (x indicates end of phragmocone).
- Fig. 4: *Kosmermoceras elegans* (Douvillé). Nearly complete specimen, small-sized form with thick section and coarse ribbing (UCBL-FSL 178 021). Lateral (4a) and ventral (4b) views. Upper D2 Unit (Dhibi Limestone), lowest Upper Bajocian, Runcinatum Zone. *Wadi al Mulayh Quadrangle*: JMA80.80/1, As Sitarah Khashm Ushayrah, 22°38' N (x indicates end of phragmocone).
- Fig. 5: *Kosmermoceras elegans* (Douvillé). Wholly septate inner whorls with fine and dense ribbing (UCBL-FSL 178 024). Dhurma Fm, upper D2 Unit (Dhibi Limestone), lowest Upper Bajocian, Runcinatum Zone. *Wadi al Mulayh Quadrangle*: JMA80.80, As Sitarah Khashm Ushayrah, 22°38' N.



**CHARLES MANGOLD (02.02.1933 - 18.08.2014)**

Charles Mangold, Charlie for his friends, left us on August 18th, 2014 after a fight of several months against illness. He was 81 years old and his funeral (cremation) took place on August 22th.

Charles Mangold started and finished his academic career at the University Claude-Bernard-Lyon 1 where he was successively Assistant, “Maître-Assistant” and Professor. In the meantime he spent five years at the Oran University (Algeria) and ten years at Nancy 1 University where he was appointed Professor for the first time in 1981. Charles Mangold made his first steps in geology with a study of the Middle Jurassic of the Isle of Crémieu (Tabular Jura), followed by his French doctor’s degree on the Bathonian and Callovian of the southern French Jura Range. Quickly he was considered as a national and international authority concerning the Bathonian and Callovian stratigraphy and palaeontology of ammonites, especially the perisphinctids. That specialization was combined with a wide knowledge of ammonites as a whole and the Jurassic System.

He was Secretary of the French Jurassic Group and of the International Subcommittee on the Jurassic. Among his published papers, as a single author or with co-authors, are mentioned those of national or international importance. For instance the Facies Maps of the Jurassic of France and the Geological Synthesis of the S.E. France Basin, the Stratigraphy of the Jurassic of Saudi Arabia and many contributions to the Palaeobiogeography of ammonites. He took also a prominent part in the study and the choice of the boundary stratotype (GSSP = Global Stratotype Section and Point) of the Bathonian Stage in South East France.

Besides academic activities Charles Mangold contributed extensively to the mapping for the geological map of France at 1/50000 scale and to applied geology in the Southern French Jura: highway Lyon-Geneva, LEP (Large Electron-Positron Collider) project for the CERN (European Nuclear Research Center).

After retirement he was regularly working at the university (where we shared the same work-room) and published (with M.D. Arnaud Martin) two monographs



Charles Mangold leaning on a fossil tree from the Fossil Forest (Purbeck), taken during the French Jurassic Group field trip in Dorset (1990).

(perisphinctids and tulitids) on the Bathonian Ammonite faunas of the Mâconnais.

We preserve Charlie in the memory as a man enjoying good living, with plain-speaking, who enjoyed field work and was fond of good food.

[Modified from the obituary notice published in *Volumina Jurassica*, Warsaw, 2015]

## Plate XVIII

- Fig. 1: *Kosmermoceras runcinatum* Arkell. Not well-preserved, but nearly complete macroconch, the body chamber three quarter a whorl long, with adult ribbing, (UCBL-FSL 178 031), lateral (1a) and ventral (1b) views. Dhurma Fm, upper D2 Unit (Dhibi Limestone, lowest Upper Bajocian, Runcinatum Zone. *Wadi al Mulayh Quadrangle*: JMA80.80, As Sitarah Khashm Ushayrah, 22°38' N (x indicates end of phragmocone).
- Fig. 2: *Kosmermoceras runcinatum* Arkell. Macroconch, wholly septate middle whorl (UCBL-FSL 178 032), lateral (2a) and ventral (2b) views. Dhurma Fm, upper D2 Unit (Dhibi Limestone, lowest Upper Bajocian, Runcinatum Zone. *Wadi al Mulayh Quadrangle*: JMA80.80, As Sitarah Khashm Ushayrah, 22°38' N.
- Fig. 3: *Metazigzagiceras subarabicum* Fernández-López & Pavia. Holotype, large-sized microconch (UCBL-FSL 177 639), lateral (3a) and ventral (3b) views. Middle Dhurma Fm, top of unit D3, Lower Bathonian, Tuwaiquensis Zone. *Durma Quadrangle*: JMA82.285 Wadi al Hisyan, 24°45' N.



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 Plate XIX

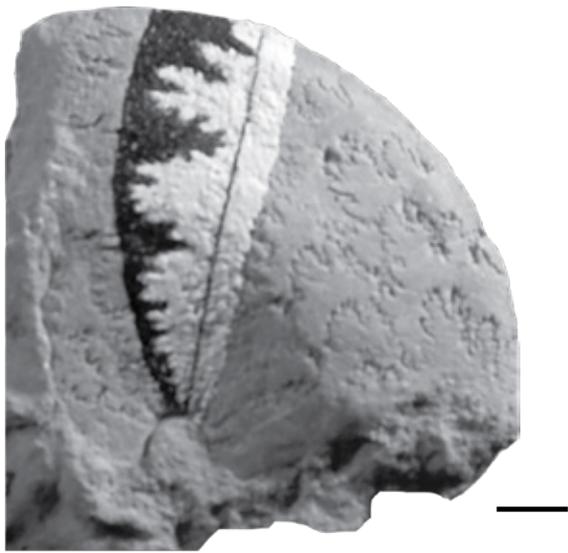
- Fig. 1: *Kosmocereras runcinatum* Arkell. Macroconch, half a whorl long body chamber, the septate whorls crushed (UCBL-FSL 178 033), lateral (1a) and ventral (1b) views. Dhurma Fm, upper D2 Unit (Dhibi Limestone, lowest Upper Bajocian, Runcinatum Zone. *Wadi ar Rayn Quadrangle*: VD.80.544, lonely place north of Wadi al Hawtah, about 23°39' N.
- Fig. 2: *Kosmocereras runcinatum* Arkell. Macroconch (UCBL-FSL 177 904), lateral (2a) and ventral (2b) views. Dhurma Fm, upper D2 Unit (Dhibi Limestone, lowest Upper Bajocian, Runcinatum Zone. *Shaqrā' Quadrangle*: VD82.478, Jurayfah South, 25°30' N.
- Fig. 3: *Kosmocereras runcinatum* Arkell. Macroconch, inner whorls and the beginning of the living chamber (UCBL-FSL 177 877), lateral view. Dhurma Fm, upper D2 Unit (Dhibi Limestone, lowest Upper Bajocian, Runcinatum Zone. *Shaqrā' Quadrangle*: VD82.478A, Jurayfah South, 25°30' N.
- Fig. 4: *Ermocereras mogharensis* Douvillé. Young specimen with half a whorl long of the body chamber preserved (UCBL-FSL 177 818), lateral (4a) and ventral (4b) views. Dhurma Fm, lowest D3 Unit, Upper Bajocian, Mogharensis Zone. *Darmā' Quadrangle*: JMA82. 297, lonely place north of Khashm adh Dhibi, about 24°16' N.
- Fig. 5: *Ermocereras mogharensis* Douvillé. Part of the body chamber (UCBL-FSL 177 808), lateral (5a) and ventral (5b) views. Dhurma Fm, lowest D3 Unit, Upper Bajocian, Mogharensis Zone. *Darmā' Quadrangle*: JMA82. 298, lonely place north of Khashm adh Dhibi, about 24°16' N.
- Fig. 6: *Kosmocereras inerme* (Douvillé). Lappeted microconch specimen (UCBL-FSL 177 810), lateral (6a) and ventral (6b) views. Dhurma Fm, lowest D3 unit, Upper Bajocian, Mogharensis Zone. *Darmā' Quadrangle*: JMA82.294, lonely place north of Khashm adh Dhibi, 24°14' N.
- Fig. 7: *Kosmocereras inerme* (Douvillé). Macroconch, half a whorl, wholly septate, flat-sided whorls and narrow, tabulate venter with a prominent mid-ventral groove. (UCBL-FSL 177 838), lateral (7a) and ventral (7b) views. Dhurma Fm, lowest D3 unit, Upper Bajocian, Mogharensis Zone. *Wadi ar Rayn Quadrangle*: VD80.547, south of Khashm al Jufayr, 23°58' N.
- Fig. 8: *Kosmocereras inerme* (Douvillé). Macroconch, inner whorls, wholly septate UCBL-FSL 177 865), lateral (8a) and ventral (8b) views. Dhurma Fm, upper D2 Unit, Upper Bajocian, Runcinatum Zone. *Shaqrā' Quadrangle*: VD82.651, south of Jurayfah South, about 25°40' N.
- Fig. 9: *Spiroceras annulatum* (Deshayes). Part of the body chamber (UCBL-FSL 177 812), lateral (9a) and ventral (9b) views. Dhurma Fm, lowest D3 Unit, lower Upper Bajocian, Mogharensis Zone. *Darmā' Quadrangle*: JMA82.297, lonely place north of Khashm adh Dhibi, about 24°16' N.



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 Plate XX

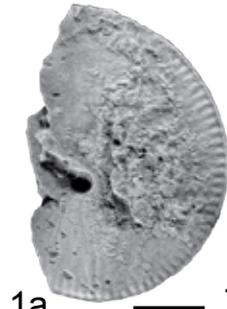
- Fig. 1: *Thamboceras mirabile* Arkell. Wholly septate and well-preserved specimen (UCBL-FSL 177 955, 956), lateral (1a) and ventral (1b) views. Dhruma Fm, upper D2 Unit, lowest Upper Bajocian, Runcinatum Zone. *Shaqrā' Quadrangle*: VD82.478B, Jurayfah South, about 25°22' N.
- Fig. 2: *Thambites oxynotus* Arkell. Well-preserved quarter whorl of a small specimen, wholly septate (UCBL-FSL 177 730), lateral (2a) and ventral (2b) views. Dhruma Fm, D3 Unit, Uppermost Bajocian, Planus Zone. *Wadi al Mulayh Quadrangle*: JMA80.554/2, between Fara'id al Ahmar 22°27' N and As Sitarah Khashm Ushayrah, 22°38' N.
- Fig. 3: *Thambites planus* Arkell. Large-sized, wholly septate specimen (UCBL-FSL 177 666), lateral (3a) and ventral (3b) views. Dhruma Fm, D3 Unit, uppermost Bajocian, Planus Zone. Wadi ar Rayn Quadrangle: VD80.517, lonely place at the same latitude as Khashm Birk 23°18' N.
- Fig. 4: *Thambites planus* Arkell. Medium-sized, wholly septate specimen, with beginning of the uncoiling of the outer whorl and fairly broad ventral groove (UCBL-FSL 177 701), lateral (4a) and ventral (4b) views. Dhruma Fm, D3 Unit, uppermost Bajocian, Planus Zone. *Sulayyimah Quadrangle*: VD81.278, south of Khashm Abu Jiwar, about 21°50' N.
- Fig. 5: *Thambites planus* Arkell. Large, wholly septate specimen, with very compressed whorl-section and relatively narrow ventral groove (UCBL-FSL 177 775), lateral (5a) and ventral (5b) views. Dhruma Fm, D3 Unit, uppermost Bajocian, Planus Zone. *Shaqrā' Quadrangle*: VD82.350, Jurayfah, 25°30' to 25°38' N.
- Fig. 6: *Thambites planus* Arkell. Large-sized, wholly septate specimen, with relatively broad ventral groove (UCBL-FSL 177 712), lateral (6a) and ventral (6b) views. Dhruma Fm, D3 Unit, uppermost Bajocian, Planus Zone. *Sulayyimah Quadrangle*: VD81.188/1, South of Khashm Abu Jiwa, about 21°51' N.
- Fig. 7: *Thambites* sp. Possible or supposed microconch of *T. planus*, half a whorl long body chamber, the aperture not preserved (UCBL-FSL 177 780), lateral (7a) and ventral (7b) views. Dhruma Fm, D3 Unit, uppermost Bajocian, Planus Zone. *Sulayyimah Quadrangle*: VD81.99, Kashm Abu Jiwar, 21°53' N.



2a



2b



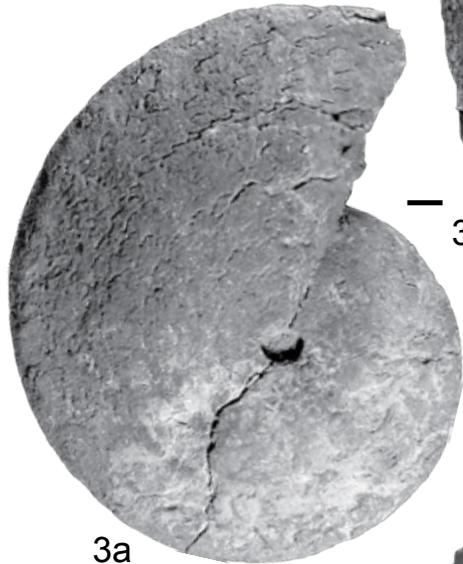
1a



1b



3b



3a



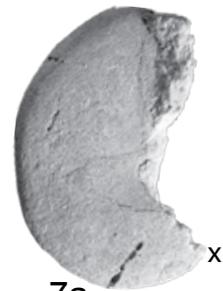
4a



4b



7b



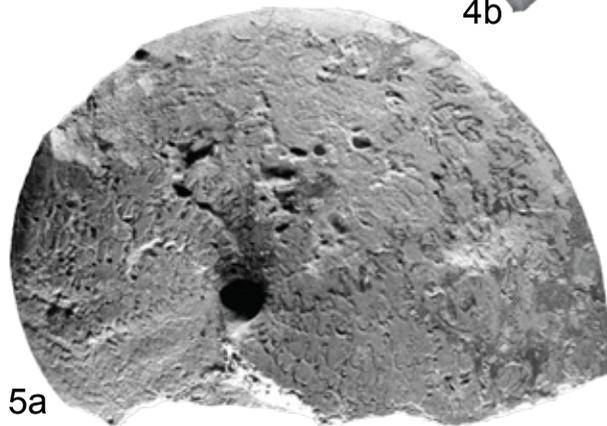
7a



6b



5b



5a

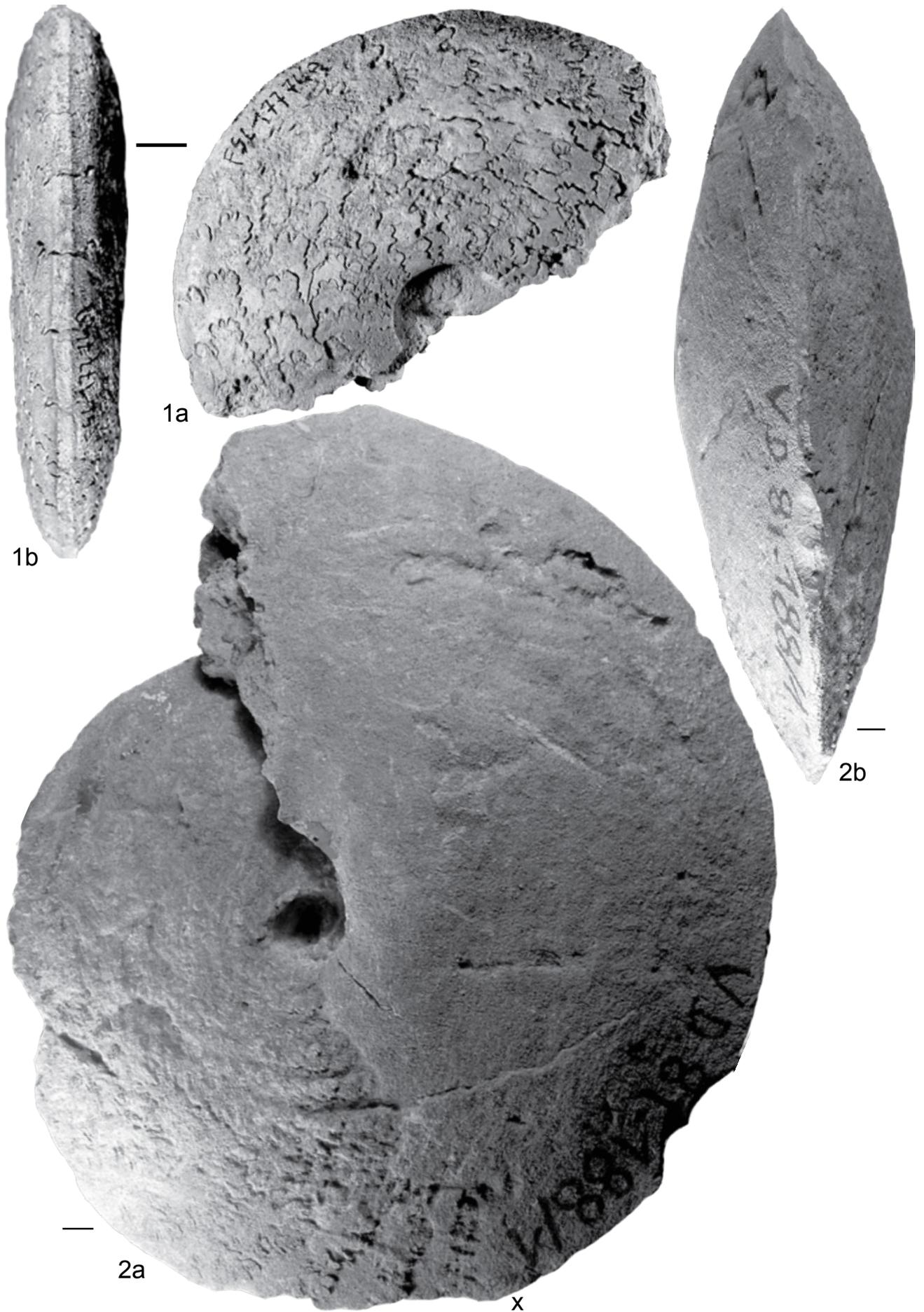


6a

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Plate XXI

- Fig. 1: *Thambites* nov. sp. A. Half a whorl long, wholly septate specimen with more open umbilicus, thick whorl-section and broad ventral furrow (UCBL-FSL 177 749), lateral (1a) and ventral (1b) views. Dhruma Fm, D3 Unit, Uppermost Bajocian, Planus Zone. *Wadi al Mulayh Quadrangle*: JMA80.521, lonely place north of Khashm Abu al Jiwar, about 22°05' N.
- Fig. 2: *Mulayites avus* (Arkell). Nearly complete and full-grown specimen (UCBL-FSL 177 453), with the body chamber half a whorl long, slightly contracted dorsally, but aperture missing, probably simple, lateral (2a) and ventral (2b) views. Dhruma Fm, D3 Unit, uppermost Bajocian, Planus Zone. *Sulayyimah Quadrangle*: VD81.188/1, south of Khashm Abu al Jiwar, 21°50' N (x indicates end of phragmocone).



1a

1b

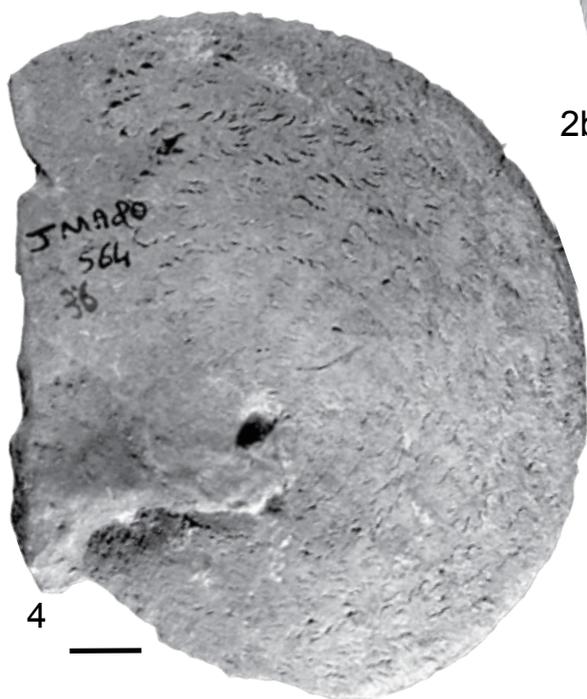
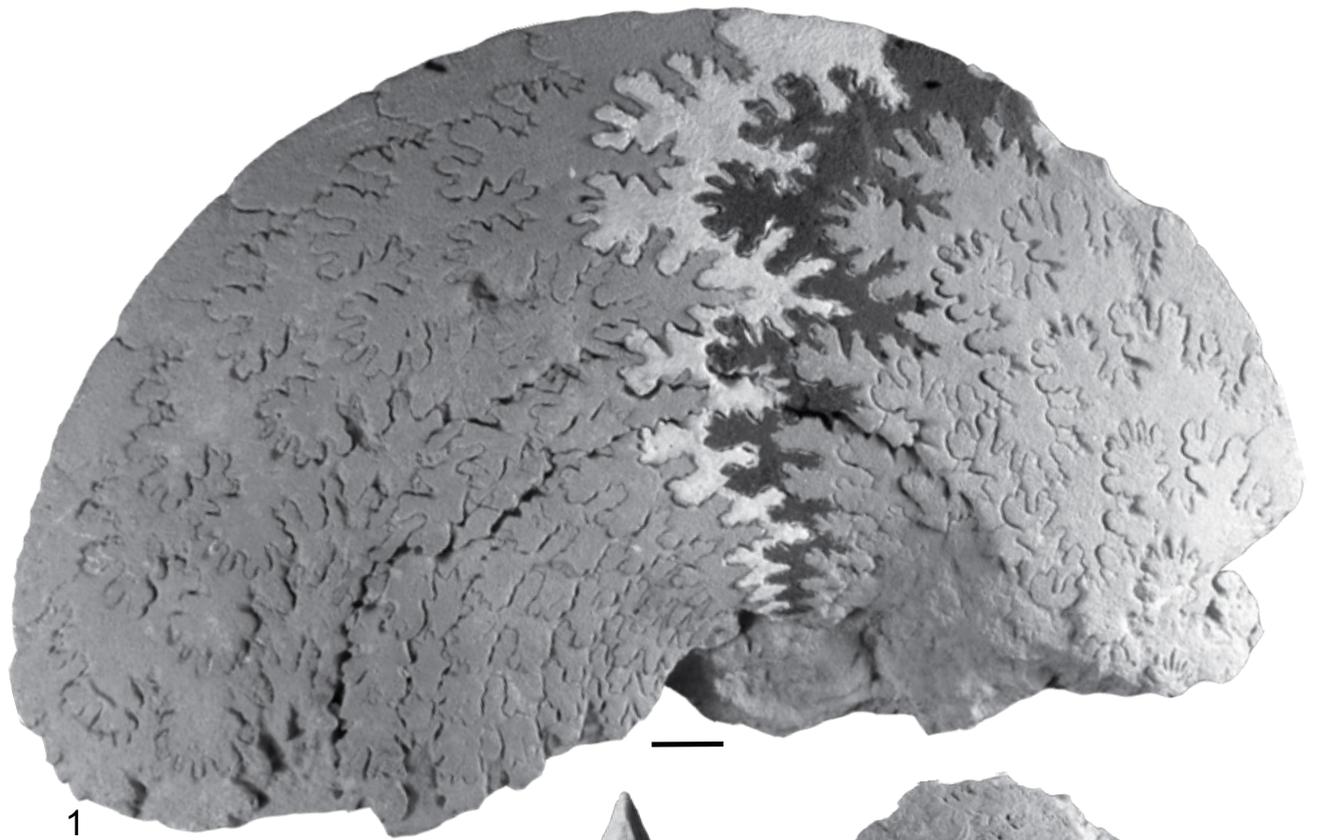
2a

2b

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 Plate XXII

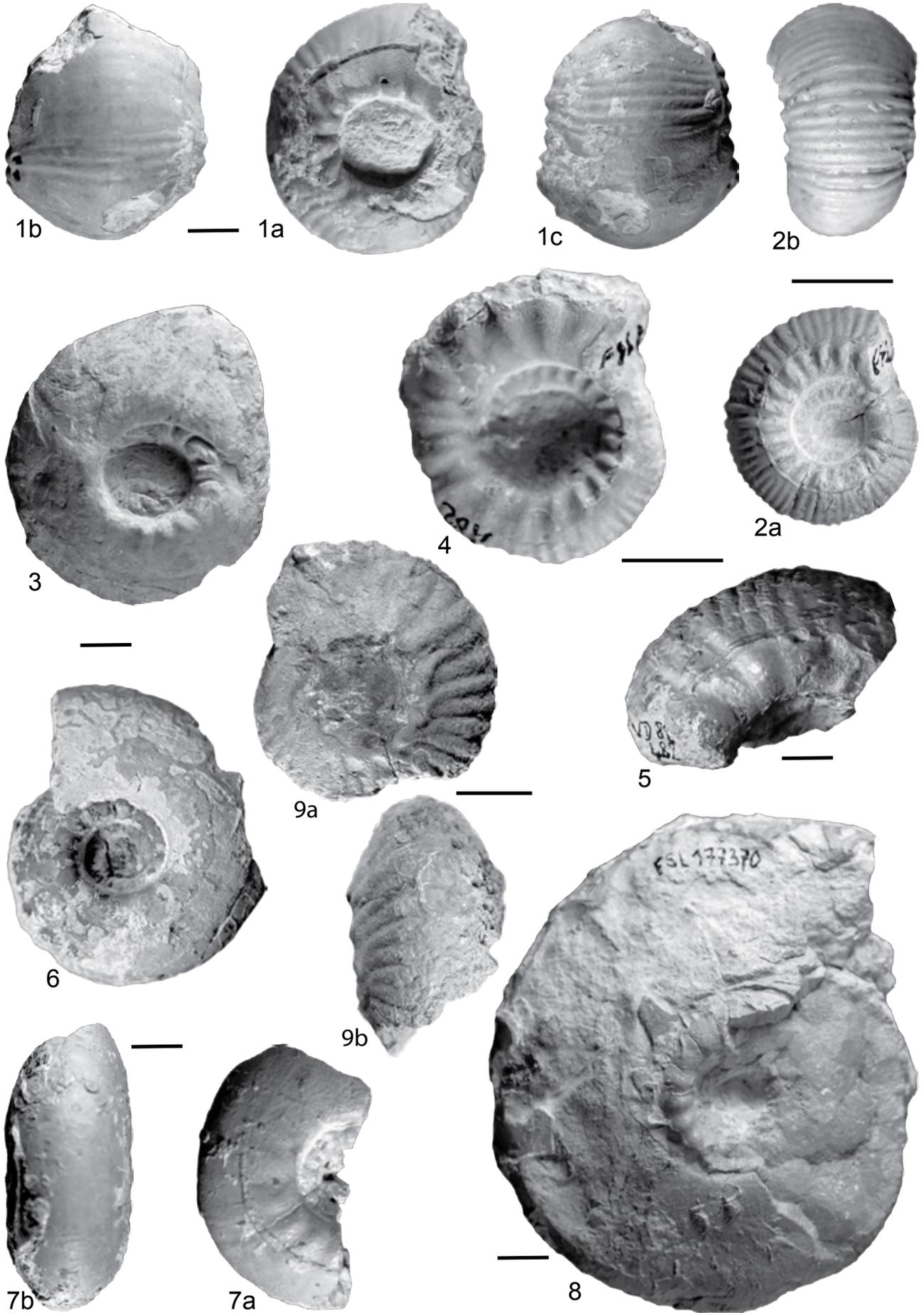
- Fig. 1: *Mulayites avus* (Arkell). Half- a whorl long wholly septate example (UCBL-FSL 177 471), lateral view. Dhruma Fm, D3 Unit, uppermost Bajocian, Planus Zone. *Wadi al Mulay Quadrangle*: JMA80.554/1 lonely place between Fara'id al Ahmar, 22°27' N and As Sitarah Khashm Ushayrah, 22°38' N.
- Fig. 2: *Mulayites avus* (Arkell). Inner whorls showing traces of ribbing (UCBL-FSL 177 472), lateral (2a) and ventral (2b) views. Dhruma Fm, D3 Unit, uppermost Bajocian, Planus Zone. *Wadi al Mulay Quadrangle*: JMA80.554/0 lonely place between Fara'id al Ahmar, 22°27' N and As Sitarah Khashm Ushayrah, 22°38' N.
- Fig. 3: *Mulayites avus* (Arkell). Inner whorls showing traces of ribbing (UCBL-FSL 177 541), lateral view. Dhruma Fm, D3 Unit, uppermost Bajocian, Planus Zone. Dhruma Fm, D3 Unit, Uppermost Bajocian, Planus Zone. *Wadi al Mulayh Quadrangle*: JMA80.556), between Fara'id al Ahmar and As Sitarah Khashm Ushayrah, about 22°34' N.
- Fig. 4: *Pseudochydoniceras pseudodiscus* (Arkell). Medium-sized, wholly septate specimen (UCBL-FSL 177 629), lateral, view. Dhruma Fm, D3 Unit, uppermost Bajocian, Planus Zone. *Wadi al Mulayyih Quadrangle*: JMA80.564, Khashm Munayyifiyah, 22°11' N.
- Fig. 5: *Saudisphinctes arabicus* nov. sp. (m). Nearly complete adult microconch, the body chamber about half a whorl long, aperture missing (UCBL-FSL 177 418), lateral (5a) and ventral (5b) views. Dhruma Fm, D4 Unit, uppermost part, lower Bathonien, Tuwaiqensis Zone. *Shaqra' Quadrangle*: VD82.632, Al Lughf, 25°10' N (x indicates end of phragmocone).



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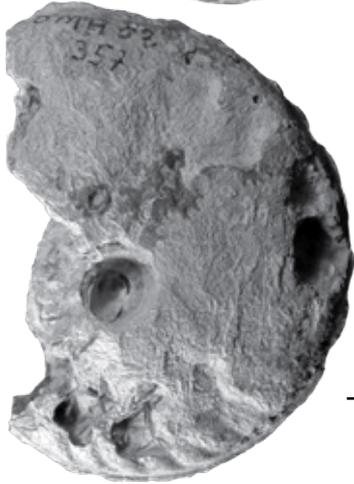
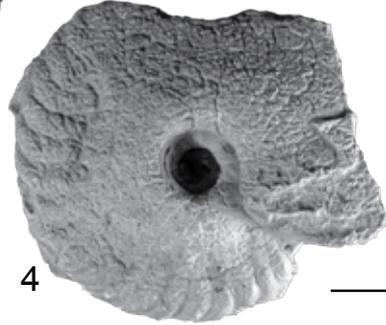
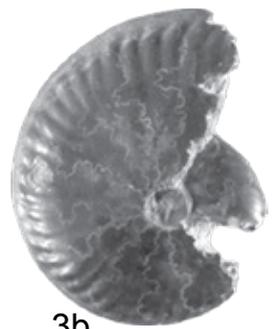
Plate XXIII

- Fig. 1: *Tulites arabicus* Arkell. Complete immature specimen (UCBL-FSL 177 402), lateral (1a) and ventral 1b, c) ventral views. Dhurma Fm, D4 Unit, Lower Bathonian, Tuwaiqensis Zone. *Shaqrā'* *Quadrangle*: VD82.482 Jurayfah South.
- Fig. 2: *Tulites arabicus* Arkell. Wholly septate inner whorls (UCBL-FSL 177 403), lateral (2a) and ventral (2b) views. Dhurma Fm, D4 Unit, Lower Bathonian, Tuwaiqensis Zone. *Shaqrā'* *Quadrangle*: VD82.482 Jurayfah South.
- Fig. 3: *Tulites arabicus* Arkell. Nearly complete specimen, with the body chamber, slightly compressed (UCBL-FSL 177 372), lateral view. Dhurma Fm, D4 Unit, Lower Bathonian, Tuwaiqensis Zone. *Shaqrā'* *Quadrangle*: VD82.354A, lonely place between Jurayfah South and Jurayfah, 25°30' N to 38' N.
- Fig. 4: *Tulites erymnooides* Arkell. Wholly septate inner whorls (UCBL-FSL 177 390), lateral view enlarged. Dhurma Fm, D4 Unit, Lower Bathonian, Tuwaiqensis Zone. *Shaqrā'* *Quadrangle*: VD82.482, Jurayfah South.
- Fig. 5: *Tulites erymnooides* Arkell. Better preserved whorl fragment (UCBL-FSL 177 391), lateral view. Dhurma Fm, D4 Unit, Lower Bathonian, Tuwaiqensis Zone. *Shaqrā'* *Quadrangle*: VD82.482, Jurayfah South.
- Fig. 6: *Tulites tuwaiqensis* Arkell (UCBL-FSL 177 371). Dhurma Fm, D4 Unit, Lower Bathonian, Tuwaiqensis Zone. *Shaqrā'* *Quadrangle*: VD82.354 B, lonely place between Jurayfah South and Jurayfah, 25°30' N to 38' N.
- Fig. 7: *Tulites tuwaiqensis* Arkell. Fragment of middle whorl with traces of a missing outer whorl (UCBL-FSL 177 395), lateral (7a) and ventral (7B) views. Dhurma Fm, D4 Unit, Lower Bathonian, Tuwaiqensis Zone. *Shaqrā'* *Quadrangle*: VD82.482 Jurayfah South.
- Fig. 8: *Tulites tuwaiqensis* Arkell. Large-sized specimen, probably complete or nearly complete, not well-preserved but offers an idea of the adult size (UCBL-FSL 177 370), lateral view. Dhurma Fm, D4 Unit, Lower Bathonian, Tuwaiqensis Zone. *Shaqrā'* *Quadrangle*: VD82.354B, lonely place between Jurayfah South and Jurayfah, 25°30' N to 38' N.
- Fig. 9: *Tulites* n. sp. A. Small-sized specimen, enlarged (UCBL-FSL 177 424), lateral (9a) and ventral (9b) views. Dhurma Fm, D4 Unit, uppermost part, Lower Bathonian, Tuwaiqensis Zone. *Shaqrā'* *Quadrangle*: VD82.632, Al Lughf, 25°10' N.



## Plate XXIV

- Fig. 1: *Micromphalites clydocromphalus* Arkell (UCBL-FSL 177 314), lateral (1a) and ventral (1b) views. Dhurma Fm, D5 unit, Lower Bathonian, Clydocromphalus Zone. *Shaqrā' Quadrangle*: VD82.357 Jurayfah, 25°30' to 38' N.
- Fig. 2: *Micromphalites clydocromphalus* Arkell (UCBL-FSL 177 315), lateral view. Dhurma Fm, D5 unit, Lower Bathonian, Clydocromphalus Zone. *Shaqrā' Quadrangle*: VD82.357 Jurayfah, 25°30' to 38' N.
- Fig. 3: *Micromphalites clydocromphalus* Arkell (UCBL-FSL 177 316,) lateral (3a) and enlarged lateral (3b) views. Dhurma Fm, D5 unit, Lower Bathonian, Clydocromphalus Zone. *Shaqrā Quadrangle*: VD82.357 Jurayfah, 25°30' to 38' N.
- Fig. 4: *Micromphalites elegans* Arkell (UCBL-FSL 177 307), lateral view. Dhurma Fm, D5 unit, Lower Bathonian, Clydocromphalus Zone. *Shaqrā' Quadrangle*: VD82.357 Jurayfah, 25°30' to 38' N.
- Fig. 5: *Micromphalites elegans* Arkell (UCBL-FSL 177 309), lateral (5a) and ventral (5b) views. Dhurma Fm, D5 unit, Lower Bathonian, Clydocromphalus Zone. *Shaqrā' Quadrangle*: VD82.357, Jurayfah, 25°30' to 38' N.
- Fig. 6: *Micromphalites elegans* Arkell (UCBL-FSL 177 334), lateral (6a) and ventral (6b) views. Dhurma Fm, D5 unit, Lower Bathonian, Clydocromphalus Zone. *Shaqrā' Quadrangle*: VD82.357, Jurayfah, 25°30' to 38' N.
- Fig. 7: *Micromphalites elegans* Arkell (UCBL-FSL 177 335), lateral view. Dhurma Fm, D5 unit, Lower Bathonian, Clydocromphalus Zone. *Shaqrā' Quadrangle*: VD82.357, Jurayfah, 25°30' to 38' N.
- Fig. 8: *Micromphalites elegans* Arkell (UCBL-FSL 177 345), lateral (8a) and ventral (8b) views. Dhurma Fm, D5 unit, Lower Bathonian, Clydocromphalus Zone. *Shaqrā' Quadrangle*: VD82.357, Jurayfah, 25°30' to 38' N.
- Fig. 9: *Micromphalites intermedius* Arkell. (UCBL-FSL 177 306), lateral view. Dhurma Fm, D5 unit, Lower Bathonian, Clydocromphalus Zone. *Darmā' Quadrangle*: VD82.357, Jurayfah, 25°30' to 38' N.
- Fig. 10: *Micromphalites intermedius* Arkell. (UCBL-FSL 177 306), lateral (10a) and ventral (10b) views. Dhurma Fm, D5 unit, Lower Bathonian, Clydocromphalus Zone. *Darmā' Quadrangle*: VD82.357, Jurayfah, 25°30' to 38' N.
- Fig. 11: *Micromphalites intermedius* Arkell. (UCBL-FSL 177 306), lateral (11a) and ventral (11b) views. Dhurma Fm, D5 unit, Lower Bathonian, Clydocromphalus Zone. *Darmā' Quadrangle*: VD82.357, Jurayfah, 25°30' to 38' N.
- Fig. 12: *Micromphalites* cf. *torrensi* Énay. (UCBL-FSL 177 276, lateral view. Dhurma Fm, D5 unit, Lower Bathonian, Clydocromphalus Zone. *Wadi ar Rayn Quadrangle*: VD80.611 (UCBL-FSL 177 276), lonely place North of Wadi al Hawtah, 23°35' N.

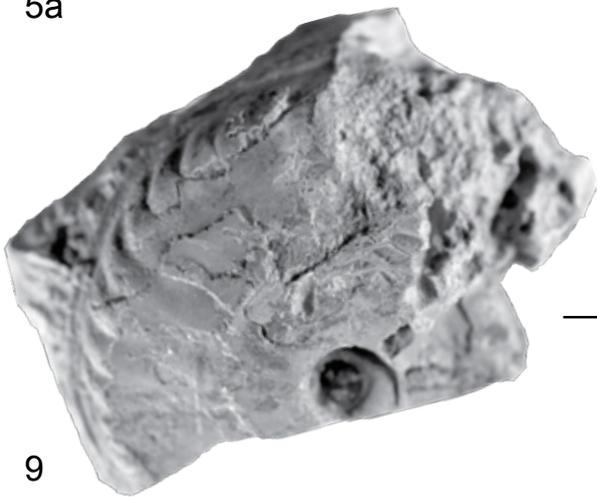


5a

5b

7

6a



8b



8a

6b

9



10b



10a



11b

11a

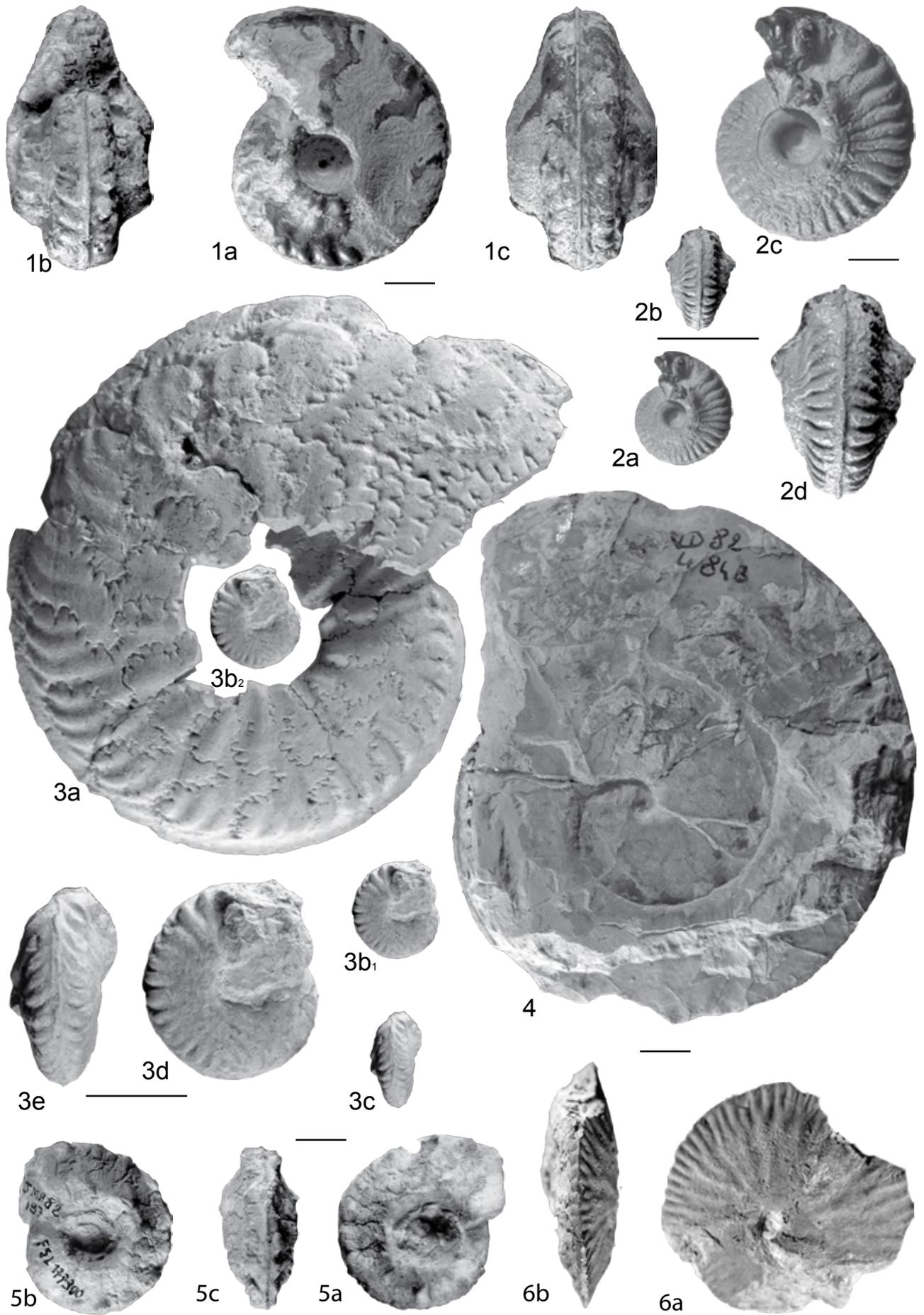


12a

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 Plate XXV

- Fig. 1: *Micromphalites busqueti* (Grossouvre). (UCBL-FSL 177 342), lateral (1a) and ventral (1b, c) views. Dhurma Fm, D5 unit, Lower Bathonian, Clydocromphalus Zone. *Darmā'* *Quadrangle*: VD82.357 Jurayfah, 25°30' to 38' N.
- Fig. 2: *Micromphalites busqueti* (Grossouvre). (UCBL-FSL 177 343, lateral (2a, 2c) and ventral (2b, d) views, natural size (2a, b) and enlarged (2c, d). Dhurma Fm, D5 unit, Lower Bathonian, Clydocromphalus Zone. *Darmā'* *Quadrangle*: VD82.357, Jurayfah, 25°30' to 38' N.
- Fig. 3: *Micromphalites* n. sp. B. (UCBL-FSL 177 280, lateral view (3a) of the large-sized specimen and lateral (3b1, 3b2, d) and ventral (3c, e) views of the innermost whorls of the same specimen. Dhurma Fm, D5 unit, Lower Bathonian, Clydocromphalus Zone. *Wadi al Mulayh Quadrangle*: JMA80.567, Khashm Munyyifiyah, 22°11' N.
- Fig. 4: *Micromphalites* n. sp. A (UCBL-FSL 177 363), lateral view. Dhurma Fm, D5 unit, Lower Bathonian, Clydocromphalus Zone. *Shaqrā'* *Quadrangle*: VD82.484A, Jurayfah South, 25°30' to 38' N.
- Fig. 5: *Micromphalites pustuliferus* (Douvillé). Not well-preserved, wholly septate specimen (UCBL-FSL 177 300), lateral (5a, b) and ventral (5c) views. Dhurma Fm, D5 unit, Lower Bathonian, Clydocromphalus Zone. *Durma Quadrangle*: JMA82.197, Khashm adh Dhibi, 26°14' N.
- Fig. 6: *Pseudomicromphalites kuntzi* Collignon. Well-preserved, wholly septate specimen (UCBL-FSL 177 187), lateral (6a) and ventral (6b) views. Upper Dhurma Fm, unit D7, upper part (Hisyan Member), Middle Callovian, Ogivalis Zone, Kuntzi horizon. *Shaqrā'* *Quadrangle*: VD82.489, Jurayfah, 25°30' to 38' N.



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Plate XXVI

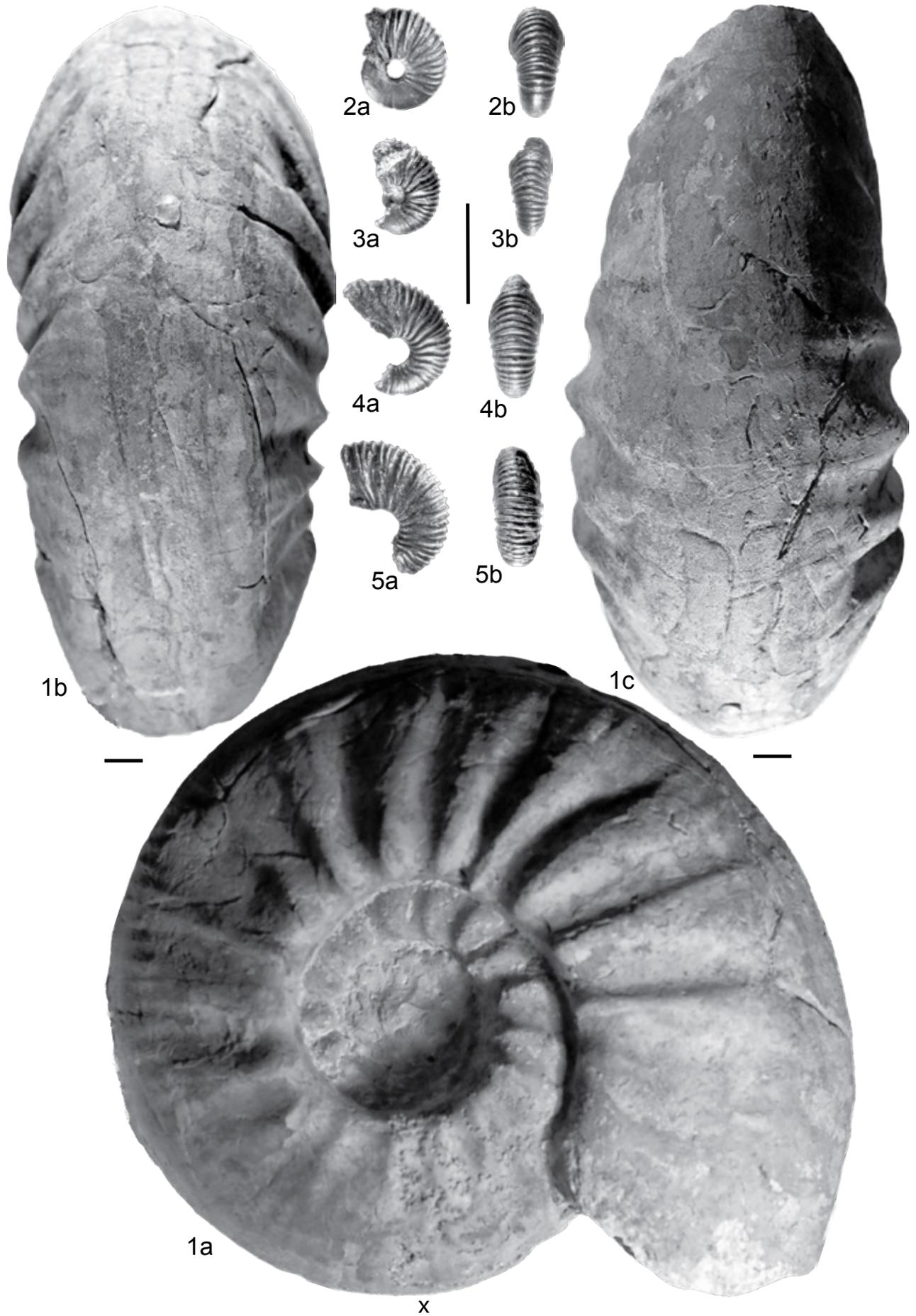
- Fig. 1: *Dhrumaites cardioceratoides* Arkell. (UCBL-FSL 177 242), lateral (1a) and ventral (1b) views. Dhruma Fm, D6 unit, Middle or, more probably, Late Bathonian, Cardioceratoides Zone. *Darmā'* *Quadrangle*: JMA82.320, Wadi al Jufayr, 24°05' N.
- Fig. 2: *Dhrumaites cardioceratoides* Arkell. (UCBL-FSL 177 241), lateral (2a) and ventral (2b) views. Dhruma Fm, D6 unit, Middle or, more probably, Late Bathonian, Cardioceratoides Zone. *Darmā'* *Quadrangle*: JMA82.198, Wadi al Jufayr, 24°05' N.



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Plate XXVII

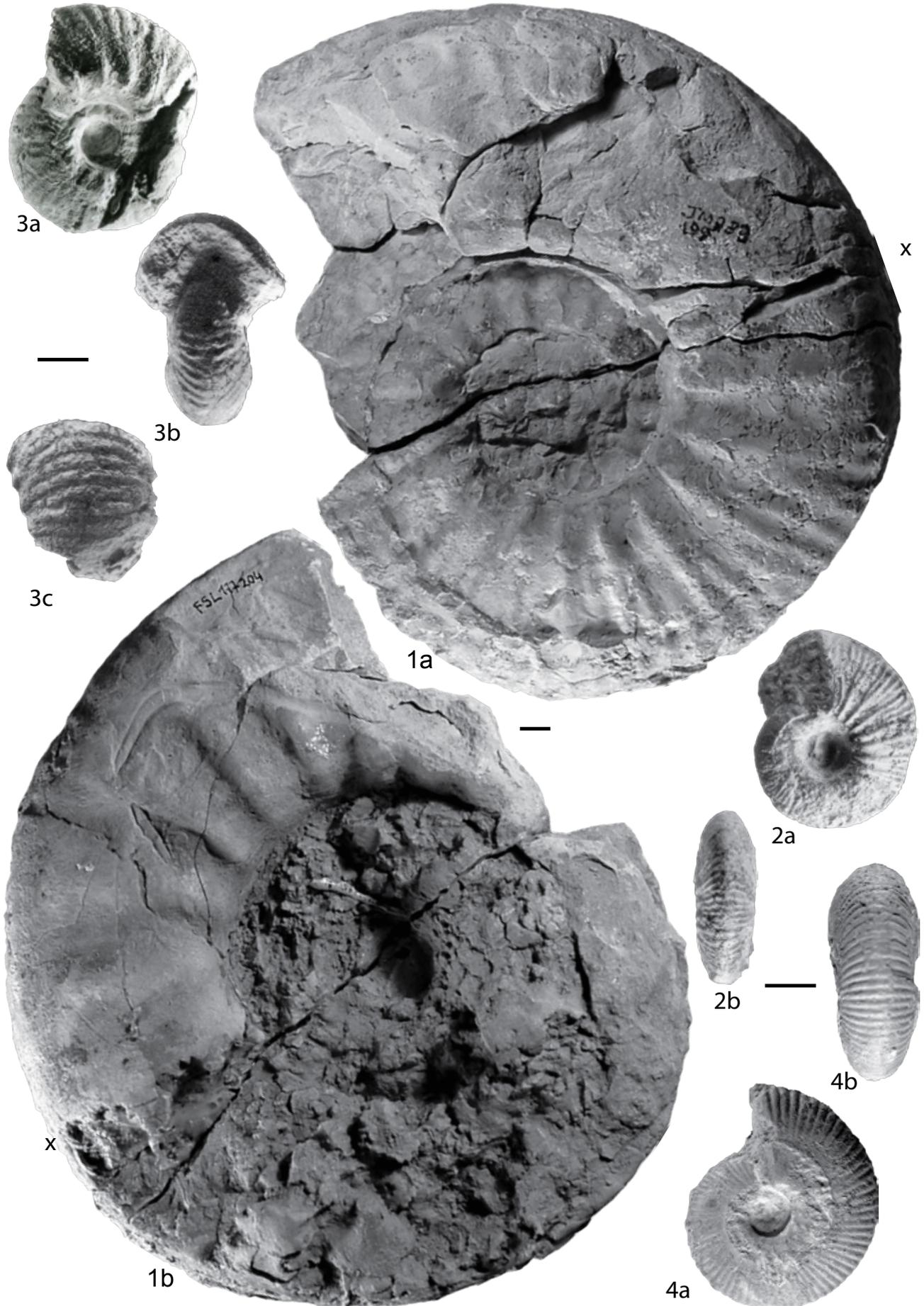
- Fig. 1: *Obtusicoelites gigas* nov. sp. Holotype, complete adult, well-preserved macroconch (UCBL-FSL 177 205), lateral (1a) and ventral views, at the beginning (1b) and the end (1c) of the outer whorl (living chamber). Upper Dhurma Fm, unit D7, upper part (Hisyan Member, Middle Callovian, Ogivalis Zone, Kuntzi horizon. *Buraydah Quadrangle*: JMA83.199, Al Liqa, 26°26' N (x indicates end of phragmocone).
- Figs 2-5: *Obtusicoelites* sp. Small pyritized specimens, small-sized, surely juveniles with nearly complete body chamber half to three quarter whorl long and simple earliest suture (UCBL-FSL 177 193-196), lateral (2a-5a) and ventral (2b-5b) views, enlarged. Upper Dhurma Fm, unit D7, upper part (Hisyan member), Middle Callovian, Ogivalis Zone, Kuntzi Horizon. *Shaqrā' Quadrangle*; VD82.509 Khashm Aba al Hayyah, 25°2' N.



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Plate XXVIII

- Fig. 1: *Obtusicosites* gr. *O. devi/O. ushas* Spath. Large, incomplete specimen with about half a quarter whorl of the body chamber (UCBL-FSL 177 204), lateral views (1a, b). Upper Dhurma Fm, unit D7, upper part (Hisyan Member), Middle Callovian, Ogivalis Zone, Kuntzi horizon. *Buraydah Quadrangle*: JMA83.195, Al Liqa, 26°26' N (x indicates end of phragmocone).
- Fig. 2: *Kinkeliniceras* or *Sivajiceras* sp. Small inner whorls, lateral (2a) and ventral (2b) views (UCBL-FSL 177 188). Upper Dhurma Fm, unit D7, upper part (Hisyan Member), Middle Callovian, Ogivalis Zone. *Shaqrā' Quadrangle*: VD82.607, Khashm Turab, 25°03' N.
- Fig. 3: *Erymnoceras* (*Erymnoceras*) nov. sp. A (UCBL-FSL 177 223), lateral (3a) and ventral (3b, c) views. Upper Dhurma Fm, unit D7, upper part (Hisyan Member), Middle Callovian, Ogivalis Zone. *Buraydah Quadrangle*: JMA83.199, Al Liqa, 26°26' N.
- Fig. 4: *Erymnoceras* (*Erymnoceras*) cf. *schloenbachi* (Roman). Fairly well-preserved inner whorls (UCBL-FSL 177 229), lateral (4a) and ventral (4b) views. Upper Dhurma Fm, unit D7, upper part (Hisyan Member), Middle Callovian, Ogivalis Zone. *Buraydah Quadrangle*: JMA83.199, Al Liqa, 26°26' N.



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Plate XXIX

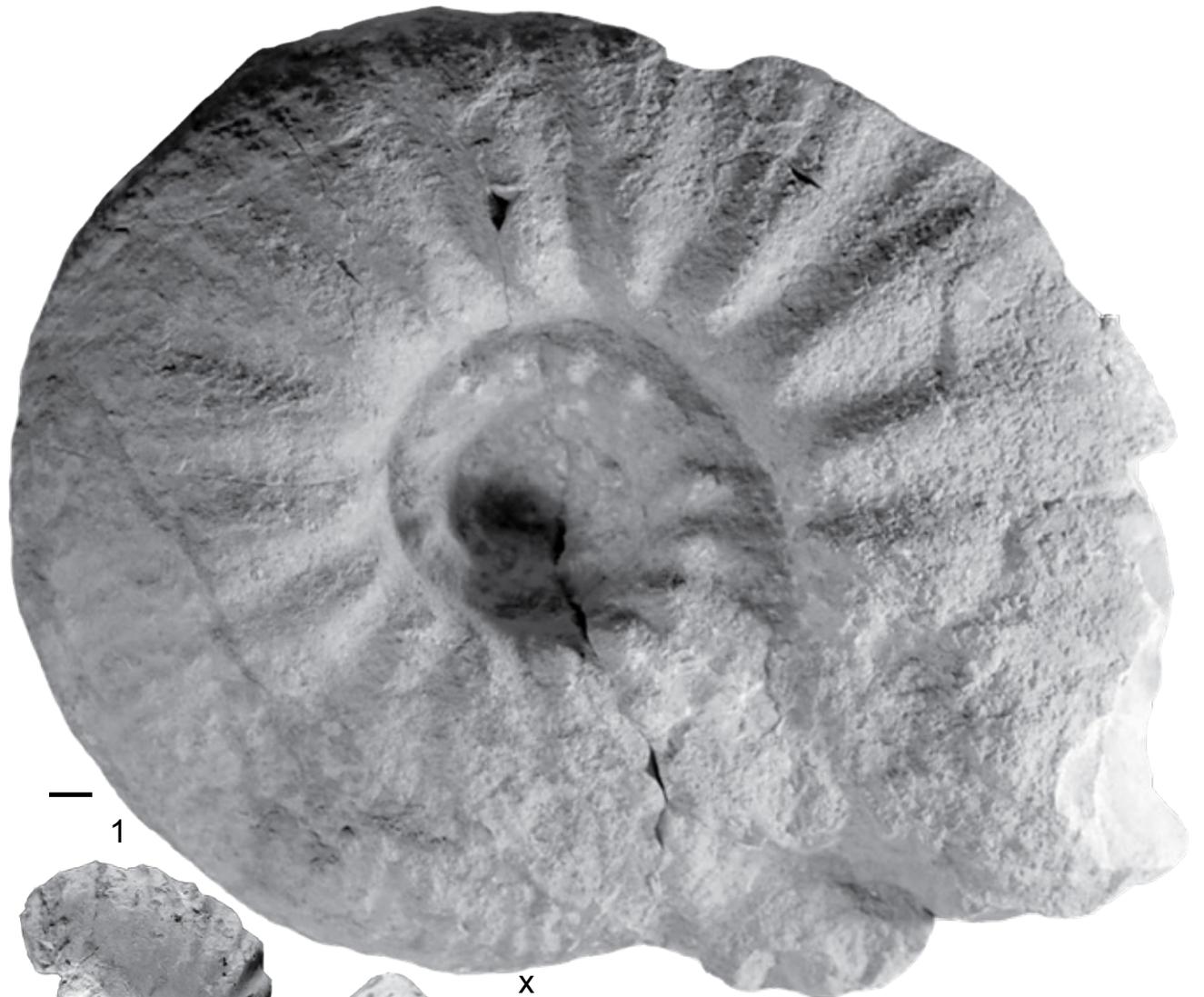
Fig. 1: *Pachyerymnoceras arabicum* n. sp. Holotype, nearly complete well-preserved macroconch without the aperture (UCBL-FSL 177 159), lateral (1a) and ventral (1b, c) views. Tuwaiq Mountain Limestone Fm, unit T1, Middle Callovian, Ogivalis Zone. *Shaqrā' Quadrangle*: VD82.618, Khashm Turab, 25°03' N (x indicates end of phragmocone).



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 Plate XXX

- Fig. 1: *Pachyerymnoceras* cf. *praecox* Mangold. Nearly complete specimen, the body chamber about three quarters whorl long, the aperture not preserved (UCBL-FSL 177 146a), lateral view of the only side better preserved side. Tuwaiq mountain limestone Fm, unit T2, Middle Callovian, Ogivalis Zone. *Durma Quadrangle*: JMA82.346, Graben Missah, 24°16' N (x indicates end of phragmocone).
- Fig. 2: *Pachyerymnoceras* nov. sp.? Small microconch, slightly crushed (UCBL-FSL 177 101), close to *Erymnoceras* (*Pachyerymnoceras*) cf. *jarryi* (Douvillé) in Imlay (1970, pl. 2, figs 1, 2) identified by Zeiss with his new species *P. imlayi* (1974, pl. 37, figs 5, 8, 9), lateral (2a) and ventral (2b, c) views. *Shaqrā' Quadrangle*: Al-Asa'ad collection, Al-Mu'ayshibah area, NW of Riyadh, about 25°34' N.
- Fig. 3: *Erymnoceras* (*Erymnoceras*) nov. sp. A. Small-sized and partially crushed specimen with less than a quarter whorl of the body chamber (UCBL-FSL 177 223), lateral (3a) and ventral (3b, c) views. Dhurma Fm, unit D7 (Hisyan), Middle Callovian, Ogivalis Zone. *Buraydah Quadrangle*: JMA83.199, Al Liqa, 26°26' N.
- Fig. 4: *Pachyerymnoceras* sp. B. UCBL-FSL 177 110). Half a whorl long body chamber of a microconch, lateral (4a) and ventral (4b) views. *Shaqrā' Quadrangle*: Al-Asa'ad collection, AlMu'ayshibah area, NW of Riyadh, about 25°34' N.



1

x



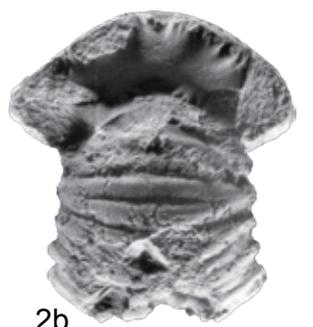
3a



3b



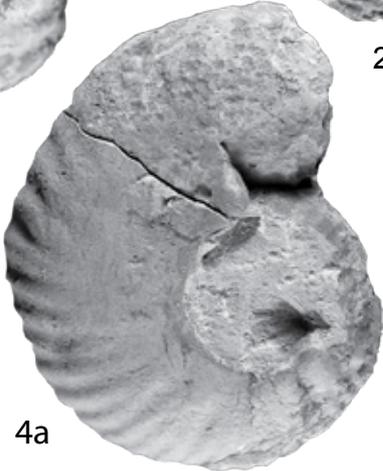
2c



2b



4b



4a



2a

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Plate XXXI

- Fig. 1: *Pachyerymnoceras* cf. *magahrense* (Lewy). Nearly complete macroconch, with the body chamber preserved, half a whorl long (UCBL-FSL 177 123), lateral (1a) and ventral (1b) views. Tuwaiq mountain limestone Fm, unit T3, basal part, Late Callovian, Solidum Zone. *Shaqrā'* *Quadrangle*: Al Asa'ad collection, Al Mu'ayshibah, 25°34' N (x indicates end of phragmocone).
- Fig. 2: *Pachyerymnoceras* cf. *magahrense* (Lewy). Supposed or possible microconch, with half a whorl long of the body chamber preserved (UCBL-FSL 177 102), lateral (2a) and ventral (2b) views. Tuwaiq mountain limestone Fm, unit T3, basal part, Late Callovian, Solidum Zone. *Shaqrā'* *Quadrangle*: Al Asa'ad collection, Al Mu'ayshibah, 25°34' N.



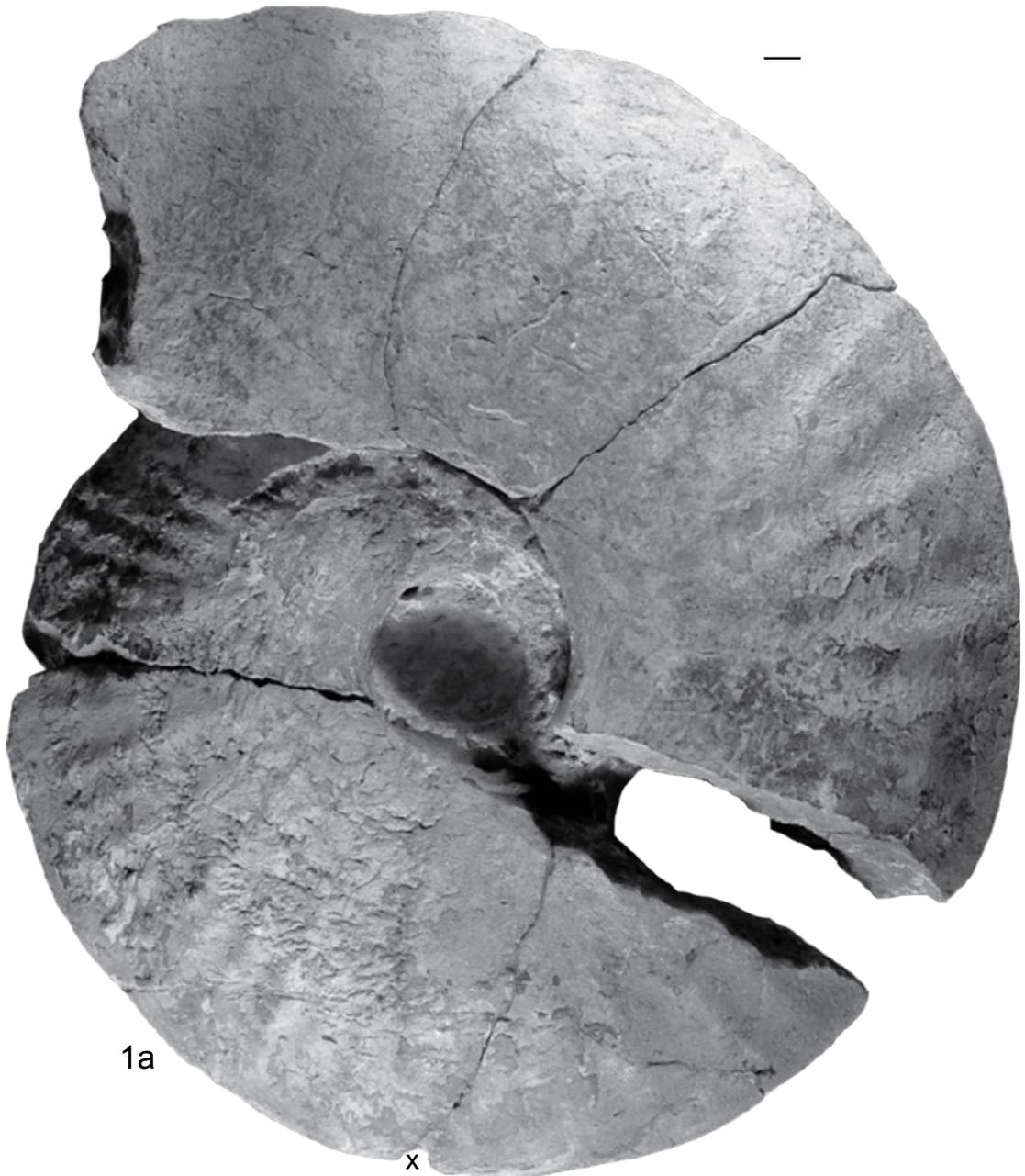
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Plate XXXII

Fig. 1: *Pachyerymnoceras magnum* n. sp. Holotype, large macroconch, with deep, craterlike umbilicus (UCBL-FSL 177 127), complete specimen, lateral (1a) and ventral (1b) views. Tuwaiq mountain limestone Fm, unit T3, basal part, Late Callovian, Solidum Zone. *Shaqrā'* Quadrangle: Al Asa'ad collection, Al Mu'ayshibah, 25°34' N (x indicates end of phragmocone).



1b



1a

x

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Plate XXXIII

Fig. 1: *Pachyerymnoceras magnum* n. sp. Paratype, incomplete specimen with part of the body chamber (UCBL-FSL 177 120), ventral view showing the ogival whorl section with acute venter whorl section, lateral (1a) and ventral (1b) views. Tuwaiq mountain limestone Fm, unit T3, basal part, Late Callovian, Solidum Zone. *Shaqrā' Quadrangle*: Al Asa'ad collection, Al Mu'ayshibah, 25°34' N (x indicates end of phragmocone).



1b

x

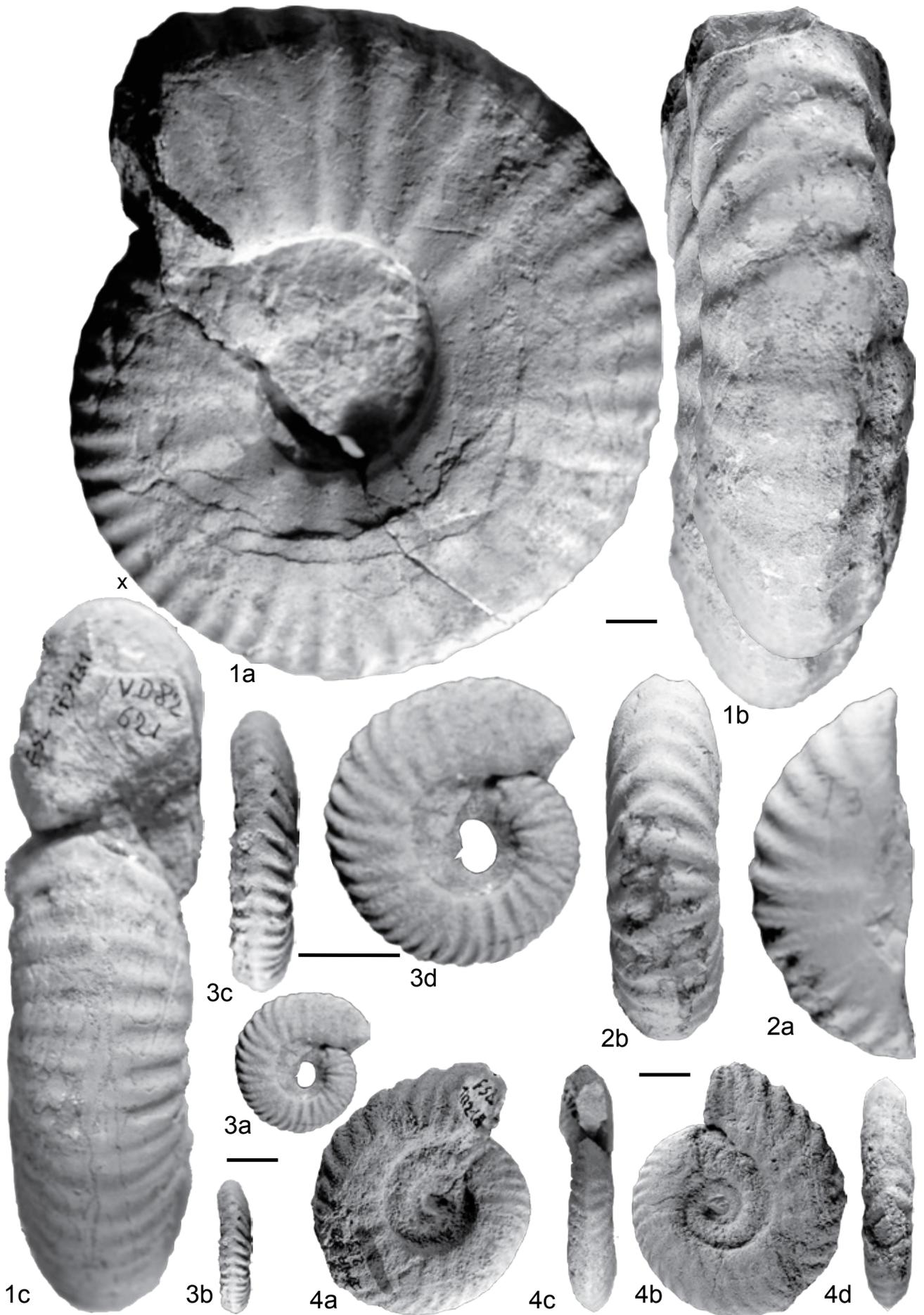


1a

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Plate XXXIV

- Fig. 1: *Kurnubiella fallax* n. sp. Holotype, adult and gerontic stages, the inner whorls and aperture not preserved (UCBL-FSL 177 131), lateral (1a) and ventral (1b, c) views. Upper Dhurma Fm, unit T2, Middle Callovian, Ogivalis Zone. *Shaqrā' Quadrangle*: VD82.621, Khashm Turab, 25°03' N.
- Fig. 2: *Kurnubiella fallax* n. sp. Possible or supposed middle whorls of the species (UCBL-FSL 177 095), lateral (2a) and ventral (2b) views. Upper Dhurma Fm, unit T3, Middle Callovian, Solidum Zone. *Sulayyimah Quadrangle*: VD81.144, Khashm al Mukasar, 21°36' N.
- Fig. 3: *Kurnubiella ogivalis* Gill, Thierry & Tintant. Well-preserved inner whorls (UCBL-FSL 177 141), lateral (3a, c) and ventral (3b, d) views, natural size (3a, b) and enlarged (3c, d). Tuwaiq Mountain Limestone, Fm, unit T2, Middle Callovian, Ogivalis Zone. *Durma Quadrangle*: JMA82.34, Khashm Hisyan, 24°45' N.
- Fig. 4: *Kurnubiella ogivalis* Gill, Thierry & Tintant. Complete and well-preserved specimen UCBL- FSL 177 218), lateral (3a, c) and ventral (3b, d) views. Upper Dhurma Fm, unit D7, upper part (Hisyan member), Middle Callovian, Ogivalis Zone. *Durma Quadrangle*: JMA82.213, Khashm adh Dhibi, 24°14' N.



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Plate XXXV

- Fig. 1: *Kurnubiella fallax* n. sp. Paratype, adult and gerontic specimen, the inner whorls and aperture not preserved (UCBL-FSL 177 132), lateral (1a) and ventral (1b) views. Upper Dhurma Fm, unit T2, Middle Callovian, Ogivalis Zone. *Shaqrā' Quadrangle*: VD82.621, Khashm Turab, 25°03' N.
- Fig. 2: *Peltoceras (Peltoceras) solidum* Spath. About a quarter whorl long of the body chamber. (UCBL-FSL 177 096), lateral (2a) and ventral (2b) views. Tuwaiq Mountain limestone Fm, unit T3, basal part, Late Callovian, Solidum Zone. *Shaqrā' Quadrangle*: Al Asa'ad collection, Al Mu'ayshibah, 25°34' N.
- Fig. 3: *Peltoceras (Peltoceras) cf. trifidum* (Quenstedt). Fragment less than a quarter whorl long (UCBL-FSL 177 105), lateral (3a) and ventral (3b) views. Tuwaiq Mountain limestone Fm, unit T3, basal part, Late Callovian, Solidum Zone. *Shaqrā' Quadrangle*: Al Asa'ad collection, Al Mu'ayshibah, 25°34' N.



1b



1a



2b



2a



3b



3a

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Plate XXXVI

Fig.1: *Paryphoceras* sp. Nearly complete and well-preserved specimen, probably a full-grown specimen, but suture lines not visible and the aperture not preserved (UCBL-FSL 177 035), lateral (1a) and ventral (1b, 1c) views. Hanifa Fm, unit H2, Late Oxfordian. *Wadi ar Rayn Quadrangle*: VD80.325, (UCBL-FSL 177 035), Ulayyah, 23°54' N.



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Plate XXXVII

- Fig. 1: *Euaspidoceras (Euaspidoceras) cf. catena* (Sowerby). Part of the body chamber with the last sutures, lateral view (1a) and inner whorls, lateral view (1b) (UCBL-FSL 177 050). Hanifa Fm, unit H1 (upper part), Middle Oxfordian, Catena Horizon. *Durma Quadrangle*: JMA82.276, Graben Nisah, 24°16' N.
- Fig. 2: *Euaspidoceras (Euaspidoceras) cf. catena* (Sowerby). Part of the body chamber with the last sutures (UCBL-FSL 177 068), lateral (2a) and ventral (2b) views. Hanifa Fm, unit H1 (upper part), Middle Oxfordian, Catena Horizon. *Shaqrā' Quadrangle*: VD82. 644A, Khashm Turab, 25°03' N.
- Fig. 3: *Paryphoceras* sp. Specimen figured on Pl. XXXVI, fig. 1, inner whorls with some trace of ribs (UCBL-FSL 177 035), lateral view. Hanifa Fm, unit H2, Late Oxfordian. *Wadi ar Rayn Quadrangle*: VD80.325, (UCBL-FSL 177 035) Ulayyah, 23°54' N.

