Newsl. Stratigr.	25 (3)	127–154	7 Pl., 4 Fig.	Berlin · Stuttgart, 20. 12. 1991

Mid-Cretaceous ammonites and associated microfossils from the Central Oman Mountains

by W. James Kennedy and Michael D. Simmons*

with 7 plates and 4 figures

Abstract. Ammonites from Lower – Middle Albian (Nahr Umr Formation), Upper Cenomanian and Lower Turonian (Natih Formation) sediments of the Oman Mountains are described for the first time. The following taxa are recorded: *Knemiceras dubertreti* Basse 1940, *Neolobites vibrayeanus* (D'Orbigny 1841), *Calycoceras (Proeucalycoceras)* sp., *Pseudaspidoceras* sp., *Vascoceras durandi* (Peron 1890), *Fagesia catinus* (Mantell 1822), *Paramammites* sp., *Thomasites* cf. *gongilensis* (Woods 1911), *Wrightoceras* sp., *Eotissotia* cf. *simplex* Barber 1957, *Herrickiceras?* sp. and *Turrilites (Turrilites) costatus* Lamarck 1801.

The microfossils (chiefly foraminifera and calcareous algae) from the ammonite-bearing horizons are also briefly described.

The record of these ammonite faunas is important for establishing a firm age for the formations they are found in, for determining the stratigraphic range of the associated microfossils, and for improving our knowledge of the palaeobiogeography of the genera and species involved.

Zusammenfassung. Ammoniten aus dem Unter- bis Mittelalb (Nahr Umr Formation), dem Obercenoman und dem Unterturon (Natih Formation) der Oman Mountains werden zum ersten Mal beschrieben. Nachfolgende Arten werden nachgewiesen: *Knemiceras dubertreti* Basse 1941, *Neolobites vibrayeanus* (D'Orbigny 1841), *Calycoceras (Proeucalycoceras)* sp., *Pseudaspidoceras* sp., *Vascoceras durandi* (Peron 1890), *Fagesia catinus* (Mantell 1822), *Paramammites* sp., *Thomasites* cf. *gongilensis* (Woods 1911), *Wrightoceras* sp., *Eotissotia* cf. *simplex* Barber 1957, *Herrickiceras?* sp. und *Turrilites (Turrilites) costatus* Lamarck 1801.

Auch die Mikrofossilien (meist Foraminiferen und Kalkalgen) aus den Ammoniten-führenden Horizonten werden kurz beschrieben.

Das Verzeichnis dieser Ammonitenfaunen ist von Bedeutung für die Datierung der betreffenden Ablagerungen, für die Bestimmung der stratigraphischen Reichweite der begleitenden Mikrofossilien und für die Verbesserung unserer Kenntnis der Palaeobiogeographie der vorliegenden Gattungen und Arten.

Introduction

The Oman Mountains form an arcuate range along the northeastern margin of the Arabian Peninsula. The geology of this range is complicated as a result of the obduction of an ophiolite complex during Campanian times (Glennie et al. 1974). Within the Central Oman Mountains an allochthonous ophiolitic suite (the Semail Ophiolite) and basinal sediments (the Hawasina

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0078-0421/91/0025-0127 $ 7.00

Complex) occur together with autochthonous, mainly platformal sediments (the Hajar Supergroup). GLENNIE et al. (1974), GLENNIE (1977), HUTIN et al. (1986), RABU et al. (1986) and HUGHES CLARKE (1988) have described the geology of this region in detail. Recently a set of papers on the geology of Oman have been published in a special publication of the Geological Society of London edited by ROBERTSON et al. (1990).

An important series of autochthonous shelf carbonates lying within the Hajar Supergroup is the mid-Cretaceous Wasia Group. It is within these carbonates that the oil reserves of the Fahud and Natih Fields are located. Previous studies of the sedimentology and biostratigraphy of the Wasia Group in Oman include those of TSCHOPP (1967), HARRIS & FROST (1984), SIMMONS & HART (1987), HUGHES CLARKE (1988), SCOTT et al. (1988), SCOTT (1990) and SMITH et al. (1990). ALSHARHAN & NAIRN (1988) discuss the regional context of the Wasia Group.

The age of sediments within the Wasia Group of the Oman Mountains has been discussed by most previous workers. However, there has been some debate as to the precise age range of the various formations and members (SMITH et al. 1990). Imprecise or inaccuarate age assignment of lithostratigraphic units precludes regional correlation which is important for developing a picture of basin history. This paper describes the occurrence of ammonites in the Wasia Group of the Oman Mountains for the first time. These provide a relatively precise age assignment for the sediments they are found in, since they can be referred to a global biozonation scheme. The microfossil assemblages associated with the ammonites are also described. These support the age assignments provided by the ammonites. More important, the co-occurrence of ammonites with microfossils provides an independent means of determining the age significance of the microfossils.

Location and stratigraphy

Mid-Cretaceous ammonites were found at three localities in the Central Oman Mountains area: Jebel Salakh, Jebel Hinaydil and Jebel Madar (see Fig. 1). These jebels are domal uplifts south of the main thrust belt and expose Hajar Supergroup carbonates.

The Wasia Group forms the second major depositional cycle recognized in the Cretaceous sediments of the Arabian Peninsula (HARRIS et al. 1984; ALSHARHAN & NAIRN 1988). It is unconformity bound, and is underlain by the Early Cretaceous carbonates of the Thamama Group (termed Kahmah Group in Oman), and overlain by the Late Cretaceous shales and carbonates of the Aruma Group (see Fig. 2). The term "Wasia Group" has had a varied history of usage which is summarized by ALSHARHAN & NAIRN (1988). However, it has now come to be accepted as describing the mid-Cretaceous carbonate dominated succession seen in the northern and eastern Arabian Peninsula.

In the Oman Mountains two formations are recognized within the Wasia Group: the Natih Formation and the Nahr Umr Formation. The Nahr Umr Formation was originally described from Iraq (OWEN & NASR 1958; DUNNINGTON et al. 1959) where it is a dominantly clastic sequence. Eastward across the Gulf region carbonate content increases, until in the Central Oman Mountains area it is formed of calcareous shales, marls and orbitolinid-rich argillaceous limestones (HUTIN et al. 1986; RABU et al. 1986; SIMMONS & HART 1987; HUGHES CLARKE

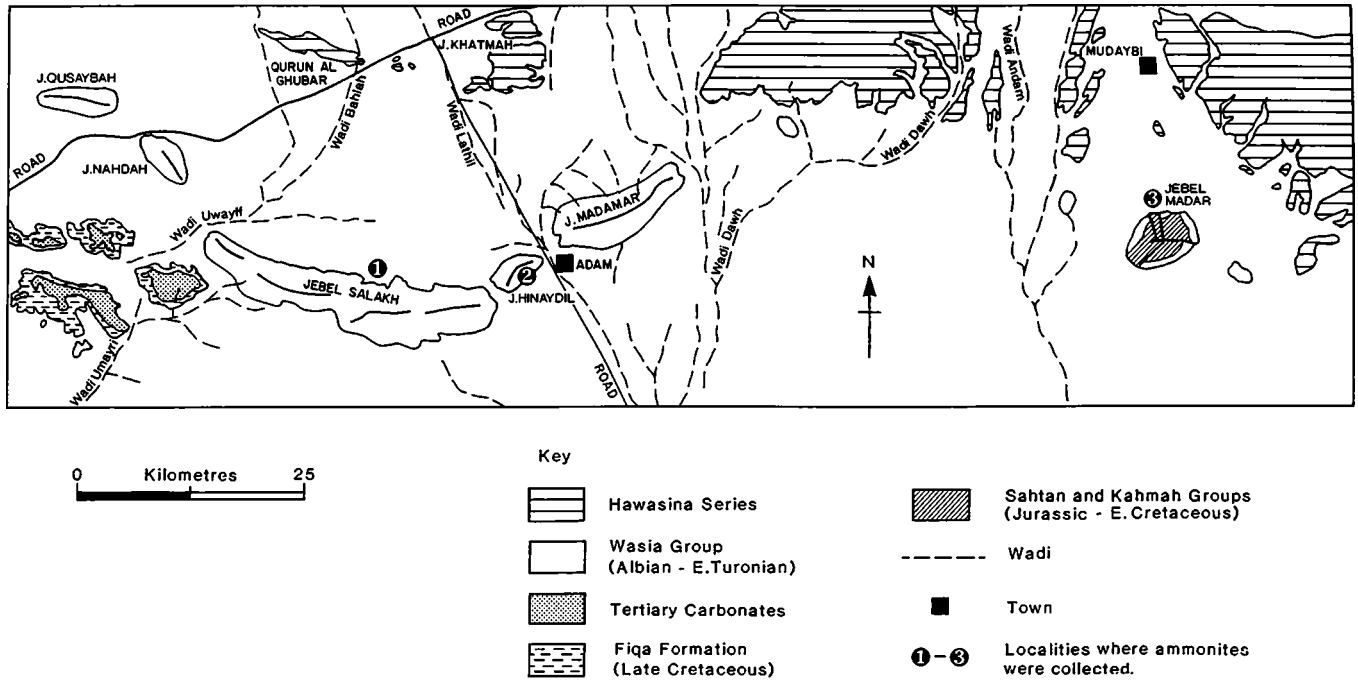

Fig. 1. Location of the studied sections.

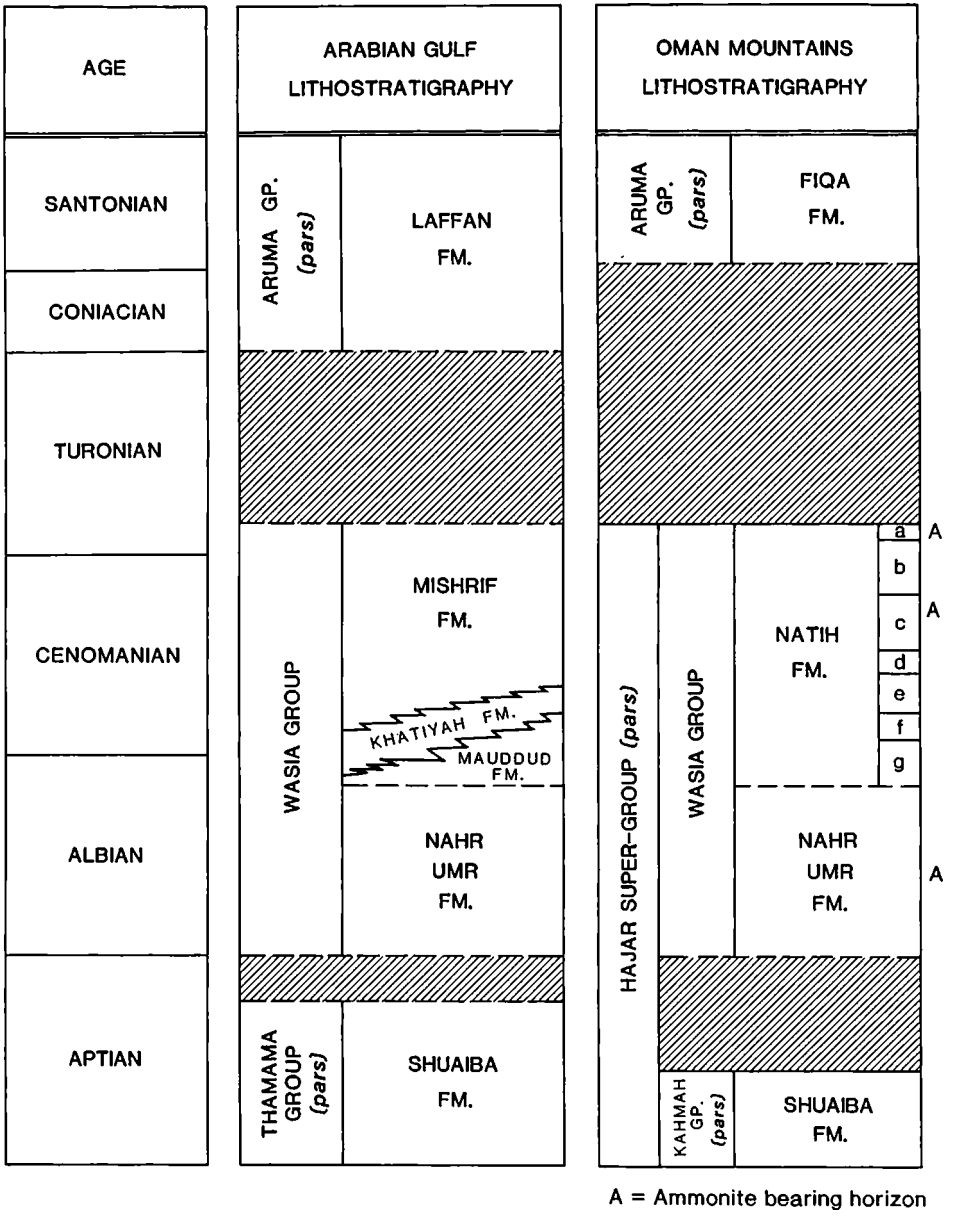

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Fig. 2. Summary of Aptian – Santonian lithostratigraphy in the Oman Mountains and Arabian Gulf region (after SMITH et al. 1990).

1988). Microfossils, particularly orbitolinid foraminifera, demonstrate that this formation is of early – late Albian age in the Oman Mountains (SIMMONS & HART 1987).

The Natih Formation was originally described as the Wasia Limestone Formation by TSCHOPP (1967), who recognized seven members within it, lettered a-g (see also SCOTT 1990; SMITH et al. 1990). GLENNIE et al. (1974) replaced the term Wasia Limestone Formation with the term Natih Formation. This term has been used by most subsequent workers, although some (eg. HARRIS & FROST 1984) prefer instead to use Mauddud Formation, Mishrif Formation and Rumaila (or Khatiyah or Shilaif) Formation. These terms are used to describe the equivalent sediments to the Natih Formation in the Arabian Gulf region. The problematic correlation between the two sets of terminology has been discussed by SMITH et al. (1990) (see also Fig. 2).

BECHENNEC et al. (1986) introduced the term Fitri Formation to describe the facies previously termed Natih Formation members a, b and c. This formation was considered to be part of the Aruma Group, rather than the Wasia Group. However, as noted by RABU et al. (1990), there is no unconformity between it and the underlying "Natih Formation", whilst a stratigraphic break is recognised prior to the overlying Muti Formation. We consider than the term Fitri Formation should be discarded since the major regional unconformity and sequence boundary lies above it (cf. HARRIS et al. 1984; WARBURTON et al. 1990). The facies referred to the Fitri Formation can adequately be described as members within the Natih Formation. RABU (1987) considered the Fitri Formation to be Early Turonian. This is in agreement with the age of Natih members a/b as described herein.

The age range of the Natih Formation has been the subject of some uncertainly, in part as a result of the fact that pre-Aruma Group erosion progressively downcuts into the Wasia Group northwards across the Oman Mountains (HARRIS & FROST 1984). Thus the full Natih Formation section seen in the Fahud oilfield (TSCHOPP 1967) is truncated around Jebel Akhdar. This may have led to an underestimation of the age range of the formation. Most workers agree that the formation is at least late Albian – late Cenomanian in age, although extension into the Turonian stage as claimed by some (eg. SIMMONS & HART 1987; SCOTT 1990) is doubted by others (eg. HARRIS et al. 1984; HUGHES CLARKE 1988). HARRIS & FROST (1984) stated that although the Natih Formation extends into the Turonian in the subsurface around the Natih and Fahud oilfields, the late Cenomanian and earliest Turonian parts of the formation are missing in outcrops to the northwest of these fields. Our preferred age range of the Natih Formation and its constituent members (as defined by TSCHOPP 1967), and supported by the data presented herein, is given in the summary stratigraphy diagram (Fig. 2).

Ammonites were recovered from three levels within the Wasia Group. At Jebel Madar a single, but quite well preserved specimen, was obtained from the middle part of the Nahr Umr Formation. At Jebel Hinaydil a few specimens were obtained from a level thought to be within Member c of the Natih Formation. At Jebel Salakh ammonites were recorded from two levels in the Natih Formation; one within Member c, probably equivalent to the level with ammonites at Jebel Hinaydil, and a further level with abundant, but not very well preserved ammonites occurs in almost the highest sediments seen within the Natih Formation at this locality. This level lies within the upper part of Member b of the Natih Formation, or perhaps more likely, within Member a as redefined by SCOTT (1990). However, separation of Members b and a is difficult even in the Fahud field where they were first defined (HUGHES CLARKE

1988). The upper level with ammonites at Jebel Salakh represents the youngest Natih Formation sediments seen at outcrop in the Oman Mountains. Their age therefore, is important for demonstrating the age range of this formation.

The ammonite fauna

The three levels with ammonites recognised in the Wasia Group can be dated with varying degrees of precision, as is discussed in the systematic descriptions below. These results may be summarised as follows:

Nahr Umr Formation, Jebel Madar. *Knemiceras dubertreti:* upper Lower to lower Middle Albian.

Natih Formation, Member c, Jebel Salakh and Jebel Hinaydil. *Calycoceras (Proeucalycoceras)* sp., *Neolobites vibrayeanus, Turrilites (T.) costatus:* lower Upper Cenomanian, equivalent to the *Calycoceras (Proeucalycoceras) guerangeri* Zone in north-west Europe, and the *Calycoceras-Neolobites* Zone in Israel (LEWY & RAAB 1978), and older than the widely recognised *Metoicoceras geslinanum* and *Vascoceras cauvini* zones of authors.

Natih Formation, Member b/a, Jebel Salakh. *Pseudaspidoceras* sp., *Vascoceras durandi, Fagesia catinus, Paramammites* sp., *Thomasites* cf. *gongilensis, Wrightoceras* sp., *Eotissotia* cf. *simplex* and *Herrickiceras?* sp.: low Lower Turonian. This fauna indicates the lower half of the Lower Turonian, above the widely recognised Upper Cenomanian *Neocardioceras juddii* Zone and its correlatives.

Systematic Palaeontology

Superfamily HOPLITACEAE H. DOUVILLÉ, 1890

Family ENGONOCERATIDAE HYATT, 1900

Genus *Knemiceras* BÖHM 1898

Type species. *Ammonites syriacus* VON BUCH, 1850, p. 20, by original designation.

Knemiceras dubertreti BASSE, 1940

Plate 1D

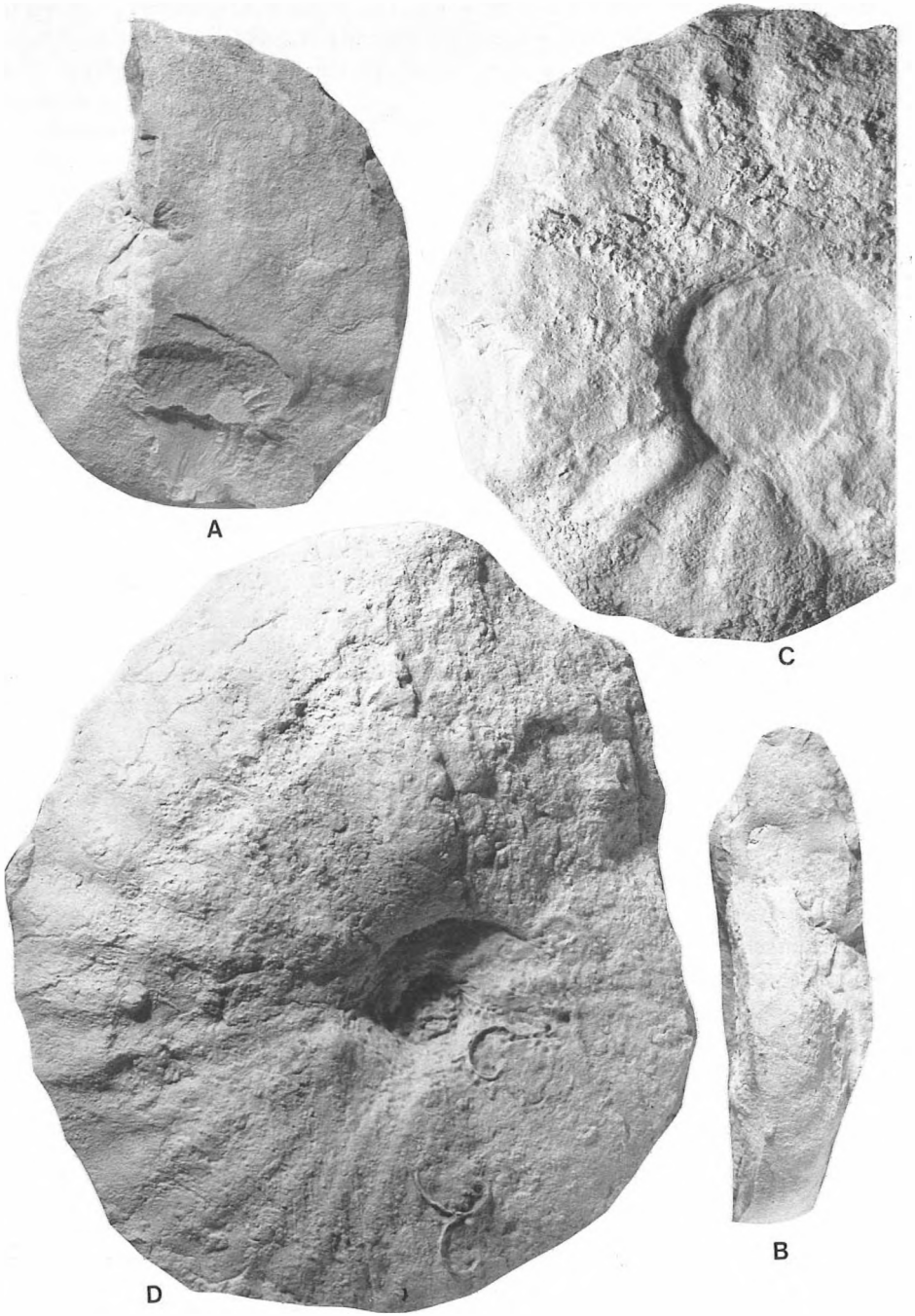
1940 *Knemiceras dubertreti* BASSE, p. 427, pl. 1, figs. 3, 4; pl. 2, figs. 1, 2; text-figs. 2a, b.

Type. Lectotype here designated, is the original of BASSE 1940, pl. 1, fig. 4 from Jebel Dourra, W. Rmeide Ham, region of Zebdani, Syria.

Dimensions	D	Wb	Wh	Wb:Wh	U
OUM KY2022 116.5	(100)	– (–)	56.6 (48.5)	–	18.3 (15.7)

Description. The specimen is somewhat corroded, with about half a whorl of body chamber preserved. Coiling is involute, with the umbilicus comprising 15.7% of the diameter, shallow, with a low wall and very broadly rounded umbilical shoulder. The whorl section is very compressed, with the greatest breadth just outside the umbilical shoulder in intercostal section, and at the massive umbilical bullae in costal section. The inner flanks are broadly

Plate 1. A, B, *Thomasites* cf. *gongilensis* (WOODS 1911). OUM KY2015, Lower Turonian, Member b/a of the Natih Formation, Jebel Salakh. C, *Pseudaspidoceras* sp. OUM KY2007, Lower Turonian, Member b/a of the Natih Formation, Jebel Salakh. D, *Knemiceras dubertreti* BASSE 1940. OUM KY2002, Albian, Nahr Umr Formation, Jebel Madar. All figures are x 1.


A
C
B
D

rounded, the outer flanks flattened and convergent, the ventrolateral shoulders sharp and the venter narrow and tabulate in intercostal section; the costal section is compressed polygonal. There are 7–8 massive umbilical bullae on the outer whorl that coarsen as size increases. They give rise to groups of up to three coarse, straight, prorsiradiate ribs that strengthen and broaden across the flanks, while additonal ribs intercalate both low and high on the flanks. A low, rounded inner ventrolateral tubercle is conspicuous on all ribs on the last third of the outer whorl. All ribs bear long, low outer ventrolateral clavi, perched on the sharp ventral shoulder. The venter is concave between clavi, which are linked by a low, broad ventral rib.

Discussion. The present specimen matches the lectotype (BASSE 1940, p. 1, fig. 4) closely in size, style and density of ribbing. Quite how many of the *Knemiceras* from Syria and Lebanon described by BASSE actually merit specific separation is impossible to determine as their relative ages are poorly known, and the material ill-preserved in most cases. *Knemiceras atennuatum* HYATT of BASSE (1940, p. 425, p. 1, fig. 1) is compressed, lacking the massive bullae and coarse ribs of the present species. *Knemiceras arambourgi* BASSE, 1940 (p. 426, pl. 1, fig. 2) has much coarser, fewer ribs and umbilical tubercles per whorl. *Knemiceras flexiloculosum* BASSE, 1940 (p. 430, pl. 2, fig. 3) is a large feebly ornamented species, lacking coarse ribs and bullae.

Occurrence. The Oman specimen is from the middle part of the Nahr Umr Formation at Jebel Madar. The species was originally described from the couches à *Knemiceras* of Syria. LEWY & RAAB (1978) state that engonoceratid ammonites occur at two distinct levels in the Albian in Lebanon and Israel, without providing details, referring only to a broad *Knemiceras* Zone. In northern Sinai (LEWY & RAAB 1978: Bir Lugama, near Djebel Maghara (DOUVILLÉ 1916)) the oldest *Knemiceras* occur with *Douvilleiceras mammilatum*, indication the upper Lower Albian (fide OWEN 1988). The upper level is probably Middle Albian (LEWY & RAAB 1978, p. XXX11.4)

Genus *Neolobites* FISHER, 1882

Type species. *Ammonites vibrayeanus* D'ORBIGNY, 1841, p. 322, pl. 96, figs. 1–3, by original designation.

Neolobites vibrayeanus (D'ORBIGNY, 1841)

Plate 2D–2G

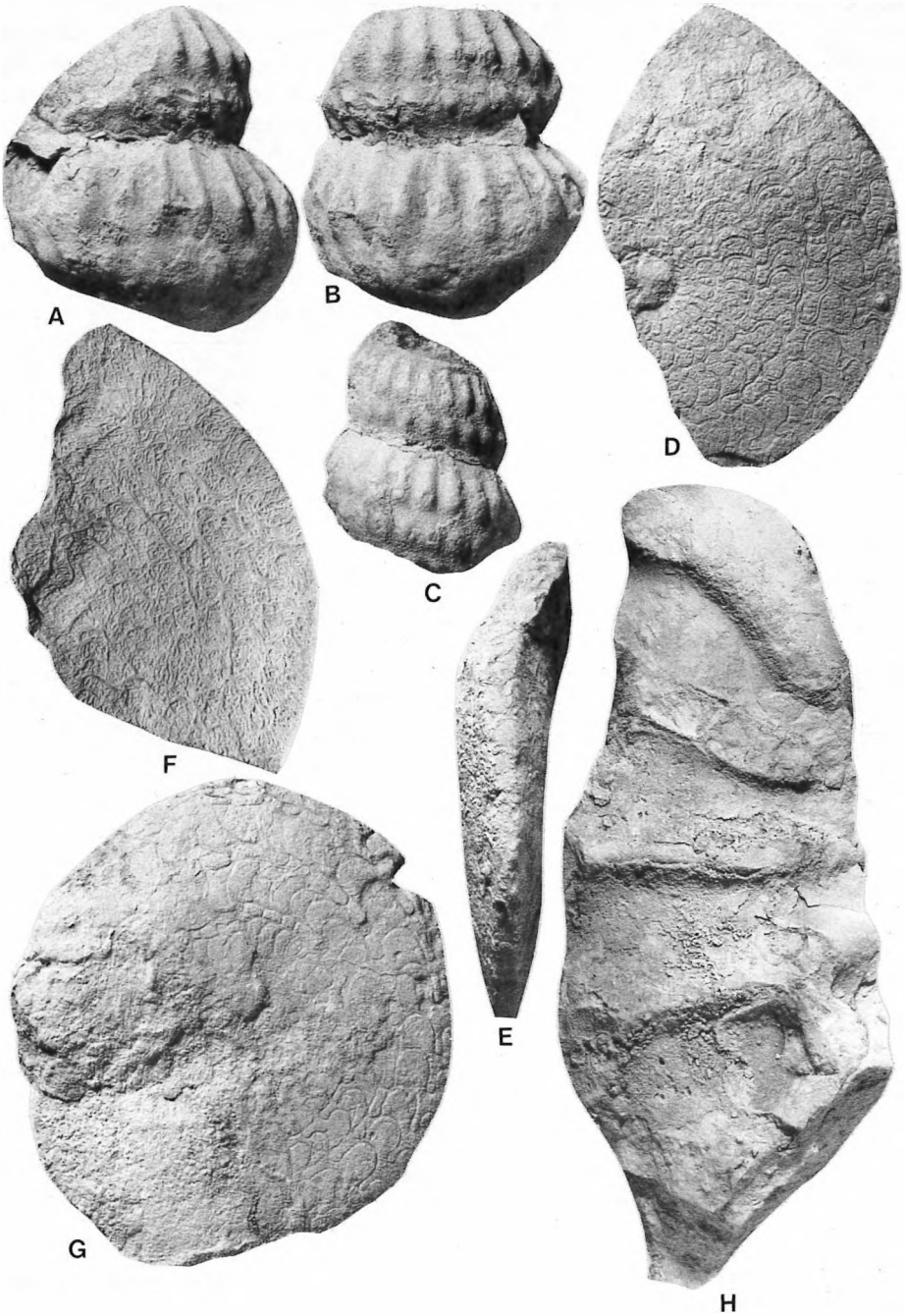
1841 *Neolobites vibrayeanus* D'ORBIGNY, p. 322, pl. 96, figs. 1–3.

1981 *Neolobites vibrayeanus* (D'ORBIGNY 1841); KENNEDY & JUIGNET, p. 23, figs. 3a–c, 4a–b, 5a (with fully synonymy).

1989 *Neolobites vibrayeanus* (D'ORBIGNY 1841); LUGER & GRÖSCHKE, p. 366, pl. 39, fig. 3; text-fig 5 (with additional synonymy).

Type. Holotype, by monotypy, is the original of D'ORBIGNY 1841 p. 322, pl. 96, figs. 1–3, in the collections of the Muséum National d'Histoire Naturelle, Paris, D'ORBIGNY Collection, No. 1896.27 (KENNEDY & JUIGNET 1981, figs. 3a–c, 6a).

Plate 2. A–C, *Turrilites (Turrilites) costatus* LAMARCK 1801. OUM KY2018–2019. D–G, *Neolobites vibrayeanus* (D'ORBIGNY 1841). OUM KY2003–2005. H, *Calycoceras (Proeucalycoceras)* sp. OUM KY2006. All specimens are from the lower Upper Cenomanian, Member c of the Natih Formation, Jebel Salakh. Figures A–G are x 1; Figure H is reduced x 0.7.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H

Description. Specimens are corroded to varying degrees, wholly septate, and up to 103 mm in diameter. The best preserved individual (OUM KY2004) is 69 mm in diameter, with a tiny umbilicus, low umbilical wall and very compressed whorl section, a whorl breadth to height ratio of 0.4, the greatest breadth around mid-flank, the flanks broadly rounded, with sharp ventrolateral shoulders and a narrow, concave venter. There are small sharp ventral clavi where the surface of the mould is well-preserved, and traces of broad, distant inner flank ribs in two specimens. Suture with entire lobes and saddles.

Discussion. The small umbilicus, feeble ornament and compressed whorls characterize *N. vibrayeanus*. Differences from other species are discussed by KENNEDY & JUIGNET (1981) and LUGER & GRÖSCHKE (1989). The latter describe, as *Neolobites* sp. (p. 366, pl. 38, figs. 4–6, text-figs. 13d, e), a more evolute species, suggesting that KENNEDY & JUIGNET (1981) may have drawn their interpretation of *N. vibrayeanus* too widely.

Occurrence. *Neolobites vibrayeanus* is a widespread and characteristic lower Upper Cenomanian species, occurring commonly in the Middle East, with records, both published and unpublished, from Morocco, Algeria, Tunisia, Egypt, Israel, Lebanon and Saudi Arabia. It also occurs in France, Spain and Portugal, Peru and Bolivia. The Oman specimens are from Member C of the Natih Formation at Jebel Salakh and Jebel Hinaydil.

Superfamily ACANTHOCERATACEAE DE GROSSOUVRE 1894

Family ACANTHOCERATIDAE DE GROSSOUVRE 1894

Subfamily ACANTHOCERATINAE DE GROSSOUVRE 1894

Genus *Calycoceras* HYATT 1900

Type species. By designation under the plenary Powers (ICZN Opinion No. 577) *Ammonites navicularis* MANTELL 1822, p. 198, pl. 22, fig. 5 (ICZN Specific Name No. 1633).

Subgenus *Proeucalycoceras* THOMEL 1972

Type species. By original designation *Calycoceras (Eucalycoceras) besairiei* COLLIGNON 1937, p. 37 (13), pl. 3, figs. 1–4; pl. 8, fig. 5.

Calycoceras (Proeucalycoceras) sp.

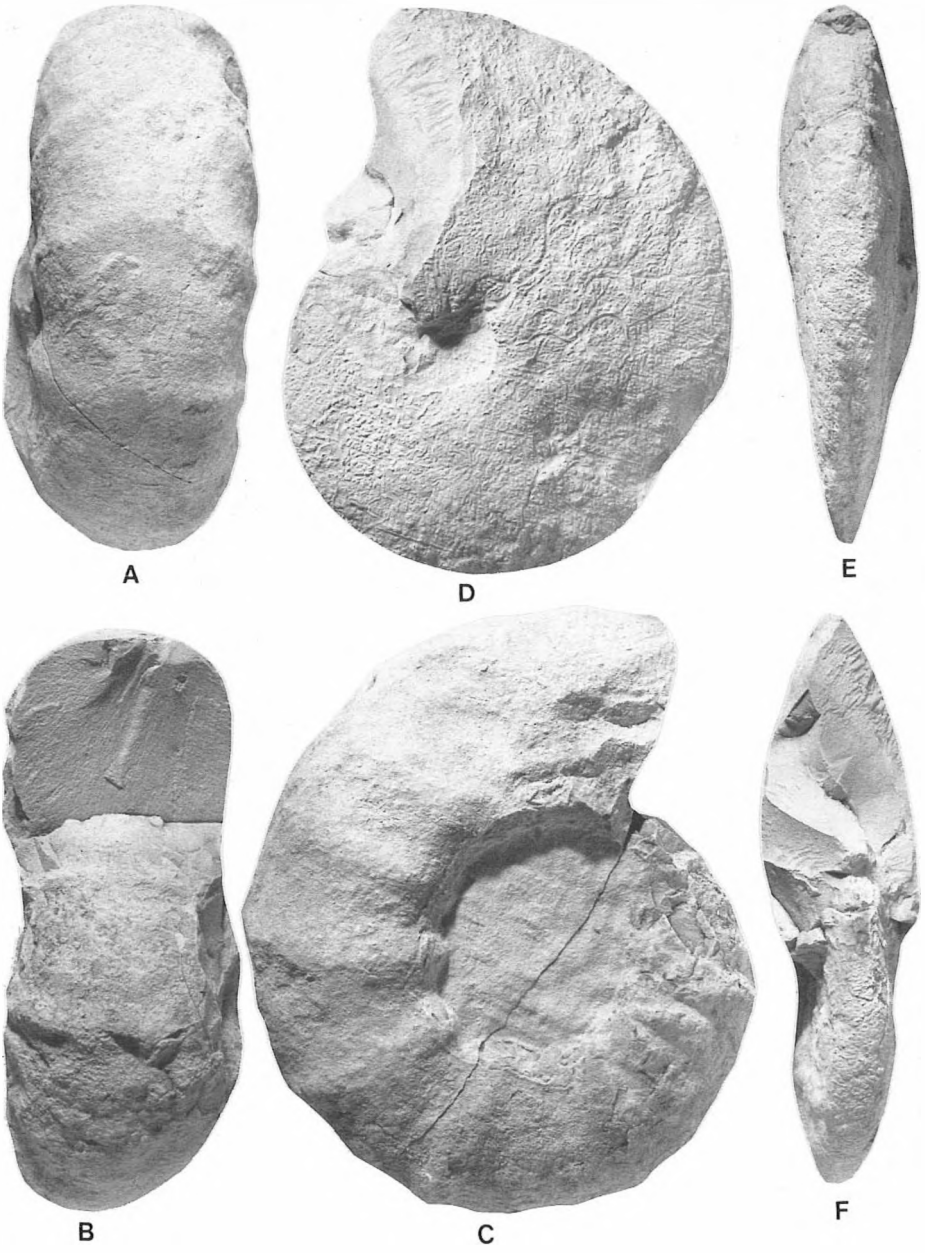
Plate 2H

Description. A single fragment from Jebel Salakh is 160 mm long, and partially septate, preserving part of the umbilical wall and inner flank of a large *Calycoceras (Proeucalycoceras)*. There are parts of five large umbilical bullae preserved, that give rise to coarse, straight, distant primary ribs; there are no secondaries preserved. The flanks appear to have been convergent with traces of a large ventrolateral tubercle.

Discussion. This fragment has been compared with more complete European and North African material; it compares most closely with adult *Calycoceras (Proeucalycoceras)* of the lower Upper Cenomanian (e.g. WRIGHT & KENNEDY 1990, text-fig. 118), and is referred to that subgenus.

Occurrence. Member C of the Natih Formation, Jebel Salakh, Oman. Comparable material occurs in the lower Upper Cenomanian in western Europe and North Africa.

Plate 3. A–C, *Paramammites* sp. OUM KY2008. D–F, *Eotissotia* cf. *simplex* BARBER 1957. OUM KY2017. Specimens are from the Lower Turonian, Member b/a of the Natih Formation, Jebel Salakh. All figures are x 1.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Subfamily EUOMPHALOCERATINAE COOPER 1978

Genus *Pseudaspidoceras* HYATT 1903

Type species. By original designation, *Ammonites footeanus* STOLICZKA, 1864, p. 101, pl. 52, figs. 1, 2.

Pseudaspidoceras sp.

Plates 1C, 4A–4B

Description. Specimens are rather worn, and up to 110 mm diameter. Coiling is evolute, with the umbilicus comprising up to 30% of the diameter. The whorls expand slowly. The umbilical wall is low, the umbilical shoulder broadly rounded, the whorl section depressed, with flattened flanks, broadly rounded ventrolateral shoulders and a broad, feebly arched venter in intercostal section. The costal section is polygonal. Primary ribs arise on the umbilical wall and strengthen into strong umbilical bullae or not, so that the primary ribs are of variable strength on the innermost flanks. The ribs are coarse, straight and prorsiradiate, and may arise either singly or in pairs from the bullae; there are occasional intercalated ribs. All ribs bear a coarse inner ventrolateral tubercle; a broad, slightly prorsiradiate rib connects to strong outer ventrolateral clavi, connected across the venter by a feeble rib.

Discussion. Apparent absence of siphonal clavi suggest these poor specimens are *Pseudaspidoceras* rather than *Kamerunoceras*. Of described species, they most closely recall *Mammites (Pseudaspidoceras) dubertreti* BASSE 1937, (p. 183, pl. 10, fig. 3, pl. 11, fig. 1) from the lower Turonian of Lebanon.

Occurrence. The Oman specimens are from Member b/a of the Natih Formation at Jebel Salakh.

Family VASCOCERATIDAE DOUVILLÉ 1912

Subfamily VASCOCERATINAE DOUVILLÉ 1912

Genus *Vascoceras* CHOFFAT 1898

Type species. *Vacoceras gamai* CHOFFAT 1898, p. 54, pl. 7, figs. 1–4; pl. 8, fig. 1; pl. 10, fig. 2; pl. 21, figs. 1, 2, 5, by the subsequent designation of ROMAN 1938, p. 452.

Vascoceras durandi (PERON, 1890)

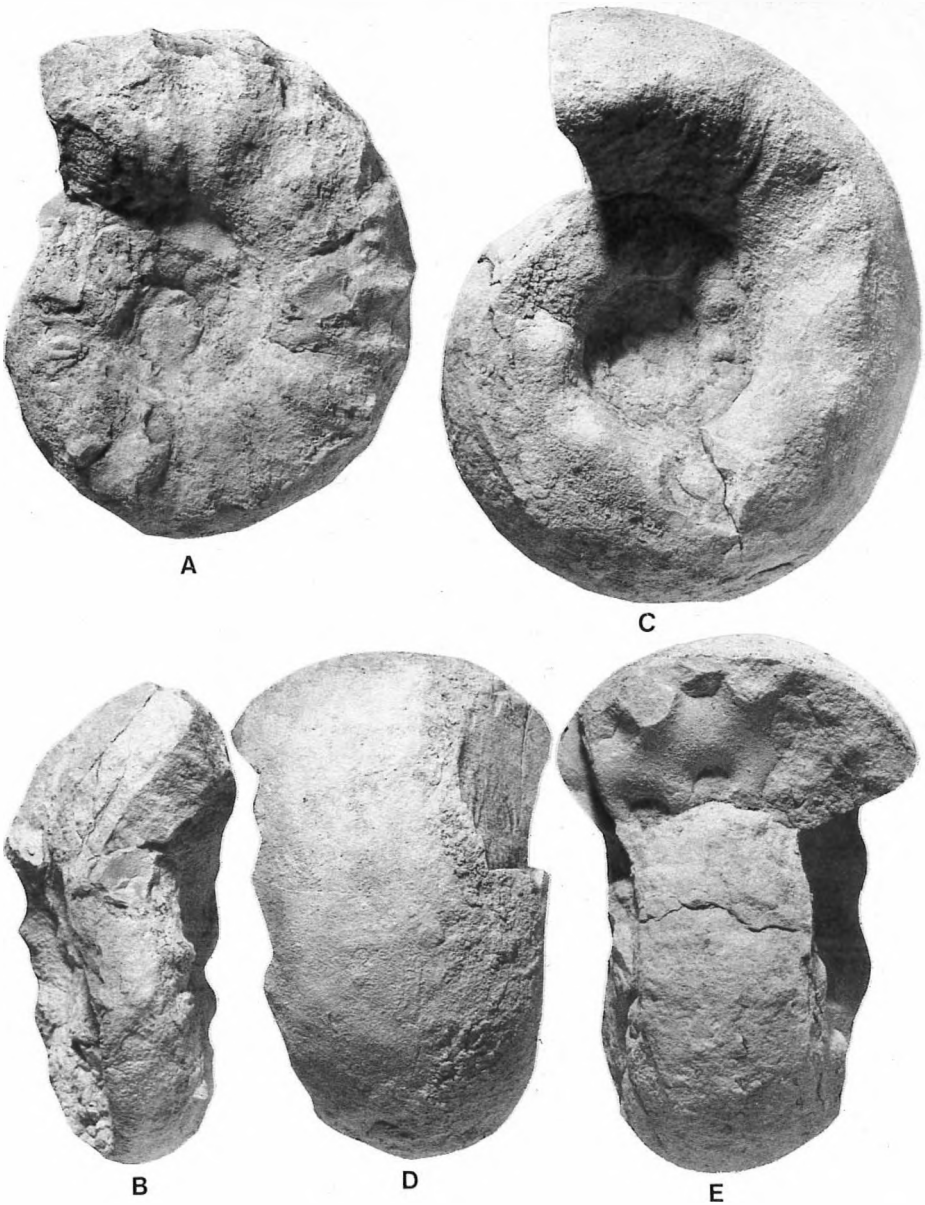
Plate 5A–5B

1985 *Vascoceras durandi* (PERON); BERTHOU, CHANCELLOR & LAUVERJAT, p. 72, pl. 4, figs. 4–9; pl. 6, figs. 1–6 (with full synonymy).

Types. Discussion of the status of the type material of this species is deferred until the original material is revised (CHANCELLOR, KENNEDY & HANCOCK, in preparation).

Description. OUM KY2010 is 95 mm in diameter. Coiling is quite involute, with the umbilicus comprising 24% of the diameter. The umbilical wall is high, flattened, and inclined outwards. The umbilical shoulder is quite narrowly rounded, the whorl section depressed, with a whorl breadth to height ratio of 1.32, the greatest breadth at the umbilical shoulder, the inner flanks broadly rounded, the outer flanks converging to an arched venter. There are estimated 10 blunt bullae perched on the umbilical shoulder that give rise to low broad ribs

Plate 4. A–B, *Pseudaspidoceras* sp. OUM KY2009. C–E, *Fagesia catinus* (MANTELL 1822). OUM KY2012. Specimens are from the Lower Turonian, Member b/a of the Natih Formation, Jebel Salakh. All figures are x 1.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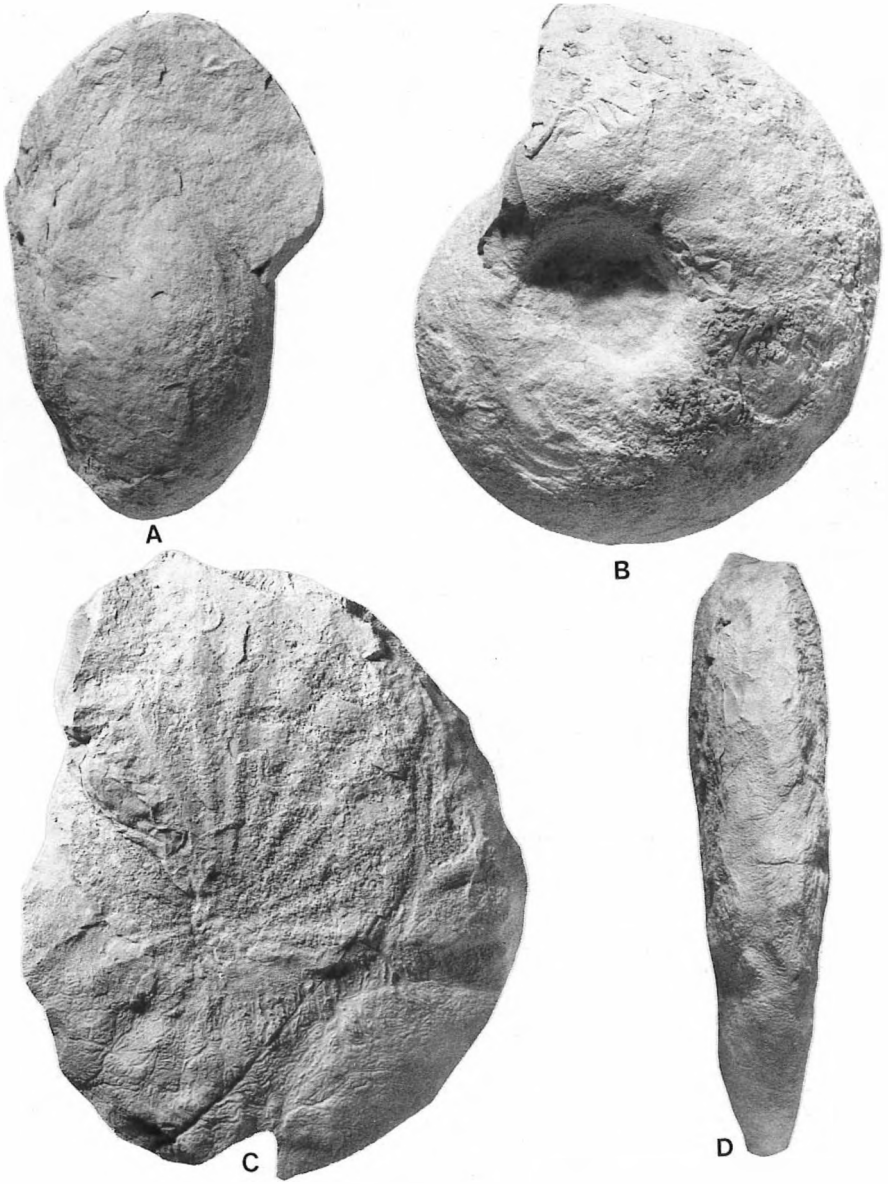


Plate 5. A, B, *Vascoceras durandi* (PERON 1890). OUM KY2010. C, D, *Herrickiceras?* sp. OUM KY2010. Specimens are from the Lower Turonian, Member b/a of the Natih Formation, Jebel Salakh. All figures are x 1.

that efface on the inner flank. There is no evidence for any other ornament, but the shell surface is badly corroded.

Discussion. *Vascoceras durandi* is discussed at length by BERTHOU et al. (1985), who review the synonymy, and differences from other species of the genus.

Occurrence. This species characterizes a very low horizon in the Turonian, with records from Portugal, Spain (?), Algeria, Tunisia, Israel, and Japan. The Oman specimen is from Member b/a of the Natih Formation at Jebel Salakh.

Genus *Fagesia* PERVINQUIÈRE 1907

Type species. By original designation, *Olcostephanus superstes* KOSSMAT, 1897, p. 26, pl. 6, fig. 1.

Fagesia catinus (MANTELL, 1822)

Plate 4C–4E

1822 *Ammonites catinus* MANTELL, p. 198, pl. 22, fig. 10 (not 5, attributed in error, = *Ammonites navicularis* MANTELL, 1822).

1981 *Fagesia catinus* (MANTELL); WRIGHT & KENNEDY, p. 88, pl. 26, fig. 2; text-figs. 31–36 (with full synonymy).

1987 *Fagesia catinus* (MANTELL); KENNEDY, WRIGHT & HANCOCK, p. 51, pl. 7, figs. 1–13; pl. 8, figs. 1–4, 6–9; text-figs. 2j, k, m, n, 10 (with additional synonymy).

1989 *Fagesia catinus* (MANTELL); COBBAN, HOOK & KENNEDY, p. 50, figs. 50, 92L-KK, 96 S, T.

Type. The holotype is No. C3379 in the collections of the Natural History Museum, London, from the Middle Chalk of Lewes, Sussex, the original of MANTELL 1822, pl. 22, fig. 10 (refigured by WRIGHT & KENNEDY 1981, text-fig. 31).

Description. OUM KY2012 is a juvenile 80 mm in diameter. Coiling is very evolute, with the umbilicus comprising 41% of the diameter, deep, with a high, flat, outward-inclined umbilical wall. The whorl section is very depressed, with a whorl breadth to height ratio of 2.19. The umbilical shoulder is narrowly rounded; there are no flanks. The venter is very broad, and evenly rounded. There are 12 massive umbilical bullae on the outer whorl. The venter is somewhat worn, but there appears to have been little or no ornament.

Discussion. WRIGHT & KENNEDY (1981) and KENNEDY, WRIGHT & HANCOCK (1987) described this species in detail, and discussed differences from others referred to the genus. The present specimen closely resembles juveniles from Texas (KENNEDY, WRIGHT & HANCOCK 1987) and New Mexico (COBBAN, HOOK & KENNEDY 1989).

Occurrence. *F. catinus* characterizes a horizon low in the Turonian in England, France, Venezuela, northern Mexico, Montana and California in the U.S.A. Doubtful fragments occur in the uppermost Cenomanian in New Mexico (COBBAN, HOOK & KENNEDY 1989). The Oman specimen is from Member b/a of the Natih Formation of Jebel Salakh.

Genus *Paramammites* FURON, 1935

Type species. *Vascoceras polymorphum* PERVINQUIÈRE 1907, p. 336, pl. 121, figs. 2–6; text-fig. 126, by the subsequent designation of REYMENT 1954b, p. 255, footnote.

Paramammites sp.
Plate 3A–3C

Description. The best specimen is OUM KY2008, an individual some 88 mm in diameter. Coiling is evolute, with the umbilicus comprising about 34% of the diameter. The whorls expand slowly, with a depressed whorl section, and whorl breadth to height ratio of 1.13, the flanks flattened and subparallel, the ventrolateral shoulders broadly rounded and the broad venter flattened. There are 7–8 umbilical bullae per half whorl. They give rise to generally single coarse, blunt, ribs that are straight across the inner and middle flanks, then projected forwards and feebly concave on the outer flanks and ventrolateral shoulder, while intercalated ribs may arise on the outer flank. The ribs bear strong, feebly clavate inner ventrolateral tubercles, connected by a transverse rib to feeble outer ventrolateral tubercles that are linked across the venter by a low rib.

Discussion. Among described species, these poor specimens most closely recall *Paramammites tuberculatus* BARBER 1957 (p. 31, pl. 12, fig. 1; pl. 13, fig. 2; pl. 31, figs. 1–3, 8) from the Lower Turonian of Nigeria.

Occurrence. Member b/a of the Natih Formation, Jebel Salakh.

Subfamily PSEUDOTISSOTINAE HYATT 1903

Genus *Thomasites* PERVINQUIÈRE 1907

Type species. By original designation, *Pachydiscus rollandi* PERON 1890, p. 25, pl. 17, figs. 1–3.

Thomasites cf. *gongilensis* (WOODS 1911)
Plates 1A, 1B, 6C–6F

Compare:

1911 *Vascoceras gongilensis* WOODS, p. 282, pl. 21, fig. 7; pl. 22, fig. 1.

1989 *Thomasites gongilensis* (WOODS 1911); MEISTER, p. 38, pl. 16, figs. 3–5; pl. 17, figs. 1–6; pl. 18, figs. 1–3; pl. 19, figs. 1–5, pl. 20, figs. 1–5; pl. 21, figs. 1–3 (with full synonymy).

Type. The holotype is No. B3283 in the collections of the Sedgwick Museum, Cambridge, from the so-called Lower Turonian of Nigeria.

Description. All specimens are worn nuclei, broken out from much larger totally abraded specimens up to 150 mm in diameter. Coiling is involute, with the umbilicus comprising less than 30% of the diameter, the whorls compressed, with flattened, convergent flanks, narrowly rounded ventrolateral shoulders and a broad, tricarinate-bisulcate venter. Only outer flank ornament is well-preserved and consists of blunt prorsiradiate ribs that terminate in blunt ventral clavi, borne on blunt ridges. These are separated by grooves from a blunt siphonal ridge with siphonal clavi in some specimens. Other specimens lack well-differentiated clavi, and bear three smooth to undulose siphonal ridges. Ill-preserved specimens referred to the species may have umbilical bullae.

Discussion. Although poor, the overall proportions and ventral ornament show these specimens to be a *Thomasites,* close to *T. gongilensis.* MEISTER (1989) is the latest reviser of this species; his specimens provide a good basis for comparison with the present material, and are compared with other species of the genus by that author.

Occurrence. *Thomasites gongilensis* first appears in the uppermost Upper Cenomanian and ranges into the lowest Turonian. There are records from Nigeria, Spain and southern England. The Oman specimens are from Member b/a of the Natih Formation at Jebel Salakh.

Genus *Wrightoceras* REYMENT 1954a

Type species. *Bauchioceras (Wrightoceras) wallsi* REYMENT 1954a, p. 160, pl. 2, fig. 4; pl. 3, fig. 3, by original designation.

Wrightoceras sp.

Plate 6A–6B

Description. A series of very corroded, highly involute, compressed specimens up to 85 mm in diameter, are septate throughout, with a narrow concave venter with sharp ventrolateral edges. A better-preserved fragment, OUM KY2016 has a whorl height of 39 mm, and a whorl breadth to height ratio of 0.53. There are traces of faint, distant, radial ribs on the inner flanks, and faint ventral clavi. The partially preserved suture has a large, asymmetrically bifid E/L and a smaller bifid L/U_2 and auxiliary elements.

Discussion. Coiling, concave venter with sharp edges and feeble ornament all suggest *Wrightoceras*, the suture at least recalling that of *W. wallsi* REYMENT 1954 (see revision in MEISTER 1989), rather than *W. munieri* PERVINQUIÈRE 1907 (see revision in KENNEDY, WRIGHT & HANCOCK 1987).

Occurrence. Member b/a of the Natih Formation at Jebel Salakh. Other species of the genus occur in Spain, Tunisia, Nigeria, northern Mexico, Texas, New Mexico, Venezuela, Colombia and Brazil, where they are best known from the Lower Turonian.

Genus *Eotissotia* BARBER, 1957

Type species. *Eotissotia simplex* BARBER 1957, p. 55, pl. 1, fig. 3; pl. 3, fig. 3; pl. 25, figs. 11–15.

Eotissotia cf. *simplex* BARBER 1957

Plate 3D–3F

Compare:

1957 *Eotissotia simplex* BARBER, p. 55, pl. 1, fig. 3; pl. 3, fig. 3; pl. 25, figs. 11–15.

Type. The holotype is No. 47707 in the collections of the Natural History Museum, London, from the Lower Turonian of Kanawa, Nigeria.

Discussion. OUM KY2017 is 80 mm in diameter, with a small umbilicus, compressed whorls with broadly rounded inner flanks, flattened and convergent outer flanks, and a narrowly rounded venter at the smallest diameter visible, a feature that distinguishes it from co-occurring *Wrightoceras*.

Occurrence. Member b/a of the Natih Formation, Jebel Salakh.

Family COILOPOCERATIDAE HYATT 1903

Genus *Herrickiceras* COBBAN & HOOK 1980

Type species. *Placenticeras costatum* HERRICK & JOHNSON 1900, p. 214, pl. 28, figs. 2, 3.

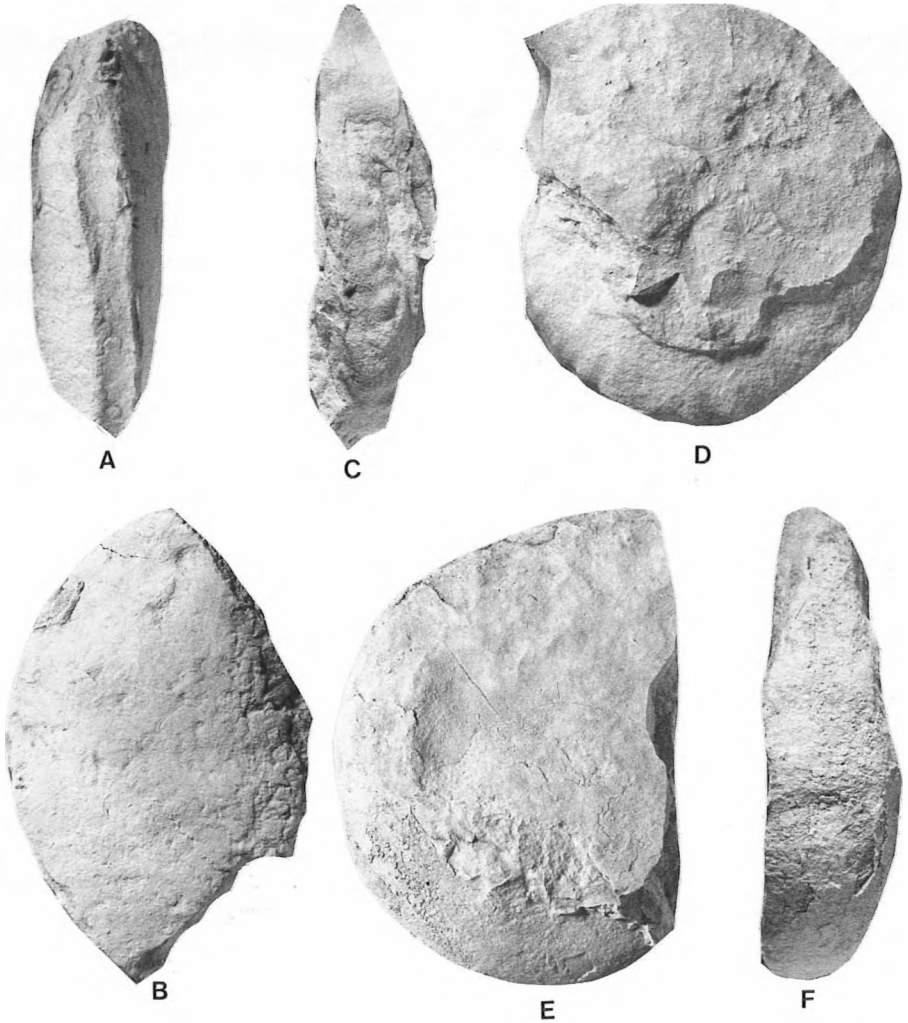


Plate 6. A, B, *Wrightoceras* sp. OUM KY2016. C–F, *Thomasites* cf. *gongilensis* (Woods 1911). OUM KY2013–2014. Specimens are from the Lower Turonian, Member b/a of the Natih Formation, Jebel Salakh. All figures are x 1.

Herrickiceras? sp.

Plate 5C, 5D

Description. OUM KY2011 is 93 mm in diameter. Coiling is very involute, with a tiny umbilicus. The whorl section is very compressed, with a whorl breadth to height ratio of 0.43, the flanks flattened and converging to a narrow, feebly concave venter with sharp edges. Ornament is of numerous narrow straight prorsiradiate ribs that strengthen across the flanks and may become feebly convex on the outer flank. Although preservation is poor, they appear to have terminated in small ventral clavi.

Discussion. Shell form and ribbing all suggest *Herrickiceras*, a genus previously unknown below the Middle Turonian and outside the U.S. Western Interior. Alternatively, it could be a costate *Wrightoceras*, but absence of sutures precludes a definite generic assignation.

Occurrence. The Oman specimen is from Member b/a of the Natih Formation at Jebel Salakh.

Suborder ANCYLOCERATINA WIEDMANN 1966

Superfamily TURRILITACEAE GILL 1871

Family TURRILITIDAE GILL 1871

Genus and subgenus *Turrilites* LAMARCK, 1801

Type species. *Turrilites costatus* LAMARCK 1801, p. 102, by original designation.

Turrilites (Turrilites) costatus LAMARCK 1801

Plate 2A–2C

1801 *Turrilites costata* LAMARCK, p. 102.

1904 *Turrilites costata* LAMARCK; DOUVILLÉ, pp. 54, 54a, 54b.

1983 *Turrilites (Turrilites) costatus* LAMARCK; KENNEDY & JUIGNET, p. 47, figs. 25a–o; 26a, b; 27a–i; 28a, b, d (with synonymy).

1985 *Turrilites (Turrilites) costatus* LAMARCK; ATABEKIAN, p. 79, pl. 31, figs. 1–5 (with synonymy).

1985 *Turrilites (Turrilites) scheuchzerianus* BOSC 1802; ZABORSKI, p. 10, figs. 7, 8.

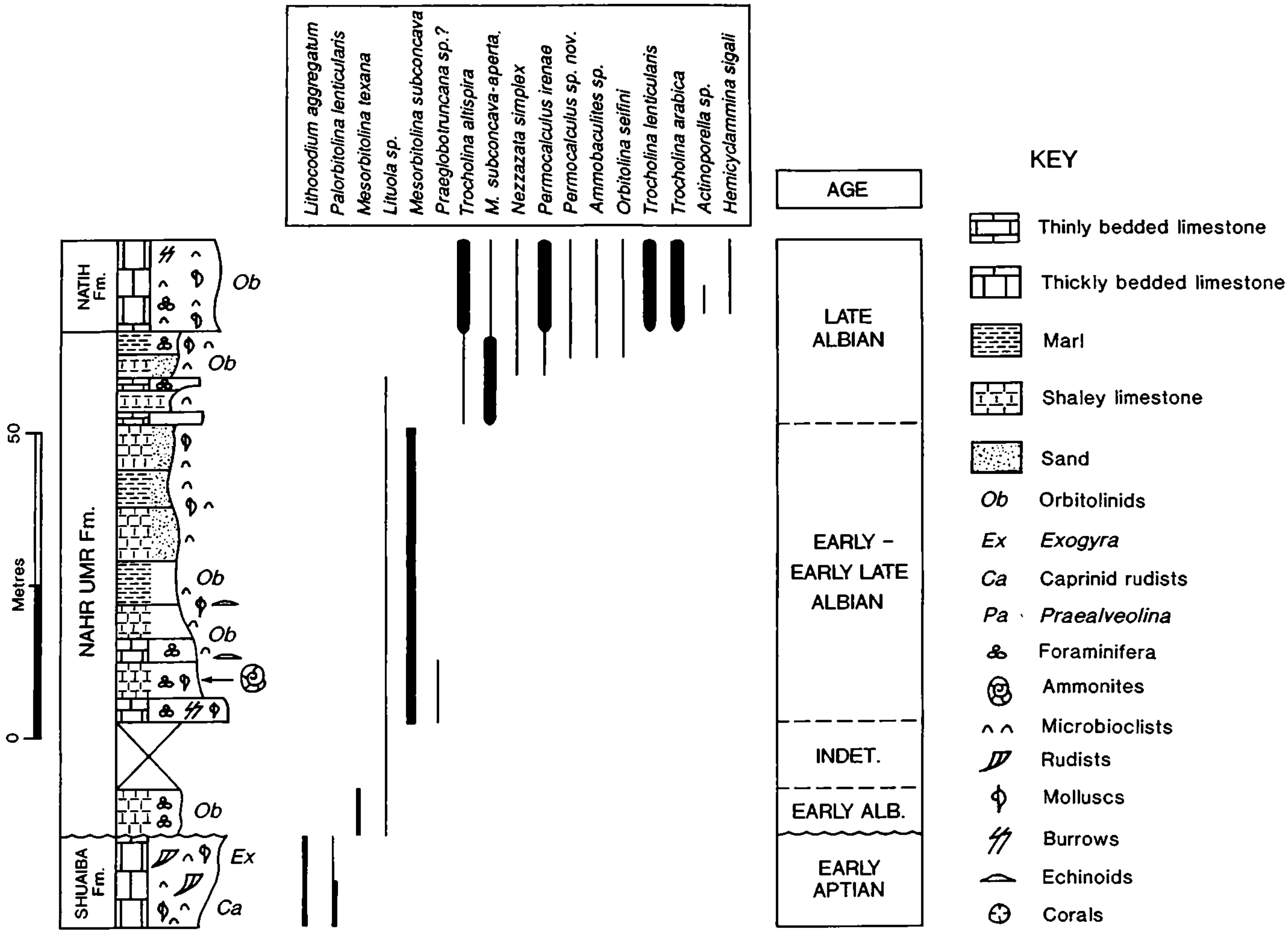
1985 *Turrilites (Turrilites) costatus* LAMARCK; ZABORSKI, p. 10, figs. 9, 10.

Discussion. This well-known species is represented by five specimens from Jebel Salakh, with whorl heights of up to 27 mm. The species is fully revised by KENNEDY & JUIGNET (1983) and ATABEKIAN (1985).

Occurrence. *T. (T). costatus* has been recorded from the top of the Lower Cenomanian, but some at least of these records are based on *T. (T). boerssumensis* SCHLÜTER 1875. It is common and widespread in the Middle Cenomanian, and ranges to the low Upper Cenomanian, with records from England, France, Spain, Portugal, Germany, Poland, the USSR east to Transcaspia, Mongolia, South India, Japan, Kamchatka, New Guinea, northern Australia, Zululand (South Africa), Madagascar, Mozambique, Angola, Nigeria, Algeria, Tunisia, Israel, Iran, Texas, California and Mexico. The Oman specimens are from Member c of the Natih Formation, at Jebel Salakh and Jebel Hinaydil.

Associated microfossils

Significant microfossils obtained from the Nahr Umr Formation at Jebel Madar from which the specimen of *Knemiceras dubertreti* was obtained are documented on Fig. 3. Orbitolinid foraminifera are by far the commonest microfaunal component. At the level from which the


Lithocodium aggregatum
Palorbitolina lenticularis
Mesorbitolina texana
Lituola sp.
Mesorbitolina subconcava
Praeglobotruncana sp.?
Trocholina altispira
M. subconcava-aperta.
Nezzazata simplex
Permocalculus irenae
Permocalculus sp. nov.
Ammobaculites sp.
Orbitolina seifini
Trocholina lenticularis
Trocholina arabica
Actinoporella sp.
Hemicyclammina sigali
AGE
LATE ALBIAN
EARLY - EARLY LATE ALBIAN
INDET.
EARLY ALB.
EARLY APTIAN
NATIH Fm.
NAHR UMR Fm.
SHUAIBA Fm.
Metres
0
50
Ob
Ex
Ca
KEY
Thinly bedded limestone
Thickly bedded limestone
Marl
Shaley limestone
Sand
Ob Orbitolinids
Ex Exogyra
Ca Caprinid rudists
Pa Praealveolina
Foraminifera
Ammonites
Microbioclists
Rudists
Molluscs
Burrows
Echinoids
Corals

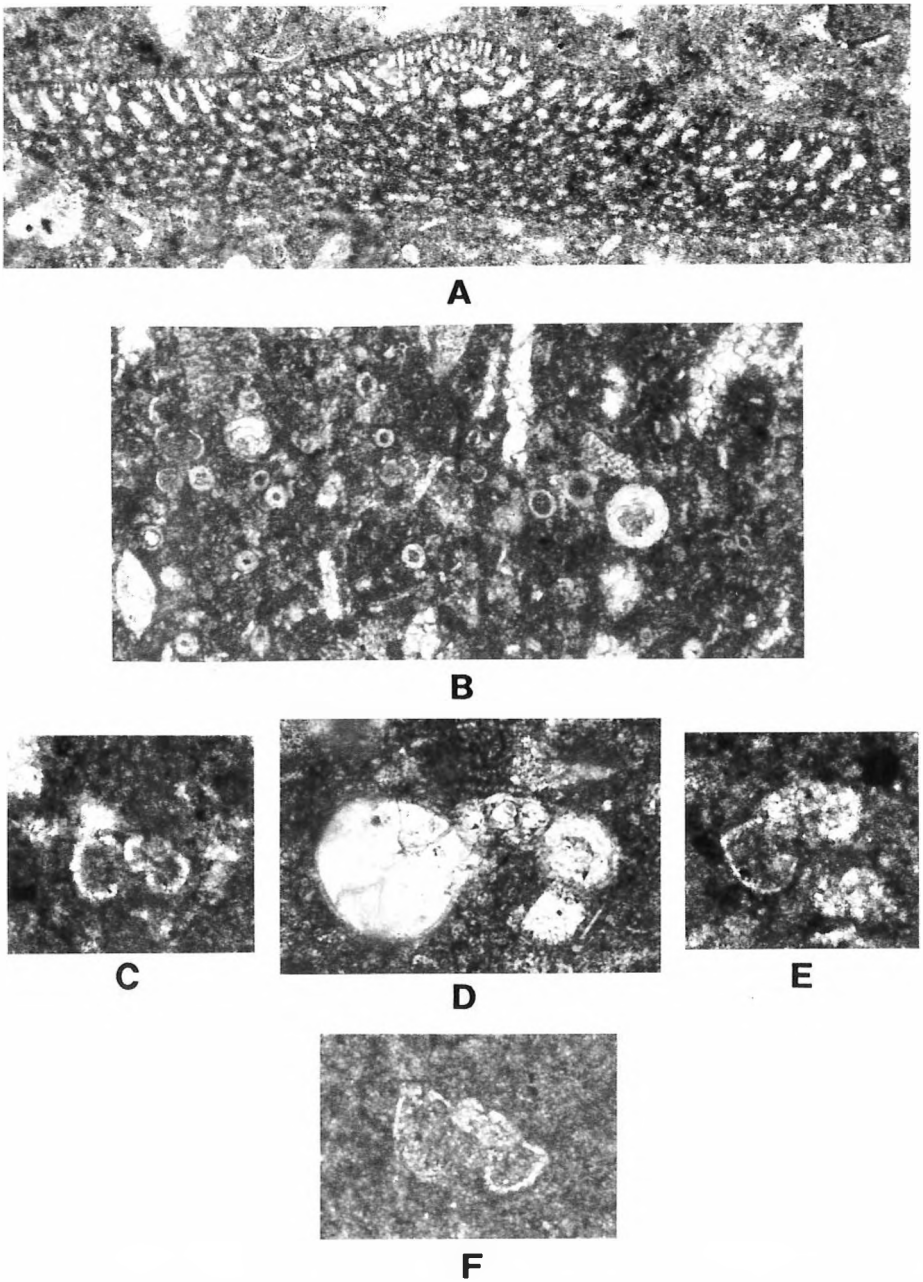


Plate 7. A, Transitional form between *Mesorbitolina subconcava* (LEYMERIE, 1878) and *Mesorbitolina aperta* (ERMAN 1854), x 40, Upper Nahr Umr Formation, Jebel Madar. B. Facies with abundant calcispheres including *Pithonella ovalis* (KAUFMANN 1865) and *Pithonella spherica* (KAUFMANN 1865), x 100, Member b/a, Natih Formation, Jebel Salakh. C, *Hedbergella* sp., x 100, upper Member c, Natih Formation, Jebel Salakh. D, *Whiteinella archaeocretacea* PESSAGNO 1967, x 100, Member b/a, Natih Formation, Jebel Salakh. E, *Helvetoglobotruncana* aff. H. *praehelvetica* (TRUJILLO 1960), x 200, Member b/a, Natih Formation, Jebel Salakh. F, *Helvetoglobotruncana praehelvetica* (TRUJILLO 1960), x 200, Member b/a, Natih Formation, Jebel Salakh.

ammonite was recovered, the orbitolinid *Mesorbitolina subconcava* (LEYMERIE 1878) is present. This suggests an early Albian – early late Albian age for this level, although the species is most typical of early or middle Albian sediments (SCHROEDER 1985).

Within the Nahr Umr Formation other significant microfossils present include early Albian *Mesorbitolina texana* (ROEMER 1849) (in the lower part of the formation); late Albian transitional forms between *Mesorbitolina subconcava* and *Mesorbitolina aperta* (ERMAN 1854) (Plate 7A), *Permocalculus* spp., *Ammobaculites* sp., *Lituola* sp. and *Trocholina altispira* HENSON 1947 (in the upper part of the formation). This assemblage suggests the Nahr Umr Formation ranges from early Albian at the base to late Albian in the upper part. Similar faunas have been recorded at other localities in the Central Oman Mountains, together with *Hemicyclammina sigali* MAYNC 1953 and *Buccicrenata subgoodlandensis* (VANDERPOOL 1933) (SIMMONS & HART 1987).

The lowermost part of the overlying Natih Formation contains abundant trocholinids (*Trocholina altispira, T. lenticularis* HENSON 1947, *T. arabica* HENSON 1949, and others), *Orbitolina sefini* HENSON 1948, *Mesorbitolina subconcava – aperta,* abundant *Permocalculus* spp. (including *P. irenae* ELLIOTT 1958) and dasyclad algae. This assemblage is suggestive of a late Albian age.

Fig. 4 summarizes the ranges of significant microfossils found in the upper part of Member c and Members b/a of the Natih Formation at Jebel Salakh and Jebel Hinaydil. At the level in Member c with the early late Cenomanian ammonite assemblage of *Turrilites (Turrilites) costatus, Neolobites vibrayeanus* and *Calycoceras (Proeucalycoceras)* sp., a low diversity microfossil assemblage occurs with rare *Praealveolina tenuis* REICHEL 1933, *Permocalculus* sp. nov. and the relatively long-ranging planktonic foraminifera *Hedbergella delrioensis* (CARSEY 1926), *Praeglobotruncana stephani* (GANDOLFI 1942) and *Hetrohelix moremani* (CUSHMAN 1938). The presence of *P. tenuis* indicates a late middle – late Cenomanian age for these sediments (NEUMANN & FOURCADE 1985). This age assignment is supported by the underlying and overlying microfossil assemblages. Below the ammonite level in Member c, in addition to *P. tenuis,* a typically late middle Cenomanian foraminiferal assemblage occurs (although it may range into the late Cenomanian) with *Taberina bingistani* HAMAOUI & SAINT-MARC 1970, *Nezzazata simplex* OMARA 1956, *Merlingina cretacea* HAMAOUI & SAINT-MARC 1970, *Trochospira avnimelechi* HAMOUI & SAINT-MARC 1970, *Biplanata peneropliformis* HAMAOUI & SAINT-MARC 1970, *Nummoloculina heimi* BONET 1956, *Buccicrenata? rugosa* (D'ORBIGNY 1850) and *Pseudedomia drorimensis* REISS, HAMAOUI & ECKER 1964 (see SMITH et al. 1990 for further discussion of this assemblage).

At the level with abundant if poorly preserved Lower Turonian ammonites (*Pseudaspidoceras* sp., *Vascoceras durandi, Fagesia catinus, Paramammites* sp., *Thomasites* cf. *gongilensis, Wrightoceras* sp., *Eotissotia* cf. *simplex* and *?Herrickiceras* sp.) at the top of the Jebel Salakh section (Member b/a of the Natih Formation), a distinctive planktonic microfossil assemblage occurs. This includes the calcispheres *Pithonella spherica* (KAUFMANN 1865) and *Pithonella ovalis* (KAUFMANN 1865) which occur in abundance (Plate 7B), and the planktonic foraminifera *Heterohelix moremani, Whiteinella archaeocretacea* PESSAGNO 1967 (Plate 7D), *Dicarinella algeriana* (CARON 1966), *Praeglobotruncana* sp. and *Helvetoglobotruncana praehelvetica* (TRUJILLO 1960) (Plate 7F). This assemblage of planktonic foraminifera is typical of Tethyan sediments at the Cenomanian – Turonian boundary. It can be referred to the short-ranging

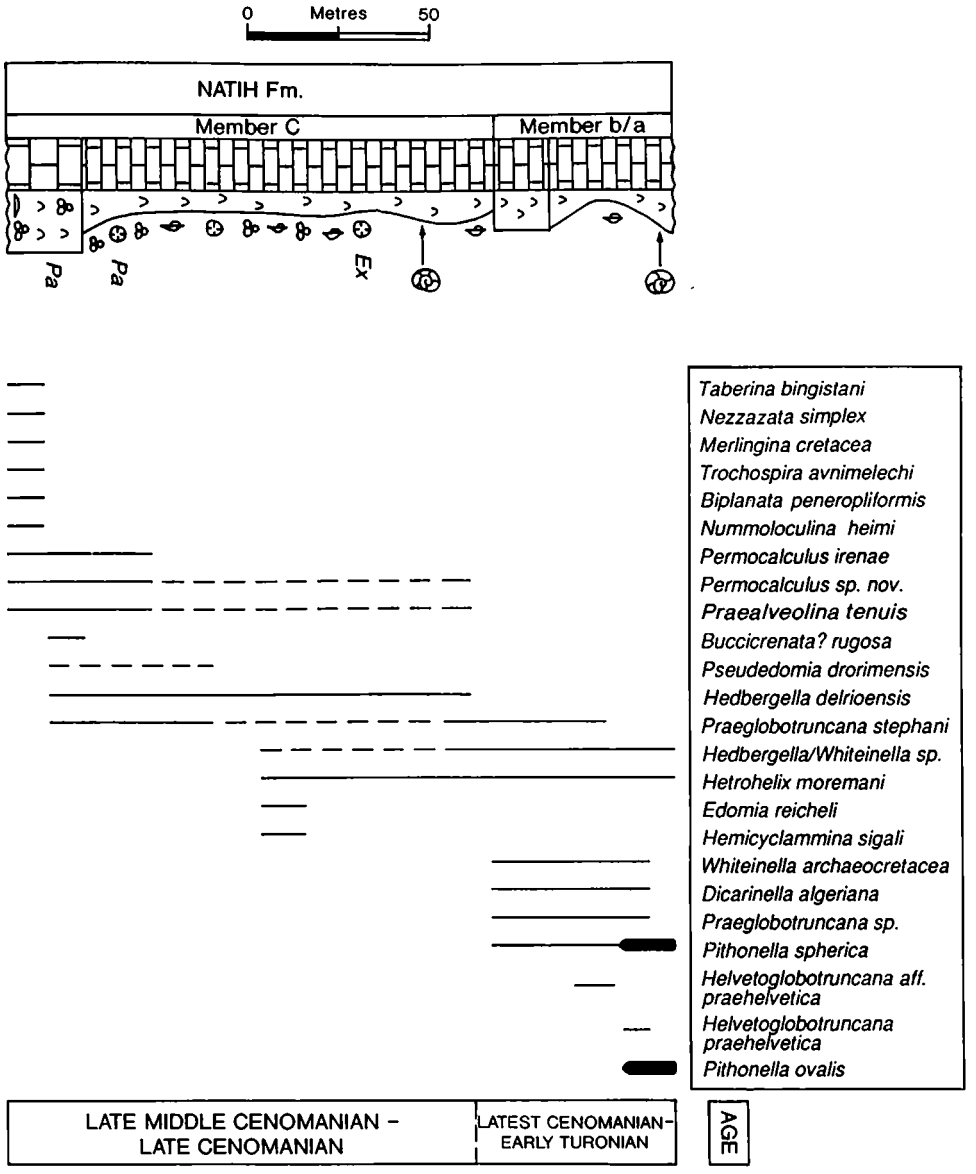


Fig. 4. Stratigraphic ranges of significant microfossils in the upper Natih Formation at Jebel Salakh and Jebel Hinaydil.

Whiteinella archaeocretacea Biozone (ROBASZYNSKI & CARON 1979; CARON 1985; SLITER 1989), which straddles the Cenomanian – Turonian boundary. The planktonic foraminifera present at this level are all relatively small and recall the Cenomanian – Turonian planktonic microfauna described from Kuwait by EL-NAGGAR & AL-RIFAY (1973). An abundance of calcisperes is a supplementary feature typical of the Cenomanian – Turonian boundary in the Tethyan region (eg. ADAMS et al. 1967).

Discussion

The presence of *Knemiceras dubertreti* within the Nahr Umr Formation at Jebel Madar demonstrates that at the level of the ammonite horizon, the sediments are of late early – early middle Albian age. This is in agreement with the microfaunal evidence. The association of *K. dubertreti* with the foraminiferid *Mesorbitolina subconcava* supports the suggested range of this microfossil as being early Albian – early late Albian. Other microfossils from the Nahr Umr Formation at Jebel Madar indicate that at this locality, the formation is early Albian – late Albian in age.

The occurrence of *Turrilites (Turrilites) costatus, Neobites vibrayeanus* and *Calycoceras (Proeucalycoceras)* sp. within the upper part of Member c of the Natih Formation at Jebel Salakh and Jebel Hinaydil indicates that these sediments are of early late Cenomanian age. This does not conflict with the microfossil evidence, and supports the view that *Praealveolina tenuis* occurs in middle – late Cenomanian sediments (NEUMANN & FOURCADE 1985).

The presence of a diverse ammonite fauna in the Member b/a of the Natih Formation at Jebel Salakh indicates that these sediments are of earliest Turonian age. This is in agreement with the microfossil evidence which indicates a position close to the Cenomanian – Turonian boundary. It also confirms the age suggested by the graphic correlation study of SCOTT (1990).

By correlation of the section at Jebel Salakh to the type section of the Natih Formation at Fahud (TSCHOPP 1967; HUGHES CLARKE 1988) it can be seen that uppermost Natih Formation *sensu stricto* (most of Member a) is missing at Jebel Salakh, presumably because of pre-Aruma Group erosion. It can therefore be inferred that the uppermost Natih Formation s.s. (i.e. that in the subsurface) must be early Turonian in age. Microfauna from Jebel Madar (Fig. 3), and elsewhere (SIMMONS & HART 1987; SCOTT et al. 1988; SCOTT 1990) suggests that the base of the Natih formation is late Albian in age. The formation thus ranges in age from late Albian to early Turonian.

Although this is the first detailed record of mid-Cretaceous ammonites from Oman, similar ammonite and microfossil associations have been recorded from other parts of the Middle East. In particular, in Lebanon a similar sequence has been documented by SAINT-MARC (1974, 1981). In the early – middle Albian *Knemiceras* Beds he records *K. dubertreti* (and many other species of *Knemiceras*) together with various orbitolinids (mainly *Mesorbitolina texana*). In his unit c43b–c51 which straddles the Cenomanian – Turonian boundary he records (amongst others) *Vascoceras* sp., together with a rich microfauna including *H. praehelvetica, W. archaeocretacea, P. ovalis, P. spherica* and *H. moremani,* as in Oman.

Acknowledgements. The original fieldword by MDS which les to the collection on the ammonite faunas and the initial evaluation of the microfauna was sponsored by AMOCO

Production Co., through the Earth Science Resources Institute at the University of South Carolina and University College of Wales, Swansea. Subsequent research and fieldwork was supported by BP Exploration. WJK acknowledges the financial support of the Natural Environment Research Council (U.K.) and the technical assistance of the staff of the Geological Collections, University Museum, Oxford, and Department of Earth Sciences, Oxford.

The authors wish to thank T. C. CONNELLY and Dr. R. W. SCOTT (AMOCO), Dr. J. D. SMEWING (ERI, Swansea), Dr. C. D. L. DODD and Dr. J. E. NEILSON (BP) for help with fieldword and for stimulating discussion concerning Wasia Group stratigraphy in Oman. Prof. M. B. HART (Polytechnic South West) and Dr. A. A. H. WONDERS (BP) provided valuable comments on the microfauna.

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Typescript received 13. 11. 1990