Cretaceous ammonites from the Sultanate of Oman (Adam Foothills)

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ABSTRACT

Twenty taxa are described from the Cretaceous of Oman (Adam Foothills). The genera *Puzosia*, *Placenticeras*, *Cunningtoniceras*, *Nigericeras*, *Metoicoceras*, *Rubroceras* and *Hoplitoides* and the subgenus *C.* (*Gentoniceras*) are recorded for the first time from the Arabian Peninsula. Based on the ammonite ranges, a sequence of nine bioevents of the Albian–Turonian is correlated within the zonation, and some markers allow correlations at a larger scale, at least along the southern Neo-Tethys margin. The ammonite data give new constraints for the correlations of the lithological units along the Adam Foothills West-East transect and they question the definition of the lithostratigraphic units within the Natih Formation, especially the Natih A and B members. From a paleogeographic point of view Oman is a landmark for the distribution of the ammonites between the western Neo-Tethys (Europe, North Africa, Middle East) and the eastern Neo-Tethys (Africa, Madagascar and India).

INTRODUCTION

The present study analyzes the taxonomy and the temporal and spatial distribution of Cretaceous ammonites collected during two missions in the mountains of Oman in 2009 and 2012. This paper follows an important related previous work by Kennedy and Simmons (1991) that has been achieved on the ammonites of Oman. Some biostratigraphic and paleogeographic results have already been discussed in a synthesis of the Cenomanian–Turonian faunas along the southern Neo-Tethys margin from Morocco to Oman (Meister and Piuz, 2013). The microfauna is the object of separate papers (Piuz and Meister, 2013; Piuz et al., 2014). These two fossil groups add greatly to the understanding of the biostratigraphy and paleoecology of the Albian–Turonian deposits of this region.

GEOGRAPHICAL AND GEOLOGICAL SETTING

The mountains of Oman constitute an arcuate range situated on the northeastern margin of the Arabian Peninsula as a result of a compressional up-folding (Figure 1). They may be considered as having been a major mountain range since the Oligocene–Miocene. They are composed of a set of nappes overlying autochthonous and parautochthonous rocks. The mid-Cretaceous deposits have an economic importance and consequently are the subject of extensive studies for geological mapping and petroleum exploration. During the Mesozoic, the eastern part of the Arabian Plate was covered by extensive carbonate platforms globally interpreted as shallow-water areas. The study of Droste and Van Steenwinkel (2004, their figure 15) reveals that the carbonate platform of Oman shows a rather complex structure as illustrated in their geological model.

The Adam Foothills form isolated relative autochthonous outcrops in the southern foreland of Al Jabal al-Akhdar. They constitute a series in relay of abraded anticlines, mainly composed of Cretaceous shelf carbonates. From east to west these are Jabal Madar, Jabal Madmar, Jabal Khaydalah, Jabal Salakh, Jabal Nadah and Jabal Fitrī. They represent a transect of about 127 km where several fossiliferous localities have been studied (the distance between each of the localities is given in figure 2 of Piuz et al. (2014).

The geological history of Oman has been extensively discussed by several authors, among them Glennie et al. (1974), Hughes Clarke (1988), Rabu (1987), Robertson et al. (1990), Pillevuit (1993), Rabu et al. (1993), Glennie (1995), Le Métour et al. (1995), Sharland et al. (2001), Droste and Van Steenwinkel (2004), Simmons et al. (2007). For detailed geology, the reader is referred to these papers.
The fossiliferous sediments studied here belong to the Wasia Group, part of the Hajar Supergroup, which is well represented in the northern and eastern Arabian Peninsula. Glennie et al. (1974) synthesized in a precise manner the different lithologic units of the Wasia Group, and subsequently several works have provided greater detail for these units including Simmons and Hart (1987), Hughes Clarke (1988), Smith et al. (1990), Philip et al. (1995), van Buchem et al. (1996, 2011), Homewood et al. (2008).

About 150 specimens of more-or-less well-preserved ammonites have been collected from the Nahr Umr Formation (Albian) and from the Natih Formation covering a period from the Albian to the early Turonian (Appendix). This period corresponds to a series of marine transgressions associated with eustasy (sea-level rise) and tectonic influences (subsidence) that led to the establishment of a wide carbonate platform with intrashelf basins.
The Natih Formation mainly consists of shallow-water, muddy limestone with local rudist occurrences, and intraplatform basin organic-rich calcareous shale. Several disconformities (hardgrounds) punctuate that formation and are commonly used for correlations (e.g. van Buchem et al., 1996, 2002, 2011; Homewood et al., 2008). The Natih Formation was subdivided into seven informal lithostratigraphic units (a to g from top to base) by petroleum geologists (Hughes Clarke, 1988; Scott, 1990). Herein these subdivisions are labelled A to G (as in many previous publications), but should be taken with reservation due to their lack of rock outcrop formal description, and regarding their variation of lithology and thickness along an East-West transect (from Jabal Madar to Jabal Fitri, see Piuz et al., 2014). New and significant constraints for correlations are given by the ammonite data exposed below.

The ammonites of the Wasia Group were studied for the first time in 1991 by Kennedy and Simmons. van Buchem et al. (2011) also listed a set of ammonites. Our study completes these works in describing additional taxa and in ageing the Natih Formation more precisely (Figures 2 to 8). It adds precision to the regional biostratigraphical framework and correlates nine bioevents with the zonation (see Meister and Piuz, 2013).

**SYSTEMATIC**

**Class Cephalopoda Cuvier, 1795**

**Subclass Nautiloidea de Blainville, 1825**

**Order Nautilida de Blainville, 1825**

**Suborder Nautilina de Blainville, 1825**

**Family Hercoglossidae Spath, 1927**

**Genus* Angulithes* de Montfort, 1808**

*Type species:* *Angulithes triangularis* de Montfort, 1808.

*Age:* Albian–Oligocene.

*Angulithes mermeti* (Coquand, 1862)

Plate 1, fig. 1–4 (Appendix)

1862 *Nautilus Mermeti* Coquand, pl. 2, fig. 1, 2.
2010 *Angulithes* sp.- Cavin et al., p. 403, fig. 7x.
2011 *Angulithes mermeti* (Coquand).- Hannaa, pl. 21, fig. 1.
cf. 2012 *Angulithes* sp.- Benyoucef et al., pl. 1, fig. 1.
2012 *Angulithes mermeti* (Coquand).- Hannaa and Fürsich, p. 64, text-fig. 7 with synonymy.

*Material:* 7 specimens.

*Discussion:* One group of nautilids having a smooth conch and a micro-umbilicus has been found in the Natih Formation. It is characterized by a compressed subogival whorl section associated with a sinuous to falciform suture line.

*Age and distribution:* This taxon is associated with *Neolobites* that characterizes the lower part of the late Cenomanian. This association is well represented on the southern Neo-Tethys margin from Morocco to Oman.

**Subclass Ammonoidea Zittel, 1884**

**Order Psiloceratida Housa, 1965**

**Superfamily Desmoceratoidea Zittel, 1895**

**Family Desmoceratidae Zittel, 1895**

**Subfamily Puzosiinae Spath, 1922**

**Genus* Puzosia* Bayle, 1878 sensu lato**
Figure 2: Jabal Madar Section (see Figure 1 for location). (a and b) Partial lithostratigraphic profile of Jabal Madar for the Nahr Umr and Natih formations. Ammonite range and numbers of collected specimens are indicated in Figure 2b. (c) Photo showing Nahr Umr Formation at outcrop with blue section corresponding to section described in Figure 2b. (d) Photo showing close-up of fossiliferous outcrop at Jabal Madar (hammer for scale). (e) View of outcrop at Jabal Madar where the section in Figure 2a was described (width of photo is approximately 100 meters). Photos by C. Meister and A. Piuz.
Type species: *Ammonites planulatus* J. de C. Sowerby, 1827.

Age: Late Aptian–Campanian.

**Puzosia** sp. indet.  
Plate 3, fig. 6 (Appendix)

Material: 1 specimen.

Discussion: Badly preserved, this rather evolute form shows a fine ribbing on the outer part crossing the venter and periodic constrictions. Its whorl section is suboval slightly compressed. This form corresponds to the *Puzosia* group taken in a wide sense. A second larger specimen has strong constrictions and ribbing.

Age and distribution: *Puzosia* has a worldwide distribution and in Oman this form has a probable middle late Cenomanian age (M. geslinianum Zone).

Superfamily Hoplitoidae Douvillé, 1890  
Family Placenticeratidae Hyatt, 1900  
Genus *Placenticeras* Meek, 1876  
(synonymy: see Klinger and Kennedy, 1989)

Type species: *Ammonites placenta* DeKay, 1828, p. 278, subsequent designation by Meek, 1876, p. 462.

Age: Late Albian–Maastrichtian. Taken in account the interpretation of Cooper and Owen (2011) the earliest *Placenticeras* are rather of Cenomanian age.

*Placenticeras* aff. *kaffrarium* Etheridge, 1904 type 1 *sensu* Klinger and Kennedy, 1989  
Plate 2, fig. 1–3 (Appendix)

cf. 1989 *Placenticeras* kaffrarium Etheridge.- Klinger and Kennedy, p. 268, only fig. 23C, D, 42, 43A, B, 44, 45A, B.

Material: 5 specimens.

Discussion: The bad preservation of our specimens does not allow a precise determination. They are characterized by a (sub)oxycone coiling, smooth whorls, elliptic strongly compressed whorl section and a complex suture line. The incision of the saddles and lobes differentiates it from the subceratitic suture lines of the Engonoceratidae (*Neolobites* and *Metengonoceras*) of the same age (see Klinger and Kennedy, 1989, p. 364). This morphological habitus corresponds well to *Placenticeras* and especially to *Placenticeras kaffrarium* Etheridge of type 1 in Klinger and Kennedy (1989) and with *P. cumminsi* Cragin, a contemporaneous species. The species *P. kaffrarium* Etheridge is considered by Klinger and Kennedy (1989) in wide sense, with a very large intraspecific variability. Our specimens are only distinguishable from *P. kaffrarium* Etheridge *sensu* Klinger and Kennedy by the venter already pinched rounded in the inner-intermediate whorls and by a smaller umbilicus. Our specimens are more peramorphic for these characters in comparison with the illustration on p. 298, fig. 45B in Klinger and Kennedy (1989). If *P. cumminsi* Cragin also has large variability, it differs with a wider umbilicus and preserves an ornamentation in all the ontogenetic stages.

Due to the preservation, we put our specimens in affinis with *Placenticeras kaffrarium* Etheridge of type 1 in Klinger and Kennedy (1989) that represents the closest morphology.

Note that the phylogenetic relationships between the primitive Placenticeratidae and the more derived ones is still under discussion (see Cooper and Owen, 2011, p. 339). In the phylogenetic interpretations of Kennedy and Wright (1983, fig. 5) and Klinger and Kennedy (1989, fig. 8), the evolutive relationships show a lack of information during the Cenomanian exactly corresponding to the position of the Omani *Placenticeras*.
Figure 3: Jabal Madmar Section (see Figure 1 for location). (a and b) Partial lithostratigraphic profile of Jabal Madmar for the Natih Formation. Ammonite range and numbers of collected specimens are indicated in Figure 3b. (c) Photo showing close-up of fossiliferous outcrop at Jabal Madmar (hammer for scale). (d) View of outcrop at Jabal Madmar where the section in Figure 3a was described. Red section corresponds to section described in Figure 3b (width of photo is approximately 100 meters). Photos by C. Meister and A. Piuz.
Figure 4: Jabal Khaydalah Section (see Figure 1 for location). (a) Partial lithostratigraphic profile of Jabal Khaydalah for the Natih Formation. (b–c) Lithostratigraphic profiles of two closely spaced sections within the upper Natih Formation. Ammonite range and numbers of collected specimens are indicated. Numbered levels show ammonite bed positions. (d) View of outcrop at Jabal Khaydalah where the section in Figure 4a was described. Red section corresponds to two closely spaced sections A and B described in Figures 4b and 4c respectively (width of photo is approximately 80 meters). Photo by C. Meister and A. Piuz.
Figure 5: Jabal Salakh Section (see Figure 1 for location). (a and b) Partial lithostratigraphic profile of Jabal Salakh for the Natih Formation. Ammonite range and numbers of collected specimens are indicated. (c) Photo showing close-up of fossiliferous outcrop at Jabal Salakh (geologist for scale). (d) View of outcrop at Jabal Salakh where the section in Figure 5a was described. The yellow, purple, red and blue colored sections are described in Figure 5a and the green colored section is expanded and described in Figure 5b (width of photo is approximately 120 meters). Photos by C. Meister and A. Piuz.
Age and distribution: *P. kaffrarium* Etheridge is known in the Turonian–Coniacian of South Africa, Madagascar, India, Namibia, and Angola. *P. aff. kaffrarium* Etheridge type 1 is only recorded from the late Cenomanian (N. juddii Zone) of Oman.

Family Knemiceratidae Hyatt, 1903
Genus *Knemiceras* Böhm, 1898
(= *Iranoknemiceras* Collignon, 1981)

Type species: *Ammonites Syriacus* von Buch, 1848, p. 20, by original designation.

Age: Albian.

Remark: See Kennedy et al. (2009), Bulot (2010, p. 169), Latil (2011, p. 347) for the discussion of the family.

*Knemiceras cf. dubertreti* Basse, 1940
Plate 2, fig. 5 (Appendix)

cf. 1940 *Knemiceras dubertreti* Basse, pl. 1, fig. 3, 4; pl. 2, fig. 1, 2.
cf. 1991 *Knemiceras dubertreti* Basse.- Kennedy and Simmons, pl. 1, fig. D.
cf. 2007 *Knemiceras dubertreti* Basse.- Bulot, p. 51, fig. 2.3.
cf. 2009 *Knemiceras dubertreti* Basse.- Kennedy et al., pl. 6, fig. 1–5; pl. 7, fig. 2–5; pl. 8, fig. 1, 2; pl. 9, fig. 1 with synonymy.

Material: 1 specimen.

Discussion: Two ribbed fragments evoke the morphological habitus of the specimen illustrated by Bulot (2007, fig. 2.3) under the name *K. dubertreti* Basse, a subinvolute species. The whorls are high and rather compressed for the genus. The whorl section is subtriangular with convergent outer flanks and rounded inner flanks bearing periodic bullae. From the bullae arise two, sometimes three, coarse, blunt, subradiate and spaced ribs; intercalatories are rather developed on the outer flanks. They form a marginal ventro-lateral blunt node. The venter is flat to slightly concave between nodes and low blunt ribs are crossing.

*K. gr. uhligi* (Choffat) described for Sinai by Geyer et al. (1997, p. 225, fig. 2i) seems to have higher whorls at a similar diameter and a finer and smoother ribbing. Our specimens are more compressed and less coarsely ornamented than *K. syriacum* (von Buch). *K. deserti* Mahmoud shows a more rectangular whorl section with a flat, rather wide venter.

Age and distribution: Its age corresponds to the basal middle Albian following Kennedy et al. (2009) and to the lower part of the late Albian (D. cristatum Zone) for Bulot (2007). The species is recorded from Lebanon, Levant, Syria and Oman.

*Knemiceras syriacum* (von Buch, 1848)
Plate 2, fig. 4 and 6 (Appendix)

1848 *Ammonites Syriacus* von Buch, p. 215 (topmost illustration).
1848-1850 *Ammonites syriacus* von Buch, pl. 6, fig. 1–3; pl. 7, fig. 1.
1903 *Knemiceras syriacum* (von Buch).- Hyatt, pl. 16, fig. 4–8.
1928 *Knemiceras syriacum* (von Buch).- Douvillé, pl. 1, fig. 1a–c.
1948 *Knemiceras syriacum* (von Buch).- Tavani, pl. 6, fig. 4.
1997 *Knemiceras sp. ex. gr. syriacum* (von Buch).- Geyer et al., p. 225, fig. 2j.
2007 *Knemiceras syriacum* (von Buch).- Bulot, p. 51, fig. 2.4.
2009 *Knemiceras syriacum* (von Buch).- Kennedy et al., pl. 1, fig. 1–8; pl. 2, fig. 1–5, 7; pl. 3, fig. 1, 2, 4; pl. 4, fig. 1, 2, 4–6; pl. 5, fig. 1–4 with synonymy.
2010 *Knemiceras syriacum* (von Buch).- Bujtor, p. 6, fig. 4.
Figure 6: Jabal Salakh NW Section (see Figure 1 for location). (a and b) Partial lithostratigraphic profile of Jabal Salakh for the Natih Formation. Ammonite range and numbers of collected specimens are indicated. (c) Photo showing close-up of fossiliferous outcrop at Jabal Salakh NW (hammer for scale). (d) View of outcrop at Jabal Salakh NW where the section in Figure 6a was described. The red colored section is described in Figure 6a and the blue colored section is expanded and described in Figure 6b (width of photo is approximately 100 meters). Photos by C. Meister and A. Piuz.
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Material: 3 specimens.

Discussion: With a strong ornamentation, specially with blunt ribs and rather massive whorls, our specimen belong to the coarse inflated *Knemiceras* like *K. syriacum* (von Buch), *K. arambourgi* Basse, *K. persicum* Collignon or *K. iraniense* (von Buch), four very close species. Their ornamental habitus is similar to that one of *K. dubertreti* Basse but with a coarser ornamental development. The whorl section is subrectangular with strongly embracing whorls and the umbilicus narrow. Our specimens are close to the Douvillé specimen (1928, pl. 1, fig. 1a–c).

Age and distribution: Early to middle Albian following Kennedy et al. (2009) and lower part of the late Albian (D. cristatum and M. pricei Zones) (see Bulot 2007, p. 52). It is known from Egypt, Lebanon, Levant, Syria and Oman.

Genus *Neolobites* Fischer, 1882

Type species: *Ammonites Vibrayeanus* d’Orbigny, 1841, p. 322, pl. 96, fig. 1–3, by original designation.

This genus includes oxycone (oppleicone to belocone) forms with ceratitic suture line (Figure 9) and with more or less expressed ornamentation according to species.

Figure 7: Jabal Nadah Section (see Figure 1 for location). (a) Partial lithostratigraphic profile of Jabal Nadah for the Natih Formation. Ammonite range and numbers of collected specimens are indicated. (b) View of outcrop at Jabal Nadah where the section in Figure 7a was described. The ammonite beds are indicated in Figures 7a and 7b with blue color (width of photo is approximately 80 meters). Photo by C. Meister and A. Piuz.

LOCALITY 6: JABAL NADAH

| LOCALITY 6: JABAL NADAH |
|-------------------------|
| ex situ: Angulithes mermeti (1) C. (Proeucaulycoceras) sp. (1) |
| N22°29.409' E57°09.893' |
| 20 m |
| Natih C |
| Natih B |
| Natih A |

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Figure 8: See facing page for continuation.
Age: Cenomanian.

**Neolobites vibrayeanus** (Orbigny, 1841) s.l.
Plate 3, fig. 1–5; Plate 4, fig. 1–2; Plate 5, fig. 1–6; Plate 15, fig. 4 (Appendix)

1841 Ammonites Vibrayeanus Orbigny, pl. 96, fig. 1–3.
1908 Neolobites Brancai Eck, p. 277, fig. 5.
1914 Neolobites Brancai Eck, pl. 12.
1914 Neolobites Schweinfurthi Eck, pl. 11, fig. 1.
1915 Neolobites Isidis Greco, pl. 1, fig. 4.
1981 Neolobites vibrayeanus (Orbigny).- Kennedy and Juignet, p. 23, fig. 3–6 with synonymy.
2005 Neolobites vibrayeanus (Orbigny).- Wiese and Schulze, p. 933, fig. 4A–E, 5A–D, 6A–J, 7A–E, 8A, B, H, 9A, B, D with synonymy.
2005 Neolobites vibrayeanus vibrayeanus (Orbigny).- Meister and Abdallah, pl. 1, fig. 3–6, 8; pl. 2, fig. 2, 3, 6 with synonymy.
2005 Neolobites vibrayeanus brancai Eck.- Meister and Abdallah, pl. 1, fig. 1, 2, 7; pl. 2, fig. 1, 5 with synonymy.
2006 Neolobites vibrayeanus (Orbigny).- El Qot, pl. 24, fig. 4, 5.
2008 Neolobites vibrayeanus (Orbigny).- Aly et al., pl. 3, fig. 2–3.
2008 Neolobites vibrayeanus (Orbigny).- El Qot, pl. 1, fig. 1, 2.
2010 Neolobites vibrayeanus (Orbigny).- Cavén et al., p. 403, fig. 7v–w.
2010 Neolobites vibrayeanus (Orbigny).- Nagm et al., p. 478, fig. 5A–F.
2011 Neolobites vibrayeanus (Orbigny).- Hannaa, pl. 21, fig. 3; pl. 22, fig. 1–2.
2011 Neolobites vibrayeanus (Orbigny).- El-Sabbagh et al., p. 711, fig. 6A–B.
2012 Neolobites vibrayeanus (Orbigny).- Benyoucef et al., pl. 1, fig. 2ab.
2012 Neolobites vibrayeanus (Orbigny).- Nagm and Wilmsen, p. 70, text-fig. 6A.
2012 Neolobites vibrayeanus (Orbigny).- Hannaa and Fürsich, p. 66, text-fig. 9.

Material: 28 specimens.

Discussion: This well-known species from North Africa and the Middle East has been described in detail by several authors (Kennedy and Juignet, 1981; Meister et al., 1994; Meister and Rhalmi, 2002; Wiese and Schulze, 2005). Most of the Omani Neolobites belong to Neolobites vibrayeanus (Orbigny), a classic species of the southern Neo-Tethys margin. Their variability is low and for the greater part they are characterized by smooth whorls and well developed margino-ventral rows of clavi.

Age and distribution: This species characterizes the lower part of the C. (P.) guerangeri Zone (lowermost late Cenomanian) and is widespread along the southern Neo-Tethys margin (Morocco to Oman, in Europe (France, Spain, Portugal) and South America (Perou, Bolivia and Venezuela). Its repartition is subequatorial (see Meister and Piuz, 2013).

**Neolobites fourtaui** Pervinquière, 1907
Plate 4, fig. 4–6 (Appendix)

Figure 8 (continuation): Jabal Fitri Section (see Figure 1 for location). (a–c) Partial lithostratigraphic profile of Jabal Fitri for the Natih Formation. Ammonite range and numbers of collected specimens are indicated. (d) View of outcrop at Jabal Fitri with green, red and blue sections corresponding to sections described in Figure 8a. The red section is described and expanded in Figures 8b and 8c (width of photo is approximately 150 meters). (e) Photo showing close-up of fossiliferous outcrop at Jabal Fitri. Specimens collected from ammonite bed indicated by “A” are described in Figure 8b (hammer and geologist for scale). (f) Photo showing close-up of fossiliferous outcrop at Jabal Fitri. Specimens collected from ammonite beds indicated by “B” and “C” are described in Figures 8b and 8c respectively (width of photo is approximately 9 meters). Photos by C. Meister and A. Piuz.
1907 *Neolobites Fourtau* Pervinquière, pl. 8, fig. 2–6.
1908 *Neolobites Fourtau* Fourtau.- Staff and Eck, p. 280, fig. 8, 9.
1914 *Neolobites Fourtau* Fourtau.- Eck, pl. 14, fig. 6.
1915 *Neolobites Fourtau* Pervinquière.- Greco, pl. 1, fig. 2, 3.
1928 *Neolobites Fourtau* Pervinquière.- Douvillé, pl. 1, fig. 2, 3.
1992 *Neolobites fourtau* Pervinquière.- Thomel, pl. 22, fig. 1.

**Material:** 3 specimens.

**Discussion:** Following Kennedy and Juignet (1981, p. 28) we consider *N. fourtau* Pervinquière as a separate species, older than *N. vibrayeanus* (Orbigny). It is characterized by strong elongated umbilical bullae and strong concave, sometimes biplicate ribs on the upper part of the flanks. The suture line is ceratitic, similar to that of *N. vibrayeanus* (Orbigny) and rather different from *Engonoceras* (Figure 9). For the Omani specimens, the umbilical size seems wider than in Orbigny’s species. *N. peroni* Hyatt is broader, coarser and has more spaced ribs; the whorl section seems more rectangular (see Dominik, 1985, pl. 14, fig. 7).

**Age and distribution:** This species is present in the middle Cenomanian (A. rhotomagense Zone following Wiese and Schulze [2005: 941, *N. fourtau* Pervinquière is associated with *A. rhotomagense* (Brongniart)] and in the extreme base of the late Cenomanian (Thomel, 1992, Wiese and Schulze, 2005). It is distributed along the southern Neo-Tethys margin from Tunisia to Oman.

**Superfamily Acanthoceratoidea de Grossouvre, 1894**

**Family Acanthoceratidae de Grossouvre, 1894**

**Subfamily Acanthoceratinae de Grossouvre, 1894**

**Genus Acompsoceras Hyatt, 1903**

**Type species:** *Ammonites bochumensis* Schlüter, 1871 original designation (= *Ammonites renevieri* Sharpe, 1854).

**Remark:** The genus *Acompsoceras* is characterized by a subdiscocone shell shape and shows a large diversity in ornamentation, umbilical size and in whorl section.

**Age:** *Acompsoceras* ranges from early Cenomanian (M. mantelli Zone) to middle Cenomanian (M. dixoni Zone).

**Acompsoceras renevieri** (Sharpe, 1857)
Plate 6, fig. 1; Plate 7, fig. 1–2; Plate 8, fig. 1 (Appendix)

1857 *Ammonites Renevieri* Sharpe, pl. 20, fig. 2.
1987 *Acompsoceras renevieri* (Sharpe).- Wright and Kennedy, pl. 43, fig. 2, text-fig. 34G, 35D–F, 36A–F, 37–40 with synonymy.
1992 *Acompsoceras renevieri* (Sharpe).- Thomel, pl. 33, fig. 5.
1993 *Acompsoceras renevieri* (Sharpe).- Kennedy and Juignet, p. 148, fig. 2b, c, e, f, p. 149, fig. 3a–c, p. 150, fig. 4a, p. 151, fig. 5a, b, p. 152, fig. 6c, d, p. 155, fig. 8d–h, p. 153, fig. 7c, d.
1993 *Acompsoceras renevieri* (Sharpe).- Robaszynski et al., pl. 11, fig. 4.
2011 *Acompsoceras renevieri* (Sharpe).- Kennedy et al., p. 223, fig. 12A–C.

**Material:** 6 specimens.

**Discussion:** As shown by Wright and Kennedy (1987), the variability of the morphology and the ornamentation of *A. renevieri* (Sharpe) is wide. A large variability is also observed in the Omani fauna where discocone coarse, massive ornamented forms co-occur with smooth oxycone ones, probably the expression of intraspecific variability. So the smooth forms are close to the specimen illustrated p. 145, fig. 37 (Wright and Kennedy, 1987) whereas the ornamented ones are similar to that of fig. 2, pl. 43 (Wright and Kennedy, 1987) and to the specimen of Thomel (1992, pl. 33, fig. 5).
Two specimens with a diameter of about 150 mm are moderately evolute (umbilicus/diameter = 24%) and are characterized by a weak blunt ribbing, strong umbilico-lateral bullae, small high lateral tubercles and acute ventro-lateral tubercles. The ribs are biplicate from the bullae and end at the ventro-lateral tubercle. The whorl section is suboval with a tabulate smooth venter (Figures 10a, d). Tracks of a siphonal keel are visible. The ornamentation, coarse in the inner whorls, gets weaker on the outer whorls with the loss of the ribbing and of the high lateral tubercles. The ratio whorl width/whorl height = 1.2 at a diameter of 80 mm slightly increases to 1.3 at 135 mm of diameter.

A larger specimen (D = 240 mm) is more involute (U/D = 16%) with smooth, more compressed subelliptical whorls with rather flat flanks. By comparison with the other specimens at the same size, it is already smooth whereas the others still bear umbilico-lateral bullae and ventro-lateral tubercles; moreover their whorls are broader. In term of variability this form corresponds to the peramorphic pole in comparison with the ornamented ones (paedomorphic pole). Some A. renevieri (Sharpe), rather smooth specimens illustrated by Kennedy and Juignet (1993, p. 150, fig. 4, p. 151, fig. 5) or Wright and Kennedy (1987, p. 148, fig. 40) show intermediate morphologies.

Several specimens are also recorded from Jabal Fitri. They are large smooth fragments with part of the body chamber and characterized by high and compressed whorls similar to a specimen of A. renevieri (Sharpe) illustrated by Wright and Kennedy (1987, p. 145, fig. 37) previously known as A. essendiensis (Schlüter).

Some affinities exist with the late Cenomanian Paracompsoceras landisi Cobban (1971, pl. 6, pl. 7); but at adult diameters Cobban's species clearly has a wider umbilicus. For the ornamented stage, the
bullae are expressed less than in the Omani specimens. The ornamentation is rather different with less expressed bullae and ventro-lateral tubercles. *A. sarthense* (Guéranger) in Pervinquière (1907, pl. 17, fig. 4, 6) has a similar morphology.

In *A. inconstans* (Schlüter) the ribbing is stronger and persist longer and the umbilicus is wider (see lectotype in Wright and Kennedy, 1987, p. 149, fig. 41). Moreover a lateral row of tubercles is well developed until the intermediate whorls.

**Age and distribution:** *A. renevieri* (Sharpe) ranges from the *M. mantelli* Zone (early Cenomanian) to the *A. rhotomagense* Zone (middle Cenomanian) maybe to the *?A. jukesbrownei* Zone if we follow Thomel (1992). Indeed for this author *A. rhotomagense* (Brongniart), *A. jukesbrownei* Spath and *Acompsoceras* are in association. Sharpe's species occurs in Europe (France, Germany, UK, Poland, Russia), north and west Africa, Madagascar and Arabian Peninsula (Oman).

**Genus Cunningtoniceras** Collignon, 1937

**Type species:** *Ammonites cunningtoni* Sharpe, 1855 by original designation.

**Age:** Middle Cenomanian to early late Cenomanian.

**Cunningtoniceras sp.**
Plate 9, fig. 2–3 (Appendix)

**Material:** 4 specimens.

**Discussion:** A quite evolute form with lateral spaced and blunt ribs ending in coarse horns. The venter is flat and smooth and the horns are laterally outspread (Figure 10e). A peri-umbilical reinforcement of the rib is also obvious. These characters evoke those of the holotype of *C. cunningtoni* (Sharpe) (see Wright and Kennedy, 1987, p. 199, fig. 76). Because of the incomplete preservation of our specimens however, we do not give a specific determination.

There are also close morphological convergences with the genus *Euomphaloceras*, especially for the outer whorls of the large specimens. This genus formerly included *C. cunningtoni* (Sharpe).

**Age and distribution:** A cosmopolitan genus of the middle Cenomanian–early late Cenomanian. *C. cunningtoni* (Sharpe) has a large distribution, but its age precisely corresponds to the *A. rhotomagense* Zone. The Omani specimens characterize the base of the late Cenomanian (*C. (P.) guerangeri* Zone).

**Genus Calycoceras** Hyatt, 1900

**Type species:** *Ammonites navicularis* Mantell, 1822 (ICZN opinion 557 and ICZN specific name 1633).

**Age:** Middle to early late Cenomanian.

**Subgenus Proeucalycoceras** Thomel, 1972
(syn. *Haugiceras* Thomel, 1972)

**Type species:** *Calycoceras (Eucalycoceras) besairei* Collignon, 1937 original designation by Thomel, 1972.

**Age:** Middle to early late Cenomanian.

*Calycoceras (Proeucalycoceras) cf. canitaurinum* (Haas, 1949)
Plate 10, fig. 1–4; Plate 11, fig. 1–2; Plate 12, fig. 2; Plate 13, fig. 1; Plate 14, fig. 1 (Appendix)
Cretaceous ammonites of Oman

Figure 10: Whorl sections: (a and d) Acompsoceras renevieri (Sharpe, 1857); (b) Calycoceras (Proeucalyccoceras) sp. indet; (c) Calycoceras (Gentoniceras) aff. gentoni (Brongniart, 1822); (e) Cunningtoniceras sp.; (f–i) Calycoceras (Proeucalyccoceras) cf. canitaurinum (Haas, 1949).
1949 *Mantelliceras canitaurinum* Haas, pl. 1–3; pl. 4, fig. 1, 2, 4.

1990 *Calycoceras* (*Proeucalycoceras*) *canitaurinum* (Haas). - Cobban and Kennedy, pl. 1, fig. 1–12; pl. 2, fig. 1–12; pl. 3, fig. 1–7; pl. 4, fig. 1–2 with synonymy.

**Material:** 18 specimens.

**Discussion:** These inflated moderately evolute (planorbicone-platycone) forms are characterized by rather strong ornamentation. The whorl section is subcircular and weakly depressed, varying from the juvenile to the adult stage with a ratio $Ww/Wh = 1$ to $1.25$ (Figures 10f–h). The venter is flat rounded. The embracing whorl overlap is moderate to strong. The ribbing is annular and regular, bearing strong peri-umbilical bullae and ventro-lateral spiny tubercles. One to three ribs originate from the bullae and some intercalatories appear on the third part of the flank. In the inner whorls, the ribs are subradiate slightly flexuous becoming rigid by the adult. A variability in rib-density can be observed [Plate 10, fig. 2 and Plate 11, fig. 2 (Appendix)]. In some specimens, two rows of discrete remaining lateral tubercles, one margino-ventral and another siphonal, are obvious in the inner whorls.

In the adult stage the bullae are still well expressed; but the ornamentation varies in the outer part with a tendency of a smoothing; the tuberculation is reduced and the ventro-lateral tubercles more or less disappear [Plate 11, fig. 1 (Appendix)] but still remain in some specimens [Plate 11, fig. 1 (Appendix)]. The ventral ribbing clearly becomes evanescent [Plate 10, fig. 3 (Appendix)]. Some specimens [Plate 11, fig. 1 (Appendix)] are more inflated with stronger, blunt and spaced ornamentation, expressing a rather wide variability in this species.

The Omani *C.* (*Proeucalycoceras*) are closely related to *C.* (*P.*) *guerangeri* (Spath), a rather cosmopolitan species and to *C.* (*P.*) *canitaurinum* (Haas) a species only recorded from the Western Interior (USA). These two contemporary species have a large, partly overlapping variability. In the inner-intermediate whorls Haas’ species (see Cobban and Kennedy, 1990, pl. 1, fig. 2–9) is more paedomorphic than *C.* (*P.*) *guerangeri* (Spath) for the persistence of a strong multituberculation (see Wright and Kennedy, 1990, pl. 73, fig. 1, 2, 4). At this ontogenic stage, our specimens better correspond to *C.* (*P.*) *canitaurinum* (Haas) with the rib density and the flexuosity of the ribs but they are distinguishable with the early loss of the multituberculation. At similar size, *C.* (*P.*) *guerangeri* (Spath) has a coarser and more spaced ribbing (see Ahmad et al., 2013, p. 26, fig. 3a–c, 4a–b). At the adult size some of our specimens [Plate 14, fig. 1 (Appendix)] are similar to the holotype of *C.* (*P.*) *canitaurinum* (Haas, 1949, pl. 1, fig. 1, 2), others [Plate 10, fig. 3; Plate 11, fig. 1 (Appendix)] have more inflated and less ornamented whorls closer to the specimen illustrated by Haas (1949, pl. 3, fig. 1, 2). At this size, some *C.* (*P.*) *guerangeri* (Spath) are also close to our specimens (e.g. Reyment and Bengtson, 1986, pl. 9, fig. 6, 7 or Wright and Kennedy, 1990, pl. 70, fig. 1) but this species always keeps a coarser and more spaced ribbing.

*C.* (*P.*) *besairiei* (Collignon) shows more developed ventral tuberculation (ventro-lateral and siphonal) at comparable size. *C.* (*P.*) *haugi* (Pervinquière) is more compressed with stronger spaced ribs.

Although very close to *C.* (*C.*) *naviculare* (Mantell), Haas’ species is classically put in the subgenus *Proeucalycoceras* mainly based on the inner whorls which show a more rounded venter, more depressed and broader whors and a persisting ribbing in the adult, mainly on the venter. Moreover the ventro-lateral tubercle remains clearly more prominent in *C.* (*Proeucalycoceras*) during the ontogeny, and the ventral part remains more flat. The subgenus *Gentoniceras* clearly differs with a wider umbilicus. Some *C.* (*Newboldiceras*) like *C.* (*N.*) *planeocostatum* (Kossmat) also shows some affinities with the ribbing.

**Age and distribution:** This is the index species of the *C.* (*P.*) *canitaurinum* Subzone (lower part of the *C.* (*P.*) *guerangeri* Zone), the first subzone of the late Cenomanian. It is recorded from USA (Western Interior) and Oman.
**Calycoceras (Proeucalycoceras) sp. indet**
Plate 12, fig. 1 (Appendix)

**Material:** 2 specimens.

**Discussion:** Our two *C. (Proeucalycoceras) sp. indet.* share rather compressed whorls; the second one has only the body chamber preserved. They are characterized by coarse spaced annular ribs. On the flank, the ribs are taut and subradiate with intercalatories at the mid-flank. A reinforcement of the ribs (tubercles) is obvious at the peri-umbilical part and the ribs become rather acute and prominent on the venter. The whorl section with a ratio Ww/Wh of about 0.83 is subrounded with flat parallel flanks. The morphology of the whorls (Figure 10b) and a wider umbilicus distinguish them from *C. (P.) guerangeri* (Sharpe). The small specimen evokes the *C. (P.) haugi* (Pervinquière) in Kennedy and Juignet (1994b, p. 479, fig. 6d, e) and is similar to the specimen described by Kennedy and Simmons (1991, pl. 2, fig. H) for Oman.

**Age and distribution:** Probably the same age than the *Neolobites vibrayeanus* beds (early late Cenomanian).

**Subgenus Gentoniceras Thomel, 1972**
(syn: Subeucalycoceras, Thomel, 1972)

**Type species:** *Ammonites gentoni* Brongniart, 1822 by original designation.

**Age:** Middle to late Cenomanian.

**Calycoceras (Gentoniceras) aff. gentoni** (Brongniart, 1822)
Plate 9, fig. 1 (Appendix)

aff. 1822 *Ammonites gentoni* Brongniart, pl. 6, fig. 6.
aff. 1907 *Acanthoceras paucinodatum* Crick, pl. 13, fig. 3.
aff. 1940 *Metacalycoceras Bruni* Fabre, pl. 8, fig. 1–2, text-fig. 34.
aff. 1990 *Calycoceras (Gentoniceras) gentoni* (Brongniart).- Wright and Kennedy, pl. 56, fig. 1–3, 6–8; pl. 57, fig. 2, 3, 8; pl. 58, fig. 7, pl. 66, fig. 1, 2; text- fig. 88a, c; 89a, b; 90a–c, with synonymy.
aff. 1990 *Calycoceras (Gentoniceras) subgentoni* (Spath).- Wright and Kennedy, pl. 56, fig. 4, 5; pl. 57, fig. 4; pl. 58, fig. 5, 6; pl. 59, fig. 1–4; text- fig. 88k; 90d–f, with synonymy.
aff. 1994a *Calycoceras (Gentoniceras) gentoni* (Brongniart).- Kennedy and Juignet, p. 30, fig. 1a; 2d, e; 6d, e, j; k; 7a–l; 8a–e; 22a, b.
aff. 2010 *Calycoceras (Gentoniceras) gentoni* (Brongniart).- Kennedy and Klinger, p. 9, fig 31, with synonymy.

**Material:** 1 specimen.

**Discussion:** With a more opened umbilicus, slender whorls and regular rather dense ribbing, this form differs from the other Omani Acanthoceratinae. The single specimen is of moderate size and has a half a whorl of the body chamber. It is characterized by annular ribs, a subcircular whorl section with flat flanks and moderately embracing whorl overlap (Figure 10c). The conch is planorbicorne-platycone evolute with a rather open umbilicus (U/D = 33%). The ribbing is subradiate with peri-umbilical bullae sometimes subdivided into two ribs on the flank, and with intercalatories appearing near the base of the flank. At this ontogenetic stage, siphonal and latero-ventral tubercles are already absent. If we follow the dimorphic hypothesis, our form represents the microconch (see Wright and Kennedy, 1990).

The specimen illustrated by Crick (1907) under the name *C. (G.) paucinodatum* Crick is close to our specimen with its ribbing habitus but has a slightly smaller umbilicus; this 'species' now is included in the *C. (G.) gentoni* (Brongniart). *C. (G.) sarthense* (Bayle) shows a similar evolute coiling but differs with its more spaced and coarser ribbing.
Age and distribution: The genus is well represented in Europe, in South Africa, Madagascar, India, Japan, USA, ? Iran and now from the Arabian Peninsula; the species C. (G.) gentoni (Brongniart) occurs in Europe, South Africa, South India, Oman and ? Iran. The species ranges from middle Cenomanian to early late Cenomanian. In Oman, C. (G.) gentoni (Brongniart) is associated with M. geslinianum (Orbigny) and has a younger age (middle late Cenomanian).

Genus Nigericeras Schneegans, 1943

Type species: Nigericeras gignouxi Schneegans, 1943, subsequent designation by Reyment, 1955, p. 62.

Age: Late Cenomanian.

Remark: Several Omani specimens are attributed to the genus Nigericeras because of a) the ontogeny of the ornamentation [it is well developed in the inner whorls and smoothing or evanescent as in the paedomorphic N. gadeni (Chudeau) or disappears completely as in the peramorphic N. jacqueti Schneegans]; b) the habitus of the suture line; although corroded, the tracks of the suture line show very large shallow saddles and lobes like in Nigericeras (see fig. 2c in Wright et al., 1996, p. 161); c) their platycone evolute coiling with suboval more or less compressed whorl section; d) their close similarities with the Nigericeras described in Niger (Meister et al., 1992, 1994); and e) the morphological variability of our forms is close to that described for Nigericeras by Meister et al. (1992, fig. 15).

There are also some similarities with Vasoceras like V. cauvinii Chudeau and there are some morphological convergences with Paracompsoceras Cobban, a genus of the middle (or late for Wright et al., 1996) Cenomanian that shows a similar ontogeny with the loss of the ornamentation relatively early during growth, especially the specimen illustrated by Kennedy et al. (1988, p. 39, fig. 2c, e). Nevertheless the ornamentation persists longer in Paracompsoceras. Moreover Cobban's genus shows narrower and deeper suture lines.

The convergences with V. cauvinii Chudeau mainly rest on smooth evolute adult forms like those in Meister et al. (1992, pl. 6, fig. 1). A strong ornamentation in the inner whorls and the suture line habitus distinguish the Nigericeras group (Meister et al., 1992, pl. 3, fig. 1).

The Omani forms come from a rich level in Jabal Fitri and with rare specimens from Jabal Salakh.

Nigericeras gadeni (Chudeau, 1909)
Plate 14, fig. 2–3; Plate 15, fig. 1–3; Plate 16, fig. 1 and 3; Plate 17, fig. 4 (Appendix)

1909 Acanthoceras (?) Gadeni Chudeau, pl. 3, fig. 6.
1943 Nigericeras Lambertti Schneegans, pl. 6, fig. 1–7.
1943 Nigericeras Gignouxi Schneegans, pl. 5, fig. 10–15.
1989 Nigericeras gadeni (Chudeau).- Kennedy et al., fig. 9L, M; fig. 11O, P, with synonymy.
1992 Nigericeras gadeni (Chudeau).- Meister et al., pl. 3, fig. 1–3, 5, 7; pl. 4, fig. 1, with synonymy.
2012 Nigericeras gadeni (Chudeau).- Meister and Abdallah, pl. 2, fig. 1, 2; pl. 3, fig 1; pl. 12, fig 9, with synonymy.

Material: 17 specimens.

Discussion: Nigericeras is considered in the very wide sense, and the Omani specimens correspond well to the concept discussed in detail by Meister et al. (1992, fig. 13). They are close to the N. gadeni (Chudeau) characterized by a morphological habitus somewhere between the strong ornamented N. scotti Cobban and the smooth forms like N. jacqueti Schneegans and N. jacqueti involutus Meister et al.

The inner-intermediate whors are characterized by strong umbilical bullae extending in ribs that diminish in intensity on the upper part of the flank. In rare cases, ribs crossing the venter are
obvious at small diameters. In adults, some tracks of ornamentation are still present towards the outer part of the body chamber. One specimen develops rather fine ribs near the aperture [Plate 15, fig. 1 (Appendix)]. The whorl section is suboval, weakly compressed in the inner-intermediate whorls and a little more depressed in the body chamber.

Our specimen also evokes the rather badly preserved Nigericeras from Texas (Kennedy et al., 1989, fig. 9L, M; 11O, P). In N. scotti Cobban the ornamentation persists throughout the ontogeny (see Cobban, 1971, pl. 19, fig. 1–4) and represents the paedomorphic pole in this genus.

**Age and distribution:** N. gadeni (Chudeau) ranges from the upper part of M. geslinianum Zone to probably the lowermost N. juddii Zone. It is present in Europe, Tukestan, USA, Morocco, Levant, Oman and especially along the Trans-Saharan seaway from Tunisia to Northern Nigeria where its morphological variability is very high.

**Nigericeras jacqueti** Schneegans, 1943

Plate 21, fig. 7 (Appendix)

1943 *Nigericeras jacqueti* Schneegans, pl. 6, fig. 8; pl. 7, fig. 1.

2012 *Nigericeras jacqueti* Schneegans.- Meister and Abdallah, pl. 3, fig. 5, 7, with synonymy.

**Material:** 1 specimen.

**Discussion:** Following Meister et al. (1992) these forms represent the platycone involute and smooth morphologies of Nigericeras, compared with *N. gadeni* (Chudeau). Their whorl sections are suboval slightly more compressed and their umbilicus are narrower.

**Age and distribution:** It co-occurs with *N. gadeni* (Chudeau) in the upper part of the M. geslinianum Zone and maybe in the lowermost part of the N. juddii Zone. It is recorded from Tunisia, Niger, Northern Nigeria, in Oman and probably southern France.

**Subfamily Mammitinae Hyatt, 1900**

**Genus Metoicoceras, Hyatt, 1903**

**Type species:** *Ammonites swallovii* Shumard, 1861, p. 591, subsequent designation by Shimer and Shrock, 1944, p. 56.

**Age:** Late Cenomanian.

**Metoicoceras gr. geslinianum** (Orbigny, 1850)

Plate 13, fig. 2–3; Plate 14, fig. 4 (Appendix)

1850 *Ammonites geslinianus* Orbigny, p. 146.

2005 *Metoicoceras geslinianum* (Orbigny).- Meister and Abdallah, pl. 8, fig. 1, with synonymy.

2009 *Metoicoceras gr. geslinianum* (Orbigny).- Lehmann and Herbig, pl. 1, fig. T–U.

2010 *Metoicoceras geslinianum* (Orbigny).- Nagm et al., p. 482, fig. 8A–C.

**Material:** 3 specimens.

**Discussion:** Our poorly preserved specimens are characterized by an involute coiling (suboxycone form) and high compressed subrectangular whors with a flat external part. The ribbing is broad, blunt and spaced, well developed on the outer flanks. Primary ribs are slightly prorsiradiate starting from the umbilicus, evanescent on the lower half of the flank and strong on the upper half where they alternate with secondaries. Despite the preservation, one specimen shows small periumbilical bullae. The ventro-lateral edge is marked by a reinforcement of the ribs that become blunt and cross the venter.
Our specimens are close to the *M. geslinianum* (Orbigny) illustrated by Meister et al. (1992, p. 65, fig. 1, 3).

**Age and distribution:** A cosmopolitan species and the index species of the *M. geslinianum* Zone (middle late Cenomanian). Along the southern margin of the Neo-Tethys, this species allows acute correlations from Morocco to Oman, and to Nigeria in the South.

**Subfamily Euomphaloceratininae, Cooper, 1978**

**Genus *Pseudaspidoceras* Hyatt, 1903**

**Type species:** *Ammonites footeanus* Stoliczka, 1864

**Age:** Late Cenomanian–early Turonian.

*Pseudaspidoceras* sp.
Plate 16, fig. 2; Plate 17, fig. 2; Plate 18, fig. 1 (Appendix)

**Material:** 3 specimens.

**Discussion:** Three badly preserved specimens evoke the morphology of the *Pseudaspidoceras* with their rather evolute coiling with massive whorls, latero-ventral and peri-siphonal tubercles. One of the specimens [Plate 17, fig. 2ab (Appendix)] shows some affinities with some Nigerian *P. pseudonodosoides* (Choffat) (Zaborski 1990) or with *P. tassaraensis* Meister, Alzouma, Lang and Mathey from Niger. Another [Plate 16, fig. 2ab (Appendix)] has a narrower umbilicus that evokes rather *P. flexuosum* Powell-*P. barberi* Meister group.

This genus was already recorded from Jabal Salakh by Kennedy and Simmons (1991, pl. 1, fig. C and pl. 4, fig. A, B).

**Age and distribution:** A rather cosmopolitan genus ranging from the late Cenomanian (*N. juddii* Zone or maybe even *M. geslinianum* Zone) to early Turonian (*W. coloradoense* Zone).

**Family Vascoceratidae Douvillé, 1912**

**Subfamily Vascoceratininae Douvillé, 1912**

**Genus *Rubroceras* Cobban, Hook and Kennedy, 1989**

**Type species:** *Rubroceras alatum* Cobban, Hook and Kennedy, 1989 by original designation.

**Age:** Late Cenomanian.

**Remark:** Originally placed in the Pseudotissotinae by Cobban et al. (1989), following Wright et al. (1996) this genus is now included in the Vascoceratidae.

*Rubroceras* aff. *burroense* Cobban, Hook and Kennedy, 1989
Plate 17, fig. 1 (Appendix)

? 1991 *Paramammites* sp. Kennedy and Simmons, pl. 3, fig. A–C.
aff. 1989 *Rubroceras burroense* Cobban, Hook and Kennedy.– Cobban et al., p. 55, fig. 93A–C, 94Q–S.
aff. 2012 *Rubroceras* gr. *burroense* Cobban, Hook and Kennedy.– Meister and Abdallah, pl. 10, fig. 1, 3–5, 7, 9; pl. 11, fig. 1, 3, 5.
2012 *Rubroceras* sp. Meister and Abdallah, pl. 4, fig. 11; pl. 10, fig. 2, 6, 8; pl. 11, fig. 2.

**Material:** 1 specimen.

**Discussion:** A weakly depressed whorl section with strongly embracing whorl overlap, a coarse ornamentation and a subdiscocone shell shape (type 8–9 in Meister and Piuze, 2013, fig. 13)
characterize this specimen. The ornamentation is represented by coarse peri-umbilical nodes, blunt lateral subradiate ribs crossing the venter and periodically alternating with weaker ribs.

The Omani *Rubroceras* is distinguishable from *R. burroense* Cobban, Hook and Kennedy s.s. by the more compressed whorls, On the other hand it is close to the Tunisian specimens, having a rather open umbilicus. It is especially close to the coarse blunt ornamented *Rubroceras* sp. of Meister and Abdallah (2012).

Our specimen also evokes the *Paramammites* sp. of Kennedy and Simmons (1991), but that has a more open umbilicus.

**Age and distribution:** This species characterizes the N. juddii Zone and is known in New Mexico (USA), Tunisia, Oman and maybe in Nigeria and Ibericas (Spain). Another *Rubroceras, R. alatum* Cobban, Hook and Kennedy is recorded from Sinai and Portugal as well as the USA.

**Genus Vascoceras Choffat, 1898**

**Type species:** *Vascoceras gamai* Choffat, 1898, p. 54, pl. 7, fig. 1–4, pl. 8, fig. 1, pl. 10, fig. 2, pl. 21, fig. 1–3, subsequent designation from Diener, 1925, p. 182.

**Age:** Late Cenomanian–early to ? middle Turonian.

**Vascoceras cauvini** Chudeau, 1909

Plate 20, fig. 1 (Appendix)

1909 *Vascoceras Cauvini* Chudeau, pl. 1, fig. 1, 2; pl. 2, fig. 3, 5; pl. 3, fig. 1, 4.
1990 *Vascoceras cauvini* Chudeau.- Zaborski, pl. 6, fig. 12–15.
1992 *V. (Paravascoceras) cauvini* Chudeau.- Meister et al., pl. 4, fig. 6; pl. 5, fig. 1; pl. 6, fig. 2, with synonymy.
1993 *Vascoceras gr. cauvini* Chudeau.- Courville, pl. 4, fig. 1, 2, 3.
? 2004 *Vascoceras cauvini* Chudeau.- Abdel-Gawad et al., pl. 4, fig. 2, 3, 5.
2009 *Vascoceras cauvini* Chudeau.- Lehmann and Herbig, pl. 2, fig. A–B.
2010 *Vascoceras cauvini* Chudeau.- Nagm et al., p. 484, fig. 9A–B.
? 2011 *Vascoceras cauvini* Chudeau.- El-Sabbagh et al., p. 711, fig. 6C–D.
2012 *Vascoceras cauvini* Chudeau.- Nagm and Wilmsen, p. 73, text-fig. 9A.

**Material:** 1 specimen.

**Discussion:** This specimen is characterized by strong ornamentation on the phragmocone mainly on the outer part of the whorl. There is an alternation of blunt ribs starting from the base of the flanks with some intercalatories appearing at the mid flank and crossing the venter. The coiling is planorbicone-platycone and the whorl section is suboval, weakly depressed and with a moderately embracing whorl overlap.

The body chamber is smooth (preservation?) or similar to the variety *semiglabra* of Furon (1935, pl. 4, fig. 3). Our specimen corresponds well to the ornamentation of *V. cauvini* Chudeau s.s. (see Chudeau, 1909 or Furon, 1935) and to the wide interpretation of this species by Meister et al. (1992, p. 76, fig. 17).

**Age and distribution:** This species (*sensu stricto*) is known in Nigeria, Niger, Algeria, Egypt, Levant, Oman, and possibly in Angola and Texas. It indicates the late Cenomanian (M. geslinianum and N. juddii Zones).

**Vascoceras aff. barcoicensis exile** Cobban, Kennedy and Hook, 1989

Plate 17, fig. 3 (Appendix)

aff. 1989 *Vascoceras barcoicensis exile* Cobban, Kennedy and Hook, pl. 87, fig. Q–S; pl. 89, fig. M–GG.
2012 *Vascoceras cf. barcoicensis exile* Cobban, Kennedy and Hook.- Meister and Abdallah, pl. 412, fig. 4.
Material: 1 specimen.

Discussion: One specimen with discocone involute smooth shell shape (type 5 in Meister and Piuz, 2013), weakly compressed whorls and very strongly embracing whorl overlap is near the group of V. barcoicensis exile Cobban, Kennedy and Hook. Only its narrower umbilicus (U/D = ca. 10%) is distinguishable from the holotype. It is also similar to the small Tunisian specimen (Meister and Abdallah, 2012, pl. 12, fig. 4).

Age and distribution: Known from New Mexico, Tunisia and Oman, this taxon is present in the N. juddii Zone.

Vascoceras sp.
Plate 19, fig. 2, 3 and 5 (Appendix)

Material: 3 specimens.

Discussion: Under this name we group several badly preserved Vascoceras. Among them, one specimen [Plate 19, fig. 2 (Appendix)] with a rather opened umbilicus and relatively compressed whorls, shows large similarities with the specimen illustrated by Kennedy and Simmons (1991, pl. 5, fig. A, B) under the name Vascoceras durandi (Peron) or with the specimens of Barroso-Barcellina and Goy (2010, pl. 3, fig. A–G). Due to the bad preservation we give only the generic determination.

Another specimen of Salakh [Plate 19, fig. 3 (Appendix)] corresponds to subsphaerocone Vascoceras with small umbilicus. Its habitus evokes several forms like V. kosmati Choffat or to a lesser extend V. proprium (Reymont), V. tectiforme Barber or V. crassum Furon.

The third, [Plate 19, fig. 5 (Appendix)] with its narrow umbilicus and compressed whorls, evokes the V. barcoicensis exile of Cobban, Kennedy and Hook or maybe the broader V. arnesensis Choffat.

Age and distribution: All these form are from the late Cenomanian–? early Turonian of Jabal Salakh.

Genus Fagesia Pervinquière, 1907

Type species: Olcostephanus superstes Kossmat, 1897 original designation by Pervinquière, 1907, p. 322.

Age: Early Turonian.

Fagesia cf. catinus (Mantell, 1822)
Plate 19, fig. 4; Plate 20, fig. 4 (Appendix)

cf. 1822 Ammonites catinus Mantell, pl. 22, fig. 10 only.
cf. 1981 Fagesia catinus (Mantell).- Wright and Kennedy, pl. 26, fig. 2; text- fig. 31–36, with synonymy.
cf. 1987 Fagesia catinus (Mantell).- Kennedy et al., pl. 7, fig. 1–13; pl. 8, fig. 1–4, 6–9; text- fig. 2j, k, m, n; 10, with synonymy.
cf. 1991 Fagesia catinus (Mantell).- Kennedy and Simmons, pl. 4, fig. C–E.
cf. 1992 Fagesia catinus catinus (Mantell).- Thomel, pl. 84, fig. 1; pl. 85; pl. 86, fig. 1; pl. 89, fig. 3; pl. 90, fig. 1, 2.
cf. 1994 Fagesia catinus (Mantell).- Kennedy, pl. 7, fig. 6, 8.
1998 Fagesia catinus (Mantell).- Callapez Tornicher, pl. 13, fig. 5, 6.
2009 Fagesia catinus (Mantell).- Barroso-Barcenilla and Goy, p. 23, fig. 4.1–3.

Material: 2 specimens.

Discussion: Two fragments of Fagesia are characterized by very broad, less high, subtrapezoidal whors, a smooth less convex ventral part, narrow flanks ornamented with large tubercles and by
a large umbilicus. The smoothing of the ribbing begins to develop at small diameters. This form belongs to the smooth *Fagesia* that include *F. peroni* Pervinquière, *F. levis* Renz, *F. fleuryi* Pervinquière and *F. catinus* (Mantell). Our specimens are attributed to the Mantell's species because of their large umbilicus that distinguish this species from all other *Fagesia*. However, *F. fleuryi* Pervinquière also seems to have sporadic large ribs at larger sizes.

**Age and distribution:** According to Kennedy and Simmons (1991) this species characteristic of the lower part of the Turonian. It occurs in Europe (UK, France), in America (USA, Venezuela and ? Mexico) and Arabian Peninsula (Oman).

*Fagesia tevesthensis* (Peron, 1896)
Plate 19, fig. 1 (Appendix)

1896 *Mammoites ? tevesthensis* (Peron), pl. 7, fig. 2, 3.
2009 *Fagesia tevesthensis* (Peron).- Barroso-Barcenilla and Goy, p. 25, fig. 4(4), 5(1), with synonymy.

**Material:** 1 specimen.

**Discussion:** This rather cadicone form is characterized by a strong ventral ribbing and more or less expressed tubercules on the low part of the ‘flank’. The ventral part is convex and the whorl thickness is weak in comparison with the other *Fagesia*. *F. superstes* (Kossmat) is broader, massive, more depressed and more coarsely ornamented in ribbing and tubercles. This may represent the expression of a wide intraspecific variability for a *F. superstes* (Kossmat)-*F. tevesthensis* (Peron) group.

**Age and distribution:** *F. tevesthensis* (Peron) is known from early Turonian (upper part of the W. coloradoense Zone and M. nodosoides Zone). It is recorded from South Europe (France, Portugal, Spain), North Africa (Tunisia, Algeria), Egypt, Levant, Oman and Japan.

**Family Coilopoceratidae Hyatt, 1903**

**Genus Hoplitoides von Koenen, 1898**

**Type species:** *Hoplitoides latesellatus* von Koenen, 1898, p. 56, pl. 6, fig. 1–3, subsequent designation by Solger, 1904, p. 127.

**Age:** Early to middle Turonian.

*Hoplitoides wohltmanni* (von Koenen, 1897)
Plate 21, fig. 1 (Appendix)

1897 *Neoptychites ? (Hoplites) wohltmanni* von Koenen, pl. 1, fig. 2; pl. 2, fig. 3, 9.
1897 *Neoptychites ? (Hoplites) lentiformis* von Koenen, pl. 2, fig. 1, 4, 7.
1904 *Hoplitoides wohltmanni* (von Koenen).- Solger, pl. 5, fig. 7.
2005 *Hoplitoides gr. wohltmanni* (von Koenen).- Meister and Abdallah, pl. 14, fig. 2; pl. 25, fig. 1, with synonymy.

**Material:** 1 specimen.

**Discussion:** Typical smooth oocystic form of the early Turonian that belongs to the *H. wohltmanni* (von Koenen) because of a pinched rounded ventral part, only the beginning of the last whorl shows a narrow tabular venter. This character is longer developed during the ontogeny (paedomorphic) in *H. mirabilis* Pervinquière or in *H. latefundatus* Zaborski. *H. ingens* (von Koenen) has broader whorls.

**Age and distribution:** Recorded from America (Trinidad, Venezuela, Colombia and USA), western and northern Africa (Nigeria, Cameroon and Tunisia) and Oman, this species indicates the early Turonian (W. coloradoense and M. nodosoides Zones).
Suborder Ancyloceratina Wiedmann, 1966
Superfamily Turrilitoidea Gill, 1871
Family Turrilitidae Gill, 1871
Genus Turrilites Lamarck, 1801

Type species: Turrilites costatus Lamarck, 1801 by original designation. Subsequent designation by Kennedy (1971) for a lectotype (Douvillé, 1904, fig. 1, fiche 54a).

Age: Cenomanian.

**Turrilites costatus** Lamarck, 1801
Plate 20, fig. 2–3; Plate 21, fig. 2–6 and 8 (Appendix)

1801 *Turrilites costata* Lamarck, p. 102.
1904 *Turrilites costata* Lamarck.- Douvillé, p. 54, 54a, 54b.
1983 *Turrilites*(Turrilites) *costatus* Lamarck.- Kennedy and Juignet, p. 47, fig. 25a-o, 26a, b, 27a-i, 28a with synonymy.
1985 *Turrilites*(Turrilites) *costatus* Lamarck.- Atabekian, pl. 31, fig. 1–5 with synonymy.
1996 *Turrilites*(Turrilites) *costatus* Lamarck.- Wright and Kennedy, pl. 103, fig. 1, 2, 5; pl.104, fig. 1–4, 6, 8–10; pl. 105, fig. 1, 5, 6, 10, 12, 13, 16, 17, 19; pl. 106, fig. 1–6, 9, 10; text-fig. 137C, 139A-C, 142A, F, G, 143A-G, I–P with synonymy.
2013 *Turrilites costatus* Lamarck.- Reboulet et al., p. 177, fig. 5D.

**Material:** 37 specimens.

**Discussion:** The Omani specimens range in size from 2 cm to 20 cm. They correspond well to the detailed description given by Wright and Kennedy (1996, p. 357). As demonstrated by these authors, the variability in ornamentation intensity is rather high. The coarse ornamentation is dominant among the Omani specimens, with well-developed and coarse ribs on the upper half part of the exposed whorl face ending in an elongated tubercle nearby the mid-flank. A spiral groove obliterating the ornamentation is situated above a row of rounded tubercles on the lower part of the exposed whorl face and separates them from the overlying row of elongated tubercles. A third row of smaller spirally tubercles just marks the inter whorl junction and is separated from the second row of tubercles by a second groove.

Some of these specimens show a finer, closer ribbing and more tiny tubercles. These forms have superficial affinities with *T. scheuchzerianus* Bosc (eg. Atabekian, 1985, pl. 31, fig. 7, 10) but the grooves and tubercles are less developed.

*T. acutus* Passy differs by the more depressed whorls, with only two well expressed rows of tubercles and a less developed ribbing in the upper part of the exposed whorl face.

**Age and distribution:** A cosmopolitan species rather common in the middle Cenomanian and rarer in the lower part of the late Cenomanian (C. (P.) guerangeri Zone). The Omani fauna belongs to the second period.

**BIOSTRATIGRAPHY AND PALEOBIOGEOGRAPHY**

A range chart for the Cenoman–Turonian ammonites (Figure 11) adds precision to the biostratigraphical framework proposed for Oman by Meister and Piuz (2013, their figure 6).

The succession of the Albian–Turonian ammonites in the Adam Foothills allows us to propose a set of nine bioevents for this period (Figure 12).
### Cretaceous ammonites of Oman

**Mammites nodosoides**
- C. (Proeucalycoceras) cf. canitaurinum
- C. Proeucalycoceras sp.
- Neolobites fourdrui
- Neolobites vibrayeanus
- Neolobites fourdrui
- V. (G.) birchbyi
- (? = T. rollandi)
- (? = ~ W. coloradoense)

**Nigericeras scotti**
- Nigericeras gadeni
- Neocardioceras juddii
- Nigericeras sp.

**Sciponoceras gracile**
- Sciponoceras gracile

**Burroceras clydense**
- Neolobites fourtaui
- Neolobites fourtaui
- Calycoceras canitaurinum

**Metoicoceras mosbyense**
- Metoicoceras geslinianum
- Metoicoceras geslinianum
- Metoicoceras geslinianum

**Calycoceras canitaurinum**
- Calycoceras canitaurinum

**V. (G.) birchbyi**
- (? = ~ T. rollandi)
- (? = ~ W. coloradoense)

**Neolobites vibrayeanus**
- Neolobites vibrayeanus

**Sciponoceras gracile**
- Sciponoceras gracile

**Burroceras clydense**
- Burroceras clydense
- Burroceras clydense

**C. Proeucalycoceras sp.**
- C. Proeucalycoceras sp.

**C. (Proeucalycoceras) cf. canitaurinum**
- C. (Proeucalycoceras) cf. canitaurinum

**Watinoceras devonense**
- Watinoceras devonense
- Watinoceras devonense

**Vascoceras sp.**
- Vascoceras sp.
- Vascoceras sp.
- Vascoceras sp.

**Metoicoceras geslinianum**
- Metoicoceras geslinianum
- Metoicoceras geslinianum
- Metoicoceras geslinianum

**Nigericeras gadeni**
- Nigericeras gadeni
- Nigericeras gadeni
- Nigericeras gadeni

**C. (Gentoniceras) aff. gentoni**
- C. (Gentoniceras) aff. gentoni
- C. (Gentoniceras) aff. gentoni

**Placenticeras aff. kaffrarium type 1**
- Placenticeras aff. kaffrarium type 1
- Placenticeras aff. kaffrarium type 1
- Placenticeras aff. kaffrarium type 1

**Vascoceras aff. barroceras exele**
- Vascoceras aff. barroceras exele
- Vascoceras aff. barroceras exele
- Vascoceras aff. barroceras exele

**Rubroceras aff. burroense**
- Rubroceras aff. burroense
- Rubroceras aff. burroense
- Rubroceras aff. burroense

**Hoplitoides wohltmanni**
- Hoplitoides wohltmanni
- Hoplitoides wohltmanni
- Hoplitoides wohltmanni

**Pseudaspidoceras flexuosum**
- Pseudaspidoceras flexuosum
- Pseudaspidoceras flexuosum
- Pseudaspidoceras flexuosum

**Sciponoceras gracile**
- Sciponoceras gracile
- Sciponoceras gracile
- Sciponoceras gracile

**Burroceras clydense**
- Burroceras clydense
- Burroceras clydense
- Burroceras clydense

**C. Proeucalycoceras sp.**
- C. Proeucalycoceras sp.
- C. Proeucalycoceras sp.
- C. Proeucalycoceras sp.

**C. (Proeucalycoceras) cf. canitaurinum**
- C. (Proeucalycoceras) cf. canitaurinum
- C. (Proeucalycoceras) cf. canitaurinum
- C. (Proeucalycoceras) cf. canitaurinum

**Vascoceras durandi**
- Vascoceras durandi
- Vascoceras durandi
- Vascoceras durandi

**Wrightoceras sp.**
- Wrightoceras sp.
- Wrightoceras sp.
- Wrightoceras sp.

**Fagesia cf. grangeri**
- Fagesia cf. grangeri
- Fagesia cf. grangeri
- Fagesia cf. grangeri

**Rubroceras aff. burroense**
- Rubroceras aff. burroense
- Rubroceras aff. burroense
- Rubroceras aff. burroense

**Thomasites cf. gongilensis**
- Thomasites cf. gongilensis
- Thomasites cf. gongilensis
- Thomasites cf. gongilensis

**Paramammites sp.**
- Paramammites sp.
- Paramammites sp.

**Eotissotia simplex**
- Eotissotia simplex
- Eotissotia simplex
- Eotissotia simplex

**Vascoceras sp.**
- Vascoceras sp.
- Vascoceras sp.
- Vascoceras sp.

**Rubroceras aff. burroense**
- Rubroceras aff. burroense
- Rubroceras aff. burroense
- Rubroceras aff. burroense

**Fagesia levisseriae**
- Fagesia levisseriae
- Fagesia levisseriae
- Fagesia levisseriae

**Hoplites sp.**
- Hoplites sp.
- Hoplites sp.
- Hoplites sp.

**Additional Data**
- Kennedy and Simmons (1991)

**Figure 11:** Synthetic range chart proposed for late Cenomanian–early Turonian ammonites of Oman and correlation with the zonation (in grey additional data of Kennedy and Simmons, 1991).
### Zonation

Kennedy (1984); Kennedy and Cobb (1991); Chancellors et al. (1994); Gale (1995); Rawson and Hoedemaeker (1999); Kennedy et al. (2000); Gale et al. (2011) and Owen (2012)

| Bioevent Succession in Adam Foothills, Oman |
|---------------------------------------------|

| Age (Ma) | Bioevent Succession |
|----------|---------------------|
| 89.8     | Subprionocyclus neptuni |
| 93.9     | Romaniceras deverianum |
| 100.5    | Romaniceras ornatissimus |
| 125.0    | Romaniceras kallesi |
|          | Kamerunoceras turioniense |

#### Turonian

- Early:
  - Mammites nodosoides
  - Watinoceras colorodoense
  - Neocardioceras juddii
  - Metoicoceras geslinianum
  - C. (Proeucaulycoceras) quengeri

- Middle:
  - Acanthoceras jukesbrownei
  - Acanthoceras rhotomagense
  - Cunningtoniceras inerme
  - Mantelliceras dixonii
  - Mantelliceras mantelli

- Late:
  - Arrhaphoceras briacensis
  - Mortonoceras perforatum
  - Mortonoceras rostratum
  - Mortoniceras fallax
  - Mortonoceras inflatum
  - Mortonoceras pricei
  - Diplomiceras cristatum

#### Cenomanian

- Early:
  - Oxytropidoceras rossyianum
  - Lyelliceras lyelli

- Middle:
  - Douvilleiceras mammillatum

- Late:
  - Leymeriella tardefurcata

#### Albian

- Early:
  - Acompsoceras renevieri - Neolobites fourtau bed(s)

- Middle:
  - Neolobites vibrayeanus bed(s)
  - Meboicoceras geslinianum bed(s)
  - Nigericeras gadeni bed(s)
  - Placenticeras aff. kaffrarianum bed(s)

- Late:
  - Fagesia catinus - Fagesia tevesthensis beds

**Figure 12:** Ammonite bioevent succession in the Adam Foothills for the Albian, Cenomanian and early Turonian of Oman and correlation with the zonation. The numerical ages correspond to the International Chronostratigraphical Chart (Cohen et al., 2013).
Age of the Fauna

**Albian**

The age of the *Knemiceras* beds with *K. syriacum* and *K. cf. dubertreti* is poorly constrained and still under discussion. Moreover in the recent literature, there is no consensus. Indeed *K. syriacum* indicates the early–middle Albian for Kennedy et al. (2009), most probably of middle Albian age if we follow Lewy and Raab (1978) and the early late Albian for Bulot (2007). Whereas *K. cf. dubertreti* corresponds to the basal middle Albian sensu Kennedy et al. (2009), and to the base of the late Albian for Bulot (2007) (D. cristatum and M. pricei Zones), respectively hypothesis A and B in Figure 12. For the moment without better local biostratigraphical constraints, we cannot determine the precise age of this fauna: either middle Albian (hypothesis A) or late Albian (hypothesis B).

**Cenomanian**

The association of the long-ranging *Acompsoceras renevieri* and *Neolobites fourtaui* indicates an age situated in the middle part of the middle Cenomanian (*Acanthoceras rhotomagense* Zone). *A. renevieri* ranges from early Cenomanian to the middle Cenomanian although doubtfully until the *Acanthoceras jukesbrownei* Zone, whereas *N. fourtaui* ranges from the middle Cenomanian (*A. rhotomagense* Zone) to the base of late Cenomanian.

The presence of *N. fourtaui* alone above the previous bioevent corresponds to the upper part of the middle Cenomanian (*Acanthoceras jukesbrownei* Zone)—early late Cenomanian (base of C. (P.)*guerangeri* Zone). *Neolobites vibrayeanus* as well as *C. (Proeuclideanoceras)* *cantaurinum* (subzonal index species) are restricted to the base of late Cenomanian (C. (P.)*guerangeri* Zone). They are associated with *Turrilites costatus* and *Cunningtoniceras* sp. *Metoicoceras geslinianum* is the index species of the eponymous zone (middle part of the late Cenomanian). *C. (Gentoniceras)* *aff. gentoni* is also present in this zone.

The presence of *Nigericeras gadeni* and *N. jacqueti* indicates a period situated in the upper part of the *Metoicoceras geslinianum* Zone and the lowermost part of the *Neocardioceras juddii* Zone. *Puzosia* sp. is also present. *Vascoceras barcoicense exile* and *V. cauvini* are known from *Neocardioceras juddii* Zone, rather the lower part; but may already appear in the *Metoicoceras geslinianum* Zone. The *Placenticeras* *aff. kaffrarium* correspond to a period in the *Neocardioceras juddii* Zone (upper part of the late Cenomanian). *Rubroceras* *aff. burroense* also characterizes this zone.

The presence of some undeterminate *Vascoceras* and *Pseudaspidoceras* does not allow attributing a precise age near the Cenomanian/Turonian boundary (topmost Cenomanian–basal Turonian).

In some part of the southern Neo-Tethys margin (Egypt, Jordan) *Vascoceras proprium* is used to delineate this boundary (see discussion in Meister and Piuz, 2013).

**Turonian**

*Fagesia* (*F. catinus*, *F. tevesthensis*) as well as *Hoplitoides wohltmanni* attest to the presence of the early Turonian. *F. tevesthensis* could be a little younger (upper part of the early Turonian). Kennedy and Simmons (1991) also cited some early Turonian taxa like *Vascoceras durandi*, *? Thomasites* *cf. gongilensis*, *? Eotissotia simplex* and *Wrightoceras* sp. which we have not rediscovered and that could represent three other bioevents (Figures 11 and 12). All these bioevents are correlated with the standard zonation. For regional correlations along the southern Neo-Tethys margin we refer to the detailed discussion recently published by Meister and Piuz (2013).

**Paleobiogeographical Remark**

Ammonite distributions along the southern Neo-Tethys margin from Morocco to Oman have recently been presented and discussed by Meister and Piuz (2013). Only worldwide paleogeographical distributions of some characteristic taxa present in Oman are shown from the middle Cenomanian to the early Turonian (Figure 13).
Figure 13: Worldwide paleobiogeographic reconstitution for the Cenomanian–Turonian and distribution of some characteristic Omani ammonites.
For the middle–early late Cenomanian *A. renevieri* has a distribution restricted to Europe and western and eastern part of Africa, *N. vibrayeanus* shows a rather subequatorial/tropical repartition as does *C. (P.) cantaurinum*. If the latter is not present in Central and North America, it is recorded from South America, Peru and Bolivia, and possibly following Wiese and Schulze (2005) from Venezuela and Columbia. *N. fourtauui* is endemic to the southern Neo-Tethys margin.

For the late Cenomanian, *T. costatus* is a cosmopolitan species whereas *C. (G.) gentoni* is distributed in Europe and eastern and southern part of Africa. *P. kaffrarium* is only known around Africa. For the early Turonian *Fagesia* is a cosmopolitan genus. The species *F. tevesthensis* and *F. catinus* are also widely distributed, but they are not known in the South Atlantic. *H. wohltmanni* is present along the southern Neo-Tethys margin, in the Gulf of Guinea and in Central America more or less according to a subequatorial trend.

### CONCLUSIONS

New discoveries of ammonites in Oman (Adam Foothills) allow further precision of their taxonomy and provide better chronostratigraphical constraints for the Albo-Turonian period. Regionally the sequence of nine bioevents gives greater precision for dating the Nahr Umr and Natih formations, especially for the Natih A and B members. In the Adam Foothills, the ammonite correlations along a West-East transect raises questions regarding the definitions of the lithostratigraphic units of the Natih Formation. Obviously the facies of Natih A and B differs from the western part (Jabal Fitri, Nadah and Salakh NW) to the eastern part (Jabal Salakh, Khaydalah and Madmar) (see Piuz et al., 2014, their figure 2).

A sequence of nine bioevents is correlated with the zonation. Moreover, some ammonite are good temporal markers, among them *Neolobites vibrayeanus* (Orbigny), *Calycoceras* (*Proeucalycoceras*) cf. *cantaurinum* (Spath), *Metiococeras geslinianum* (Orbigny) and *Vascoceras cauvini* Chudeau. They allow good correlations at a large scale, at least along the southern Neo-Tethys margin. Several taxa including *Puzosia*, *Placenticeras*, *Cunningtoniceras*, *P. (Gentoniceras)*, *Nigericeras*, *Metiococeras*, *Rubroceras* and *Hoplitooides* are recorded from Oman for the first time.

From a paleogeographic point of view Oman is a landmark for correlation between western Neo-Tethys (Europe, North Africa, Middle East) and southeast Neo-Tethys (Africa, Madagascar, India. Moreover the presence of *Placenticeras* in a key period for understanding its evolution (still in discussion) is to be underlined.

### APPENDIX

All the material is figured with accompanying scales and is whitened with ammonium chloride. After study, the material will be stored in Geological Survey of Oman, moreover, a collection of casts will be deposited in the Natural History Museum of Geneva (Switzerland).

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Plate 1: Figures 1–4: *Angulithes mermeti* (Coquand, 1862); (1 and 2) Jabal Khaydalah; (3) Jabal Nadah; and (4) Jabal Salakh NW.
Plate 2: Figures 1–3: Placenticeras aff. kaffrarium Etheridge, 1904 type 1 sensu Klinger and Kennedy, 1989; (1–3) Jabal Fitri. Figures 4 and 6: Knemiceras syriacum (von Buch, 1848); (4 and 6) Jabal Madar. Figure 5: Knemiceras cf. dubertreti Basse, 1940; (5) Jabal Madar.
Plate 3: Figures 1–5: Neolobites vibrayeanus (Orbigny, 1841) s.l.; (1) Jabal Fitri; (2–5) Jabal Khaydalah. Figure 6: Puzosia sp. indet.; (6) Jabal Fitri.
Plate 4: Figures 1 and 2: *Neolobites vibrayeanus* ( Orbigny, 1841) s.l.; (1 and 2) Jabal Fitri. Figure 3: *Neolobites* sp.; (3) Jabal Salakh NW. Figures 4–6: *Neolobites fourtaui* Pervinquière, 1907; (4) Jabal Nadah; (5) Jabal Fitri; and (6) Jabal Nadah.
Plate 5: Figures 1–6: Neolobites vibrayeanus (Orbigny, 1841) s.l.; (1, 2, 4, 6) Jabal Khaydalah; (3) Jabal Salakh NW and (5) Jabal Madmar.
Plate 6: Figure 1: *Acompsoceras renevieri* (Sharpe, 1857); (1) Jabal Salakh NW.
Plate 7: Figures 1 and 2: *Acompsoceras renevieri* (Sharpe, 1857); (1 and 2) Jabal Salakh NW; (2) enlarged part of Plate 6, Figure 1c.
Plate 8: Figure 1: *Acompsoceras renevieri* (Sharpe, 1857); (1) Jabal Salakh NW.
Plate 9: Figure 1: Calycoceras (Gentoniceras) aff. gentoni (Brongniart, 1822); (1) Jabal Salakh. Figures 2 and 3: Cunningtoniceras sp.; (2 and 3) Jabal Khaydalah.
Plate 10: Figures 1–4: *Calycoceras* (*Proeucalycoceras*) cf. *canitaurinum* (Haas, 1949); (1, 3 and 4) Jabal Khaydalah and (2) Jabal Madmar.
Plate 11: Figures 1 and 2: *Calycoceras* (*Proeucalycoceras*) cf. *canitaurinum* (Haas, 1949); (1 and 2) Jabal Khaydalah.
Plate 12: Figure 1: Calycoceras (Proeucalycoceras) sp. indet.; (1) Jabal Madmar. Figure 2: Calycoceras (Proeucalycoceras) cf. canitaurinum (Haas, 1949); (2) Jabal Khaydalah.
Plate 13: Figure 1: *Calycoceras* (*Proeucalycoceras*) cf. *canitaurinum* (Haas, 1949); (1) Jabal Khaydalah. Figures 2 and 3: *Metoicoceras* gr. *geslinianum* (Orbigny, 1850); (2 and 3) Jabal Salakh.
Plate 14: Figure 1: *Calycoceras* (*Proeucalycoceras*) cf. *canitaurinum* (Haas, 1949); (1) Jabal Khaydalah. Figures 2 and 3: *Nigericeras gadeni* (Chudeau, 1909); (2) Jabal Fitri; 3: Jabal Salakh. Figure 4: *Metoicoceras* gr. *geslinianum* (Orbigny, 1850); (4) Jabal Salakh.
Plate 15: Figures 1–3: *Nigericeras gadeni* (Chudeau, 1909); (1–3) Jabal Fitri. Figure 4: *Neolobites vibrayeanus* (Orbigny, 1841) s.l.; (4) Jabal Madmar.
Plate 16: Figures 1 and 3: *Nigericeras gadeni* (Chudeau, 1909); (1–3) Jabal Fitri. Figure 2: *Pseudaspidoceras* sp.; (2) Jabal Salakh.
Plate 17: Figure 1: *Rubroceras* aff. *burroense* Cobban, Hook and Kennedy, 1989; (1) Jabal Salakh. Figure 2: *Pseudaspidoceras* sp.; (2) Jabal Salakh. Figure 3: *Vascoceras* aff. *barcoicensis exile* Cobban, Kennedy and Hook, 1989; (3) Jabal Salakh. Figures 4: *Nigericeras gadeni* (Chudeau, 1909); (4) Jabal Fitri.
Plate 18: Figure 1: *Pseudaspidoceras* sp.; (1) Jabal Salakh.
Plate 19: Figure 1: *Fagesia tevesthensis* (Peron, 1896); (1) Jabal Fitri. Figures 2, 3 and 5: *Vascoceras* sp.; (2, 3 and 5) Jabal Salakh. Figure 4: *Fagesia cf. catinus* (Mantell, 1822); (4) Jabal Salakh.
Plate 20: Figure 1: *Vascoceras cauvini* Chudeau, 1909; (1) Jabal Fitri. Figures 2 and 3: *Turrilites costatus* Lamarck, 1801; (2 and 3) Jabal Khaydalah. Figure 4: *Fagesia cf. catinus* (Mantell, 1822); (4) Jabal Salakh.
Plate 21: Figure 1: *Hoplitoides wohltmanni* (von Koenen, 1897); (1) Jabal Salakh. Figures 2–6 and 8: *Turrilites costatus* Lamarck, 1801; (2–6 and 8) Jabal Khaydalah. Figure 7: *Nigericeras jacqueti* Schneegans, 1943; (7) Jabal Salakh.
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