

# Cenomanian ammonites of the Shuayb Formation, Jordan

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## Abstract

Four species of ammonites belonging to the Family Acanthoceratidae (HYATT 1900) are described herein from sediments of the Late Cenomanian of northwestern Jordan. Calycocheras (Proeucalycocheras) guerangeri (SPATH, 1926), Calycocheras (Proeucalycocheras) picteti WRIGHT and KENNEDY, 1990, Calycocheras (Newboldiceras) asiaticum asiaticum (JIMBO, 1894), and Pseudocalycocheras harpax (STOLICZKA, 1864), are reported from marly layers of the top of the Shuayb Formation outcropping in Ibin within the Ajlun District. This assemblage of ammonites allowed for the assignment of these Jordanian sediments to the basal Late Cenomanian Calycocheras (Proeucalycocheras) guerangeri Zone of the standard biozonal scheme for the Mediterranean Faunal Province. The descriptions of these specimens of ammonoid genera and their species for Jordan shed additional information on their paleobiogeographic distribution through the Late Cenomanian interval.

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**Keywords:** : Ammonites, Acanthoceratidae, Cenomanian, Shuayb Formation, Jordan.

## 1. Introduction

The sedimentary cover of northwestern Jordan consists mainly of Upper Cretaceous fossiliferous marine facies. During the Cenomanian and Turonian stages, shallow warm seas largely covered Jordan depositing the strata of the Ajlun Group, which includes well-established lithostratigraphic units formally described as the Naur, the Fuheis, the Hummar, the Shuayb, and the Wadi As Sir Formations (Figure 1). Previous studies of these sedimentary rocks concentrated mainly on the petrography, micropaleontological interpretations and occasionally on macrofossil analyses (Bandel and Geys, 1985; Powell, 1989; Abed and Kraishan, 1991; Aqrabawi, 1993; Nazzal and Mustafa, 1993; Shinaq and Bandel, 1998; Bandel et al., 1999; Neumann, 1999; Sabaheen and Mustafa, 2000; Ahmad and Al-Hammad, 2002; and Perrilliat, et al., 2006).

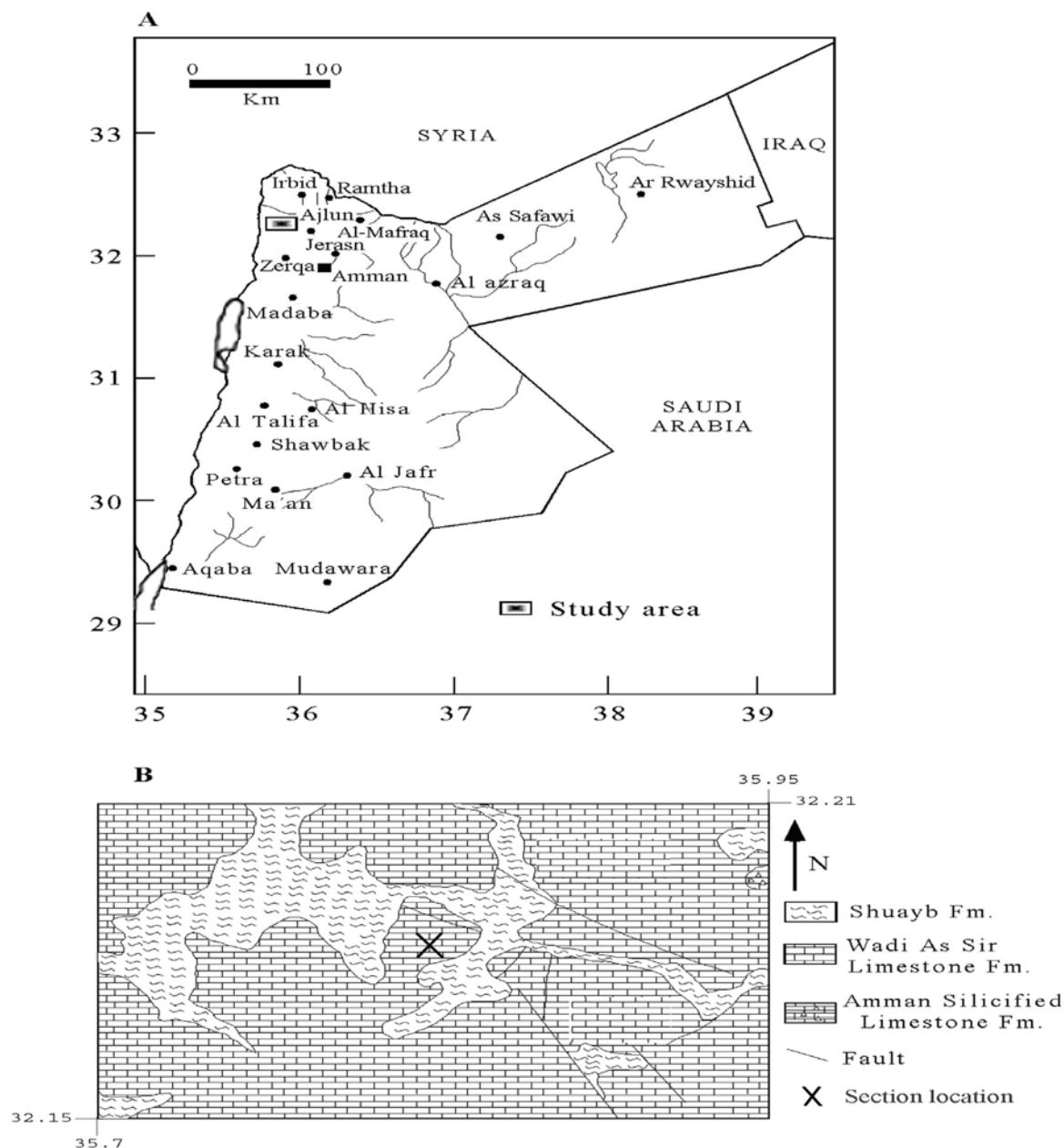
In northwestern Jordan, the Shuayb Formation is overlain by the limestones of the Wadi As Sir Formation (Figure 2). The Shuayb Formation consists of a rhythmic alternation of thinly bedded limestones and mostly fossiliferous marly limestones. The overall composition of

this formation becomes totally marly towards its top Powell (1989).

GROUP	STAGE	FORMATION
Ajlun	Turonian	Wadi As Sir
	Middle-Late Cenomanian	Shuayb Hummar
	Middle Cenomanian	Fuheis
	Late Albian- Early Cenomanian	Naur

**Figure 1.** Regional stratigraphy of northwestern Jordan. The Ajlun Group includes well established lithostratigraphic units formally described as the Naur, the Fuheis, the Hummar, the Shuayb, and the Wadi As Sir Formations Powell (1989).

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**Figure 2.** Location of the area of study. A) Geographic map of Jordan displaying the quadrant of the area of study to the northwest of the country. B) Geologic map of the area of study displaying the lateral relation of the Shuayb Formation on regards to the Wadi As Sir Limestone Formation.

Nazzal and Mustafa (1993) assigned a Middle Cenomanian age to the Shuayb Formation, restricting its deposition to the span of time of the ammonite biozone *Acanthoceras rhotomagense*. However, the exact age of this Upper Cretaceous stratigraphic unit remained uncertain, because most of the published fauna lacked precise stratigraphic control impeding broad regional correlations. In the publication of Naji (1996), a stratigraphic chart places the

Shuayb Formation into the Late Cenomanian, although the author himself had not provided nannofossil data from this formation. In contrary, Schulze *et al.* (2004) followed

the works of Powell (1989) and Schulze *et al.* (2003), who put the age of the formation into the Early Turonian.

Thus, brief support was given to this assignment and in consequence, further work based on better material was desirable for a more complete understanding of the time of deposition of this lithostratigraphic unit. Recent collections of several well-preserved specimens referable to the genera *Pseudocalycoceras* and *Calycoceras* from the top of the Shuayb Formation set the basis for this new study. The newly ammonite findings reported herein suggest that even though this lithostratigraphic unit initiated its deposition in the Middle Cenomanian, this may have continued at least through the Late Cenomanian ammonite biozone *Calycoceras (Proeucalycoceras) guerangeri*.

## 2. Brief History of Ammonite Studies in Jordan and Palestine

Studies on Mid- and Late Cretaceous ammonites of Jordan and adjacent areas go back to the beginning of the twentieth century (i.e., Douvillé, 1916; Taubenhaus, 1920). The works of Mahmoud (1956), Wetzel and Morton (1959), Avnimelech and Shores (1962), Parnes (1964), Lewy (1989), Nazzal and Mustafa (1993), and Mouty *et al.* (2003), also gave a glimpse of the ammonite fauna of the area. In the past few years, the complex paleontological and lithostratigraphical researches of the central carbonate platform of Jordan were in focus (Schulze *et al.*, 2003, 2004). In Schulze *et al.* (2004), the Albian-Turonian ammonite data for the west-central Jordan carbonate platform is given mentioning that “*N. vibrayanus* locally occurs together with *Proeucalycoceras haugi*, *Pseudocalyoceras harpax* or with *Turrilites acutus*”, and that “these association indicates a Middle to middle-Late Cenomanian age”. These data fit to our ammonoid biostratigraphical results presented herein.

## 3. Systematic Paleontology

The studied ammonites from the Shuayb Formation are generally preserved as internal complete and fragmentary casts. The systematic nomenclature and diagnoses used herein are followed the "Treatise on Invertebrate Paleontology (Wright *et al.*, 1996)" to the genus level. Descriptions, diagnoses, synonyms, and references used for specific determinations are also included. In the descriptions, the following abbreviations are used for measured parameters: (D) for the shell diameter of reference, (Ud) for the diameter of the umbilicus, (Wh) for the whorl-height, and (Ww) for the whorl-width. All measurements are expressed in millimeters. The ammonite specimens subject of this study are housed in the Invertebrate Collection of the Museum of Paleontology at the Institute of Geology, Universidad Nacional Autónoma de México, Ciudad Universitaria, 04510 México, UNAM under catalogue numbers IGM-9541 through IGM-9555.

Order Ammonoidea Zittel, 1884

Suborder Ammonitina Hyatt, 1889

Superfamily Acanthoceratoidea Grossouvre, 1894

Family Acanthoceratidae Grossouvre, 1894

Subfamily Acanthoceratinae Grossouvre, 1894

Genus *Calycoceras* Hyatt, 1900

**Type Species.** *Ammonites navicularis* Mantell, 1822, p. 198.

**Diagnosis.** Rather evolute to semiinvolute, with whorl section depressed and subcircular, oval, polygonal, or subquadrate; ribs strong, generally straight, continuous over rounded or flat but not concave venter; on early whorls at least umbilical, ventrolateral, siphonal, and, in most specimens, midlateral tubercles. In multituberculate forms umbilical tubercle more prominent than midlateral; tubercles may disappear with age and may or may not be rejuvenated on last part of shell. Marked dimorphism in

size apparently general. Due to significant morphological and time gaps between species groups, the genus embraces several subgenera.

Subgenus *Calycoceras* (*Proeucalycoceras*) Thomel, 1972

**Type Species.** *Calycoceras* (*Eucalycoceras*) *besairiei* Collignon, 1937, p. 37: by original designation.

**Diagnosis.** Inner whorls relatively compressed; sides and venter commonly flat; ribs dense, fine, and flexuous, with weak to strong umbilical bullae and weak outer ventrolateral clavi; inner ventrolateral and siphonal tubercles present initially but disappearing early; whorl section tending to become square, with blunt, well-rounded ribs.

***Calycoceras* (*Proeucalycoceras*) *guerangeri* (Spath, 1926)**

Figures 3a-c, 4a-b

*Ammonites rothomagensis*? “Lamck” – Guéranger, 1867, p. 5, pl. 4, fig. 4.

\**Metacalycoceras guerangeri* Spath, 1926, p. 431.

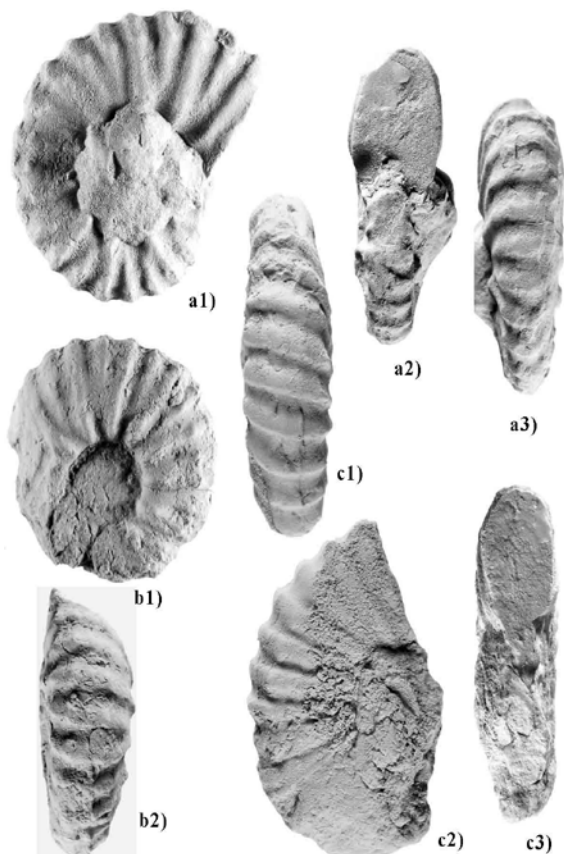
*Calycoceras* (*Proeucalycoceras*) *guerangeri* Spath, 1926; Cobban, Hook and Kennedy, 1989,

p. 25, figs. 26, 27 p-r, t, u; Wright and Kennedy, 1990, p. 277, pl. 60, fig. 1, pl. 70, fig. 1, pl. 73, figs. 1-2, 4, pl. 74, fig. 2, pl. 75, fig. 1, text-figures 118, 119d-e, 120a-e, 121, 122, 123b; Thomel, 1992, pl. 37, figs. 1-2, pl. 40, figs. 4-5, pl. 41, figs. 11-12, pl. 42, figs. 8-10; Kennedy and Juignet, 1994, p. 478, figs. 6 a-c, 7 a-d, 8 a-d, 9 a-d.

**Material.** Eight specimens. The specimens illustrated are identified with catalog numbers IGM-9541 through IGM-9545.

**Dimensions of the illustrated specimens (mm).** IGM-9541, D: 78, U: approximately 20, Wh: 27, Ww: 23; IGM-9542, D: 65, U: 23, Wh: 25, Ww: 21; IGM-9543, D: approximately 90, U: ----, Wh: 35, Ww: 21; IGM-9544, D: 98, U: approximately 34, Wh: 32, Ww: 28; IGM-9545, D: 73, U: approximately 25, Wh: 33, Ww: 28.

**Description.** Rather involute (U/D ranging from 0.25 to 0.35), medium-sized specimens around the diameter of 60-80 mm. The umbilical region not observable due to sediment infill. The involution of the shell can be interpreted only on the specimen identified as IGM-9542 (Figure 3b), where the umbilical region is not occluded completely. Whorl section is slightly compressed, but most of the specimens are deformed. The ornamentation consists of the alternation of very distinctive, rigid ribs. The rib index in almost every case is 21. Primary ribs arise in a well-developed umbilical bullae and cross the flanks and the venter straight. On the last whorl some ribs tend to be slightly rursiradiate. Sometimes an intercalated rib is present between two primaries on the inner flank. The intercalated ribs do not wear umbilical or inner lateral tubercle or bullae. Otherwise, primary ribs are quadrituberculate and additionally a slight siphonal tubercle may appear. The most prominent tubercles are the umbilical and the outer ventrolateral. Venter is well rounded or flat-topped. The siphonal tubercle is very weak.



**Figure 3.** a-c: *Calycocheras (Proeulalycoceras) guerangeri* (Spath, 1926), a: IGM-9541, a1: flank view, a2: whorl section view, a3: ventral view; b: IGM-9542, b1: flank view, b2: ventral view; c: IGM-9543, c1: ventral view, c2: flank view, c3: whorl section view. All figures at natural size Shuayb Formation, northwestern Jordan.

**Remarks.** The rather involute coiling; the rigid, distinctive ribbing together with the strong tuberculation are characteristic features of the species. Furthermore, Kennedy and Juignet (1994) mentioned the “flattened venter” as a diagnostic feature as well. In this case most of the specimens are deformed or the venter is not flat, so in this pre-adult stage of the ontogeny, the flat venter is not a specific character. Some of the specimens assigned to *Calycocheras (Proeulalycoceras) guerangeri* (Spath, 1926) in this work, resemble to *C. (P.) haugi* (Pervinquieré, 1907), whose morphology is very similar and has also been reported from the region previously (Schulze *et al.* 2004). However, their flattened flanks are more characteristic of *C. (P.) guerangeri*.

**Occurrence.** The species has been reported from lower Upper Cenomanian deposits of France, England, Portugal, and the Western Interior of the USA.

***Calycocheras (Proeulalycoceras) picteti* Wright and Kennedy, 1990**

Figures 4c, 5a-b

*Ammonites cenomanensis* d’Archiac, 1846, pp. 62, 78 (*nomen nudum*); Pictet, 1863, p. 28, pl. 3, Fig. 2.

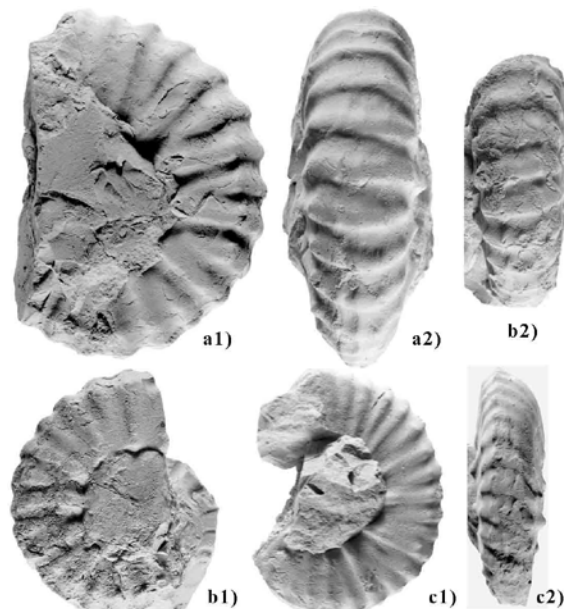
*Calycocheras (Proeulalycoceras) picteti*, Wright and Kennedy, 1990, p. 264, pl. 54, fig. 2, pl. 64,

fig. 4, pl. 68, figs. 1-2, pl. 74, fig. 3, pl. 75, figs. 2-6, text-figs. 110 d, g, 113, 114, 116 a-d, 117, 119 a-c ;

Kennedy and Juignet, 1994, p. 471, figs. 1 a, 2 a-b, 3 a-d, 4 a-d, 5 a-d, 13 a.

**Material.** Eight specimens. The specimens illustrated are identified with catalog numbers IGM-9546 through IGM-9548.

**Dimensions of the illustrated specimens (mm).** IGM-9546, D: 70, U: 25, Wh: 25, Ww: approximately 18; IGM-9547, D: approximately 88, U: approximately 38, Wh: approximately 30, Ww: approximately 32; IGM-9548, D: approximately 75.



**Figure 4.** a-b: *Calycocheras (Proeulalycoceras) guerangeri* (Spath, 1926), a: IGM-9544, a1: flank view, a2: ventral view; b: IGM-9545, b1: flank view, b2: ventral view. c: *Calycocheras (Proeulalycoceras) picteti* Wright and Kennedy, 1990, IGM-9546, c1: flank view, c2: ventral view. All figures at natural size Shuayb Formation, northwestern Jordan.

**Description.** Considering the genus, the specimens assigned to this species are rather evolute (U/D ranging from 0.35 to 0.43). The umbilical areas are more or less occluded by sediment in a way that early whorls are not visible. Whorl sections of some specimens are compressed as in IGM-9546 (Figure 4c), but in others as in IGM-9547 (Figure 5a) are strongly depressed. Otherwise, the whorl section is moderately depressed as in specimen IGM-9548 (Figure 6b). Most of the specimens are deformed, so the shape of the whorl section is rather uninformative. The ornamentation consists of strong, distant, alternating long and short ribs. Rib index is variable between 14 and 20 ribs per half whorl. There are distinct, strong umbilical tubercles from where primary ribs start their development. Primary ribs are straight, sometimes slightly rursiradate. Between the primaries, one or two intercalated secondary ribs appear on mid-flank. The pattern of alternating short and long ribs is characteristic. Both ribs wear well visible outer lateral and ventrolateral tubercles. The inner lateral tubercle is missing in most cases. Siphonal clavi are present but get less prominent through ontogeny. Venter is deformed, but supposedly rounded or slightly flattened.

**Remarks.** Wright and Kennedy (1990, p. 264) have discussed the original species of *A. cenomanensis* d’Archiac as “*nomen nudum*” and interpreted *C. (P.) picteti* based on the description of *A. cenomanensis* of

Pictet (1863). "The evolute coiling, depressed whorl section, somewhat flattened, broadly rounded flanks and venter, and characteristic very distant, narrow, high flared ribs which are alternately long and short" (Kennedy and Juignet, 1994), characterize the species. Moreover, ribs are more numerous and less rigid than those of *C. (P.) guerangeri*.

**Occurrence.** This species has been reported from lower Upper Cenomanian deposits of Jordan, and Dorset and Devon, England.

***Calycoceras (Proeulycoceras) aff. picteti* Wright & Kennedy, 1990**

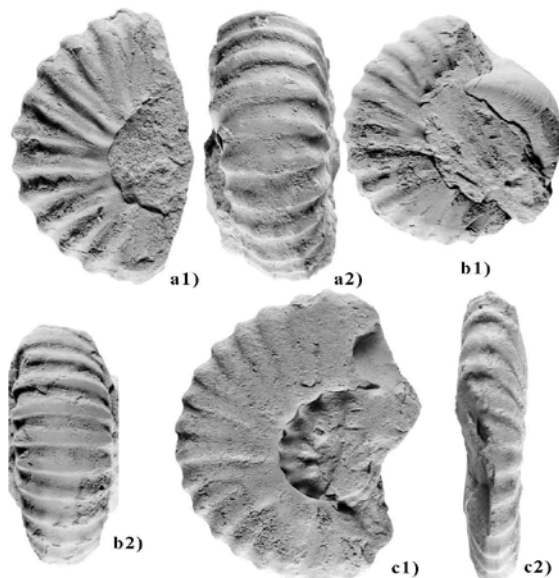
Figure 5c

**Material.** One specimen identified with catalog number IGM-9549.

**Dimensions of the illustrated specimen (mm).** IGM-9549, D: 95, U: 38, Wh: 30, Ww: 18.

**Description.** This specimen is different from the rest of the assemblage of the species because of its greater size and less prominent ornamentation of the outer whorl, which can be interpreted as the body chamber. The inner whorls are strongly tuberculated, the umbilical and the inner ventrolateral tubercles very big.

**Remarks.** The ornamentation of the inner whorls resembles that of *C. (P.) picteti* Wright and Kennedy, 1990. However, the greater evolution and the weak ornamentation of the outer whorl make the relation dubious and it is preferably to keep an open nomenclature. This specimen is in consequence much more evolutes, and its weak ornamentation of the last whorl, especially the lack of the umbilical tubercles, makes it different from the rest of the specimens assigned to this species.



**Figure 5.** a-b: *Calycoceras (Proeulycoceras) picteti* Wright and Kennedy, 1990, a: IGM-9547, a1: flank view, a2: ventral view; b: IGM-9548, b1: flank view, b2: ventral view. c: *Calycoceras (Proeulycoceras) aff. picteti* Wright & Kennedy, 1990, IGM-9549, c1: flank view, c2: ventral view. All figures at natural size Shuayb Formation, northwestern Jordan.

ubgenus *Calycoceras (Newboldiceras)* Thomel, 1972

**Type Species.** *Acanthoceras newboldi* Kossmat, 1897, p. 112: by original designation.

**Diagnosis.** Large; whorl section tending to be polygonal with marked ventrolateral facet or subquadrate throughout; outer ventrolateral and in many cases inner ventrolateral and siphonal tubercles persisting.

***Calycoceras (Newboldiceras) asiaticum asiaticum* (Jimbo, 1894)**

Figures 6a-b

*Acanthoceras rothomagense* var. *asiatica* Jimbo, 1894, p. 177, pl. 20, fig. 1.

*Acanthoceras Newboldii* n. sp. Kossmat, 1897, p. 5(112), pl. 1(12), figs. 2-3, pl. 3(14), fig. 2.

*Calycoceras newboldi newboldi* (Kossmat), Kennedy, 1971, p. 75, pl. 39, figs. 2 a-c, pl. 40, figs. 2 a-b.

*Calycoceras (Newboldiceras) asiaticum asiaticum* (Jimbo), Wright and Kennedy, 1990, p. 239, pl. 58, fig. 1, pl. 64, figs. 1-2, pl. 65, figs. 1-3, 5, 7, pl. 72, fig. 3, text-figs. 87 a-c, 88 f, 97, 98; Thomel, 1992, p. 94, 328, pl. 7, fig. 1, pl. 15, figs. 5-6, pl. 17, figs. 1-2, p. 340, pl. 41, figs. 8-9; Kennedy and Jolkicev, 2004, p. 375, pl. 3, fig. 1, pl. 4, figs. 6-7, pl. 5, fig. 1-4.

**Material.** Three specimens. The two specimens illustrated are identified with catalog numbers IGM-9550 and IGM-9551.

**Dimensions of the illustrated specimens (mm).** IGM-9550, D: 75, U: 25, Wh: 28, Ww: approximately 23; IGM-9551, D: 75, U: 17, Wh: 25, Ww: approximately 22.

**Description.** The following description is based on specimen IGM-9551 (Figure 6b). Relatively involute (U/D ranging from 0.22 to 0.33) internal mould with flattened sides and deformed compressed whorl section. Slightly rounded venter. The umbilical wall is steep with well-rounded umbilical shoulder. More than thirty-four, slightly prorsiradiate, alternated short and long ribs on the last whorl. Primary ribs arise on the umbilical seam and strengthen into a sharp, strong bullae on the umbilical shoulder. Ribs are crowded and strong but no rigid, and wear prominent inner and outer ventrolateral tubercles and row of weak siphonal tubercles.

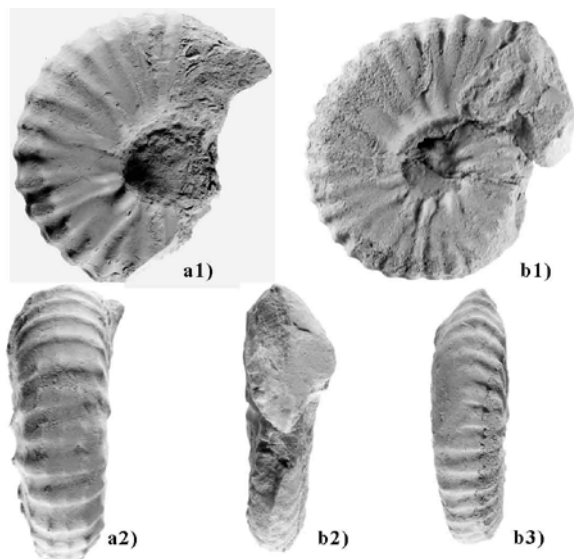
**Remarks.** The alternating long and short ribs make *Calycoceras (Newboldiceras) asiaticum asiaticum* (Jimbo, 1894) very similar to *Calycoceras (Proeulycoceras) canitaurinum* (Hass, 1949 fide Cobban and Kennedy, 1990). However, *C. (P.) canitaurinum* displays a flat venter, less number of ribs, and an early loss of the siphonal tubercles.

**Occurrence.** This species has been reported from lower Upper Cenomanian deposits of Japan, southern India, Madagascar, Zululand, southern England, France, Spain, Bulgaria, Romania, and Tunisia.

Genus *Pseudocalycoceras* Thomel, 1969

**Type Species.** *Ammonites harpax* Stoliczka, 1864, p. 72: by original designation

**Diagnosis.** Slightly compressed to slightly depressed; ribs flexuous to convex and prorsiradiate, more or less regularly branching or long and short; primaries arising from umbilical bullae, characteristically twisted; all ribs with inner ventrolateral nodes or clavi and outer ventrolateral and siphonal clavi; on latter part of body chamber ribs narrow, approximate, and generally recurve; tubercles disappear.



**Figure 6.** a-b: *Calycocheras (Newboldiceras) asiaticum asiaticum* (Jimbo, 1894), a: IGM-9550, a1: flank view, a2: ventral view; b: IGM-9551, b1: flank view, b2: whorl section view, b3: ventral view. All figures at natural size Shuayb Formation, northwestern Jordan.

***Pseudocalycocheras harpax* (Stoliczka, 1864)**

Figures 7a-b

*Ammonites harpax* Stoliczka, 1864, p. 72, pl. 39, figs. 1, 1a.

*Acanthoceras harpax* (Stoliczka), Collignon, 1937, p. 33, pl. 1, figs. 1, 1a, pl. 1, figs. 1-2.

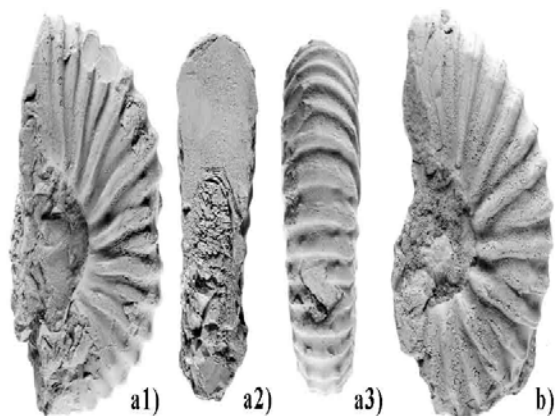
*Eucalycocheras harpax* (Stoliczka), Porthault, Thomel and De Villoutreys, 1966, p. 428.

*Pseudocalycocheras harpax* (Stoliczka), Thomel, 1972, p. 88.

*Pseudocalycocheras* ex. gr. *harpax* (Stoliczka), Vašiček, 1992, p. 70, pl. 5, figs. 1-2.

**Material.** Two specimens identified with catalog numbers IGM-9552 and IGM-9553.

**Dimensions of the illustrated specimens (mm).** IGM-9552, D: approximately 70, U: approximately 25, Wh: 25, Ww: 24; IGM-9553, D: approximately 75, U: approximately 28, Wh: 26, Ww: approximately 22.



**Figure 7.** a-b: *Pseudocalycocheras harpax* (Stoliczka, 1864), a: IGM-9552, a1: flank view, a2: whorl section view, a3: ventral view; b: IGM-9553, ventral view. All figures at natural size Shuayb Formation, northwestern Jordan.

**Description.** The following description is based on specimen IGM-9552 (Figure 7a). Moderately evolute (U/D ranging from 0.35 to 0.37) fragment of a half whorl. The umbilical region and the inner whorls are completely destroyed. The whorl section is compressed with the maximum diameter around the outer ventrolateral tubercle. The umbilical wall is steep and rounded. The ornamentation consists of nine primary ribs together with ten intercalated ones in a half whorl. Ribs are prominent, flexuous, and slightly rursiradial. The umbilical bullae are strong when present, otherwise ribs wear umbilical, inner and outer ventrolateral, and siphonal tubercles. The venter is well rounded. Specimen IGM-9553 (Figure 7b) is very similar, apart from the lack of the flexuosity of the ribs.

**Remarks.** The alternating prominent, flexuous, long and short ribs characterize the species. Moreover, the prominent umbilical tubercles allow the differentiation of this species from *P. angolaense* (Spath, 1931) to which is very similar. Kennedy, Juignet and Hancock (1981) referred four subspecies (*harpax tulearensis*, *ankomakensis*, *ramondaense* and *talinorensis*) of Collignon (1937, pl. 1) as synonyms of *P. harpax* (Stoliczka).

**Occurrence.** This species has been reported from lower Upper Cenomanian deposits of India, Madagascar, England, France, and the Bohemian Basin in the Czech Republic.

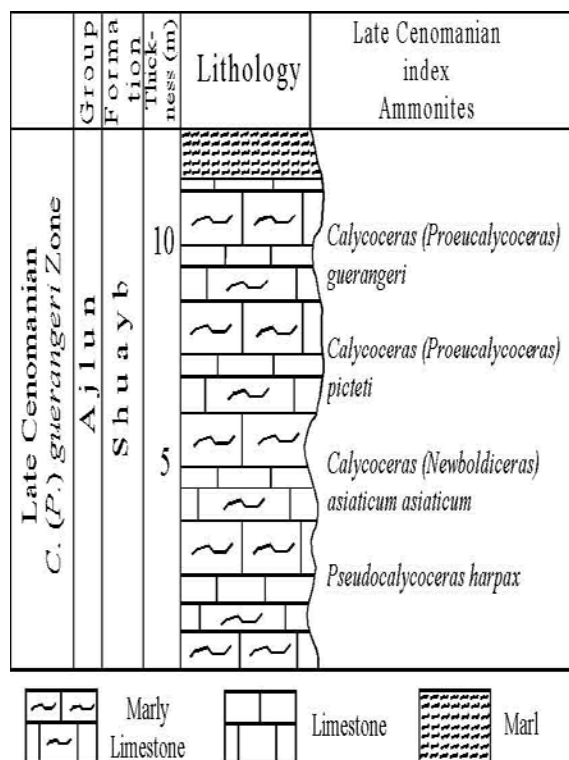
#### 4. Conclusions

Taxonomy and biostratigraphy of Upper Cretaceous ammonite assemblages have been useful conventional media used in stratigraphic correlation in Jordan and other areas of the region, as advocated in the works by Mahmoud (1956); Wetzel and Morton (1959); Avnimelech and Shorsh (1962); Parnes (1964); Lewy (1989); Nazzal and Mustafa (1993); and Mouty *et al.* (2003).

Locally, the Shuayb Formation (Ajlun Group) in northwestern Jordan has been assigned a Middle Cenomanian age (Nazzal and Mustafa, 1993), a Late Cenomanian age (Naji, 1996), and even an Early Turonian age (Schulze *et al.*, 2003). In this work, abundant specimens belonging to three species of the genus *Calycocheras*, namely *C. (Proeucalycocheras) guerangeri*, *C. (P.) picteti*, *C. (Newboldiceras) asiaticum asiaticum*, have been found associated with specimens of the species *Pseudocalycocheras harpax*.

Despite the lack of precision in the assignment of the age of deposition for rocks of the Shuayb Formation, this ammonoid association fits well with the idea that the stratigraphic interval studied herein, can be regarded as part of the Upper Cenomanian *C. (P.) guerangeri* Zone, *sensu* Western European zonal scheme (Tröger *et al.*, 1996; Gradstein, Ogg and Smith, 2004; and Kennedy and Jolkevic, 2004) (Figure 8).

By means of these reports, this work also sheds new light on the paleobiogeographic distribution of the elements of the family Acanthoceratidae (Ammonoidea) in the Middle East seas.



**Figure 8.** Stratigraphic framework of the section of the Shuayb Formation (Ajlun Group) from northwestern Jordan studied herein, displaying lithology and ammonite assemblage. Based on the index ammonites identified, the interval studied is regarded to the Upper Cenomanian *C. (P.) guerangeri* Zone (sensu Western European zonal scheme).

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### References

- [1] Abed, A., Kraishan, G., 1991, Evidence for shallow-marine origin of a 'Monterey-Formation Type' chert-phosphorite-dolomite sequence: Amman Formation (Late Cretaceous), Central Jordan: *Facies* 40, 25-38.
- [2] Ahmad, F., Al-Hammad, A., 2002, Oysters and echinoids from the Naur Formation (late Aptian-early Cenomanian) of central Jordan: *Neues Jahrbuch fuer Geologie und Palaeontologie. Monatshefte*, 2002(8), 449-464.
- [3] Aqrabawi, M., 1993, Oysters (*Bivalvia-Pteriomorpha*) of the Upper Cretaceous rocks of Jordan; Paleontology, stratigraphy and comparison with the Upper Cretaceous oysters of northwest Europe: *Universität Hamburg, Mitteilungen aus dem Geologisch- Paläontologischen Institut*, 75, 1-135.
- [4] Avnimelech, M.A., Shores, R., 1962, Les céphalopodes cénomaniens des environs de Jérusalem : *Bulletin de la Société Géologique de France*, 7<sup>th</sup> Séries, 4, 528-535.
- [5] Bandel, K., Geys, J., 1985, Regular echinoids in the Upper Cretaceous of the Hashemite Kingdom of Jordan: *Annales Société Géologique du Nord*, 104, 97-115.
- [6] Bandel, K., Shinaq R., Nazzal, J., 1999, Palaeoecological and diagenetical significance of a silicified soft bottom fauna of

- Campanian age (Qatrana Unit, Jordan): *Universität Hamburg, Mitteilungen aus dem Geologisch-Paläontologischen Institut*, 83, 203-218.
- [7] Cobban, W.A., Hook, S.C., Kennedy, W.J., 1989, Upper Cretaceous rocks and ammonite faunas of southwestern New Mexico: *New Mexico Bureau of Mines and Mineral Resources, Memoir* 45, 137 p.
- [8] Cobban, W.A., Kennedy, W.J., 1990, Variation and Ontogeny of *Calycocheras (Proeucalycocheras) canitaurinum* (Hass 1949) from the Upper Cretaceous (Cenomanian) of the Western Interior of the United States: *U. S. Geological Survey Bulletin, Shorter contributions to Paleontology and Stratigraphy*, B1-B7, pls. 1-4.
- [9] Collignon, M., 1937, Ammonites Cénomaniennes du Sud-ouest de Madagascar: *Annales Géologiques du Service des Mines, Madagascar*, 8, 31-69, pls. i-xi.
- [10] D'Archiac, A., 1846, études sur la formation crétacée des versants su-ouest, nord et nord-ouest du Plateau Central de la France (2<sup>e</sup> partie): *Mémoires de la Société Géologique de France, Série Géologique* 2, 2(1), 148 p.
- [11] Douvillé, H., 1916, Les terrains secondaires dans le massif du Moghara à l'est de l'isthme de Suez, d'après les explorations de M. Couyat-Barthoux. *Paléontologie: Memoire de l'Academie des Sciences de l'Institute de France, series* 2, 54, 1-184, figs. 1-50, pls. 1-21.
- [12] Guéranger, E., 1867, *Album paléontologique du département de la Sarthe: Beauvois et Vallienne, Le Mans*, 77 p., 25 photographs.
- [13] Gradstein, F., Ogg, J., Smith, A., 2004, *A Geological Time Scale: Cambridge University Press, Cambridge*, 344-384.
- [14] Grossouvre, A. De, 1894, *Recherches sur la Craie supérieure, 2. Paléontologie. Les ammonites de la Craie supérieure: Mémoires pour servir à l'explication de la carte géologique détaillé de la France, Paris*, 267 p., 39 pls.
- [15] Hass, O., 1949, *Acanthoceratid Ammonoidea from near Greybull, Wyoming: American Museum of Natural History Bulletin*, 93(1), 39 p., 15 pls.
- [16] Hyatt, A., 1889, *Genesis of the Arietitidae: Washington, D. C., Smithsonian Contributions to Knowledge*, 673, xi + 238 p., 14 pl.
- [17] Hyatt, A., 1900, *Cephalopoda, in Zittel, K. A. (ed.), Textbook of Palaeontology, 1<sup>st</sup> English Edition, translated by C. R. Eastman: Macmillan, London and New York*, p. 502-592.
- [18] Jimbo, K., 1894, *Beiträge zur Kenntniss der Fauna der Kreideformation von Hokkaido: Paläontologische Abhandlungen, (n. s.)* 2, 147-194.
- [19] Kennedy, W.J., 1971, *Cenomanian ammonites from southern England: Special papers in Palaeontology*, 8, 1-133.
- [20] Kennedy, W.J., Jolkicev, N., 2004, *Middle Cenomanian ammonites from the type section of the Sandinovo Formation of northern Bulgaria: Acta Geologica Polonica*, 54(3), 369-380.
- [21] Kennedy, W.J., Juignet, P., 1994, *A revision of the ammonite faunas of the type Cenomanian. Acanthoceratinae (Calycocheras (Proeucalycocheras), Eucalycocheras, Pseudocalycocheras, Neocardioceras), Euomphaloceratinae, Mammitinae, and Vascoceratinae: Cretaceous Research*, 15, 469-501.
- [22] Kennedy, W.J., Juignet, P. and Hancock, J.M. 1981. *Upper Cenomanian ammonites from Anjou and Vendee, western France. Palaeontology* 24, 25-84, pls. 3-17, 17 text-figs.
- [23] Kossmat, F., 1895-1897, *Untersuchungen über die Südlindische Kreideformationen: Beitrage zur Palaontologie und Geologie Österreich-Ungarns und des Orients*, 9 (1985), 97-203 (1-107), pl. 15-25 (1-11); 11 (1897), 1-46 (108-153), pl. 1-8 (12-19); 11 (1898), 89-152 (154-217), pl. 14-19 (20-25).

- [24] Lewy, Z., 1989, Correlation of lithostratigraphic units in the upper Judea Group (Late Cenomanian-Late Coniacian) in Israel: Israel Journal of Earth sciences, 38, 37-43.
- [25] Mahmoud, I.G. el-Din, 1956, Études paléontologiques sur la faune crétacique du massif du Moghara (Sinai, Egypt): Publications de l'Institut du Desert d'Égypte, 8, 1-192, pl. 1-19.
- [26] Mantell, G.A., 1822, The fossils of the South Downs, or Illustrations of the Geology of Sussex: L. Rolfe, London, xiv + 238 p., 3 figs., 43 pls.
- [27] Mouty, M., Al-Maleh, A.K., Laban, H.A., 2003, Le Crétacé moyen de la chaîne des Palmyrides (Syrie centrale): Geodiversitas, 25(3), 429-443.
- [28] Naji, F., 1996, Biostratigraphy and economic significance of Cretaceous sediments in Jordan: Mitteilungen aus dem Geologisch-Paläontologischen Institut, Universität Hamburg, 77, 443-460.
- [29] Nazzari, J., Mustafa, H., 1993, Ammonites from the Upper Cretaceous of north Jordan: Abhath Al-Yarmouk, Pure Science and Engineering Series, 2(2), 87-120.
- [30] Neumann, C., 1999, new spatangoid echinoids (Echinodermata) from the Upper Cretaceous of Jordan: their taxonomy and phylogenetic importance: Berliner Geowissenschaftliche Abhandlungen, Reihe E, 30, 175-189.
- [31] Parnes, A., 1964, Coniacian ammonites from the Negev (Southern Israel): Geological Survey of Israel Bulletin, 39, 1-42.
- [32] Perrilliat, M.C., Ahmad, F., Vega, F.J., 2006, Upper Cretaceous (Cenomanian-Turonian) bivalves from northern Jordan, Middle East: Revista Mexicana de Ciencias Geológicas, 23(1), 96-106.
- [33] Pervinquière, L., 1907, Études de paléontologie tunisienne. I. Céphalopodes des Terrains secondaires: Carte Géologique de la Tunisie, Rudeval, Paris, 438 p., 158, figs., 27 pls.
- [34] Pictet, F.J., 1863, Mélanges paléontologiques. 4. Discussion sur les variations et les limites de quelques espèces d'ammonites du groupe de *A. rotomagensis* et *mantelli*: Mémoires de la Société de Physiques et d'Histoire Naturelle de Genève, 17, 15-39.
- [35] Porthault, B., Thomel, G., De Villoutreys, O., 1966, Étude biostratigraphique du Cénomanien du Bassin Supérieur de l'Esteron (Alpes-Maritimes). Le problème de la limite Cénomanien-Turonien dans le sud-est de la France: Bulletin de la Société géologique de France, 7(8), 423-439.
- [36] Powell, J.H., 1989, Stratigraphy and sedimentation of the Phanerozoic rocks in Central and South Jordan; part B, Kurnub, Ajlun and Belqa Groups: Amman, Jordan, Natural Resources Authority, Bulletin, 11, 130 p.
- [37] Sabaheen, L., Mustafa, H., 2000, Echinoids from Late Cretaceous in Northern Jordan: Abhath Al-Yarmouk, Pure Science and Engineering Series, 9(2), 35-81.
- [38] Schulze, F., Lewy, Z., Kuss, J., Gharaibeh, A., 2003, Cenomanian-Turonian carbonate platform deposits in west-central Jordan: International Journal of Earth Sciences, 92, 641-660.
- [39] Schulze, F., Marzouk, A., Bassiouni, A.A., Kuss, J., 2004, The Late Albian-Turonian carbonate-platform succession of west-central Jordan: stratigraphy and crisis: Cretaceous Research, 25, 709-737.
- [40] Shinaq, R., Bandel, K., 1998, Lithostratigraphy of the Belqa Group (Late Cretaceous) in northern Jordan: Universität Hamburg, Mitteilungen aus dem Geologisch-Paläontologischen Institut, 81, 163-184.
- [41] Spath, L.F., 1926, On the zones of the Cenomanian and the uppermost Albian: Proceedings of the Geologists' Association, 37, 420-432.
- [42] Spath, L.F., 1931, A Monograph of the Ammonoidea of the Gault: Monographs of the Palaeontographical Society, London, Part 8, 313-378, figs. 103-124, pls. 31-36.
- [43] Stoliczka, F., 1864, Ammonitidae, with revision of the Nautilidae, 57-106, in H. F. Blandford and F. Stoliczka (eds.), The fossil Cephalopoda of the Cretaceous rocks of southern India: Memoirs of the Geological Survey of India, Palaeontologica Indica (series 3), 1, 216 p, 94 pls.
- [44] Thomel, G., 1969, Réflexions sur les genres *Eucalycoceras* et *Protacanthoceras* (Ammonoidea): Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences, Séries D, Sciences Naturelles, 268, 649-652.
- [45] Thomel, G., 1972, Les Acanthoceratidae cénomaniens des chaînes subalpines méridionales: Mémoires de la Société Géologique de France, n. s. 116, 1-204.
- [46] Thomel, G., 1992, Ammonites du Cénomanien et du Turonien du sud-est de la France, Tome 1, Le Cénomanien des Chaînes subalpines méridionales et de la Provence Orientale (Alpes de Haute-Provence, Alpes-Maritimes, var): Nice Serre Editeur, 422 p., 42 pls.
- [47] Tröger, K.-A., Kennedy, W.J., Burnett, J.A., Caron, M., Gale, A.S., Robaszynski, F., 1996, The Cenomanian stage: Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Sciences de la Terre, 66, 57-68.
- [48] Taubenhaus, H., 1920, Die Ammoniten der Kreideformation Palästinas und Syriens: Deutschen Palästina-Vereins Zeitschrift, 43, 1-58.
- [49] Vašiček, Z., 1992, Cenomanian ammonites from the Bohemian Cretaceous Basin: Cas. Národní Muzei v Praze, Rada přírodoved., 158 (1-4), 67-77.
- [50] Wetzel, R., Morton, D.M., 1959, Contribution a la géologie de la Transjordanie: Muséum National d'Histoire Naturelle, Paris, Notes et Mémoires sur le Moyen-Orient, 7, 95-191.
- [51] Wright, C.W., Calloman, J.H., Howarth, M.K., 1996, Treatise on Invertebrate Paleontology, Part L revised, Mollusca 4, Cretaceous Ammonoidea: Boulder, Colorado, and Lawrence, Kansas, The Geological Society of America Inc. and the University of Kansas Press, 362 p.
- [52] Wright, C.W., Kennedy, W.J., 1990, The Ammonoidea of the Lower Chalk: Palaeontographical Society Monographs, Part 3, 219-294.
- [53] Zittel, K.A. von, 1884, Cephalopoda, in K.A. Zittel (ed.), Handbuch der Palaeontologie: Muenchen und Leipzig, R. Oldenbourg, Band 1, Abt. 2, Lief 3, 329-522.