Acta Geologica Polonica, Vol. 61 (2011), No. 2, pp. 175–192

Cenomanian Acanthoceratoidea (Cretaceous Ammonoidea) from the Koppeh Dagh, NE Iran: taxonomy and stratigraphic implications

ABDOLMAJID MOSAVINIA[1] AND MARKUS WILMSEN[2]

[1]*Payame Noor University, Science Department, Vakilabad Blv., Satari Street, PO Box 433, Mashad, Iran.*
E-mail: mmosavinia@gmail.com
[2]*Senckenberg Naturhistorische Sammlungen Dresden, Museum für Mineralogie und Geologie, Sektion Paläozoologie, Königsbrücker Landstr., 159, D–01109 Dresden, Germany.*
E-mail: markus.wilmsen@senckenberg.de

ABSTRACT:

Mosavinia, A. and Wilmsen, M. 2011. Cenomanian Acanthoceratoidea (Cretaceous Ammonoidea) from the Koppeh Dagh, NE Iran: taxonomy and stratigraphic implications. *Acta Geologica Polonica*, **61** (2), 175–192. Warszawa.

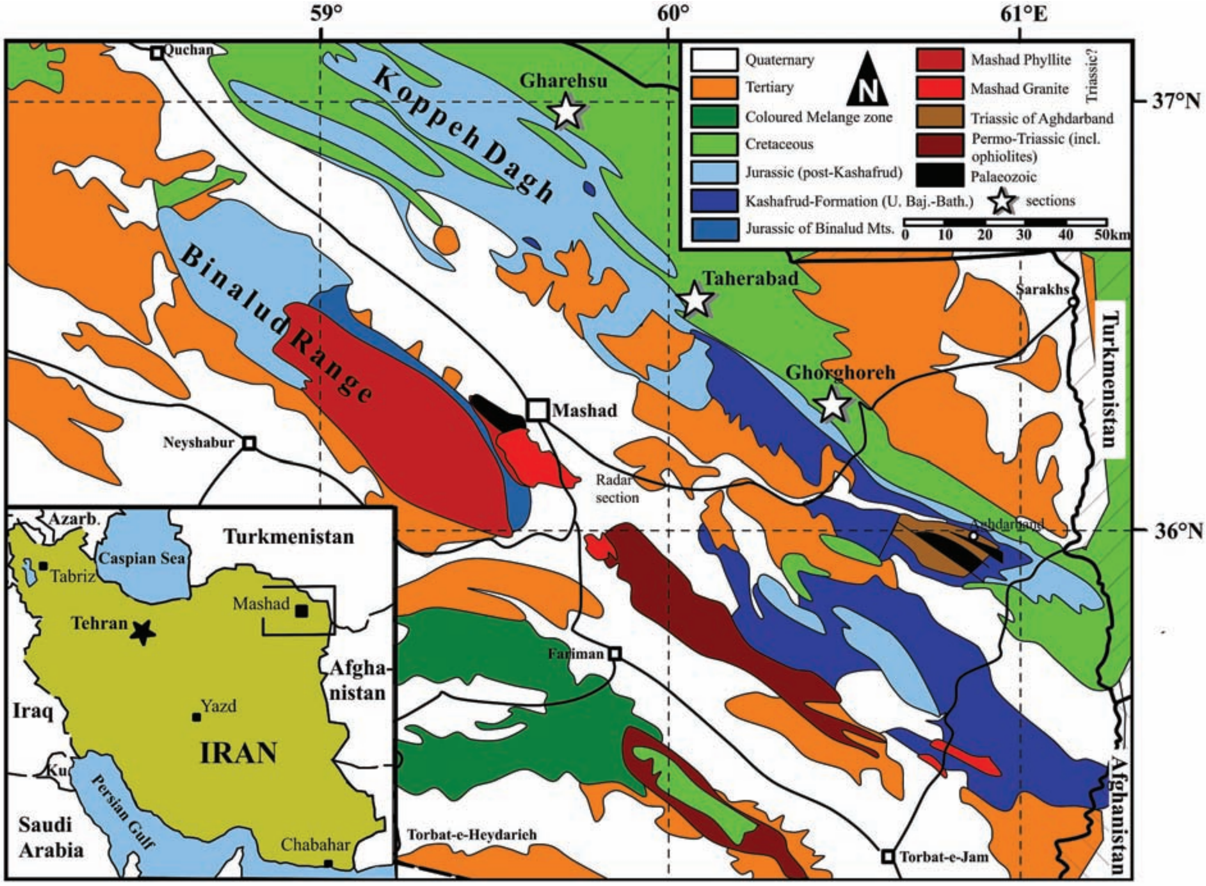
Seven species of the acanthoceratoidean genera *Forbesiceras* Kossmat, 1897, *Mantelliceras* Hyatt, 1903, *Acanthoceras* Neumayr, 1875 and *Cunningtoniceras* Collignon, 1937 are described and illustrated from the upper (i.e., Cenomanian) part of the Aitamir Formation of the Koppeh Dagh, northeast Iran. The mantelliceratines were collected from Lower Cenomanian silty shales while the rest of the fauna stems from lower Middle Cenomanian glauconitic sandstones in the upper part of the formation. The ammonite association allows recognition of the lower Lower Cenomanian *Mantelliceras mantelli* and the lower Middle Cenomanian *Acanthoceras rhotomagense* zones. The upper Lower Cenomanian *M. dixoni* Zone is not proven by its index but is most likely represented by a unit of fossil-poor shales intercalated between the two above-mentioned zones. The lowermost Middle Cenomanian *Cunningtoniceras inerme* Zone, however, is potentially at least partly missing due to a major sea-level fall and lowstand in the latest Early to earliest Middle Cenomanian. A preliminary sequence stratigraphic interpretation of the successions suggests the presence of Lower Cenomanian sequence boundaries SB Ce 1–3. The Aitamir Formation is truncated along a major regional unconformity at the base of the overlying Abderaz Formation (Turonian–Coniacian). The Upper Cenomanian and most likely also (parts of) the Lower Turonian are missing. This major unconformity has a tectonic origin as it deviates from the eustatic sea-level trend which was very high at this time. Furthermore, contemporaneous tectonic unconformities are also known from Central Iran and may have their origins in rotational movements of the Central-East Iranian Microcontinent.

Key words: Upper Cretaceous; Ammonites; Systematic palaeontology; Biostratigraphy; Sequence stratigraphy.

INTRODUCTION

Cretaceous strata are widespread, very thick and often fairly fossiliferous in different regions of Iran (Zagros and Alborz Mountains, Koppeh Dagh and Central Iran; see Afshab-Harb 1994 and Davoudzadeh 1997 for overview). However, there is only limited information to date on the exact chronostratigraphy of the units and their depositional environments.

Ammonoids are comparatively common in the Cretaceous strata of the Koppeh Dagh and have previously been used for the zonation of lithostratigraphic



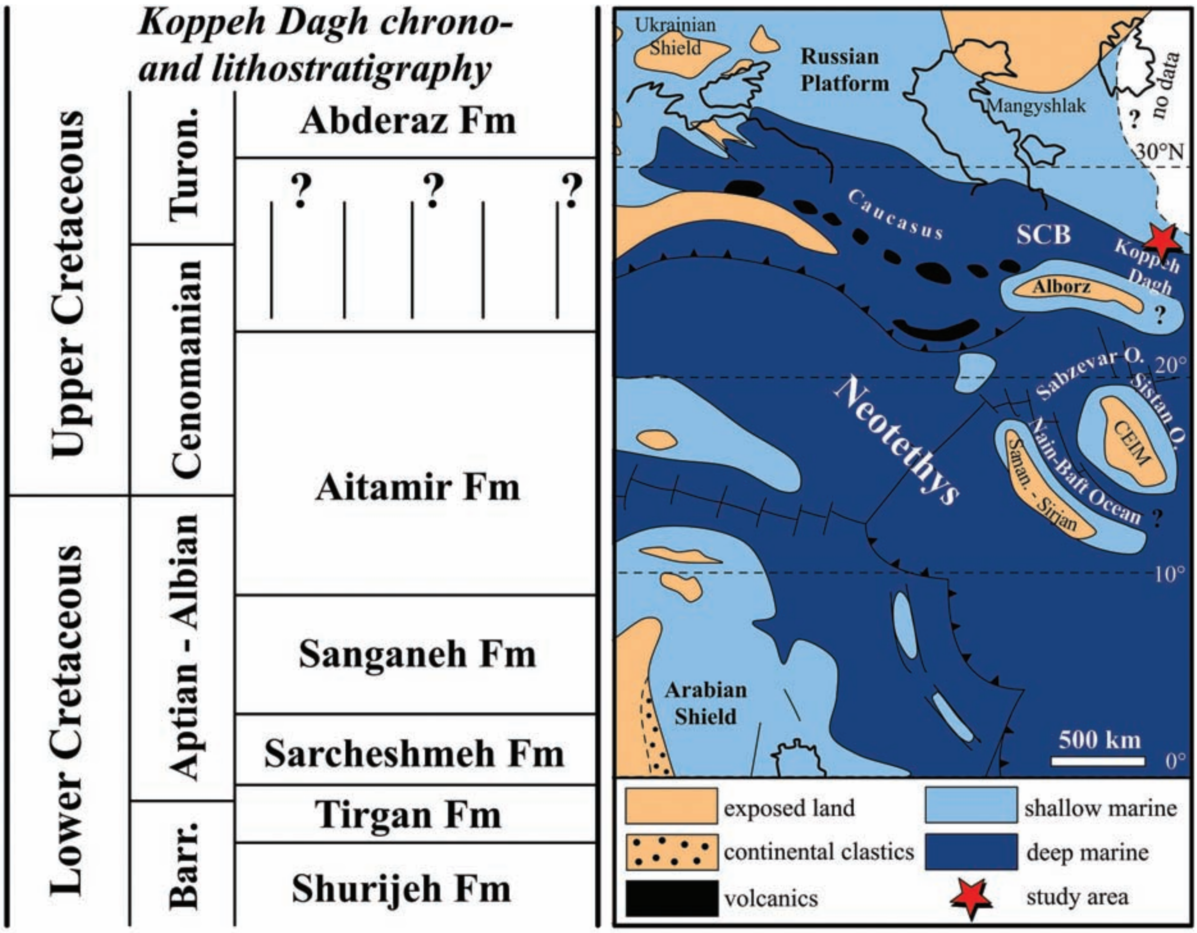
Text-fig. 1. Geological map of NE Iran with indication of measured sections

formations (e.g., Immel *et al*. 1997). During fieldwork in the eastern Koppeh Dagh (Text-fig. 1), abundant and well preserved ammonoids have been collected from the Aitamir Formation, and the exact stratigraphic levels of the specimens indicated in the measured sections (Mosavinia 2008). This paper focuses on the Cenomanian Acanthoceratoidea of the upper Aitamir Formation of the eastern Koppeh Dagh of NE Iran. Here, we use an ammonoid association for discussion of the biostratigraphy and sequence stratigraphy of the upper, i.e. Cenomanian part of the Aitamir Formation.

GEOLOGICAL SETTING

The Koppeh Dagh Mountains (Text-fig. 1) preserve a very thick succession of marine Cretaceous strata ranging from the Barremian/Aptian to the Maastrichtian (e.g. Berberian and King 1981; Afshab-Harb 1994; Immel *et al.* 1997). The sequence was deposited on the northern shelf of a deeper marine basin separating the Iran Plate from Eurasia (Turan Plate) during the Cretaceous (Text-fig. 2). Fault-related subsidence resulted in the deposition of several kilometres of Cretaceous sediments in the Koppeh Dagh Basin (e.g., Berberian and King 1981; Afshab-Harb 1994). Depositional environments comprise carbonate platform (Tirgan Formation, Barremian–lowermost Aptian), deeper marine marly shelf (Sarcheshmeh and Sanganeh formations, Aptian–Lower Albian), siliciclastic shelf (Aitamir Formation, Albian–Cenomanian) and pelagic chalky limestones (Abderaz Formation, Turonian–Coniacian). The Aitamir Formation (Text-fig. 2) represents an up to 1,000 m thick succession of fairly fossiliferous, fine- to medium-grained, often glauconitic and/or bioclastic sandstones, with sandstone-siltstone intercalations, and thick packages of dark grey to green, silty to fine sandy shales. The depositional environment was a graded shelf with of inner, mid- and outer shelf subenvironments (Mosavinia 2008).

The rich ammonite faunas of Boreal (NW European) affinity (Seyed-Emami and Aryai 1981; Seyed-Emami *et al.* 1984; Seyed-Emami 1988; Immel *et al.* 1997; Raisossadat 2006; Mosavinia *et al.* 2007; Wilmsen and Mosavinia 2011) allow a precise biostratigraphic corre-



Text-fig. 2. Litho- and chronostratigraphy of the Iranian part of the Koppeh Dagh (cf. Afshab-Harb 1994) and plate tectonic setting of the study area (modified after Philip and Floquet 2000)

lation with the mid-Cretaceous standard biozonations (Hancock 1991; Gale 1995; Gradstein *et al*. 2004).

SECTIONS

Sections have been logged in the Koppeh Dagh Mountains north, northeast and east of Mashad at the following localities (Text-fig. 1):

1 - Ghorghoreh, situated ca. 70 km E of Mashad (coordinates: N 36° 13′ 34″, E 60° 24′ 18″; altitude: 942 m). At Ghorghoreh, the upper Aitamir Formation is fairly thick, consisting of 350 m of Cenomanian shales. Close to the Albian–Cenomanian boundary, a sharp-based, glauconitic bioclastic sandstone bed, 3–5 m thick, is overlain by ca 20 m of sandy, glauconitic shale, followed by a thick, monotonous sequence of dark, olive-green silty shales. 250 m and 300 m above the basal bioclastic sandstone bed, two sharp-based, glauconitic-bioclastic sandstone beds, 2–3 m thick, are intercalated, up to which ammonoids of the lower Lower Cenomanian *Mantelliceras mantelli* Zone occur. 350 m above the base, the marls and limestones of the Abderaz Formation (Turonian–Coniacian) follow, overlying an erosion surface. The age of the uppermost 50-m-thick shale sequence of the Aitamir Formation at Ghorghoreh is uncertain, but a late Early Cenomanian age is inferred based on sequence stratigraphic correlations (see below).

2 - Taherabad, situated ca. 50 km NE of Mashad (co-ordinates: N 36° 37′ 05″, E 60° 04′ 03″; altitude: 982 m). The Taherabad section consists of ca. 250 m of Lower Cenomanian dark, silty shales, followed by ca. 60 m of Middle Cenomanian strata. In the middle of the Lower Cenomanian, a 3-m-thick, sharp-based bioclastic, fossililiferous sandy limestone yielding bivalves and an 11-m-thick bundle of two sandstone beds embracing sandy shale punctuate the succession. Below those coarse-grained beds, ammonoids of the *M. mantelli* Zone occur while the shales above yielded no age-diagnostic ammonoids. Based on the

superposition by lower Middle Cenomanian strata, they are of inferred late Early Cenomanian age. The Lower Cenomanian succession is unconformably overlain by a 16-m-thick unit of sandstone and sandy shale, glauconitic in the upper part and containing lower Middle Cenomanian ammonoids. Above that, ca. 40 m of dark, silty shales follow, erosionally overlain by the Abderaz Formation.

3 - Gharehsu, situated ca. 90 km N of Mashad (co-ordinates: N 36° 58′ 36″, E 59° 41′ 02″; altitude: 1147 m). The Cenomanian part of the Aitamir Formation is relatively thick here, consisting of >300 m of silty shales and intercalated glauconitic sandstone. Overlying shales with Upper Albian ammonoids (Mosavinia 2008), a ca. 10-m-thick set of two glauconitic sandstones with Lower Cenomanian *Schloenbachia varians* at the top occurs near the Albian–Cenomanian boundary. Like in Taherabad, two sandstone intercalations punctuate the Lower Cenomanian succession, which is unconformably overlain by a set of 10-m-thick glauconitic sandstones yielding lower Middle Cenomanian ammonoids at the top. The Aitamir Formation is erosionally truncated at the unconformable base of the overlying Abderaz Formation consisting of (hemi-) pelagic marl and limestone.

Synoptic sections, including all data concerning litho-, bio- and sequence stratigraphy, are shown in the discussion at the end of the paper.

SYSTEMATIC ACCOUNT

The studied ammonoids are arranged systematically and described according to Wright *et al.* (1996). All linear dimensions, taken with a Vernier Caliper, are given in millimetres. The abbreviations used are: maximum diameter (D), whorl breadth (Wb), whorl height (Wh), breadth of umbilicus (U).

Cenomanian ammonoid faunas are well known. The descriptions are thus kept short and the synonymies contain only the first reference of the taxa, those being of regional interest, important revisions and subsequent references. The material is stored in the Museum für Mineralogie und Geologie (MMG) of the Senckenberg Naturhistorische Sammlungen Dresden (SNSD), Germany (repository AsK) and the institutional collection of the Payame Noor University, Mashad, Iran (PNU).

Superfamily Acanthoceratoidea de Grossouvre, 1894
Family Forbesiceratidae Wright, 1952

Genus *Forbesiceras* Kossmat, 1897
Forbesiceras baylissi Wright and Kennedy, 1984
Text-fig. 3F

1984. *Forbesiceras baylissi* sp. nov. Wright and Kennedy, p. 92, pl. 13, figs 3–5.
1998. *Forbesiceras* cf. *baylissi* Wright and Kennedy, 1984; Kaplan *et al.* p. 114, pl. 11, fig. 4.

DIMENSIONS:

Specimen	D	Wh	Wb	Wb/Wh	U
At. Ta. F6	–	22	8	0.36	–

MATERIAL: 5 specimens from the upper part of the Aitamir Formation at Taherabad and Ghorghoreh.

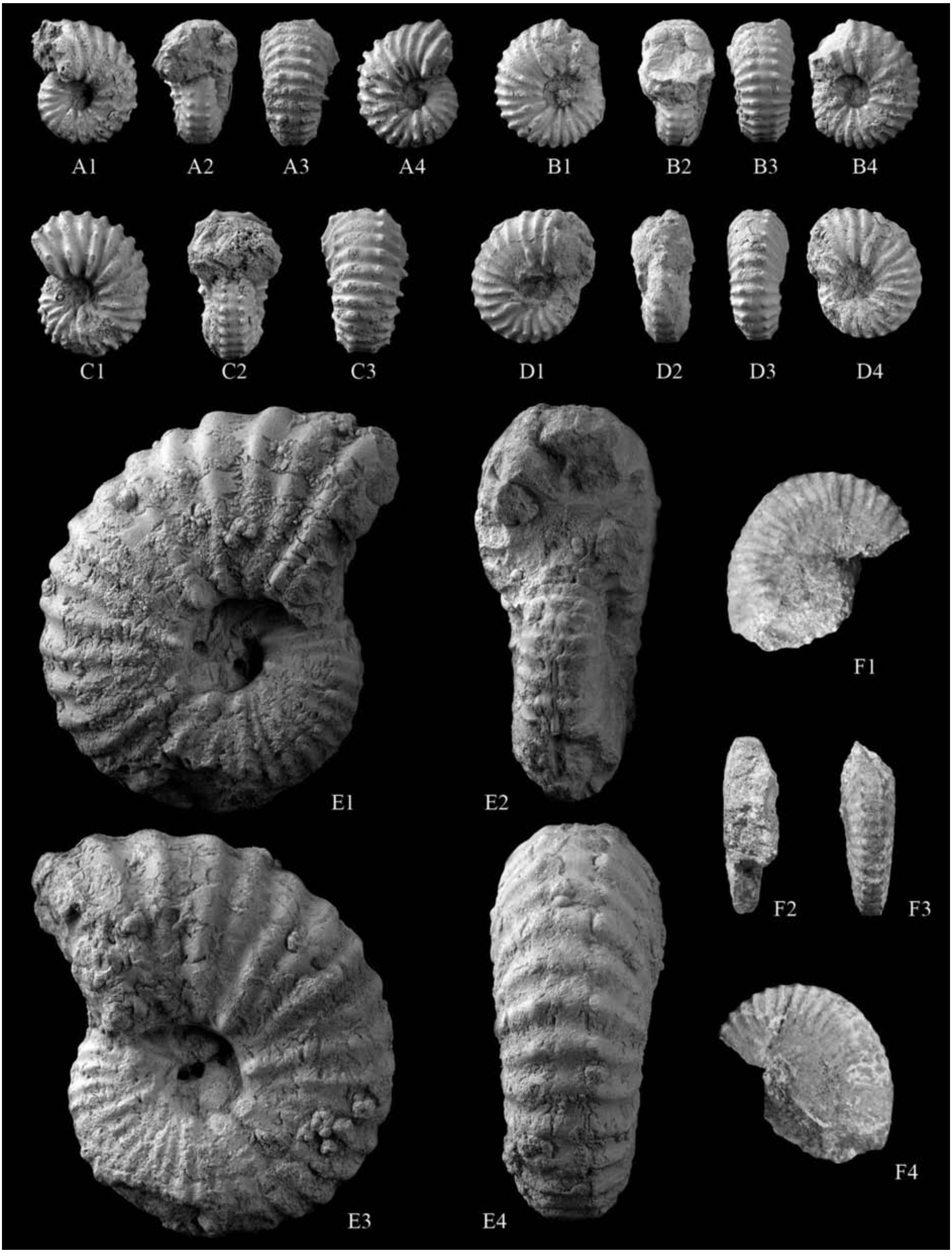
DESCRIPTION: The whorl section is compressed, much higher than wide (Wb/Wh = 0.36). Even in fragmentary preservation, the involute coiling is clearly visible. The ribs originate from faint tubercles situated at mid-flank. On the outer flank, they flex forward and form clavate tubercles. A row of siphonal tubercles is clearly visible.

DISCUSSION: According to Wright and Kennedy (1984, p. 93) and Kaplan *et al.* (1998, p. 114), *Forbesiceras baylissi* is transitional between *F. largilliertianum* (d'Orbigny, 1841) und *F. obtectum* (Sharpe, 1853). *F. baylissi* differs from other forbesiceratids in its prominent, strong ribs which are bent forwards. Furthermore, the row of siphonal tubercles is a characteristic feature of the species. The specimens described herein are similar to the holotype as illustrated by Wright and Kennedy (1984, pl. 13, fig. 4).

DISTRIBUTION: The material from Taherabad stems from the upper, sandy beds of the Aitamir Formation and has been collected together with *Acanthoceras rhotomagense* (Brongniart, 1822), confirming an early Middle Cenomanian age. The specimens from Ghorghoreh are from the upper Lower Cenomanian (uppermost *Mantelliceras mantelli* or lower *M. dixoni* Zone). The type specimens from England are either late Early (*M. dixoni* Zone) or early Middle Cenomanian (*Acanthoceras rhotomagense* Zone) in age (Wright and Kennedy 1984). The species is reported for the first time from Iran.

Family Acanthoceratidae de Grossouvre, 1894
Subfamily Mantelliceratinae Hyatt, 1903
Genus *Mantelliceras* Hyatt, 1903

Mantelliceras mantelli (J. Sowerby, 1814)
Text-figs 3A–E



Text-fig. 3. Mantelliceratinae and Forbesiceratidae from the Aitamir Formation of the Koppeh Dagh, NE Iran. All figures in natural size. **A-E** – *Mantelliceras mantelli* (J. Sowerby, 1814) from Ghorghoreh (A1-A4, specimen At.Go.f34.2; B1-B4, specimen At.Go.f27.3; C1-C3, specimen At.Go.f34.3; D1-D4, specimen At.Go.f36.1; E1-E4, specimen At.Go.f2). **F** – *Forbesiceras baylissi* Wright and Kennedy, 1984; specimen At.Ta. F6 from Taherabad

1814. *Ammonites mantelli* J. Sowerby, p. 119, pl. 55 [only lower figure].
1981. *Mantelliceras mantelli* (J. Sowerby); Seyed-Emami and Aryai, p. 32, pl. 8, figs 5a–c.
1984. *Mantelliceras mantelli* (J. Sowerby, 1814); Wright and Kennedy, p. 99, pl. 16, fig. 5; pl. 17, figs 1, 3; pl. 18, figs 1–3; pl. 19, figs 1–6; pl. 21, figs 2, 4; pl. 24, fig. 3; pl. 36, fig. 1; text-figs 20A–D, 26A, C, E. [with synonymy]
1986. *Mantelliceras mantelli* (J. Sowerby, 1814); Kennedy *et al.*, p. 22, figs 2, 4a–g, 10d, e, 23a, b, f.
1994. *Mantelliceras mantelli* (J. Sowerby, 1814); Kennedy, p. 222, pl. 7, figs 1, 2, 9.
1996. *Mantelliceras mantelli* (J. Sowerby, 1817); Gale *et al.*, p. 561, figs 7q, 15d, 19d, i.
1997. *Mantelliceras mantelli* (J. Sowerby); Immel *et al.*, p.169.
1997. *Mantelliceras mantelli* (J. Sowerby); Wilmsen, pl. 6, fig. 6; pl. 23, fig. 4.
1998. *Mantelliceras mantelli* (J. Sowerby, 1814); Kaplan *et al.*, p. 115, pl. 17, figs 12, 13; pl. 19, figs 1–9; pl. 22, figs 3, 4; pl. 23, fig. 8; pl. 24, figs 4–6; pl. 25, figs 1-5.
2002. *Mantelliceras mantelli* (J. Sowerby, 1814); Amédro *et al.*, p. 10, pl. 3, fig. 1, pl. 4, fig. 1.
2009. *Mantelliceras mantelli* (J. Sowerby, 1814); Wilmsen *et al.*, p. 114, fig. 3.
2010. *Mantelliceras mantelli* (J. Sowerby, 1814); Wilmsen and Niebuhr, p. 270, fig. 4A.

DIMENSIONS:

Specimen	D	Wh	Wb	Wb/Wh	U
At.Go. F_{34}III	27	12	16	1.33	ca.7
At.Go. F_{2}	70	34	31	0.91	19
At.Go. F_{34}II	21	10	14	1.4	6
At.Go. F_{36}I	24	12	ca. 12	ca. 1	6
At.Go. F_{27}III	23	11	14	1.27	7
At.Go. F_{27}I	30	15	14	0.93	ca.8

MATERIAL: More than 150 specimens from Ghorghoreh. Most specimens are fully septate inner whorls and diameters range between 21 and 70 mm.

DESCRIPTION: Coiling is involute to moderately evolute. The whorl section is slightly depressed in small and slightly compressed in larger specimens, with circular to oval intercostal and polygonal costal whorl sections. The umbilicus is moderately deep, with a steep wall. The ornament consists of primary ribs arising at the umbilical margin and irregularly long secondary ribs. All ribs are radial on the inner flank, flexing forward slightly on the outer flank. Primary ribs carry umbilical, lateral as well as inner and outer ventrolateral tubercles, the former ones being absent on secondary ribs. Tuberculation is less distinct in larger specimens. On the venter, the ribs are straight and somewhat weakened.

DISTRIBUTION: *Mantelliceras mantelli* has long been used as the ammonoid zonal index of the lower Lower Cenomanian (e.g., Hancock 1991), but the base of the Cenomanian Stage is now placed at the first occurrence of the planktonic foraminifer *Rotalipora globotruncanoides* Sigal, slightly below the entry of representatives of the genus *Mantelliceras* (Gale *et al.* 1996; Tröger and Kennedy 1996). However, in the absence of microfossil data, ammonoids are still fairly precise secondary markers, and *M. mantelli* is widely distributed in Europe, northern Africa, Madagascar, Iran, India and Japan (Wright and Kennedy 1984).

Mantelliceras cantianum Spath, 1926a
Text-figs 4A, B, H

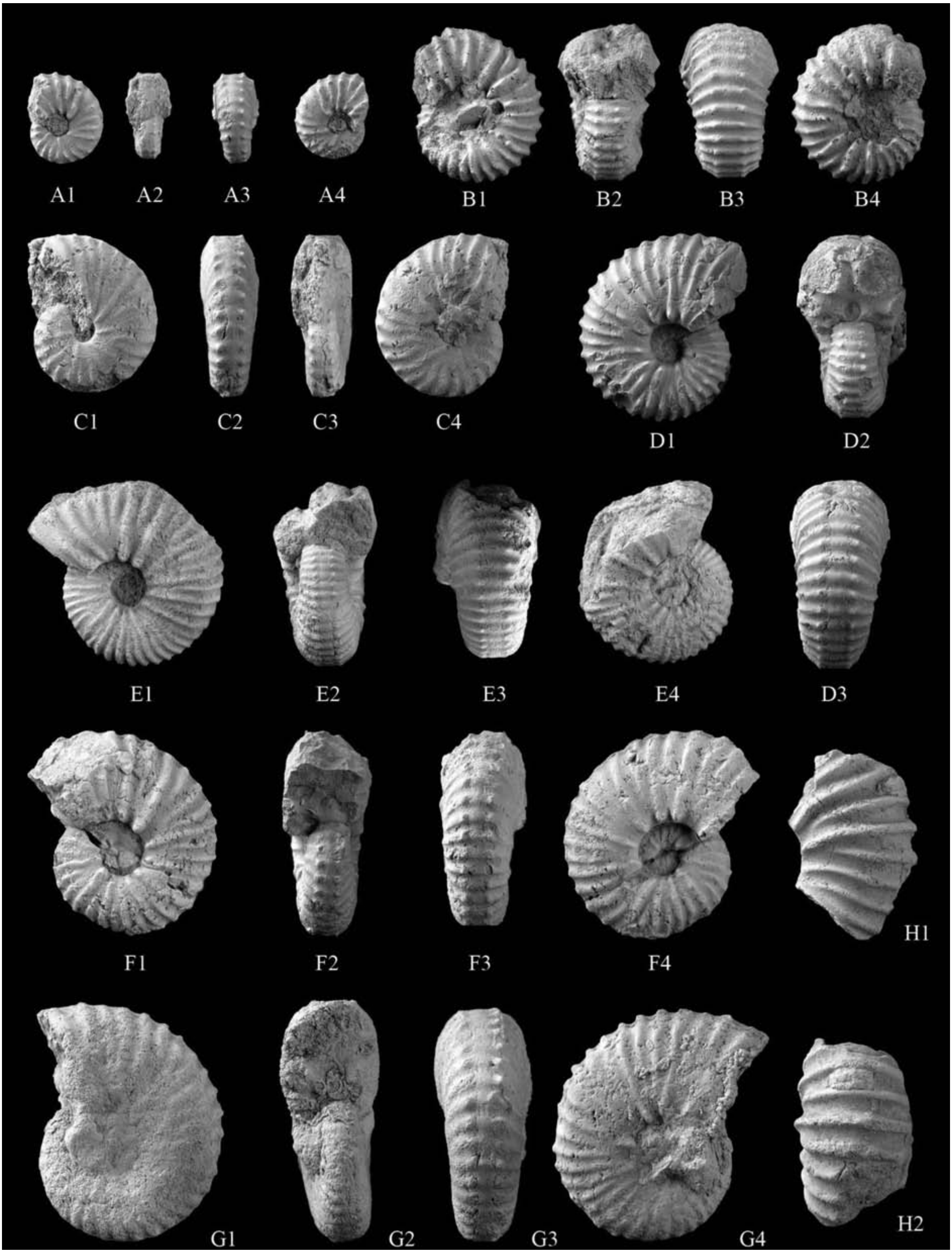
1926a. *Mantelliceras cantianum* Spath, p. 82.
1984. *Mantelliceras cantianum* Spath, 1926a; Wright and Kennedy, p. 103, pl. 17, fig. 2; pl. 20, fig. 3; pl. 21, fig. 3; pl. 24, figs 1, 2, 4–6; pl. 25, figs 1–6; pl. 26, figs 1, 2, 4, 5; text-figs 25a, 27e-n, j–l. [with synonymy]
1985. *Mantelliceras cantianum* Spath; Immel and Seyed-Emami, pl. 4, fig. 6.
1986. *Mantelliceras cantianum* Spath, 1926; Kennedy *et al.*, p. 31, figs 2b, e, 6a–e, 7, 8a–c; 16i–j, 18a–e, 20e–f.
1994. *Mantelliceras cantianum* Spath, 1926a; Kennedy, p. 223, pl. 8, figs 10, 11.
1997. *Mantelliceras cantianum* Spath; Immel *et al.*, p. 170.
1998. *Mantelliceras cantianum* Spath, 1926a; Kaplan *et al.*, p. 116, pl. 18, figs 5, 6, 10, 11; pl. 20, figs 2, 3; pl. 21, figs 1–3; pl. 26, fig. 6. [with additional synonymy]
2002. *Mantelliceras cantianum* Spath, 1926a; Amédro *et al.*, p. 10, pl. 3, fig. 3, pl. 4, fig. 2.

DIMENSIONS:

Specimen	D	Wh	Wb	Wb/Wh	U
At. Go. F_{24} II	29	13	18	1.38	9
At. Go. F_{37} III	–	22	ca. 26	ca. 1.18	–
At. Go. F_{35} III	16	10	9	0.9	4

MATERIAL: 17 specimens from Ghorghoreh.

DESCRIPTION: The present specimens are moderately involute with a deep umbilicus. The whorl section is subquadrate in early stages, becoming depressed with a rounded venter during ontogeny. The ornament consists of coarse, slightly flexuous primary ribs alternating with one or two short unlevelny long interca-



Text-fig. 4. Mantelliceratinae from the Aitamir Formation of the Koppeh Dagh, NE Iran. All specimens from Ghorghoreh and in natural size. **A, B** – *Mantelliceras cantianum* Spath, 1926a (A1-A4, specimen At.Go.f35.3; B1-B4, specimen At.Go.f24.2). **C, F, G** – *Mantelliceras saxbii* (Sharpe, 1857) (C1-C4, specimen At.Go.f35.1; F1-F4, specimen At.Go.f14.1; G1-G4, specimen At.Go.f24). **D, E** – *Mantelliceras lymense* (Spath, 1926b) (D1-D3, specimen At.Go.f13; E1-E4, specimen At.Go.f6). **H** – *Mantelliceras cantianum* Spath, 1926 (specimen At.Go.f37.3) lated ribs. The primaries of early whorls are quadrituberculate with umbilical, lateral as well as inner and outer ventrolateral tubercles, resulting in polygonal costal whorl sections (Text-fig. 4B). The inner ventrolateral tubercles usually disappear soon during ontogeny so that straight to slightly convex, largely untuberculated ribs cross the broad venters of larger specimens (Text-fig. 4H). Ribs are relatively distant (28–30 per whorl).

DISTRIBUTION: *Mantelliceras cantianum* occurs in the Lower Cenomanian *M. mantelli* and *M. dixoni* Zones. It is known from many places in Europe, Iran, Madagascar and Japan (Wright and Kennedy 1984).

Mantelliceras lymense (Spath, 1926b)
Text-figs 4D, E

1926b. *Eucalycoceras lymense* Spath, p. 427, 431.
1984. *Mantelliceras lymense* (Spath, 1926b); Wright and Kennedy, p. 102, pl. 10, figs 9; pl. 22, figs 1–6; pl. 23, figs 1–3; pl. 31, figs 1, 2; pl. 36, fig. 4; text-figs 19; 24 A, B; 26 D; 28 F–J. [with synonymy]
1986. *Mantelliceras lymense* (Spath, 1926b); Kennedy *et al.*, p. 27, fig. 19j, l.
1994. *Mantelliceras lymense* (Spath, 1926a); Kennedy, p. 224, pl. 7, figs 3, 4, 10, 11; pl. 11, fig. 2.
1996. *Mantelliceras lymense* (Spath, 1926b); Gale *et al.*, p. 563, figs 7q, 15d, 19d, i.
1997. *Mantelliceras lymense* (Spath); Wilmsen, pl. 18, fig. 7.
2008. *Mantelliceras lymense* (Spath, 1926b); Kennedy *et al.*, p. 131, pl. 5, fig. 16.

DIMENSIONS:

Specimen	D	Wh	Wb	Wb/Wh	U
At. Go. F_{13}	34	17	18	1.06	7
At. Go. F_6	37	–	17	–	8

MATERIAL: More than 30 specimens from Ghorghoreh.

DESCRIPTION: The general ribbing pattern of this species is similar to that of *M. mantelli*. However, the whorl section is slightly depressed and the tuberculation is different: lateral tubercles are absent and the inner ventrolateral tubercles disappear early in ontogeny; the umbilical tubercles may be strong and overhang the vertical umbilical wall. Furthermore, the ribbing density is slightly higher in *M. mantelli* (ca. 40 per whorl) and the intercalated ribs are more numerous (up to three).

DISTRIBUTION: *Mantelliceras lymense* occurs in the lower Lower Cenomanian *M. mantelli* Zone and is known from Europe, northern Africa, Madagascar and the Middle East, including Iran and Kazakhstan (Wright and Kennedy 1984; Kennedy *et al*. 2008).

Mantelliceras saxbii (Sharpe, 1857)
Text-fig. 4C, F, G

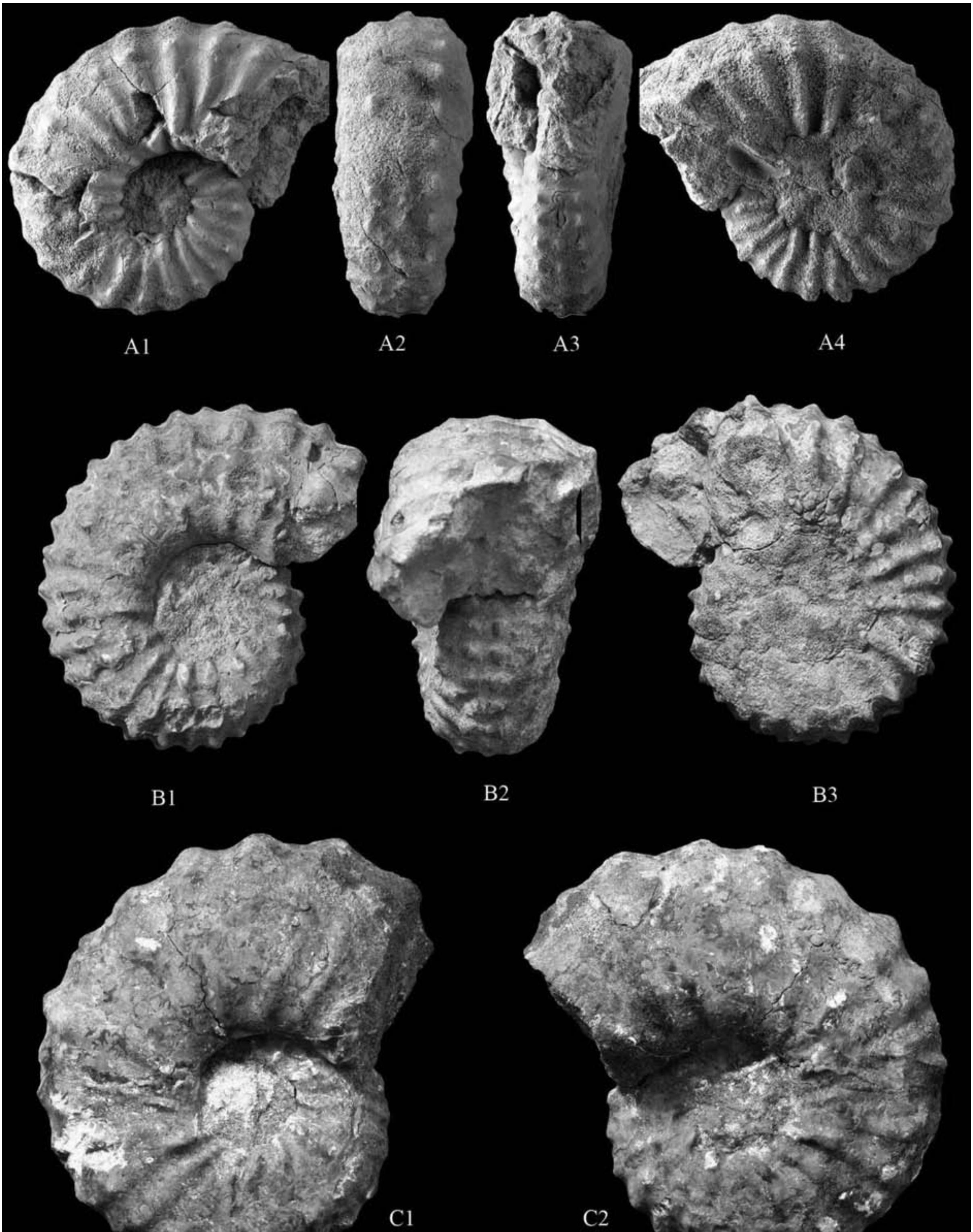
1857. *Ammonites saxbii* Sharpe, p. 45, pl. 20, fig. 3.
1981. *Mantelliceras saxbii* (Sharpe); Seyed-Emami and Aryai, p. 34, pl. 8, fig. 7, 8a–b; pl. 9, figs 1a–c, 2a–c.
1984. *Mantelliceras saxbii* (Sharpe, 1857); Wright and Kennedy, p. 121, pl. 23, fig. 4; pl. 32, figs 1–3; pl. 33, figs 1–4; pl. 34, figs 1–4; pl. 35, figs 1–5; pl. 36, figs 2, 3; pl. 39, fig. 1; text-figs 25B–D, I, 26B, 28L–P. [with synonymy]
1986. *Mantelliceras saxbii* (Sharpe, 1857); Kennedy *et al.*, p. 43, figs 1c; 2d; 9; 11e; 14b, c; 16a–d, g, h, k, l.
1994. *Mantelliceras saxbii* (Sharpe, 1857); Kennedy, p. 224, pl. 7, fig. 11; pl. 8, fig. 7.
1997. *Mantelliceras saxbii* (Sharpe, 1857); Immel *et al.*, p. 170.
1997. *Mantelliceras saxbii* (Sharpe); Wilmsen, pl. 24, figs 1, 2.
1998. *Mantelliceras saxbii* (Sharpe, 1857); Kaplan *et al.*, p. 118, pl. 18, figs 1, 9 pl. 20, fig. 1; pl. 24, fig. 3; pl. 26, figs 7, 8; pl. 41, 2, 4. [with additional synonymy]
2003. *Mantelliceras saxbii* (Sharpe); Kawabe *et al.*, pl. 2, fig. 1.
2005. *Mantelliceras saxbii* (Sharpe, 1857); Aly *et al.*, p. 370, pl. 7, figs 2, 3.
2008. *Mantelliceras saxbii* (Sharpe, 1857); Kennedy *et al.*, p. 130, pl. 5, fig. 13.

DIMENSIONS:

Specimen	D	Wh	Wb	Wb/Wh	U
At. Go. F_{14}I	39	20	16	0.8	11
At. Go. F_{24}I	42	21	17	0.81	11
At. Go. F_{35} I	29	16	10	0.62	6

MATERIAL: More than 20 specimens from Ghorghoreh.

DESCRIPTION: The coiling is rather involute, with a compressed whorl section. The flanks are flat to slightly convex. Primary ribs arise at the umbilical margin, often strengthened into umbilical bullae (Text-fig. 4F). Up to four irregularly long secondary ribs are intercalated. All ribs are prosiradiate and somewhat flexuous, carrying weak inner and prominent outer ventrolateral tubercles, the latter ones



Text-fig. 5. Acanthoceratinae from the Aitamir Formation of the Koppeh Dagh, NE Iran. All specimens from Taherabad and in natural size. **A-C** – *Acanthoceras rhotomagense* (Brongniart, 1822) (A1-A4, specimen At.Ta. 1F1.54; B1-B3, specimen At.Ta. F1; C1-C2, specimen At.Ta. 2F14) being clavate. The two rows of clavi join the flat, narrow venter which is crossed by straight, weakened ribs. Specimen At.Go.f24 (Text-fig. 4F) shows weak lateral tubercles at the end of the preserved whorl.

DISTRIBUTION: *Mantelliceras saxbii* is an Early Cenomanian species of the *M. mantelli* Zone that may range, as a rarity, into the succeeding *M. dixoni* Zone (Wright and Kennedy 1984). It is particularly common in the upper of the three subzones of the *M. mantelli* Zone, i.e. the *M. saxbii* Subzone. The species is known from Europe, northern and southern Africa, Madagascar and the Middle East, including Iran and Kazakhstan (Kennedy *et al*. 2008).

Subfamily Acanthoceratinae de Grossouvre, 1894
Genus *Acanthoceras* Neumayr, 1875

Acanthoceras rhotomagense (Brongniart, 1822)
Text-figs 5A–C

1822. *Ammonites rhotomagensis* Defr. Brongniart, p. 83, 391, pl. 6, fig. 2.
1984. *Acanthoceras tapara* Wright; Seyed-Emami *et al.*, p. 161, text-fig. 2, fig. 2a, b.
1987. *Acanthoceras rhotomagense* (Brongniart, 1822); Wright and Kennedy, p. 156, pl. 42, fig. 8; pl. 44, figs 1–11; pl. 45, figs 1–5; pl. 46, figs 1–4, 6; pl. 47, figs 1, 2; pl. 48, figs 1, 2; pl. 49, 1, 5, 6; text-figs 47–54; 63F–J; 64A, B; 65A–D, K; 66D, F, G, J; 67A–G; 68; 69. [with synonymy]
1993. *Acanthoceras rhotomagense* (Brongniart, 1822); Kennedy and Juignet, p. 171, figs 1c; 10b, c; 11a, q; 12a–h; 13a–d; 14a–e, h, I; 15a, b; 16a–c; 17a, b.
1994. *Acanthoceras rhotomagense* (Brongniart, 1822); Kennedy, p. 225, pl. 7, figs 5, 6; pl. 8, figs 8, 9; pl. 10, figs 5, 6.
1997. *Acanthoceras tapara* Wright, 1963; Immel *et al.*, p. 170.
1997. *Acanthoceras rhotomagense* (Brongniart); Wilmsen, pl. 12, figs 5, 6; pl. 15, fig. 2.
1998. *Acanthoceras rhotomagense* (Brongniart, 1822); Kaplan *et al.*, p. 140, pl. 41, fig. 3; pl. 42, fig. 1, 2; pl. 43, 44–46; pl. 47, fig. 1–3; pl. 54, fig. 1, 3, 4 [with additional synonymy]
2004. *Acanthoceras rhotomagense* (Brongniart, 1822); Barroso Barcenilla, p. 88, pl. 1, figs 1a, b.
2007. *Acanthoceras rhotomagense* (Brongniart, 1822); Wilmsen *et al.*, p. 433, fig. 4I, J.
2008. *Acanthoceras rhotomagense* (Brongniart, 1822); Wilmsen and Rabe, fig. 5I, J.

DIMENSIONS:

Specimen	D	Wh	Wb	Wb/Wh	U
At. Ta. F1	51	24	30	1.25	14
At. Ta. F3	44	20	22	1.1	–
At. Ta. F4	62	30	38	1.26	ca. 20

MATERIAL: 15 in part complete specimens from the top of the uppermost glauconitic sandstone of the Aitamir Formation at Taherabad and Gharehsu.

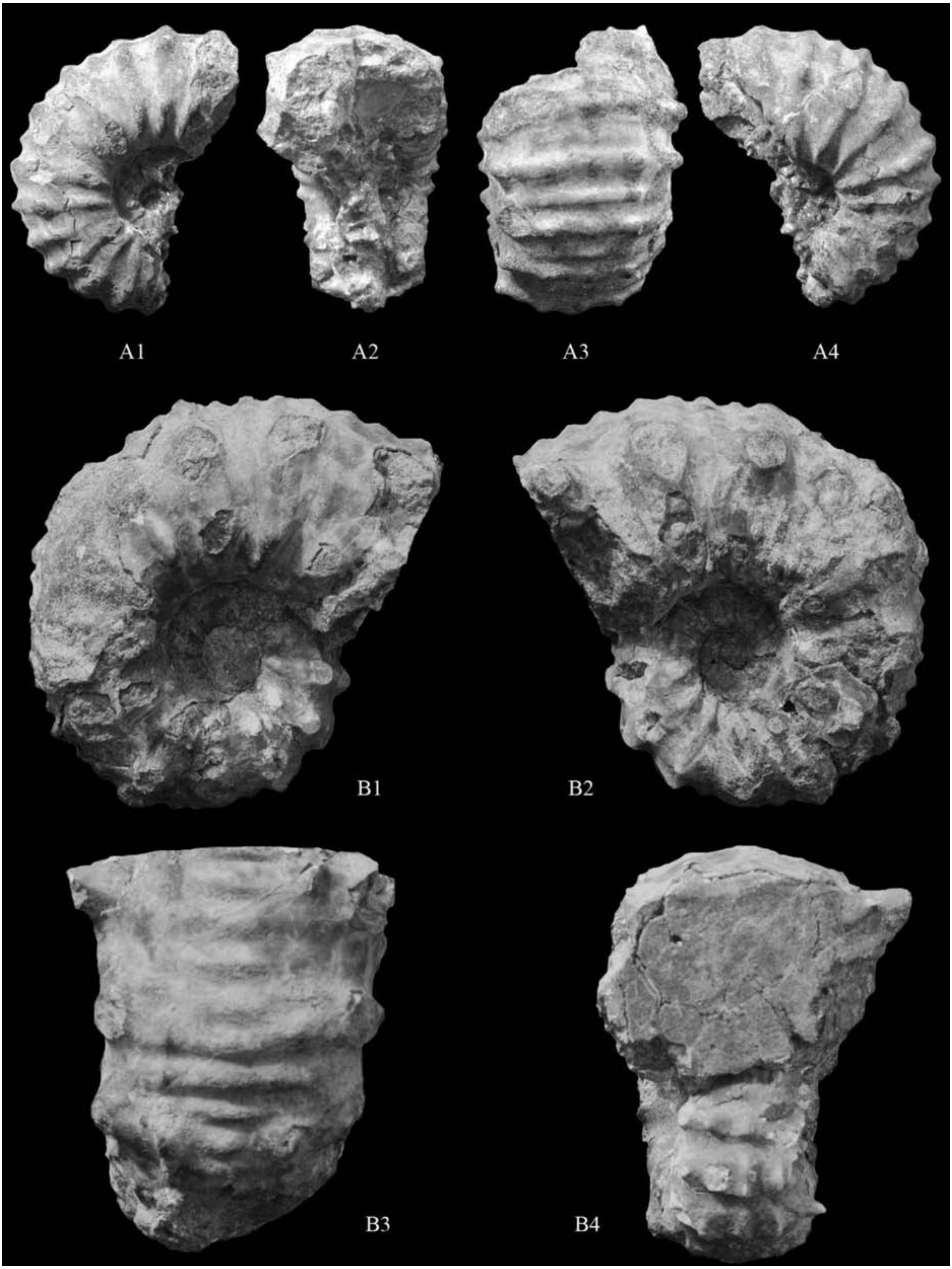
DESCRIPTION: The studied specimens are fairly evolute with quadrate to slightly depressed intercostal whorl sections (costal sections are polygonal). The umbilicus is deep with vertical walls and a rounded umbilical shoulder. Strong ribs carrying weak umbilical bullae arise from the upper part of the umbilical wall. Rare intercalated ribs are present. The ribs are straight to slightly flexed and carry conical inner and slightly clavate outer ventrolateral tubercles. The ribs weaken across the venter and bear a row of siphonal clavi. Larger specimens show the egression of the body chamber.

DISTRIBUTION: The Koppeh Dagh specimens were collected from the uppermost sandy-glauconitic beds of the Aitamir Formation at Taherabad and Gharehsu. The species is the index for the eponymous lower Middle Cenomanian ammonite zone, being known from many parts of Europe, northern Africa, the Middle East (including Iran) and northern Australia (Wright and Kennedy 1987).

Genus *Cunningtoniceras* Collignon, 1937

Cunningtoniceras cunningtoni (Sharpe, 1855)
Text-figs 6A, B, 7A, B

1855. *Ammonites cunningtoni* Sharpe, p. 35, pl. 15, fig. 2.
1984. *Euomphaloceras cunningtoni* (Sharpe); Seyed-Emami *et al.*, p. 160, text-fig. 2, fig. 1a, b, text-fig. 5, fig. 3a, b,.
1987. *Cunningtoniceras cunningtoni* (Sharpe, 1855); Wright and Kennedy, p. 196, pl. 52, fig. 2; pl. 53, fig. 4; text-figs 76–78. [with synonymy]
1993. *Cunningtoniceras cunningtoni* (Sharpe, 1855); Kennedy and Juignet, p. 174, figs 15c, d; 21c; 27c, d.
1994. *Cunningtoniceras cunningtoni* (Sharpe, 1855); Kennedy, p. 226.
1997. *Cunningtoniceras cunningtoni* (Sharpe, 1855); Immel *et al.*, p. 170, pl. 8, fig. 1.
1998. *Cunningtoniceras cunningtoni* (Sharpe, 1855); Kaplan *et al.*, p. 146, pl. 56, fig. 5, pl. 57.



Text-fig. 6. Acanthoceratinae from the Aitamir Formation of the Koppeh Dagh, NE Iran. All specimens from Taherabad and in natural size. **A, B** – *Cunningtoniceras cunningtoni* (Sharpe, 1855) (A1-A4, specimen At.Ta. 2F15; B1-B4, specimen At.Ta. F7)

DIMENSIONS:

Specimen	D	Wh	Wb	Wb/Wh	U
At. Ta. F2	–	30	46	1.53	–
At. Ta. F5	74	36	52	1.44	22
At. Ta. F7	74	42	46	1.09	22
At. Ta.1F1.33	74	32	50	1.56	26

MATERIAL: Five specimens from the uppermost sandstone layer of the Aitamir Formation at Taherabad, associated with *Acanthoceras rhotomagenese*.

DESCRIPTION: The specimens are evolute, mostly depressed, and strongly tuberculate. The umbilicus is deep and ca. 15 ribs per whorl arise at the upper umbilical wall, carrying strong tubercles low on the flanks, close to the umbilical shoulder. The ribs are straight to slightly flexed and bear spinose inner and conical to clavate outer ventrolateral tubercles. A row of slightly clavate siphonal tubercles is also present. On the venter, between the rather distant primary ribs, one to two intercalated ribs appear, carrying weakened outer ventrolateral and siphonal tubercles.

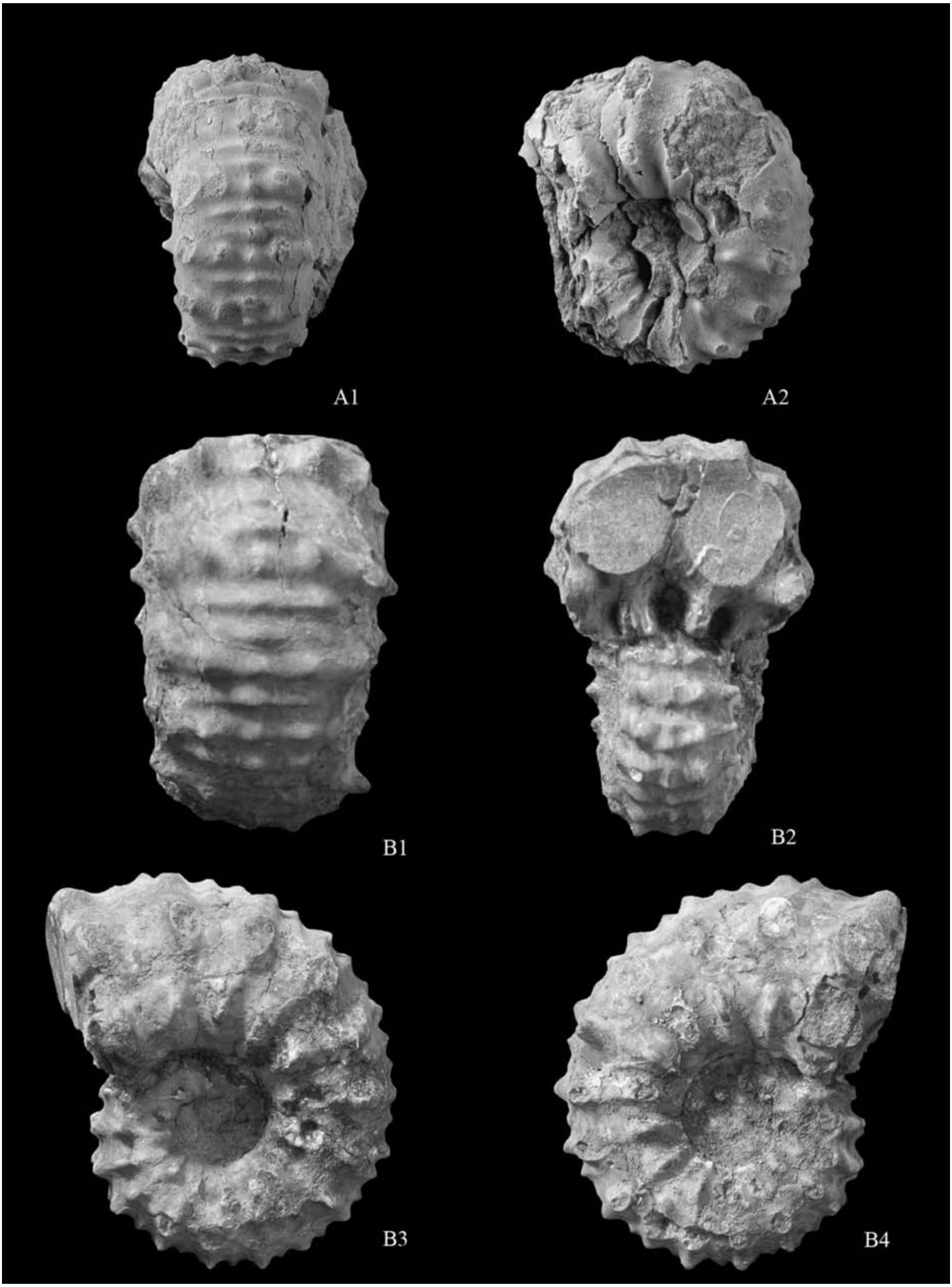
Zaborski (1985) illustrated a number of subspecies of *Cunningtoniceras cunningtoni* from Nigeria which mainly fall into the synonymy of the nominate species (Wright and Kennedy 1987). In particular, some of the specimens figured as *C. cunningtoni meridionale* (Stoliczka) by Zaborski (1985, figs 45, 46) are very similar to the Koppeh Dagh material.

DISTRIBUTION: The specimens were collected from the uppermost sandy-glauconitic bed of the Aitamir Formation at Taherabad. According to Wright and Kennedy (1987), *C. cunningtoni* occurs in the Middle Cenomanian (where stratigraphically well constrained in the *A. rhotomagense* Zone, *T. costatus* Subzone) and is known from western Europe, northern Africa, Nigeria, Angola, Madagascar, Iran, India, Japan, New Guinea, northern Australia and the U.S. Western Interior. Gale (1995), however, introduced the *C. inerme* Zone at the base of the Middle Cenomanian and mentioned *C. cunningtoni* as a common element of this pre-*A. rhotomagense* zone (see Text-fig. 8). As shown by Wilmsen *et al.* (2007), there is an overlap of *C. inerme*, *A. rhotomagense* and *T. costatus*, and the base of the *A. rhotomagense* Zone is defined by the first occurrence of its index species. Thus, the record from the Koppeh Dagh is most likely from the lower *A. rhotomagense* Zone. However, it cannot be excluded that the glauconitic bed with *C. cunningtoni* and *A. rhotomagense* is condensed and includes the upper *C. inerme* as well as the lower *A. rhotomagense* zones (see below).

DISCUSSION AND CONCLUSIONS

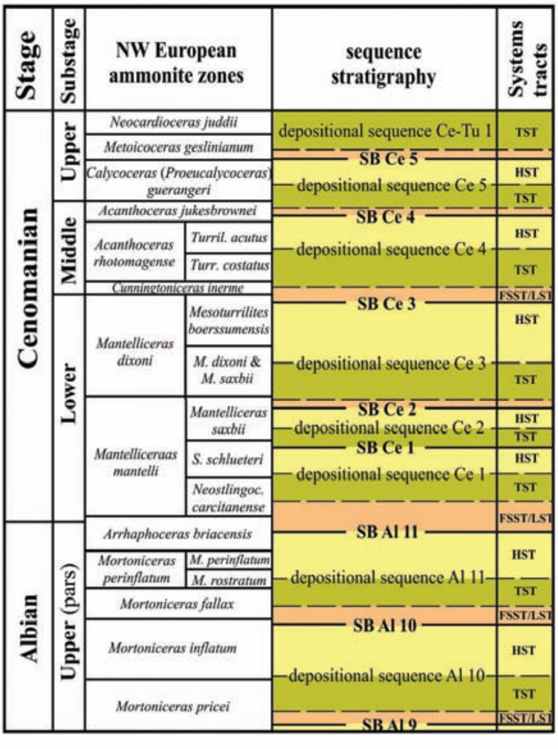
Hoplitoidea and Acanthoceratoidea characterize the ammonite association of the upper parts of the Aitamir Formation of the Koppeh Dagh, associated with a number of mainly turrilitid heteromorphs (Immel *et al.* 1997; Mosavinia 2008) which are also well known from the Turkmenistan (formerly Soviet Union) part of the Koppeh Dagh (Atabekian 1985). Apart from *Forbesiceras baylissi*, all acanthoceratoidean species briefly discussed herein have been mentioned or described from the region before (Kennedy et al. 1979; Seyed-Emami and Aryai 1981; Seyed-Emami *et al.* 1984; Immel *et al.* 1997). However, the excellent preservation and abundance of the fauna, together with significant progress in taxonomy and biostratigraphy, call for publication of the present study. Furthermore, the biostratigraphic data are used for a first attempt at a sequence stratigraphic interpretation of the upper Aitamir Formation.

The ammonite fauna allows unequivocal recognition of the lower Lower Cenomanian *Mantelliceras mantelli* and lower Middle Cenomanian *Acanthoceras rhotomagense* zones of the Cenomanian standard zonation (Hancock 1991; Gale 1995; Gradstein *et al.* 2004; Text-figs 8, 9). The *M. mantelli* Zone is proven by its index and other mantelliceratines as well as numerous turrilitids (Mosavinia 2008). The Albian–Cenomanian boundary is not well constrained by ammonoids and is tentatively placed slightly above a sedimentary unconformity below which upper Albian ammonoids (such as *Idiohamites dorsetensis* Spath of the *Mortoniceras perinflatum* Zone) and above which (Lower) Cenomanian ammonoids such as *Schloenbachia varians* (J Sowerby) and *Placenticeras mediasiaticum* Luppov occur (Kennedy *et al.* 2008; Wilmsen and Mosavinia 2011; cf. Text-fig. 8). The upper Lower Cenomanian *M. dixoni* Zone is not proved by its index but is most likely represented by a 50–70-m-thick unit of shales above the *M. mantelli* Zone and below the basal sandstone beds of the Middle Cenomanian. The lowermost Middle Cenomanian *Cunningtoniceras inerme* Zone, however, is potentially at least partly missing due to a gap at the base of the glauconitic sandstones in the upper part of the formation that yield *A. rhotomagense* at the top associated with *C. cunningtoni*. According to Gale (1995), *C. cunningtoni* is a typical element of the *C. inerme* Zone, but its co-occurrence with *A. rhotomagense* suggests a slightly younger position of the ammonite level at the base of the succeeding *A. rhotomagense* Zone (Text-fig. 8). Alternatively, it indicates a slightly condensed level (see below). The widespread absence of



Text-fig. 7. Acanthoceratinae from the Aitamir Formation of the Koppeh Dagh, NE Iran. All specimens from Taherabad and in natural size. **A, B** – *Cunningtoniceras cunningtoni* (Sharpe, 1855) (A1-A2, specimen At.Ta. 1F1.33; B1-B4, specimen At.Ta. F5) the (lower) *C. inerme* Zone is related to a major sea-level fall and lowstand in the Lower–Middle Cenomanian boundary interval that is known from many Cretaceous basins (sequence boundary Cenomanian 3; Robaszynski *et al.* 1998; Wilmsen 2003, 2007; Wilmsen *et al*. 2007). The presence of *A. rhotomagense* in the upper part of the Aitamir Formation indicates the lower Middle Cenomanian *A. rhotomagense* Zone, associated with the subzonal index *Turrilites costatus* Lamarck (cf. Text-figs 8, 9). Upper Cenomanian ammonoids have not yet been proved for the Iranian Koppeh Dagh (Immel *et al*. 2007; Mosavinia 2008), suggesting a major stratigraphic gap at the base of the overlying Abderaz Formation.

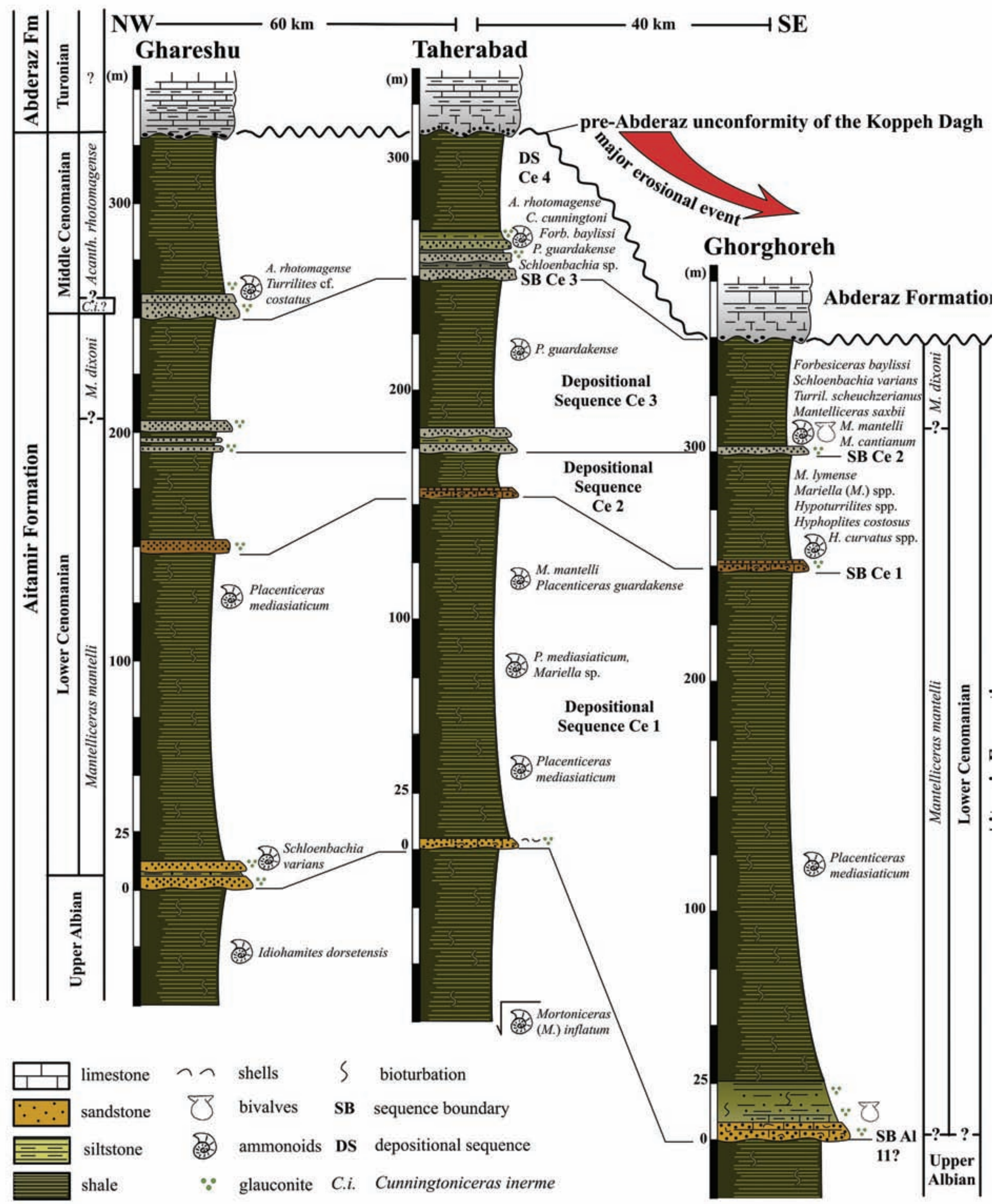
The aforementioned discussion on the potential absence of the *C. inerme* Zone as a result of a sea-level fall and lowstand raises the question of sequence stratigraphy. Eustatic sea-level changes of the Cenomanian Stage are well known and the major unconformities can be traced over large distances (Robaszynski *et al.* 1998; Gale *et al.* 2002, 2008; Wilmsen 2003, 2007). A sequence stratigraphic interpretation of the upper Aitamir Formation is suggested in Text-fig. 9.



Text-fig. 8. Bio- and sequence stratigraphic chart of the Upper Albian – Cenomanian (compiled after Robaszynski *et al.* 1998, Wilmsen 2003 and Amédro 2008, 2009). FSST = falling stage systems tract; LST = lowstand systems tract; TST = transgressive systems tract; HST = highstand systems tract

A 5–10-m-thick sandstone intercalation into the outer shelf silty shales of the Aitamir Formation may be the expression of shallowing associated with a sequence boundary (SB) in the Albian–Cenomanian boundary interval (sequence boundary SB Al 11 of Hardenbol *et al.* 1998). Support for this comes from the ammonoid record (Text-fig. 9). The sandstone bed is overlain by lower Lower Cenomanian offshore marine silty shales of the *M. mantelli* Zone. At all three localities, the sharp bases of either several metres thick shallow-water sandy bioclastic limestone or glauconitic sandstone beds in the middle part of the Lower Cenomanian are tentatively interpreted as sequence boundaries Cenomanian 1 and 2 (mid- and uppermost *M. mantelli* Zone; see Wilmsen 2003). Above the upper sandy unit, an interval of offshore shales is attributed to the transgressive and highstand of depositional sequence (DS) Ce 3 (upper Lower Cenomanian *M. dixoni* Zone; see Robaszynski et al 1998; Wilmsen 2003). The shales are unconformably overlain by a sharp-based sandstone unit, the base of which represents SB Ce 3 in the uppermost Lower Cenomanian. The lower part of the 10–16-m-thick interval of sandstone and sandy shales (preserved at Taherabad and Ghareshu) may represent the lowstand of DS Ce 4 (and then may partly be an equivalent of the *C. inerme* Zone), but the upper part of glauconitic sandstone is clearly transgressive and already yields *Acanthoceras rhotomagense* zonal ammonoids, specifically from the lower *Turrilites costatus* Subzone (Mosavinia 2008). As the transgressive onlap of DS Ce 4 clearly started in the upper part of the *C. inerme* Zone (Wilmsen *et al*. 2007), the co-occurrence of *C. cunningtoni* an *A. rhotomagense* may thus be explained by a condensation of the upper *C. inerme* and lower *A. rhotomagense* zones. The Lower–Middle Cenomanian boundary interval of the Koppeh Dagh thus displays the same pronounced regressive–transgressive cycle as reported from Europe and elsewhere (Wilmsen, 2003, 2007; Wilmsen *et al.* 2007; Gale *et al.* 2008). The offshore shales overlying the transgressive sandstones of the lower *A. rhotomagense* Zone are interpreted as later transgressive and highstand deposits of Middle Cenomanian DS Ce 4 (no Upper Cenomanian ammonoids have been reported from the Koppeh Dagh so far).

The top of the Aitamir Formation is not of the same age throughout the Koppeh Dagh (Immel *et al.*, 1997; Mosavinia, 2008; Text-fig. 9). It is nowhere younger than Middle Cenomanian but was progressively truncated from east to west before the deposition of the Turonian–(Lower) Coniacian Abderaz Formation (pre-Abderaz unconformity). Upper Cenomanian and potentially also Lower Turonian strata are missing (Afshab-Harb 1994; Immel *et al*. 1997; Mosavinia 2008). This major unconformity with the erosion of up to several hundreds of metres of sediments down into the Upper Albian (Immel *et al.* 1997) cannot be explained by eustatic sea-level changes as it deviates from the global sea-level trend, which reached a Phanerozoic high at this time (e.g., Hardenbol *et al.* 1998; in the Shotori Mountains of Central Iran, marine strata onlap a significant palaeo-relief at that time; Wilmsen *et al.* 2005). Its formation requires



Text-fig. 9. Stratigraphic correlation diagram of the upper Aitamir Formation using bio- and sequence stratigraphic data. Note major unconformity at the base of the Abderaz Formation. See text for further explanations and Text-fig. 1 for location of sections substantial regional uplift along fault-blocks. Contemporaneous tectonic activity associated with major uplift and erosion is also known from Central Iran (Wilmsen *et al.* 2010) and may have its origin in the post-Cimmerian rotation of the Central-East Iranian Microcontinent (Wilmsen *et al.* 2009b). Tectonic activity during the Late Cenomanian–Early Turonian has also been reported from northern Spain (Reitner *et al.* 1995; Wiese and Wilmsen 1999; Wilmsen 2000), and may thus not be restricted to the Middle East.

Acknowledgements

We thank AGP Editor I. Walaszczyk (Warszawa) and Associate Editor C.J. Wood (Minehead) as well as two anonymous referees for their efforts in improving the paper. A.M. acknowledges a grant of the Iranian government and logistic help by the Payame Noor University. This paper is a contribution to Deutsche Forschungsgemeinschaft (DFG) project WI 1743/6-1 granted to MW.

REFERENCES

Afshab-Harb, A. 1994. The geology of the Koppeh Dagh, Iran. 265pp.; Geological Survey of Iran; Tehran.

Aly, M.F., Abdel-Gawad, G.I. and Babir, M.A. 2005. Uppermost Albian – basal Cenomanian ammonites from north Sinai, Egypt. *Egyptian Journal of Palaeontology*, **5**, 347–385.

Amédro, F., Cobban, W.A., Breton, G. and Rogron, P. 2002. *Metengonoceras teigenense* Cobban et Kennedy, 1989: une ammonite exotique d'origine nord-Amèricaine dans le Cénomanien inférieur de Basse-Normandie (France). *Bulletin trimestriel de la Société Géologique de Normandie et Amis Muséum du Havre*, **87**, 5–28.

Amédro, F. 2008. Support for a Vraconnian Stage between the Albian *sensu stricto* and the Cenomanian (Cretaceous System). *Carnets de Géologie / Notebooks on Geology, Memoir*, **2008/02**, 1–83.

Amédro, F. 2009. Stratigraphie séquentielle des successions Albiennes du Bassin Anglo-Parisien et du Basin de Mons (Belgique). *Bulletin d'Information des Géologues du Bassin des Paris*, **46**, 12–36.

Atabekian, A.A. 1985. Turrilitids of the Late Albian and Cenomanian of the southern part of USSR. *Transactions of the Academy of Sciences of the USSR*, **14**, 1–112.

Barroso Barcenilla, F. 2004. Acanthoceratidae y zonación de ammonites del Cenomaniense superior y del Turonienses inferior en el área de Puentedey, Cuenca Vasco-Cantábria, España. *Coloquios de Paleontología*, **54**, 83–114.

Berberian, M. and King, G.C.P. 1981. Towards a palaeogeography and tectonic evolution of Iran. *Canadian Journal of Earth Sciences*, **18**, 210–265.

Brongniart, A. 1822. Sur quelques terrains de Craie hors du Bassin de Paris. 80–110. In: Cuvier, G., Brongniart, A. (eds), Description géologique des environs de Paris. 428 pp., 11 pls. Dufour et d'Cagne; Paris.

Collignon, M. 1937. Ammonites Cénomaniennes du sud-ouest de Madagascar. *Annales Géologiques du Service des Mines Madagascar*, **8**, 29–72, pls. 1–11.

Davoudzadeh, M., Soffel, H. and Schmidt, K. 1981. On the rotation of the Central-East Iran microplate. *Neues Jahrbuch für Geologie und Paläontologie, Monatshefte*, **1981**, 180–192.

Gale, A.S. 1995. Cyclostratigraphy and correlation of the Cenomanian stage in Western Europe. In: House, M.R. and Gale, A.S. (Eds), Orbital forcing timescales and cyclostratigraphy. Geological Society, London, Special Publication, **85**, 177–197.

Gale, A.S., Kennedy, W.J., Burnett, J.A., Caron, M. and Kidd, B.E. 1996. The Late Albian to Early Cenomanian succession at Mont Risou near Rosans (Hautes Alps, SE France); an integrated study (ammonites, inoceramids, planktonic foraminifera, nannofossils, oxygen and carbon isotopes). *Cretaceous Research*, **17**, 515–606.

Gale, A.S., Hardenbol, J., Hathway, B., Kennedy, W.J., Young, J.R., and Phansalkar, V. 2002. Global correlation of Cenomanian (upper Cretaceous) sequences: evidence for Milankovitch control of sea level. *Geology*, **30**, 291–294.

Gale, A.S., Voigt, S., Sageman, B.B. and Kennedy, W.J. 2008. Eustatic sea-level record fort he Cenomanian (Late Cretaceous) – Extension to the Western Interior Basin, USA. *Geology*, **36**, 859–862.

Gradstein, F.M., Ogg, J.G. and Smith A.G. 2004. A geologic time scale 2004. 589 pp. University Press; Cambridge.

Grossouvre, A.de 1894. Recherches sur la Craie supérieure. Deuxième part: Paléontologie. Les ammonites de la Craie supérieure. *Memoirs du Service de la Carte Geologique detailée de la France* **1893**, 1–264.

Hancock, J.M. 1991. Ammonite scales for the Cretaceous system. *Cretaceous Research*, **12**, 259–191.

Hardenbol, J., Thierry, J., Farley, M.B., Jaquin, T., de Graciansky, P. and Vail, P.R. 1998. Mesozoic and Cenozoic sequence chronostratigraphic framework of European basins - Chart 4: Cretaceous sequence chronostratigraphy. In: de Graciansky, P., Hardenbol, J. Jaquin, T. and Vail, P.R. (Eds), Mesozoic and Cenozoic sequence stratigraphy of European basins. *Society of Economic Palaeontologists and Mineralogists Special Publication*, **60**.

Hyatt, A. 1903. Pseudoceratites of the Cretaceous. *United States Geological Survey Monographs*, **44**, 1–351.

Immel, H. and Seyed-Emami, K. 1985. Die Kreideammoniten des Glaukonitkalkes (O.Alb – O.Cenoman) des

Kolah-Qazi-Gebirges südöstlich von Esfahan (Zentraliran). *Zitteliana*, **12**, 87–137.

Immel, H., Seyed-Emami, K. and Afshar-Harb, M. 1997. Kreide-Ammoniten aus dem iranischen Teil des Koppeh-Dagh (NE-Iran). *Zitteliana*, **21**, 159–190.

Kaplan, U., Kennedy, W.J., Lehmann, J. and Marcinowski, R. 1998. Stratigraphie und Ammonitenfaunen des westfälischen Cenoman. *Geologie und Paläontologie in Westfalen,* **51**, 1–236.

Kawabe, F., Takashima, R., Wani, R., Nishi, H and Moriyas, K. 2003. Upper Albian to Lower Cenomanian biostratigraphy in the Oyubari area, Hokkaido, Japan: toward a Cretaceous biochronology for the North Pacific. *Acta Geologica Polonica*, **53**, 81–91.

Kennedy, W.J. 1994. Cenomanian ammonites from Cassis, Bouches-du-Rhone, France. *Paleopelagos, Special Publication*, **1**, 209–254.

Kennedy, W.J. and Juignet, P. 1993. A revision of the ammonite faunas of the Type Cenomanian. 4. Acanthoceratinae (*Acompsoceras, Acanthoceras, Protacanthoceras, Cunningtoniceras* and *Thomelites*). *Cretaceous Research*, **14**, 145–190.

Kennedy, W.J., Chahida, M.R. and Djafarian, M.A. 1979. Cenomanian cephalopods from the Glauconitic Limestone southeast of Esfahan, Iran. *Acta Palaeontologica Polonica*, **24**, 3–50.

Kennedy, W.J., Juignet, P. and Wright, C.W. 1986. A revision of the ammonite faunas of the Type Cenomanian. 3. Mantelliceratinae. *Cretaceous Research*, **7**, 19–62.

Kennedy, W.J., King, C. and Ward, D.J. 2008. The upper Albian and lower Cenomanian succession at Kolbay, eastern Mangyshlak (southwest Kazakhstan). *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Sciences de la Terre*, **78**, 117–147.

Kossmat, F. 1897. Untersuchungen über die Südindische Kreideformation. *Beiträge zur Paläontologie und Geologie Österreich-Ungarns*, **11** (1897), 1–46 (108–153), pls. 1–8 (12–19).

Mosavinia, A. (2008): *Biostratigraphy of the middle Cretaceous in the eastern Koppeh Dagh, NE Iran (based on the ammonite fauna)*, 1–350, 63 pls. Mashad: Unpubl. PhD thesis, Payame Noor University. [in Farsi]

Mosavinia, A.. Wilmsen, M., Asghar Aryai, A., Chahida, M.R. and Lehmann, J. 2007. Mortoniceratinae (Ammonitina) from the Upper Albian (Cretaceous) of the Atamir Formation, Koppeh Dagh Mountains, NE Iran. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, **246**, 83–95.

Neumayr, M. 1875. Die Ammonitiden der Kreide und die Systematik der Ammonitiden. *Zeitschrift der deutschen Geologischen Gesellschaft*, **27**, 854–942.

Orbigny, A.d. 1840–1842. Paléontologie Française. Terrain Crétacé I, Céphalopodes. 662 pp., 148+3 pls. 1840, 1–120. 1841, 121–430. 1842, 431–662. Masson; Paris.

Philip, J. and Floquet, M. 2000. Late Cenomanian. In: Dercourt, J., Gaetani, M., Vrielynck, B., Barrier, E., Biju-Duval, B., Brunet, M.F., Cadet, J.P., Crasquin, S. and Sandulescu, M. (Eds), Atlas Peri-Tethys palaeogeographical maps. CCGM/CGMW, Paris, pp. 129–136.

Raisossadat, S.N. 2006. The ammonite family Parahoplitidae in the Sanganeh Formation of the Kopet Dagh Basin, north-estern Iran. *Cretaceous Research*, **27**, 907–922.

Reitner, J., Wilmsen, M. and Neuweiler, F. 1995. Cenomanian/Turonian sponge/microbialite deep-water hardground community (Liencres, Northern Spain). *Facies*. **32**, 203–212.

Robaszynski, F., Juignet, P., Gale, A.S., Amédro, F. and Hardenbol, J. 1998. Sequence stratigraphy in the Cretaceous of the Anglo-Paris Basin, exemplified by the Cenomanian stage. In: Jaquin, T., de Graciansky, P. and Hardenbol, J. (Eds), Mesozoic and Cenozoic sequence stratigraphy of European basins. *Society of Economic Palaeontologists and Mineralogists, Special Publication*, **60**, 363–385.

Seyed-Emami, K. 1988. Jurassic and Cretaceous ammonite faunas of Iran and their palaeobiogeographic significance. – In: Wiedmann, J. and Kullmann, J. (Eds), Cephalopods – Present and past. pp. 599–606; Schweizerbart; Stuttgart.

Seyed-Emami, K. and Aryai, A.A. 1981. Ammoniten aus dem unteren Cenoman von Nordostiran (Koppeh-Dagh). *Mitteilungen der Bayerischen Staatssammlung für Paläontologie und historische Geologie*, **21**, 23–39.

Seyed-Emami, K., Förster, R. and Mojtehedi, A. 1984. Ammoniten aus dem mittleren Cenoman von Nordostiran (Koppeh-Dagh). – *Neues Jahrbuch für Geologie und Paläontologie, Monatshefte*, **1984**, 159–172.

Sharpe, D. 1853–1857. Description of the fossil remains of Mollusca found in the Chalk of England. I, Cephalopoda. Palaeontographical Society (London) Monograph, 68pp., 27 pls 1853, 1–26, pls 1–10. 1855, 27–36, pls 11–16. 1857, 37–68, pls 17–27.

Sowerby, J., 1814. The mineral conchology of Great Britain; or coloured figures and descriptions of those remains of testaceous animals and shells, which have been preserved at various times and depths in the earth. 609pp., The author; London.

Spath, L.F. 1926a. On new ammonites from the English Chalk. *Geological Magazine*, **63**, 77–83.

Spath, L.F. 1926b. On the zones of the Cenomanian and the uppermost Albian. *Proceedings of the Geologist's Association*, **37**, 420–432.

Tröger, K.-A. and Kennedy, W.J. 1996. The Cenomanian stage. *Bulletin de l'Institut Royal de Sciences Naturelles de Belgique (Sciences de la Terre)*, **66**, 57–68.

Wiese, F. and Wilmsen, M. 1999. Sequence stratigraphy in the Cenomanian to Campanian of the North Cantabrian Basin

(Cantabria, N-Spain). *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, **212**(1–3), 131–173.

Wilmsen, M. 1997. Das Oberalb und Cenoman im Nordkantabrischen Becken (Provinz Kantabrien, Nordspanien): Faziesentwicklung, Bio- und Sequenzstratigraphie. *Berliner geowissenschaftliche Abhandlungen*, **E 23**, 1–167.

Wilmsen, M. 2000. Evolution and demise of a mid-Cretaceous carbonate shelf: The Altamira Limestones (Cenomanian) of northern Cantabria (Spain). *Sedimentary Geology*, **133**, 195–226.

Wilmsen, M. 2003. Sequence stratigraphy and palaeoceanography of the Cenomanian Stage in northern Germany. *Cretaceous Research*, **24**, 525–568.

Wilmsen, M. 2007. Integrated stratigraphy of the upper Lower – lower Middle Cenomanian of northern Germany and southern England. *Acta Geologica Polonica*, **57**, 263–279.

Wilmsen, M. and Rabe, M. 2008. Belemnites from the lower Middle Cenomanian of Hoppenstedt, northern Germany: significance and integrated correlation. *Cretaceous Research*, **29**, 936–942.

Wilmsen, M. and Niebuhr, B. 2010. On the age of the Upper Cretaceous transgression between Regensburg and Neuburg an der Donau (Bavaria, southern Germany). *Neues Jahrbuch für Geologie und Paläontologie,* **256**, 267–278.

Wilmsen, M. and Mosavinia, A. 2011. Phenotypic plasticity and taxonomy of *Schloenbachia varians* (J. Sowerby, 1817). *Paläontologische Zeitschrift*, **85**, 169–184.

Wilmsen, M., Wiese, F., Seyed-Emami, K. and Fürsich, F.T. 2005. First record and significance of Cretaceous (Turonian) ammonites from the Shotori Mountains, east-central Iran. *Cretaceous Research*, **26**, 181–195.

Wilmsen, M., Niebuhr, B., Wood, C.J. and Zawischa, D. 2007. Fauna and palaeoecology of the Middle Cenomanian *Praeactinocamax primus* Event at the type locality, Wunstorf quarry, northern Germany. *Cretaceous Research,* **28**, 428–460.

Wilmsen, M., Wood, C.J., Niebuhr, B. and Kaplan, U. 2009a. Cenomanian–Coniacian ammonoids of the Danubian Cretaceous Group (Bavaria, southern Germany). In: Niebuhr, B. (Ed.), Litho- und Biostratigraphie der außeralpinen Kreide von Bayern. *Schriftenreihe der Deutschen Gesellschaft für Geowissenschaften,* **65**, 111–124.

Wilmsen, M., Fürsich, F.T., Seyed-Emami, K., Majidifard, M.R. and Taheri, J. 2009b. The Cimmerian orogeny in northern Iran: tectono-stratigraphic evidence from the foreland. *Terra Nova*, **21**, 211–218.

Wilmsen**,** M., Fürsich, F.T. and Majidifard, M.R. 2010. Cretaceous stratigraphy and facies development of the Yazd Block, Khur area, Central Iran. – STRATI 2010 Paris, Abstract-Volume, 249–250.

Wright, C.W. 1952. A classification of the Cretaceous ammonites. *Journal of Paleontology*, **26**, 213–222.

Wright, C.W., Callomon, J.H., Howarth, M.K. 1996. Cretaceous Ammonoidea. In: Kaesler, R.L. (Ed.), Treatise on Invertebrate Paleontology. Part L: Mollusca, revised, Volume 4. 362 pp.. The Geological Society of America, Inc. and The University of Kansas Press; Boulder and Lawrence.

Wright, C.W. and Kennedy, W.J. 1984. The Ammonoidea of the Lower Chalk. Part I. *The Palaeontographical Society Monograph,* **567**(137), 1–126.

Wright, C.J. and Kennedy, W.J. 1987. The Ammonoidea of the Lower Chalk. Part II. *The Palaeontographical Society Monograph,* **573**(139), 127–218.

Zaborski, P.M.P. 1985. Upper Cretaceous ammonites from the Calabar region, south-east Nigeria. *Bulletin of the British Museum of Natural History (Geology Series)*, **39**(1), 1–72.

Manuscript submitted: 03rd December 2010
Revised version accepted: 15th March 2011