Albian and Cenomanian ammonites of the eastern margin of the Lut block (East Iran)

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Abstract: Upper Albian and Lower Cenomanian ammonites occur on the eastern margin of the Lut block in eastern Iran. The ammonite assemblages described herein are from the Nimbolook and Kerch sections located west of Qayen. The following taxa are described: *Mantelliceras mantelli* (J. SOWERBY, 1814), *Mantelliceras saxbii* (SHARPE, 1857), *Mantelliceras* sp. 1, *Mantelliceras* sp. 2, *Mantelliceras* sp. 3, *Sharpeiceras laticlavium* (SHARPE, 1855), *Sharpeiceras schlueteri* (HYATT, 1903), *Puzosia* (*Puzosia*) *mayoriana* (ORBIGNY, 1841), *Hyphoplites costosus* C.W. WRIGHT & E.V. WRIGHT, 1949, *Mortoniceras* (*Mortoniceras*) cf. *fallax* (BREISTROFFER, 1940), *Mantelliceras* cf. *mantelli* (J. SOWERBY, 1814), *Calycoceras* (*Gentoniceras*) aff. *gentoni* (BRONGNIART, 1822), *Idiohamites fremonti* (MARCOU, 1858), *Mariella* (*Mariella*) sp., *Mariella* (*Mariella*) *dorsetensis* (SPATH, 1926), and *Turrilites costatus* LAMARCK, 1801. The ammonite assemblages clearly indicate a late Albian-middle Cenomanian age for the Nimbolook section and late Albian-early Cenomanian age for the Kerch section.

Key-words:

- Albian;
- Cenomanian;
- Cretaceous;
- ammonites;
- systematic paleontology;
- biostratigraphy;
- Qayen;
- Lut block;
- Iran.

Citation: SHARIFI J., RAISOSSADAT S.N., MORTAZAVI MEHRIZI M. & MOTAMEDALSHARIATI M. (2016).- Albian and Cenomanian ammonites of the Eastern margin of the Lut block (East Iran).- *Carnets Geol.*, Madrid, vol. 16, no. 25, p. 591-613.

Résumé : ***Ammonites albiennes et cénomaniennes de la bordure orientale du bloc de Lut (E Iran).-*** Des ammonites de l'Albien supérieur et du Cénomanien inférieur sont présentes sur la bordure orientale du bloc de Lut dans la partie orientale de l'Iran. Les associations ammonitiques décrites ici proviennent des coupes de Nimbolook et de Kerch, toutes deux situées à l'ouest de Qayen. Les taxons suivants sont décrits : *Mantelliceras mantelli* (J. SOWERBY, 1814), *Mantelliceras saxbii* (SHARPE, 1857), *Mantelliceras* sp. 1, *Mantelliceras* sp. 2, *Mantelliceras* sp. 3, *Sharpeiceras laticlavium* (SHARPE, 1855), *Sharpeiceras schlueteri* (HYATT, 1903), *Puzosia* (*Puzosia*) *mayoriana* (ORBIGNY, 1841), *Hyphoplites costosus* C.W. WRIGHT & E.V. WRIGHT, 1949, *Mortoniceras* (*Mortoniceras*) cf. *fallax* (BREISTROFFER, 1940), *Mantelliceras* cf. *mantelli* (J. SOWERBY, 1814), *Calycoceras* (*Gentoniceras*) aff. *gentoni* (BRONGNIART, 1822), *Idiohamites fremonti* (MARCOU, 1858), *Mariella* (*Mariella*) sp., *Mariella* (*Mariella*) *dorsetensis* (SPATH, 1926), et *Turrilites costatus* LAMARCK, 1801. Les associations ammonitiques indiquent clairement un âge Albien supérieur-Cénomanien moyen pour la coupe de Nimbolook et un âge Albien supérieur-Cénomanien inférieur pour celle de Kerch.

Mots-clefs :

- Albien ;
- Cénomanien ;
- Crétacé ;
- ammonites ;
- paléontologie systématique ;
- biostratigraphie ;
- Qayen ;
- bloc de Lut ;
- Iran.

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Published online in final form (pdf) on December 12, 2016
[Editor: Bruno GRANIER; language editor: Stephen CAREY]

1. Introduction

The central Iran area is bounded to the east by the Lut Block (AGHANABATI, 2011). Cretaceous deposits are widely exposed on the eastern margin of the Lut block. TIRRUL *et al.* (1983), FAUVELET and EFTEKHAR NEZHAD (1990), RAISOSSADAT and SKELTON (2005), KHAZAEI *et al.* (2011), BABAZADEH *et al.* (2010), RAISOSSADAT *et al.* (2012), MOULODI *et al.* (2014) and SHARIFI *et al.* (2015) have published on aspects of the area's regional geology, Cretaceous stratigraphy and micro- and macropaleontology. The focus of this study is on the discovery and description of upper Albian and middle Cenomanian ammonites. The ammonite fauna described here comes from two sections. The Nimbolook section is located at 59°01' 20"E 33°52'15"N and the Kerch section is located at 58°52'45"E 33° 37'15"N (Figs. 1-2).

This paper is one of the few paleontological studies of eastern Iran. For many of the species described, this is the first record from eastern Iran.

2. Stratigraphy

2.1. KERCH SECTION:

This section consists of a succession of 255 m of marl and marly limestone which contains ammonites. The carbonate succession overlies an Albian igneous unit (FAUVELET and EFTEKHAR NEZHAD, 1990) and underlies a siliciclastic unit of red conglomerate and sandstone. The sequence straddles the Albian-Cenomanian boundary (Figs. 3-4). Ammonites are scarce with 17 specimens collected, all from the upper third of the section. Ammonites identified are *Mantelliceras mantelli* (J. SOWERBY, 1814), *Mantelliceras saxbii* (SHARPE, 1857), *Mantelliceras* sp. 1, *Mantelliceras* sp. 2, *Sharpeiceras laticlavium* (SHARPE, 1855), *Sharpeiceras schlueteri* (HYATT, 1903), *Puzosia* (*Puzosia*) *mayoriana* (ORBIGNY, 1841) and *Hyphoplites costosus* C.W. WRIGHT & E.V. WRIGHT, 1949 (Figs. 7-8). The ammonite assemblage suggests that the section is of late Albian - early Cenomanian age.

Figure 1: Present location of the Lut block, Iran, redrawn after AGHANABATI (2011), with the geographic framework of measured sections in red.

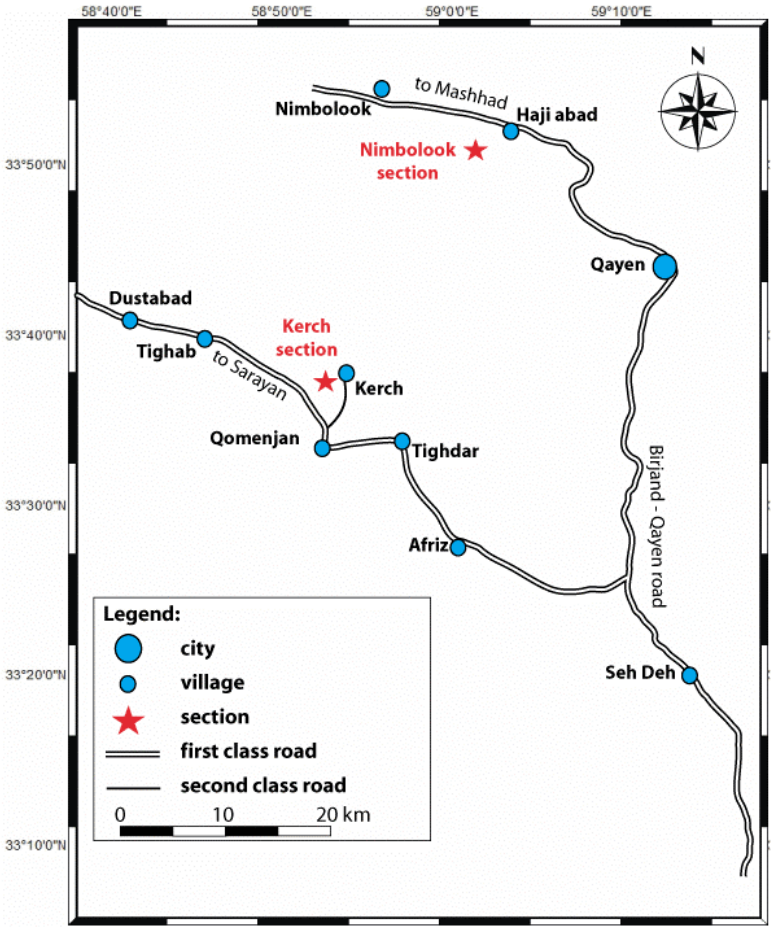
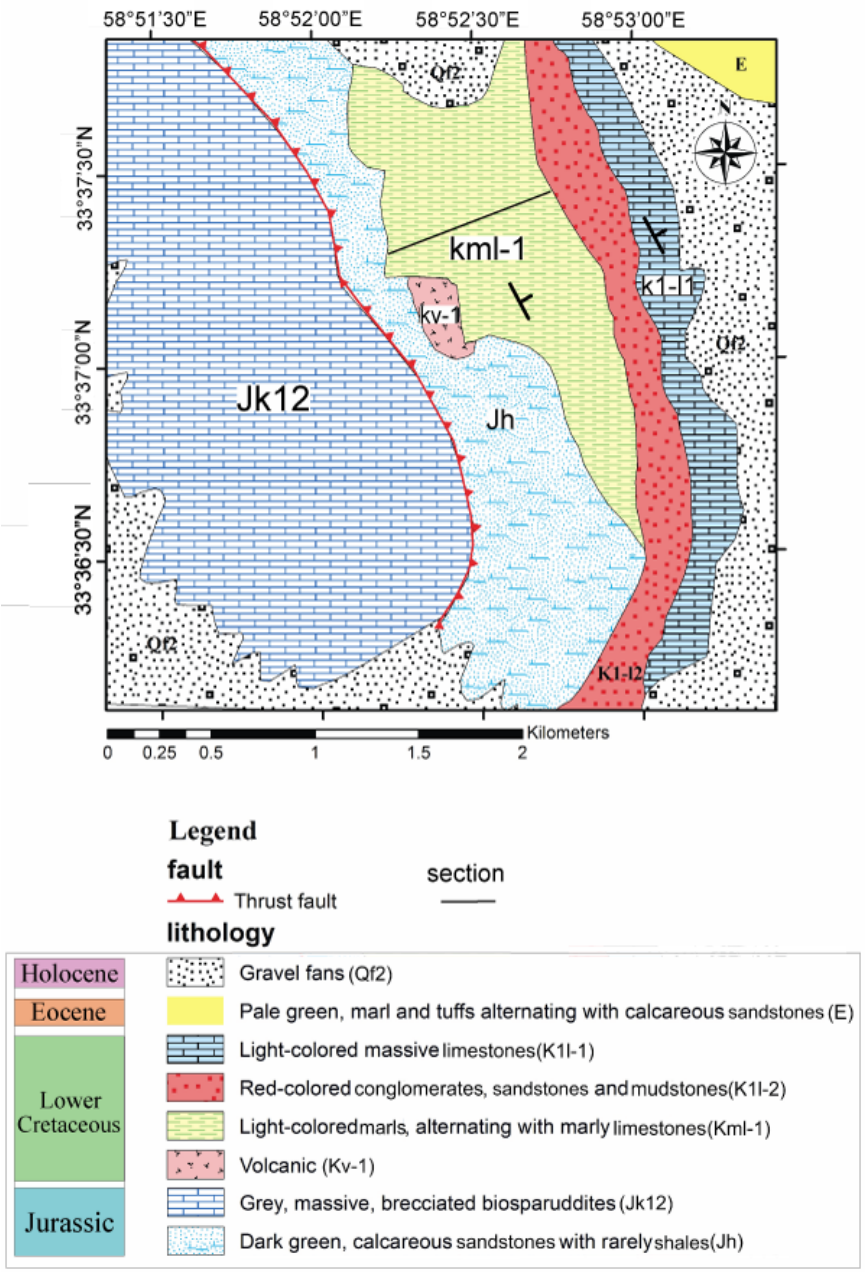


Figure 2: Location of the measured sections (stars).



◀ **Figure 3:** The Kerch section. Geological map, modified after AMIDI *et al.* (2005).

2.2. NIMBOLOOK SECTION

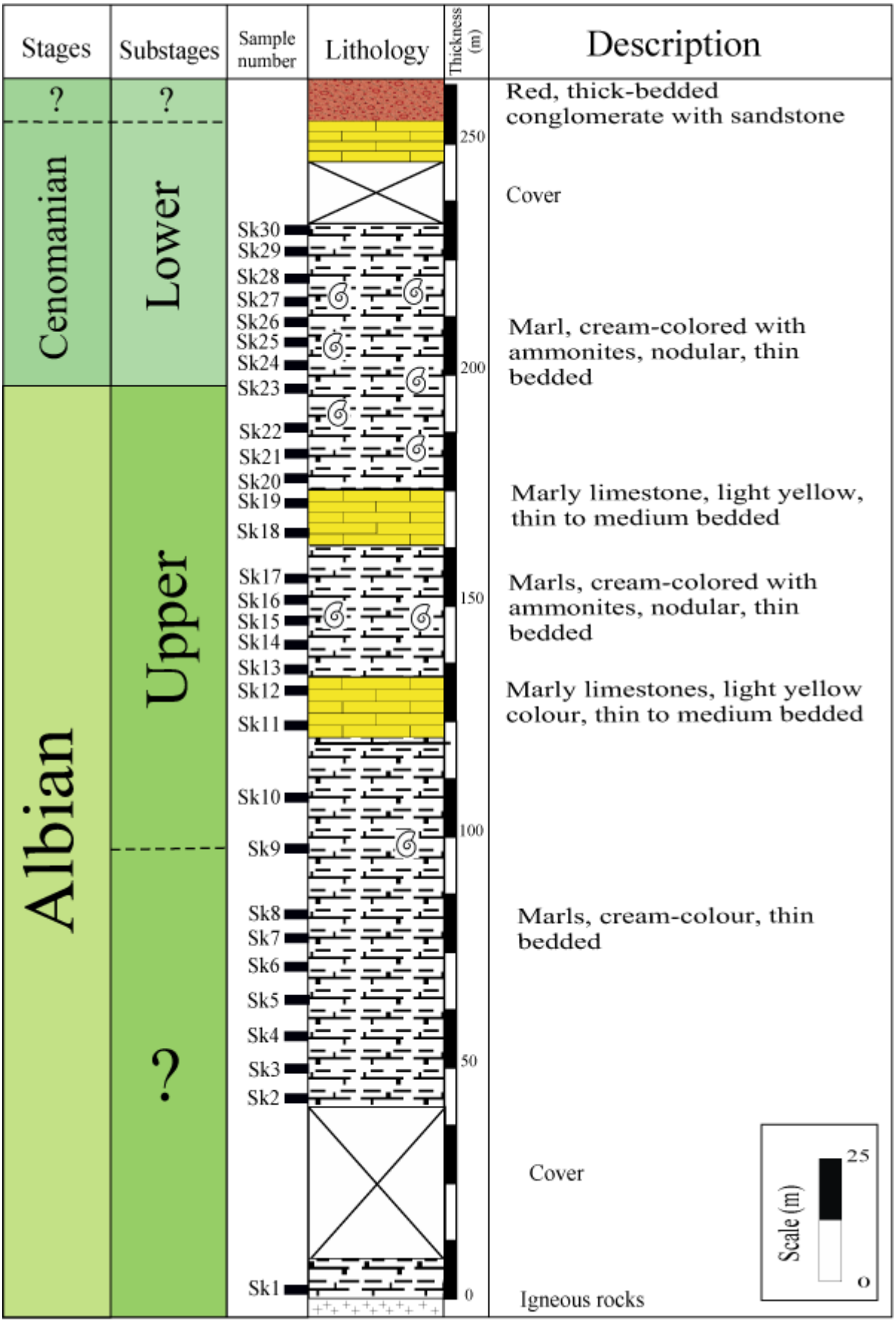
In the Nimbolook section, a carbonate succession, 92 m thick, conformably overlies Aptian-Albian sedimentary rocks (MOULODI, 2013) and underlies red conglomerate and sandstone. The carbonates are divisible into two units (Figs. 5-6). The lower unit consists of 55 m of thickly bedded light grey non-ammonite-bearing limestone and the upper consists of 33 m of medium-bedded pink limestone with ammonites. Ammonites are very scarce with eight specimens recovered. The limestone includes biosparite and biomicrosparite (wackestones and packstones), which contain abundant molluscan debris (pelecypods, gastropods, and ammonites).

Ammonites identified include *Mortoniceras* (*Mortoniceras*) cf. *fallax* (BREISTROFFER, 1940), *Mantelliceras* sp. 3, *Mantelliceras* cf. *mantelli* (J. SOWERBY, 1814), *Calycoceras* (*Gentoniceras*) aff. *gentoni* (BRONGNIART, 1822), *Idiohamites fremonti* (MARCOU, 1858), *Mariella* (*Mariella*) sp., *Mariella* (*Mariella*) *dorsetensis* (SPATH, 1926) and *Turrilites costatus* LAMARCK, 1801 (Fig. 9). Based on the ammonite occurrences, this section is assigned a late Albian - middle Cenomanian age.

3. Conventions

The collected ammonites are classified after the Treatise of Invertebrate Palaeontology, part L (WRIGHT *et al.*, 1996). Shell measurements are given in centimeters, in the following order; Diameter (D), whorl height (Wh), whorl breadth (Wb) and breadth of umbilicus (U).The abbreviations used to indicate the source of specimens are as follows: Ni, Nimbolook section; Ke, Kerch section.

A


Stages
Substages
Sample number
Lithology
Thickness (m)
Description
?
?
Cenomanian
Lower
Albian
Upper
?
Sk30
Sk29
Sk28
Sk27
Sk26
Sk25
Sk24
Sk23
Sk22
Sk21
Sk20
Sk19
Sk18
Sk17
Sk16
Sk15
Sk14
Sk13
Sk12
Sk11
Sk10
Sk9
Sk8
Sk7
Sk6
Sk5
Sk4
Sk3
Sk2
Sk1
250
200
150
100
50
0
Red, thick-bedded conglomerate with sandstone
Cover
Marl, cream-colored with ammonites, nodular, thin bedded
Marly limestone, light yellow, thin to medium bedded
Marls, cream-colored with ammonites, nodular, thin bedded
Marly limestones, light yellow colour, thin to medium bedded
Marls, cream-colour, thin bedded
Cover
Igneous rocks
Scale (m)
25
0

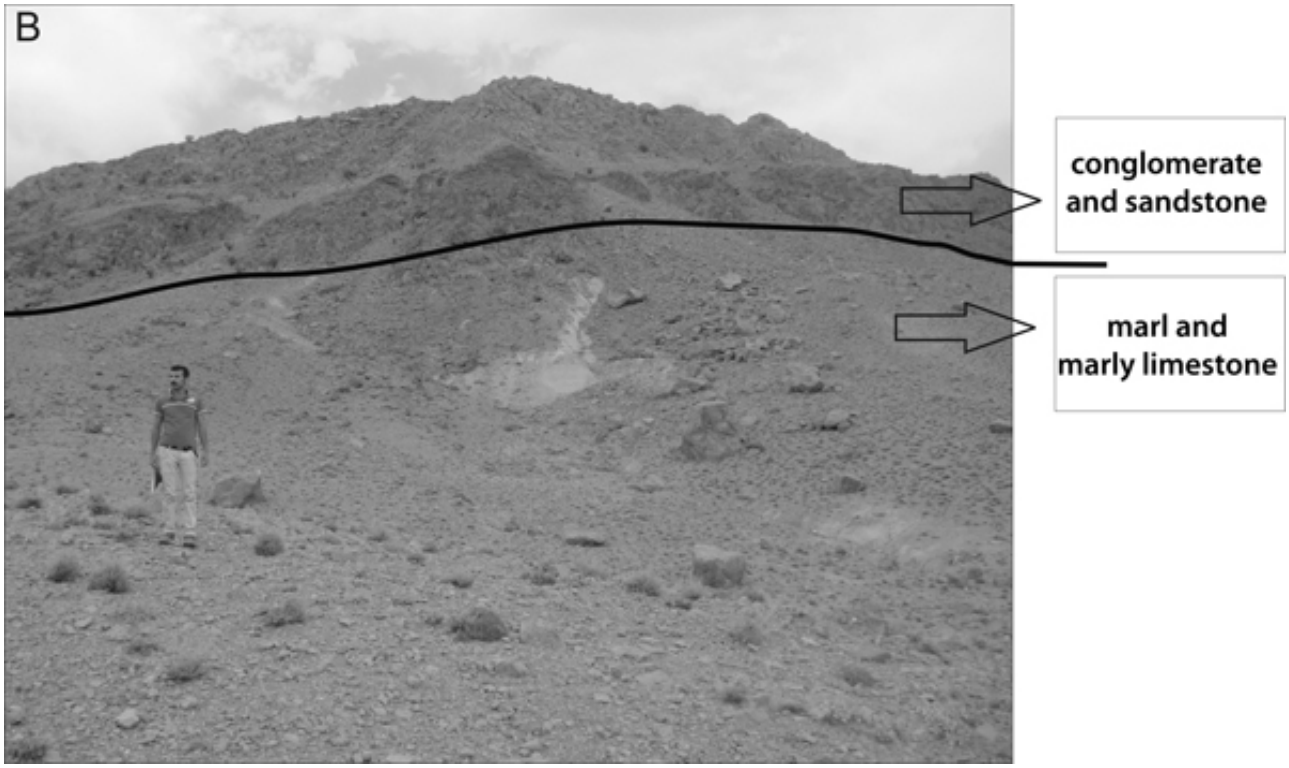
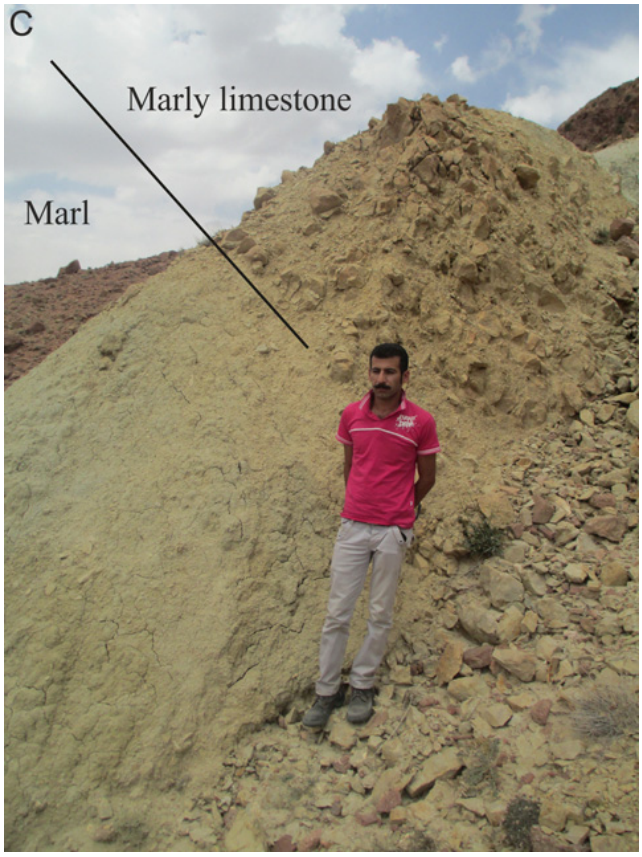


Figure 4: Stratigraphic columns of the Kerch section (◀ A), view of the Kerch section (▲ B), and marl and marly limestone beds (▼ C).



4. Systematic paleontology

Suborder Ammonitina Hyatt, 1889
Superfamily Desmoceratoidea Zittel, 1895
Family Desmoceratidae Zittel, 1895
Subfamily Puzosiinae Spath, 1922
Genus and Subgenus *Puzosia* Bayle, 1878
Puzosia (*Puzosia*) *mayoriana* (Orbigny, 1841)

Fig. 7, Ke-1, Ke-2, and Ke-3

1990 *Puzosia mayoriana mayoriana* (Orbigny, 1841); Marcinowski and Wiedmann, p. 55, Pl. 5, fig. 5.

1991 *Puzosia* (*Puzosia*) *mayoriana* (Orbigny, 1841); Delamette and Kennedy, p. 442, Pl. 8, fig. 26.

1994 *Puzosia* (*Puzosia*) *mayoriana* (Orbigny, 1841); Kennedy, p. 220, Pl. 2, figs. 10-12, 18; Pl. 5, figs. 1-9.

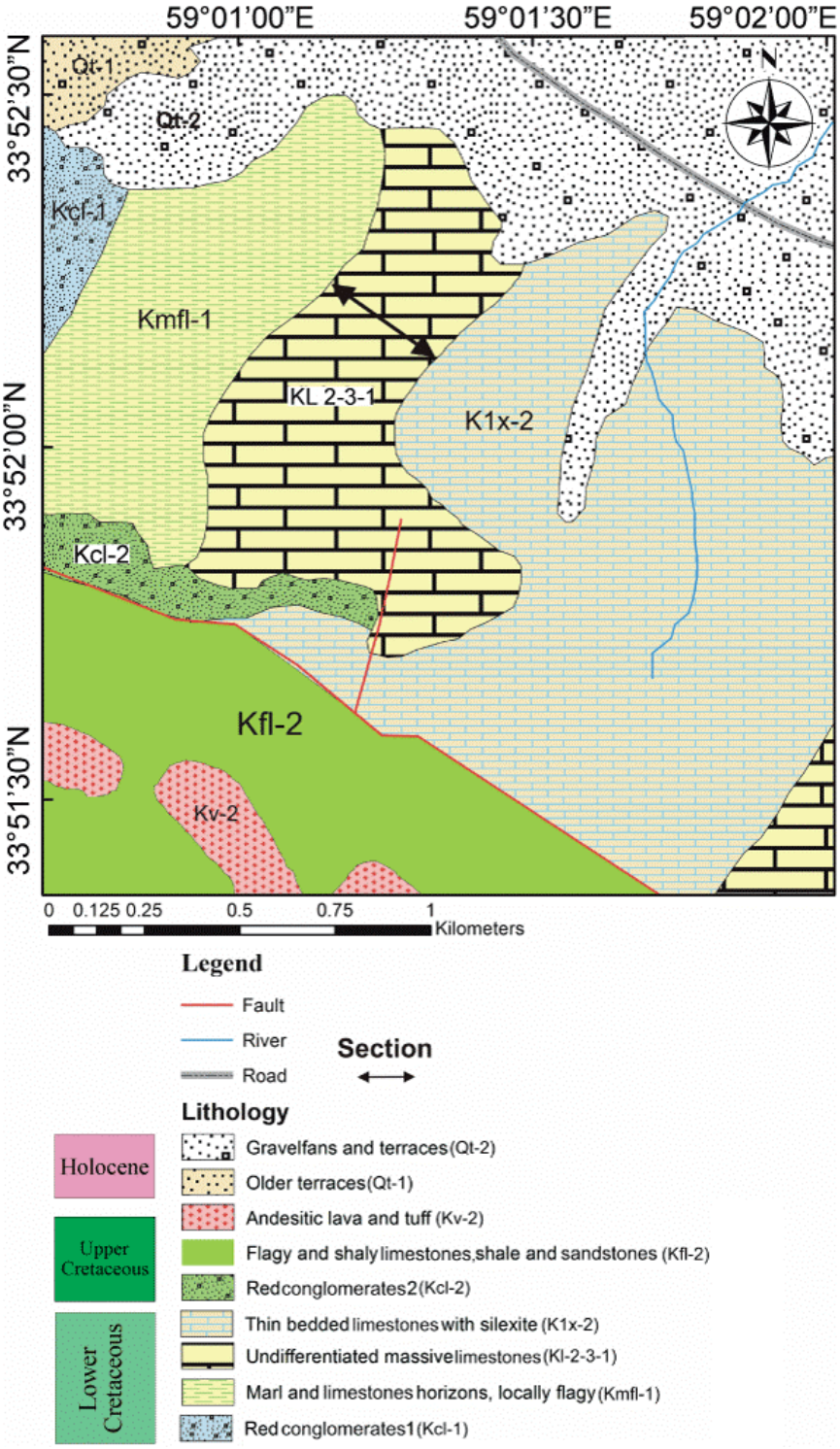
1996 *Puzosia* (*Puzosia*) *mayoriana* (Orbigny, 1841); Kennedy *et al.*, p. 312, Pl. 39, figs. 4-5.

1998 *Puzosia* (*Puzosia*) *mayoriana* (Orbigny, 1841); Kaplan *et al.*, p. 71, Pl. 1, figs. 12-13; Pl. 9, figs. 1, 11-12; Pl. 10, figs. 3-5.

2000 *Puzosia* (*Puzosia*) *mayoriana* (Orbigny, 1841); Lehmann, p. 55, Pl. 1, figs. 1, 9.

2004 *Puzosia* (*Puzosia*) *mayoriana* (Orbigny, 1841); Kennedy and Jolkicev, p. 372, Pl. 1, figs. 4-6.

2005 *Puzosia* (*P.*) *mayoriana* (Sowerby); Reboulet *et al.*, p. 125, Fig. 3.A.



◀ **Figure 5:** The Nimbolook section. Geological map, redrawn after BERTHIAUX *et al.* (1981).

2007 *Puzosia* (*Puzosia*) *mayoriana* (ORBIGNY, 1841); SZIVES *et al.*, p. 96, Pl. XIII, fig. 9; Pl. XIV, fig. 7; Pl. XIX, fig. 8; Pl. XXVIII, figs. 8, 10, 13.

2007 *Puzosia* (*Puzosia*) *mayoriana* (ORBIGNY, 1841); KENNEDY and LATIL, p. 460, Pl. 1, figs. 1-6; Pl. 3, fig. 1.

2008 *Puzosia* (*Puzosia*) *mayoriana* (ORBIGNY, 1841); KENNEDY *et al.*, Pl. 8, figs. 15-16.

2013 *Puzosia* (*Puzosia*) *mayoriana* (ORBIGNY, 1841); REBOULET *et al.*, p. 177, Fig. 5.

Material: Ke-1, Ke-2, and Ke-3, all crushed to varying degrees.

Description: Ke-1 is the largest (diameter 11.6 cm) and best preserved specimen of *P.* (*P.*) *mayoriana* from the Kerch section. All specimens have an oval whorl section, rounded flanks, broadly rounded ventrolateral shoulder and convex venter. Specimens have 1-2 well-developed constrictions on the last whorl. The constrictions are sharper in Ke-2. They arise from the umbilical wall, straight on the lower

half of the flank, convex on the ventrolateral shoulder and flexing back and concave on the venter. Convex constrictions are most visible in Ke-1 and Ke-2. Specimens have 14-38, flexuous and dense ribs, arranged parallel to the constrictions. The constrictions are flanked by a collar rib, feeble on the flanks, but coarsening on the ventrolateral shoulder and venter.

Dimensions (in cm):

Sample number	D	Wh	Wb	Wb/Wh	U
Ke-1	11.6	3.5	2.4	0.68	0.35
Ke-2	-	3.1	2.1	0.67	-
Ke-3	-	3.1	2.3	0.74	-

Occurrence: upper Albian to upper Cenomanian. Based on co-occurrence with specimens Ke-4, Ke-5, Ke-9 and Ke-10, both Ke-1 and Ke-2 are upper Albian and Ke-3 is lower Cenomanian.

Superfamily Hopliticeae H. Douvillé, 1890
Family Hoplitidae H. Douvillé, 1890
Subfamily Hoplitinae H. Douvillé, 1890
Genus *Hyphoplites* Spath, 1922
Hyphoplites costosus C.W. Wright & E.V. Wright, 1949

Fig. 7, Ke-4 and Ke-5

1949 *Hyphoplites costosus*; C.W. Wright & E.V. Wright, p. 484, Pl. XXIX, fig. 7.a-b.
1971 *Hyphoplites costosus* C.W. Wright & E.V. Wright, 1949; Kennedy, p. 43.
1984 *Hyphoplites costosus* C.W. Wright & E.V. Wright, 1949; Kennedy and Juignet, p. 116, Figs. 3.g-j, 3.p, 8.h.
1985 *Hyphoplites costosus* C.W. Wright & E.V. Wright, 1949; Immel and Seyed-Emami, p. 92, Pl. 1, figs. 4-5.
2007 *Hyphoplites costosus* C.W. Wright & E.V. Wright, 1949; Szives *et al.*, p. 101, Pl. 46, figs. 18, 23, 25-30.

Material: Ke-4 and Ke-5.

Description: Ke-4 is a half whorl of a discoidal shell. Ribs are sickle-shaped, fine and dense, and commence at the umbilicus. The ribs carry ventrolateral tubercles. The siphonal groove is engraved on the venter and passes through the ventrolateral tubercles. Ke-5 has similar ornamentation but is less well preserved.

Dimensions (in cm):

Sample number	D	Wh	Wb	Wb/Wh	U
Ke-4	4.0	1.4	0.7	0.50	0.32
Ke-5	-	0.4	0.1	0.25	-

Occurrence: This species occurs in upper Albian strata of Hungary (Szives *et al.*, 2007) and the lower and middle lower Cenomanian of southern England (C.W. Wright & E.V. Wright, 1949). *Hyphoplites costosus* has been found below *M. mantelli* (at the base of the Cenomanian) in the Kerch section.

Superfamily Acanthoceratoidea Grossouvre, 1894
Family Brancoceratidae Spath, 1934
Subfamily Mortoniceratinae H. Douvillé, 1912
Genus and subgenus *Mortoniceras* Meek, 1876
Mortoniceras (*Mortoniceras*) cf. *fallax* (Breistroffer, 1940)

Fig. 9, Ni-1

1995 *Mortoniceras fallax* (Breistroffer, 1940); Latil, 71, Pl. 3, figs. 1-3; Pl. 4.
2002 *Mortoniceras* (*Mortoniceras*) *fallax* (Breistroffer, 1940); Amédro, p. 68, Pl. 2, figs. 2-3.
2002 *Mortoniceras* (*Mortoniceras*) *pachys* (Seeley, 1865); Amédro, p. 82, Pl. 9, fig. 1.
2008 *Mortoniceras* (*Mortoniceras*) *fallax* (Breistroffer, 1940); Kennedy *et al.*, p. 60, Pl. 6, figs. 1-3; p. 68, Pl. 10, figs. 8-11, 16.

Material: Ni-1, specimen broken.

Description: Ni-1 is the only specimen attributable to this species. The whorl section is almost quadrangular. The ornamentation is distinct, and consists of eight ribs that extend in pairs from the umbilical tubercle and strengthen into bullae at mid-flank. There are eight large and prominent ventrolateral tubercles. The venter is flat and the ribs are slightly curved on it. The keel is crossed by the ventral ribs.

Dimensions (in cm):

Sample number	D	Wh	Wb	Wb/Wh	U
Ni-1	-	2.7	2.5	0.92	-

Occurrence. *Mortoniceras* (*M.*) *fallax* Zone, England, Belgium, France, Hungary, Armenia and Madagascar (Amédro, 2008; Kennedy, 2008) and Iran (this study).

Family Acanthoceratidae Grossouvre, 1894
Subfamily Mantelliceratinae Hyatt, 1903
Genus *Mantelliceras* Hyatt, 1903
Mantelliceras mantelli (J. Sowerby, 1814)

Fig. 7, Ke-6, Ke-7, and Ke-8

1979 *Mantelliceras mantelli* (J. Sowerby, 1814); Kennedy *et al.*, p. 32, Pl. 6, figs. 1, 3; Pl. 8, fig. 4.
1981 *Mantelliceras mantelli* (J. Sowerby, 1814); Seyed-Emami and Aryai, p. 32, Pl. 8, figs. 5.a-c.
1985 *Mantelliceras mantelli* (J. Sowerby, 1814); Immel and Seyed-Emami, p. 99, Pl. 4, fig. 5.
1984 *Mantelliceras mantelli* (J. Sowerby, 1814); Wright and Kennedy, p. 99, Figs. 20.A-D, 26.A, C, E; 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.
1991 *Mantelliceras mantelli* (J. Sowerby, 1814); Delamette and Kennedy, p. 447, Pl. 9, figs. 4-6, 19-21.
1994 *Mantelliceras mantelli* (J. Sowerby, 1814); Kennedy, p. 222, Pl. 7, figs. 1-2, 9.

A

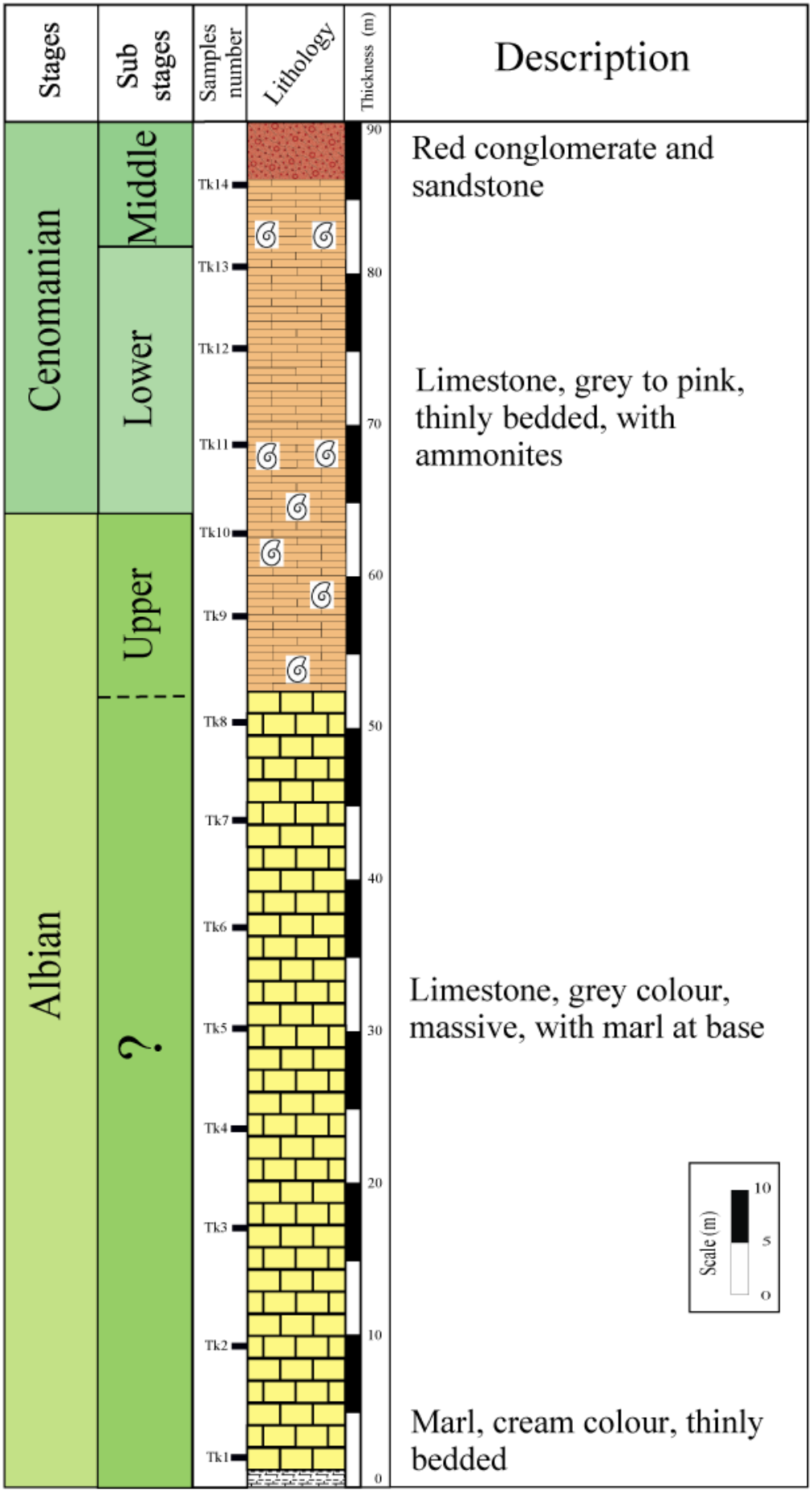
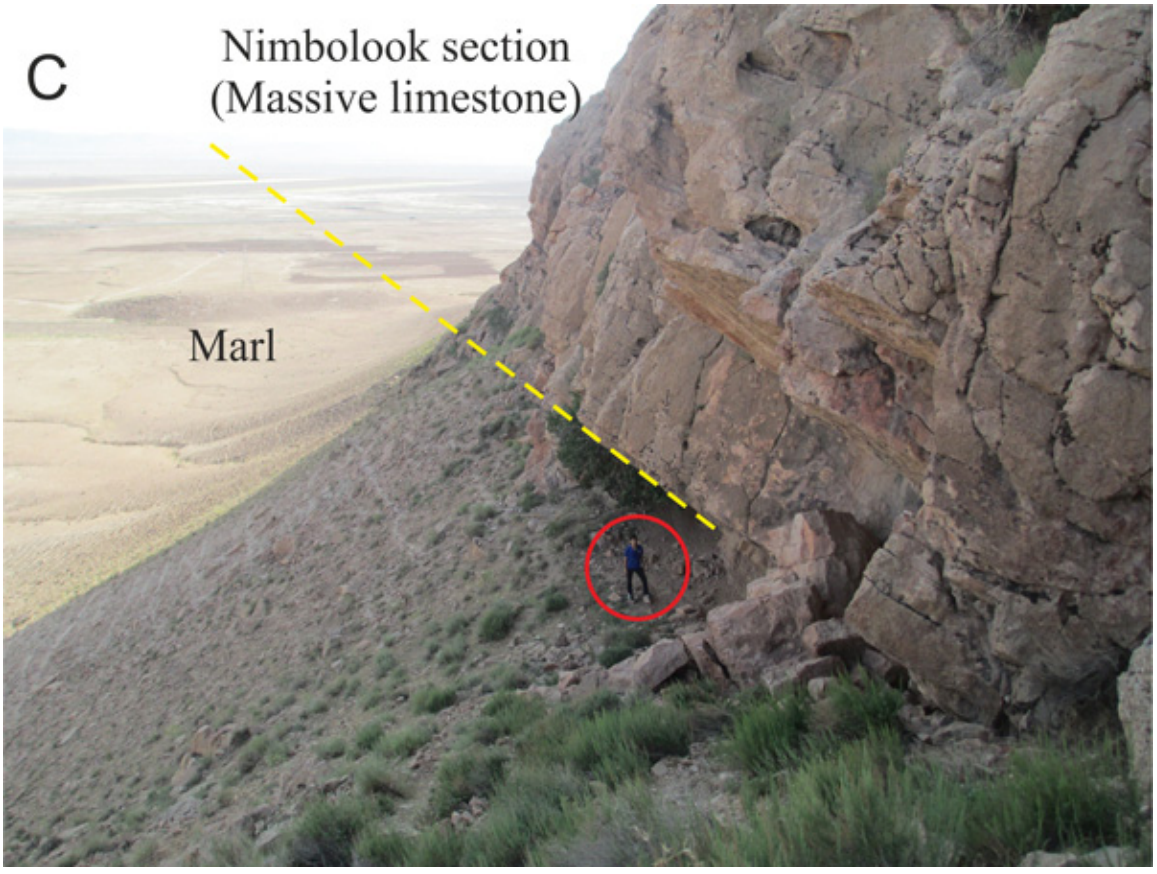

Stages
Sub stages
Samples number
Lithology
Thickness (m)
Description
Cenomanian
Middle
Lower
Albian
Upper
?
Tk14
Tk13
Tk12
Tk11
Tk10
Tk9
Tk8
Tk7
Tk6
Tk5
Tk4
Tk3
Tk2
Tk1
90
80
70
60
50
40
30
20
10
0
Red conglomerate and sandstone
Limestone, grey to pink, thinly bedded, with ammonites
Limestone, grey colour, massive, with marl at base
Marl, cream colour, thinly bedded
Scale (m)
10
5
0

Figure 6: Stratigraphic columns of the Nimbolook section (◀ A), upper half of the Nimbolook section (▲ B) and basal contact of the Nimbolook section (▼ C).



1998 *Mantelliceras mantelli* (J. SOWERBY, 1814); KAPLAN *et al.*, p. 115, Pl. 17, figs. 12-13; Pl. 19, figs. 1-9.
2011 *Mantelliceras mantelli* (J. SOWERBY, 1814); MOSAVINIA and WILMSEN, p. 178, Fig. 3.A-E (with full synonymy).
2015 *Mantelliceras mantelli* (J. SOWERBY, 1814); KENNEDY *et al.*, p. 2, Figs. 1. A-G, 3.D-G.
2015 *Mantelliceras mantelli* (J. SOWERBY, 1814); KENNEDY and GALE, p. 264, Pl. VII, fig. 3; Pl. VIII, figs. 1, 5.

Material: Ke-6, Ke-7, and Ke-8.

Description: Ke-6 is the largest and best preserved specimen of *M. mantelli* inform the Kerch section. The umbilicus is filled with sediments. Coiling is evolute to moderately involute, with a normal expansion rate and a subrounded to polygonal whorl section. Ornamentation is distinct. There are 13 primary, strong, radial and straight ribs that arise from umbilical shoulder, and secondary ribs are located between them. The primary ribs carry umbilical and lateral tubercles while ventro-lateral tubercles occur on all ribs. Ribs crossing the venter bear strong ventrolateral clavi.

Ke-7 consists of a half whorl that is smaller and less well preserved than Ke-6. Ke-7 bears 17 strong ribs that are alternately and regularly long and short. Ribs are slightly curved on the sides in contrast to those of Ke-6. Two rows of bullae are visible on the primary ribs of the flanks while a single row is present on the secondary ribs. On the venter, all ribs are linked and tubercles are arranged parallel to each other. Ke-8 is similar than Ke-7, but its lateral ribs are more sinuous and its lateral tubercles are barely visible, due to erosion.

Occurrence: *M. mantelli* has a world-wide distribution. It is common in the lower two thirds of the lower Cenomanian and only rarely found above (KENNEDY, 1994).

Dimensions (in cm):

Sample number	D	Wh	Wb	Wb/Wh	U
Ke-6	4.1	1.9	1.7	0.89	0.64
Ke-7	3.5	1.2	1.3	1.08	0.17
Ke-8	3.5	1.7	1.3	0.76	0.20

Mantelliceras cf. *mantelli* (J. SOWERBY, 1814)

Fig. 9, Ni-3

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.
1991 *Mantelliceras mantelli* (J. SOWERBY, 1814); DELAMETTE and KENNEDY, p. 447, Fig. 9.4-6.
1998 *Mantelliceras mantelli* (J. SOWERBY, 1814); KAPLAN *et al.*, p. 115, Pl. 11, figs. 1-2; 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.
1985 *Mantelliceras mantelli* (J. SOWERBY, 1814); IMMEL and SEYED-EMAMI, p. 99, Pl. 4, fig. 5.
2011 *Mantelliceras mantelli* (J. SOWERBY, 1814); MOSAVINIA and WILMSEN, p. 180, Fig. 3.A-E.
2015 *Mantelliceras mantelli* (J. SOWERBY, 1814); KENNEDY *et al.*, p. 2, Fig. 1.A-G.

Material: Ni-3, specimen broken, abraded ventrally.

Description: The specimen is a half whorl bearing 17 ribs. Seven primary ribs arise at the umbilical seam and extend across the flanks, with secondary ribs located between them. The flanks are nearly flat and the whorl section is oval to rectangular. Some of the primary ribs strengthen into rounded tubercles on the middle of the sides. Tiny ventrolateral nodes occur in places. All ribs are straight, strong and radial on the flanks but diminish toward the venter. Other *Mantelliceras* found in Kerch section have more prominent ornaments and more convex flanks than Ni-3.

Dimensions (in cm):

Sample number	D	Wh	Wb	Wb/Wh	U
Ni-3	-	3.1	2.4	0.77	-

Mantelliceras saxbii (SHARPE, 1857)

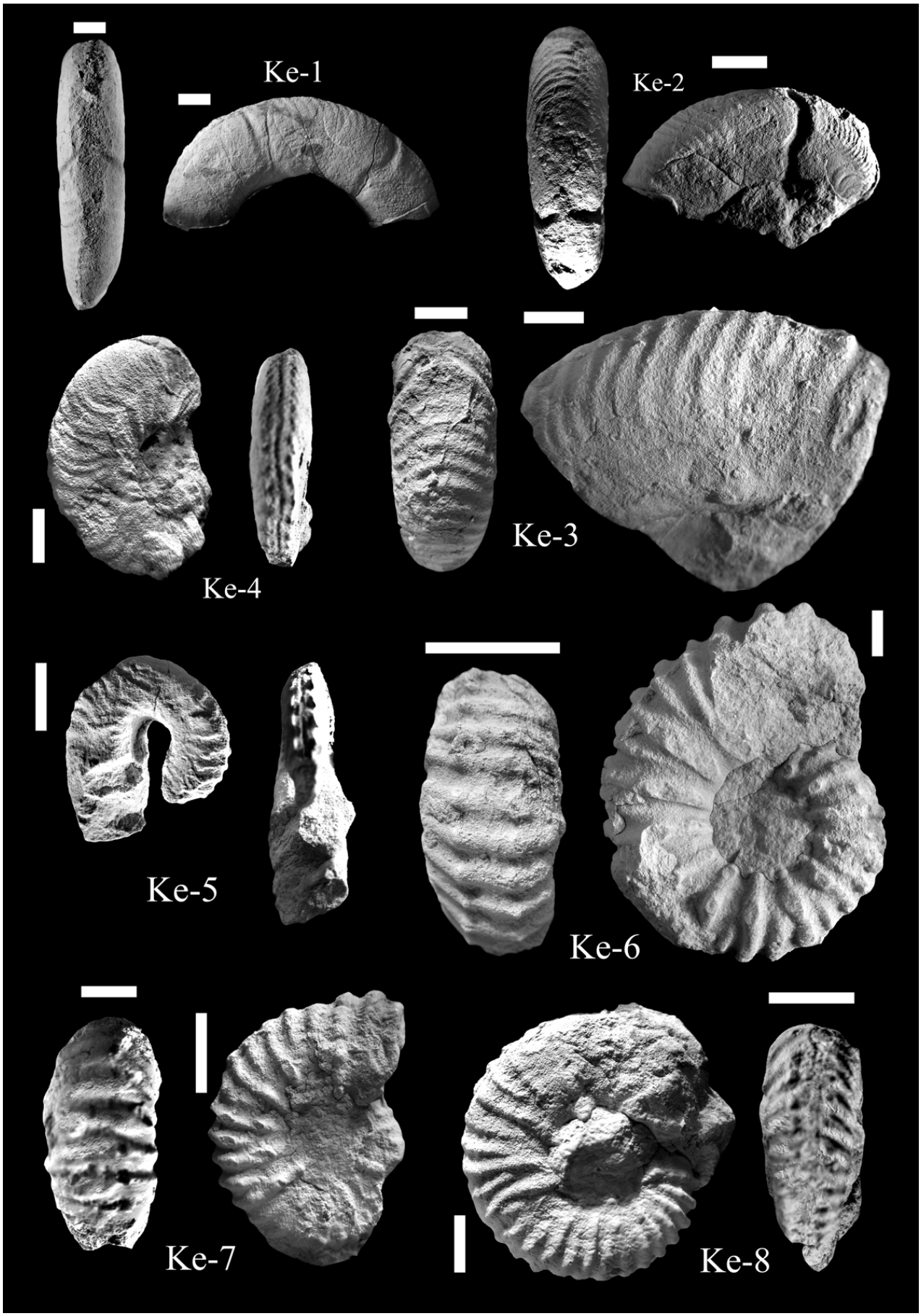
Fig. 8, Ke-9

1971 *Mantelliceras saxbii*; KENNEDY and HANCOCK, p. 437, Pl. 79, figs. 1-5; Pl. 80, figs. 1-4; Pl. 81, figs. 1, 4, 6-8; Pl. 82, figs. 2, 4-5.
1979 *Mantelliceras saxbii* (SHARPE, 1857); KENNEDY *et al.*, p. 36, Pl. 7, fig. 5.
1985 *Mantelliceras saxbii* (SHARPE, 1857); IMMEL and SEYED-EMAMI, p. 102, Pl. 6, fig. 5.
1991 *Mantelliceras saxbii* (SHARPE, 1857); DELAMETTE and KENNEDY, p. 454, Pl. 14, figs. 1-4.
1994 *Mantelliceras saxbii* (SHARPE, 1857); KENNEDY, p. 224, Pl. 7, fig. 11.
1997 *Mantelliceras saxbii* (SHARPE, 1857); IMMEL *et al.*, p. 169.
1998 *Mantelliceras saxbii* (SHARPE, 1857); KAPLAN *et al.*, p. 118, Pl. 17, fig. 1; Pl. 19, figs. 1-9.
2008 *Mantelliceras saxbii* (SHARPE, 1857); KENNEDY *et al.*, p. 130, Pl. 5, fig. 13.
2011 *Mantelliceras saxbii* (SHARPE, 1857); MOSAVINIA and WILMSEN, p. 182, Fig. 4.C, 4.F-G.
2015 *Mantelliceras saxbii* (SHARPE, 1857); KENNEDY *et al.*, p. 5, Fig. 7.K-L.
2015 *Mantelliceras saxbii* (SHARPE, 1857); KENNEDY and GALE, p. 267, Pl. VII, fig. 4; Pl. VIII, fig. 4.

Material: Ke-9.

Description: Ke-9 is oval in cross section and widest in the middle of the flanks that are gently curved near the venter. The umbilicus is moderately deep, with a steep wall. The primary ribs arise from the umbilical shoulder. Secondary ribs arise at the middle of the flanks and are arranged irregularly between the primary ribs. In total there are 30 fine (contrast those of *M. mantelli*) and crowded narrow ribs. Tubercles are absent from the flanks, but occur in two rows bordering the venter. They are tiny, rounded and, in some cases, barely visible, due to abrasion.

▶ **Figure 7:** Ke-1, Ke-2 and Ke-3: *Puzosia* (*Puzosia*) *mayoriana* (ORBIGNY, 1841), Ke-4 and Ke-5: *Hypholites costosus* C.W. WRIGHT & E.V. WRIGHT, 1949, Ke-6, Ke-7 and Ke-8: *Mantelliceras mantelli* (J. SOWERBY, 1814) (all scales: 1 cm).


Ke-1
Ke-2
Ke-3
Ke-4
Ke-5
Ke-6
Ke-7
Ke-8

Occurrence: *Manteliceras saxbii* Zone of western Europe (GALE, 1995; GALE *et al.*, 1996; AMÉDRO, 2008) and throughout the lower Cenomanian, but common only in the middle of the substage. It is recorded all over Europe, Russia, North Africa, Angola, Madagascar, Iran and Kazakhstan. KENNEDY *et al.* (2008) noted that this species is distinct from *M. mantelli* in the lack of lateral tubercles, the dense ribbing and the compressed whorl section.

Dimensions (in cm):

Sample number	D	Wh	Wb	Wb/Wh	U
Ke-9	4.0	1.8	1.1	0.61	0.22

Mantelliceras sp. 1

Fig. 8, Ke-10 and Ke-11

Material: Ke-10 and Ke-11, specimens broken.

Description: The ornamentation and the stratigraphic position suggest attribution to *Mantelliceras* but more definite identification is impossible. Ke-10 has about primary ribs (arising at the umbilical margin) and 11 irregular short secondary ribs (arising at mid-flank). The ribs are densely distributed, straight and linked on the venter, and bear ventrolateral tubercles. Ke-11 is a crushed specimen with two rows of ventolateral tubercles and abraded, relatively widely spaced radial ribs on the sides.

Dimensions (in cm):

Sample number	D	Wh	Wb	Wb/Wh	U
Ke-10	7.1	3.0	2.0	0.66	-
Ke-11	6.1	2.5	1.7	0.68	-

Mantelliceras sp. 2

Fig. 8, Ke-12 and Ke-13

Material: Ke-12 and Ke-13

Description: Ke-12 may represent *M. saxbii*, based upon the arrangement of the ribs and the lack of lateral tubercles. Ke-13 has a rounded and wide venter, a circular whorl section, 18 strong and densely distributed ribs that arise from umbilical bullae. Ke-13 is similar to *Mantelliceras nitidum* (CRICK, 1907) as described by KENNEDY *et al.* (2015) (Fig. 4. A-D, G-L) but is too poorly preserved for confident specific determination.

Dimensions (in cm):

Sample number	D	Wh	Wb	Wb/Wh	U
Ke-12	-	-	1.9	-	-
Ke-13	4.6	1.6	1.7	1.06	-

Mantelliceras sp. 3

Fig. 9, Ni-4

Material: Ni-4.

Description: Ni-4 is a composite mould of the upper part of Nimbolook section. The umbilicus is covered by sediment and the ornamentation is visible only on the right side. Ni-4 has evolute coiling and a low expansion rate. The whorl section is oval and there are no tubercles, but 23-25 sharp ribs alternately long and short and dichotomously branching from the middle of the flanks.

Dimensions (in cm):

Sample number	D	Wh	Wb	Wb/Wh	U
Ni-4	11.5	4	2.5	0.62	-

Genus *Sharpeiceras* HYATT, 1903

Sharpeiceras laticlavium (SHARPE, 1855)

Fig. 8, Ke-14

1971 *Sharpeiceras laticlavium* (SHARPE, 1855); KENNEDY, p. 64, Pl. 27, fig. 1.a-c.
1979 *Sharpeiceras laticlavium* (SHARPE, 1855); KENNEDY *et al.*, p. 38, Pl. 8, figs. 1-2.
1984 *Sharpeiceras laticlavium* (SHARPE, 1855); WRIGHT and KENNEDY, p. 127, Figs. 29, 30, 34.a; Pl. 41, fig. 4.
1985 *Sharpeiceras laticlavium* (SHARPE, 1855) *nigeriense* subsp. nov.; ZABORSKI, p. 26, Fig. 31.a-b.
1991 *Sharpeiceras laticlavium* (SHARPE, 1855); DELAMETTE and KENNEDY, p. 454, Pl. 9, figs. 9-10.
1998 *Sharpeiceras laticlavium* (SHARPE, 1855); KAPLAN *et al.*, p. 126, Pls. 27-30, 32.
1994 *Sharpeiceras laticlavium* (SHARPE, 1855); KENNEDY, p. 224.
2015 *Sharpeiceras laticlavium* (SHARPE, 1855); KENNEDY *et al.*, p. 11, Fig. 12.R.
2015 *Sharpeiceras laticlavium* (SHARPE, 1855); KENNEDY and GALE, p. 274, Pl. X, fig. 3.

Material: Ke-14.

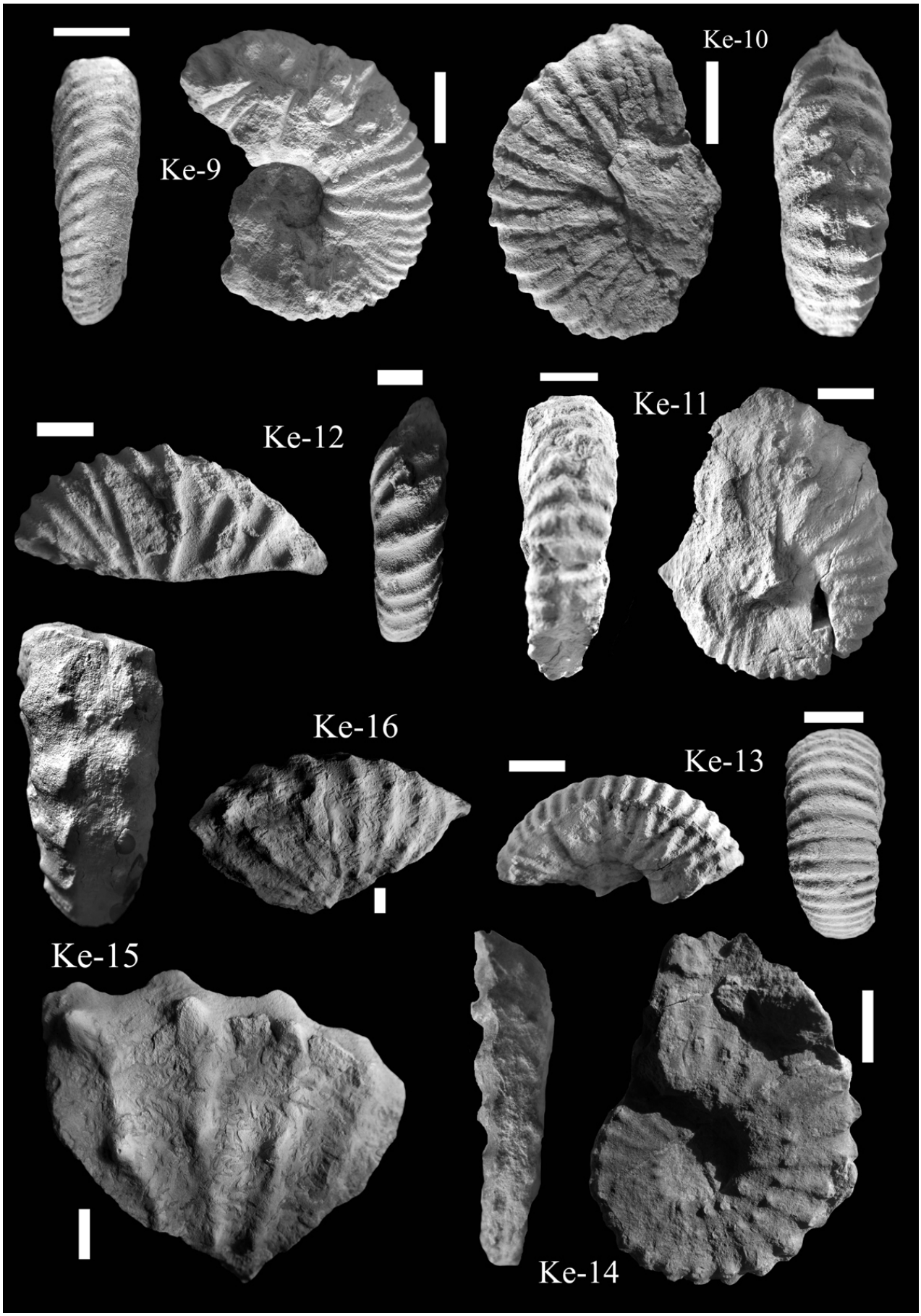
Description: The distinctive features of this species are the compressed, rectangular whorl section and very evolute coiling. The umbilicus features a steep wall. There are 24 coarse, straight ribs that originate from the umbilicus and extend across the sides of the whorl. All ribs bear umbilical, middle lateral and inner ventrolateral conical tubercles and much stronger outer ventrolateral clavi. The venter is flat and smooth. Ribs that reach the flanks disappear on the venter.

Dimensions (in cm):

Sample number	D	Wh	Wb	Wb/Wh	U
Ke-14	5.0	2.1	0.7	0.33	0.26

Discussion: The flattened flank and coarser tuberculation separate this specimen from *Sharpeiceras schlueteri*. The difference between the two species is described in DELAMETTE and KENNEDY (1991).

▶ **Figure 8:** Ke-9: *Mantelliceras saxbii* (SHARPE, 1857), Ke-10 and Ke-11: *Mantelliceras* sp. 1, Ke-12 and Ke-13: *Mantelliceras* sp. 2, Ke-14: *Sharpeiceras laticlavium* (SHARPE, 1855), Ke-15, Ke-16: *Sharpeiceras schlueteri* (HYATT, 1903) (all scales: 1 cm).


Ke-9
Ke-10
Ke-12
Ke-11
Ke-16
Ke-13
Ke-15
Ke-14

Occurrence: *Sharpeiceras laticlavium* is a cosmopolitan species indicative of the lower Cenomanian. The species occurs in *N. carcitanense*, *S. schlueteri* and *M. saxbii* Assemblage Zone faunas (KENNEDY *et al.*, 1979; DELAMETTE and KENNEDY, 1991; KAPLAN *et al.*, 1998).

Sharpeiceras schlueteri (HYATT, 1903)

Fig. 8, Ke-15 and Ke-16

1982 *Sharpeiceras mexicanum* (BOSE); MANCINI, p. 254, Fig. 6.e.
1998 *Sharpeiceras schlueteri* (HYATT, 1903); KAPLAN *et al.*, p. 128, Pls. 31-32; Pl. 33, figs. 3-4.
2005 *Sharpeiceras schlueteri* (HYATT, 1903); KENNEDY *et al.*, Figs. 10.L, 24.D-E.
2015 *Sharpeiceras schlueteri* (HYATT, 1903); KENNEDY and GALE, p. 274, Fig. 18; Pl. X, figs. 2, 5, 10; Pl. XI, figs. 1-2.

Material: Ke-15 and Ke-16.

Description: Two specimens of *S. schlueteri* are found in the Kerch section. Ke-15 is the largest ammonite found there. Four coarse ribs that swell into umbilical, middle lateral, and inner and outer ventrolateral tubercles are preserved on the sides. Tubercles are strong and conical. In the adult, the inner ventrolateral tubercles tend to develop into a horn-like process (KENNEDY, 1971). The inner ventrolateral tubercles are connected to a row of very prominent outer ventrolateral clavi by broad ribs. The sutures are clearly visible. The ornamentation of Ke-16 is similar to that of Ke-15 except that the ribs and tubercles are less prominent. Furthermore part of the umbilicus is visible although filled by sediment.

Dimensions (in cm):

Sample number	D	Wh	Wb	Wb/Wh	U
Ke-15	-	6.5	3.9	0.60	-
Ke-16	-	4.7	3.2	0.68	-

Sample number D Wh Wb Wb/Wh U Ke-15 - 6.5 3.9 0.60 - Ke-16 - 4.7 3.2 0.68 -

Occurrence: It represents the Lower Cenomanian. *Sharpeiceras schlueteri* is a Subzone of the *M. mantelli* Zone and occurs in England, France, Germany, Angola, Mozambique, Texas and Peru (KAPLAN *et al.*, 1998; KENNEDY *et al.*, 2005) and Iran in this study.

Subfamily Acanthoceratinae GROSSOUVRE, 1894
Genus *Calycoceras* HYATT, 1900
Subgenus *Gentoniceras* THOMEL, 1972
Calycoceras (*Gentoniceras*) aff. *gentoni* (BRONGNIART, 1822)

Fig. 9, Ni-5

1990 *Calycoceras* (*Gentoniceras*) *gentoni* (BRONGNIART, 1822); WRIGHT and KENNEDY, p. 219, Figs. 88.a-c, 89.a-b, 90.a-c; Pl. 56, figs. 1-3, 6-8; Pl. 57, figs. 2-3, 8; Pl. 58, fig. 7; Pl. 66, figs. 1-2.
1994 *Calycoceras* (*Gentoniceras*) *gentoni* (BRONGNIART, 1822); KENNEDY and JUIGNET, p. 30, Figs. 1a, 2.d-e; 6.d-e, 6.j-k, 7.a-l, 8.a-e, 22.a-b.
1998 *Calycoceras* (*Gentoniceras*) *gentoni* (BRONGNIART, 1822); KAPLAN *et al.*, p. 156, Pl. 26, figs. 3-5.
2015 *Calycoceras* (*Gentoniceras*) *gentoni* (BRONGNIART, 1822); MEISTER and PIUZ, p. 35, Pl. 9, fig. 1.

Material: Ni-5, broken specimen.

Description: Ni-5 is from the upper part of the Nimbolook section. The specimen has a mas-sive whorl and deep umbilicus. It has 20-22 robust ribs on the venter but no lateral or ventral tubercles are observed.

Dimensions (in cm):

Sample number	D	Wh	Wb	Wb/Wh	U
Ni-5	8.7	3.7	2.0	0.54	0.17

Occurrence: *Calycoceras* (*Gentoniceras*) *gentoni* occurs in the lower middle to lower upper Cenomanian (KENNEDY and JUIGNET, 1994; KAPLAN *et al.*, 1998). The association of *C.* (*G.*) *gentoni* and *Turrilites costatus* in the same horizon at Nimbolook section, is of early middle Cenomanian age. The species is also known from France, England, Germany and central Iran.

Superfamily Turrilitoidea GILL, 1871
Family Anisoceratidae HYATT, 1900
Genus *Idiohamites* SPATH, 1925
Idiohamites fremonti (MARCOU, 1858)

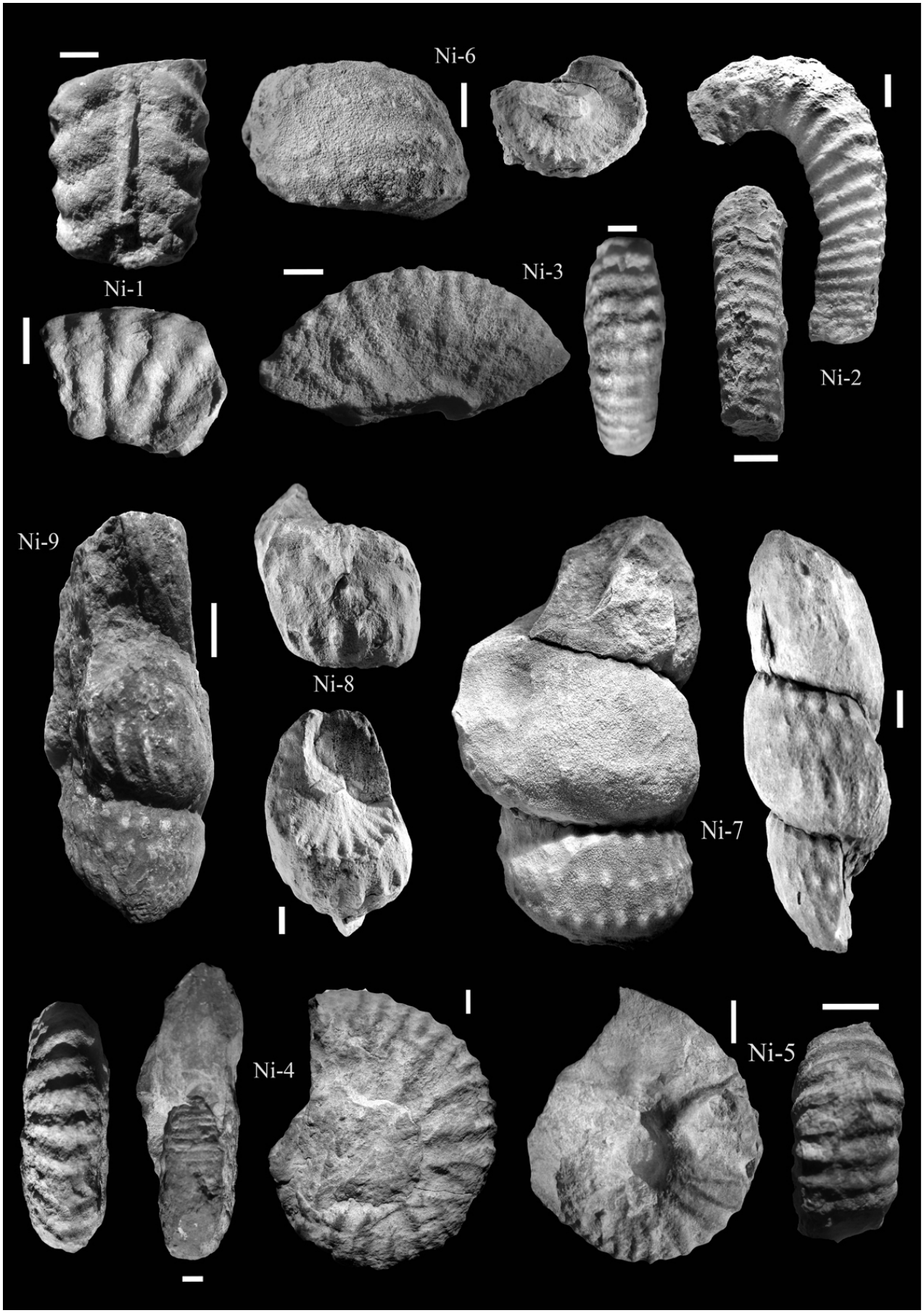
Fig. 9, Ni-2

1932 *Idiohamites fremonti* (MARCOU, 1858); ADKINS, p. 363.
1962 *Idiohamites fremonti* (MARCOU, 1858); SWENSEN, p. 72, Pl. 2, fig. 11; Pl. 3, figs. 5, 9; Pl. 5, figs. 1-7.
1965 *Idiohamites fremonti* (MARCOU, 1858); CLARK, p. 28, Pl. 2, fig. 11; Pl. 5, figs. 5, 9; Pl. 7, figs. 1-7.
1987 *Idiohamites fremonti* (MARCOU, 1858); COBBAN, p. 221, Figs. 3.N, 4.A-J, 4.L.

Material: Ni-2.

Description: Ni-2 is part of a U-shaped body chamber that is coiled in a plane open spiral. Ornaments consist of 16 oblique ribs, pro-minent on the flanks but becoming faint towards the venter where they are replaced by two rows of ventral tubercles. Lateral tubercles are absent. The ribs are densely distributed and narrow on the straight shaft but are broader with more widely spaced on the hooked whorl.

▶ **Figure 9:** Ni-1: *Mortoniceras* (*Mortoniceras*) cf. *fallax* (BREISTROFFER, 1940), Ni-2: *Idiohamites fremonti* (MARCOU, 1858), Ni-3: *Mantelliceras* cf. *mantelli* (J. SOWERBY, 1814), Ni-4: *Mantelliceras* sp. 3, Ni-5: *Calycoceras* (*Gentoniceras*) aff. *gentoni* (BRONGNIART, 1822), Ni-6: *Mariella* (*Mariella*) *dorsetensis* (SPATH, 1926), Ni-7: *Mariella* (*Mariella*) sp., Ni-8 and Ni-9: *Turrilites* (*Turrilites*) *costatus* (LAMARCK, 1801) (all scales: 1 cm).


Ni-6
Ni-1
Ni-3
Ni-2
Ni-9
Ni-8
Ni-7
Ni-4
Ni-5

Occurrence: *I. fremonti* occurs in the Duck Creek limestone of northern Texas (upper Albian) (ADKINS, 1932). Since *I. fremonti* is recorded at almost the same horizon as *M. fallax* in the Nimbolook section, its occurrence indicates the upper Albian. The present specimen is the first record from Iran.

Family Turrilitidae GILL, 1871
Genus and subgenus *Mariella* NOWAK, 1916
Mariella (*Mariella*) *dorsetensis* (SPATH, 1926)

Fig. 9, Ni-6

1937 *Mariella dorsetensis* (SPATH); SPATH, p. 513.
1970 *Mariella dorsetensis* (SPATH, 1926); MARCINOWSKI, p. 431, Pl. 3, fig. 1.
1978 *Mariella* (*Mariella*) *dorsetensis* (SPATH, 1926); KLINGER and KENNEDY, p. 31, Figs. 3.a, 8.a; Pl. 7, fig. 31.
1979 *Mariella* (*Mariella*) *dorsetensis* (SPATH, 1926); KENNEDY *et al.*, p. 18, Pl. 1, fig. 9.
1983 *Mariella* (*Mariella*) *dorsetensis* (SPATH, 1926); KENNEDY and JUIGNET, p. 59, Fig. 22.f.

Material: Ni-6.

Description: Ni-6 consists of two whorls of an internal mould with sinistral turrilitid coiling. The whorl section is rounded. Ribs are not visible between the tubercles present but they are located in the axis. The first three rows of tubercles are exposed on the whorl surface, with a fourth being concealed in the whorl suture. The first row of tubercles is pronounced and elongated across the upper half. The next three rows are arranged on the lower half of the flank equidistant from each other. They are conical, tiny and offset from the first row.

Occurrence: Lower Cenomanian of England, France, Poland, Zululand (South Africa) and central Iran. The present specimen represents the first record from east Iran.

Mariella (*Mariella*) sp.

Fig. 9, Ni-7

Material: Ni-7.

Description: Ni-7 consists of three sinistral whorls with an oval whorl section. Ornamentation is visible on the first whorl and partially on the second. There are 13 transverse ribs on the first whorl and three rows of tubercles. The ribs appear at the upper whorl suture and are most prominent on the upper part of the flank. The first row of tubercles is a litle stretched in the upper half. Tubercles on the lower half are conical and pointed and have a rounded base. In the third row, some tubercles merge to form a spiral ridge.

Genus *Turrilites* LAMARCK, 1801
Turrilites costatus LAMARCK, 1801

Fig. 9, Ni-8 and Ni-9

1965 *Turrilites* (*Turrilites*) *costatus* LAMARCK, 1801; CLARK, p. 53, Figs. 20a, b; Pl. 20, figs. 1-2, 7-8.
1971 Turrilites costatus LAMARCK, 1801; KENNEDY, p. 30, Pl. 6, fig. 3; Pl. 8, figs. 12, 14.
1982 *Turrilites costatus* LAMARCK, 1801; SEYED-EMAMI, p. 428, Fig. 4.4-5, 4.11.
1983 *Turrilites costatus* LAMARCK, 1801; KENNEDY and JUIGNET, p. 47, Figs. 25.a-o, 26.a-b, 27.a-i, 28.a-b, 28.d.
1985 *Turrilites* (*Turrilites*) *costatus* LAMARCK, 1801; ZABORSKI, Pl. 10, figs. 9-10.
1987 *Turrilites costatus* LAMARCK, 1801; COBBAN, p. 2, Fig. 4.
1991 *Turrilites costatus* LAMARCK, 1801; DELAMETTE and KENNEDY, p. 458, Figs. 17.26-27, 17.29.
1994 *Turrilites* (*Turrilites*) *costatus* LAMARCK, 1801; KENNEDY, p. 232, Pl. 12, figs. 14, 16-17, 20.
1998 *Turrilites costatus* LAMARCK, 1801; KAPLAN *et al.*, p. 214, Pl. 64, fig. 3; Pl. 65, figs. 7-8.
2007 *Turrilites costatus* LAMARCK, 1801; WILMSEN *et al.*, Fig. 5.c.
2015 *Turrilites costatus* LAMARCK, 1801; MEISTER and PIUZ, p. 67, Pl. 20, figs. 2-3; p. 68, Pl. 21, figs. 2-6, 8.
2015 *Turrilites costatus* LAMARCK, 1801; KENNEDY and GALE, p. 316, Pl. XXIV, figs. 5, 9.

Material: Ni-8 and Ni-9.

Description: Ni-8 is a specimen with a perfect whorl. Tubercles are distributed regularly and equidistant from their neighbours such that the first, second and third rows occur in the lower, middle and upper third, respectively. In the first row, tubercles are elongate and prominent. Ribs are not seen between the tubercles but they are located in the axis. Ni-9 is a broken specimen with the ornamentation visible on one side.

Our specimens (see Fig. 9, Ni-8 and Ni-9) have the same rib density and uniform separation of ribs.Also significant is that they have the same apical angle.

Occurrence: *Turrilites costatus* has a middle Cenomanian acme at the base of the *A. rhotomagense* Zone and is rarer in the lower part of the upper Cenomanian. It has a cosmopolitan distribution including the former U.S.S.R. territory, Poland, Germany, France, Iran, United States of America and England.

5. Biostratigraphy

Ammonites provide one of the most precise biostratigraphical tools for correlating Cretaceous sedimentary rocks. Cretaceous stages, boundaries and index faunas in Europe have been discussed by BIRKELUND *et al.* (1984) and HANCOCK (1991). The Albian and Cenomanian stages are discussed respectively by HART *et al.* (1996) and TRÖGER and KENNEDY (1996). Albian and Cenomanian ammonites biozonation (Table 1) have been considered by KENNEDY (1971), WRIGHT and KENNEDY (1984), OWEN (1999, 2002), HOEDEMAEKER *et al.* (2003), GALE *et al.* (2005), WILMSEN (2007), KENNEDY and LATIL (2007), and REBOULET *et al.* (2014).

The ammonite fauna collected from the Kerch section consists of seven taxa and that from the Nimbolook section is of eight taxa. Based on these faunas we suggest zones and subzones that are correlatable with the standard biozonation (Table 1).

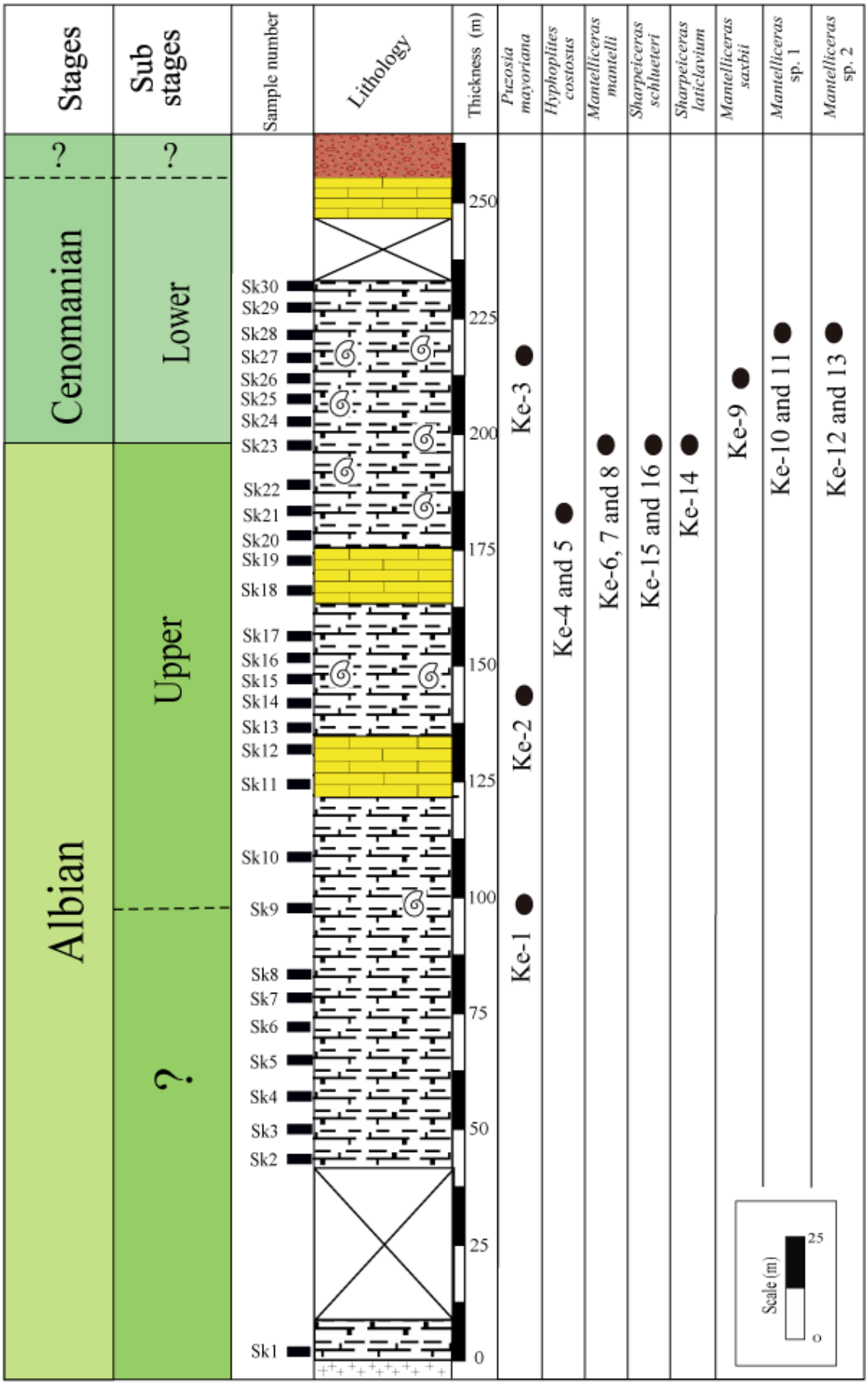


Figure 10: Ammonite range chart in the Kerch section, eastern Iran.

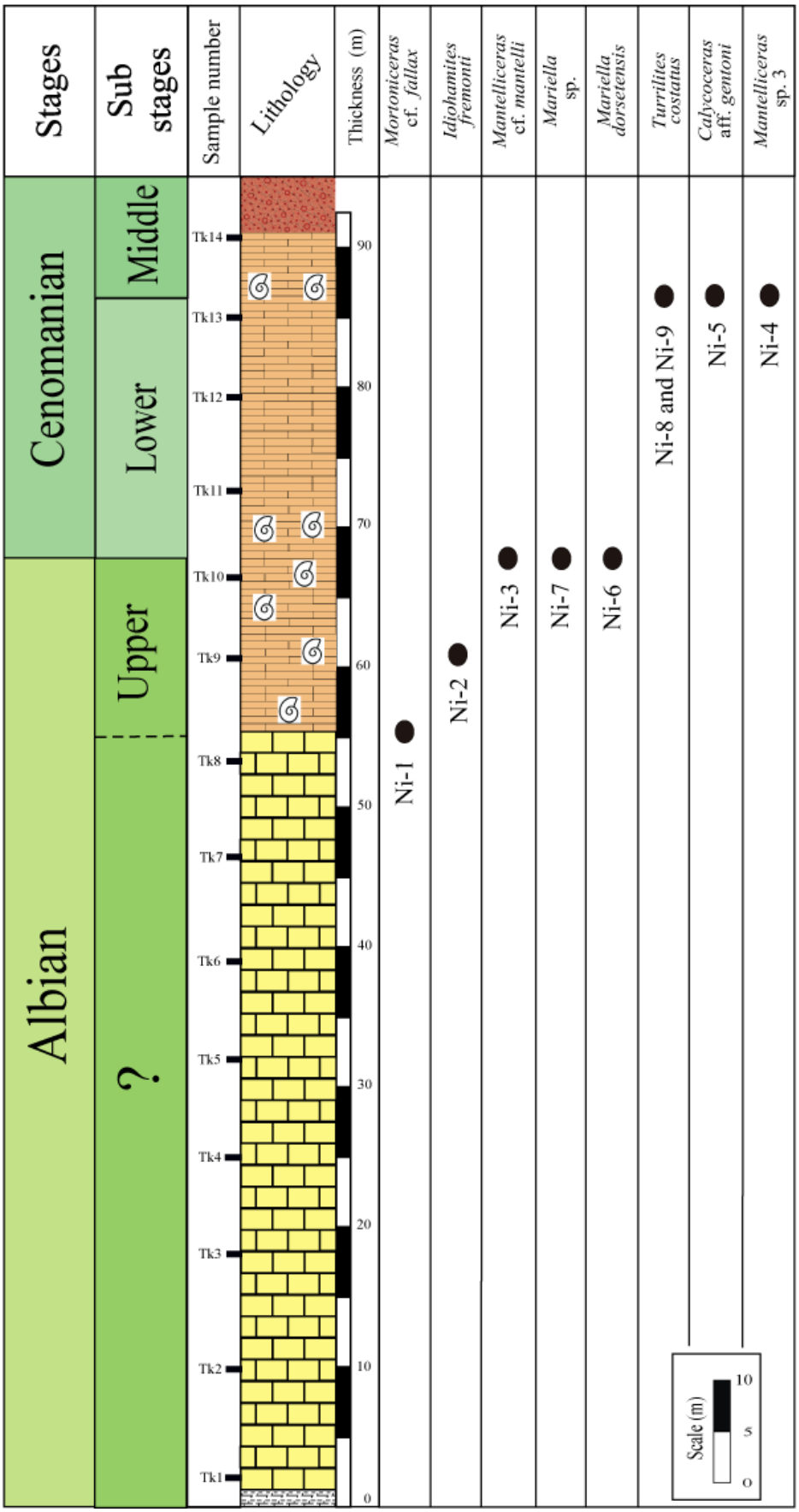


Figure 11: Ammonite range chart in the Nimbolook section, eastern Iran.

Table 1: Ammonite zonation compiled after KENNEDY (1994), WRIGHT and KENNEDY (1984), HANCOCK (1991), MARCINOWSKI *et al.* (1996), GALE *et al.* (2005), WILMSEN (2007), KENNEDY and LATIL (2007), AMÉDRO (2008), KENNEDY *et al.* (2013), and REBOULET *et al.* (2014). Items marked in bold are recorded in this study.

Stages and Substages		Zones and Subzones	
Cenomanian	Middle	*Acanthoceras rhotomagense*	*Turrilites acutus*
			Turrilites costatus
		Cunningtoniceras inerme	
	Lower	*Mantelliceras dixoni*	
		Mantelliceras mantelli	***Mantelliceras saxbii***
			Sharpeiceras schlueteri
			Neostlingoceras carcitanense
Albian	Upper	*Arrhaphoceras briacensis*	
		Mortoniceras perinflatum	
		Mortoniceras rostratum	
		Mortoniceras fallax	
		Mortoniceras inflatum	
		Mortoniceras pricei	
		Dipoloceras cristatum	

It is possible to use the *Mantelliceras mantelli* Zone for the base of the Cenomanian in both sections. The *M. mantelli* zone fauna is: *Mantelliceras mantelli*, *M. saxbii*, *M.* sp., *Sharpeiceras laticlavium*, *S. schlueteri* in the Kerch section (Fig. 10) and *Mantelliceras* cf. *mantelli*, *Mariella* (*Mariella*) *dorsetensis* in the Nimbolook section (Fig. 11). At the Kerch section, the *Sharpeiceras schlueteri* subzone and the *Mantelliceras saxbii* subzone indicate the middle and upper lower Cenomanian, respectively. The *Mortoniceras fallax* zone marks the upper Albian in Nimbolook section. The uppermost Nimbolook section belongs to the lower middle Cenomanian and is defined by the *Turrilites costatus* subzone.

The ammonite assemblages clearly indicate a late Albian-middle Cenomanian age for strata containing ammonites in the Nimbolook section and a late Albian-early Cenomanian age in the Kerch section.

6. Conclusions

Ammonites presented here come from two sections at the eastern margin of the Lut block. The Kerch section consists of marl and marly limestone and Nimbolook is of limestone. Both sections pass upward into a siliciclastic unit (red conglomerate and sandstone). During a bed-by-bed search, almost all the ammonites collected were recovered from the upper half of the sections which belong to the upper Albian and the lower Cenomanian. We determine the position of the Albian - Cenomanian boundary in both sections with *M. mantelli* zone. This paper is a preliminary contribution to our understanding of the ammonitic paleontology of the Lut block. The figured materials and the stratigraphic columns showing ammonite occurrence provide a foundation for further studies in the Lut block.

Acknowledgements

The authors thank J. KENNEDY (Oxford University) and M. WILMSEN (Senckenbergische Naturforschende Gesellschaft), for helpful discussions of the specimens. We are indebted to C. MEISTER (Natural History Museum of Geneva) and B. MATRION, who acted as referees, for their useful suggestions. Logistical support for field work and laboratory facilities were partly financed by the University of Birjand. Thanks go to Iranian friends, especially Mr. H. ABDIAN, for their help in the field.

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