Rivista Italiana di Paleontologia e Stratigrafia	volume 119	no. 2	pp. 163-174	July 2013

MIDDLE JURASSIC BELEMNITES AND AMMONITES (CEPHALOPODA) FROM TELMA-DAREH, NORTHERN IRAN

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Received: December 12, 2012; accepted: March 21, 2013

Key words: Aalenian, ammonites, belemnites, Telma-Dareh, Alborz Mountains, Iran.

Abstract. Ammonites and belemnites from a Middle Jurassic section at Telma-Dareh (Alborz Mountains, northern Iran) are described. The lithology of the studied section consists of an alternation of marls and limestones attributed to the Dalichai Fm., overlying the top of the Shemshak Fm. (sandstones) and underlying the Lar Fm. (limestones). Fossils are rather abundant but concentrated in ten scattered levels, ranging from the Aalenian (Scissum-Murchisonae zones) up to the Bajocian. Ammonites (*Tmetoceras scissum*, *Leioceras* cf. *comptum*, *Ludwigia* cf. *murchisonae*, *Onychoceras*? sp., and *Leptosphinctes* sp.), belemnites (*Brevibelus breviformis*, *Holcobelus* cf. *munieri*) and bivalves are the most abundant and well-preserved fossils; accessory elements are scarce brachiopods and gastropods. The palaeobiogeographic affinities of the belemnite fauna is Subboreal-Submediterranean, whereas the ammonites have Submediterranean-Tethyan affinities. The Aalenian age of the lower part of the Dalichai Fm. at Telma-Dareh differs from the Bajocian age attributed by other authors to this formation in other localities.

Riassunto. Una fauna a belemniti e ammoniti, provenienti da una sezione del Giurassico medio affiorante nelle vicinanze di Telma-Dareh (Monti di Alborz, Iran settentrionale) sono descritte. La successione stratigrafica è caratterizzata da una alternanza di marne e calcari appartenenti alla Fm. Dalichai. Questa formazione poggia sulla Fm. Shemshak (arenarie) ed è al di sotto della Fm. Lar (calcari). I fossili piuttosto abbondanti, anche se concentrati in dieci livelli, hanno una distribuzione stratigrafica dall'Aaleniano (Zone a Scissum e Murchisonae) al Bajociano. Le ammoniti (*Tmetoceras scissum*, *Leioceras* cf. *comptum*, *Ludwigia* cf. *murchisonae*, *Onychoceras*? sp., e *Leptosphinctes* sp.), le belemniti (*Brevibelus breviformis*, *Holcobelus* cf. *munieri*) e i bivalvi sono i fossili più abbondanti e meglio conservati; la scarsa fauna accessoria è costituita da brachiopodi e gasteropodi. Le belemniti mostrano un'affinità Subboreale-Submediterranea, mentre le ammoniti presentano un'affinità Submediterranea-Tetisiana. L'età aaleniana della della parte inferiore della Fm. Dalichai di Telma-Dareh differisce dall'età (Bajociano) ad essa attribuita da altri autori.

Introduction

Belemnites of the Middle Jurassic of Iran are poorly studied; only some illustrations are available (*e.g.* Shafeizad & Seyed-Emami 2005) but systematic descriptions had not yet been published to our knowledge. In contrast, ammonites have received extensive studies (*e.g.*, Majidifard 2003, Seyed-Emami 1971, Seyed-Emami et al. 2005, Seyed-Emami & Schairer 2011, Seyed-Emami et al. 1989, Seyed-Emami et al. 1995, Shafeizad & Seyed-Emami 2005).

The aim of this paper is to present the systematic study of recently collected Aalenian belemnites and ammonites from a section of the Dalichai Fm. at Telma-Dareh, south-eastern of Sari city, in northern Iran, and to discuss their stratigraphic distribution and palaeobiogeographic affinities.

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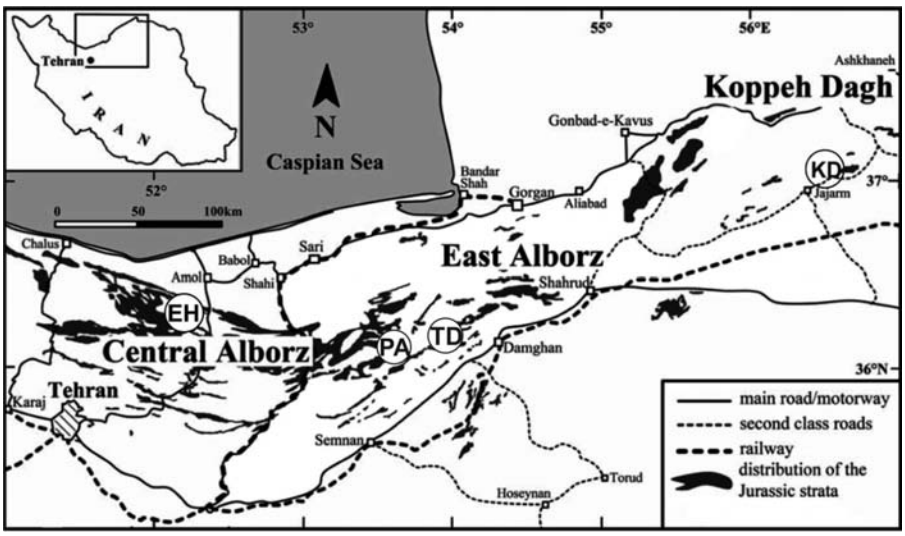

Fig. 1 - Location of the section Telma-Dareh (TD) and other localities mentioned in the text in the context of the Jurassic outcrops of the Central-East Alborz Mountains, North Iran. KD= Koppeh-Dagh, PA= Parvar area, EH= Emamzadeh-Hashem. Modified from Seyed-Emami & Schairer (2011) and Parent et al. (2012).

Stratigraphic framework

In the Alborz Zone of northern Iran (Fig. 1) the Jurassic rocks were deposited in two major sedimentary-tectonic cycles (Aghanabati 2004; Fürsich et al. 2009a, b), separated by the Mid-Cimmerian unconformity. The rocks of the first cycle are included in the Shemshak Group and those of the second (later) cycle in the Dalichai and Lar formations (Seyed-Emami et al. 2005). A different, more advanced lithostratigraphical classification and detailed studies of regional geodynamics have been presented by Wilmsem et al. (2009), Fürsich et al. (2009a, b) and references therein.

The first cycle is dominated by siliciclastic sediments, which were deposited in lagoonal and nearshore to fluvial environments, whereas the second cycle consists of marine sediments. In its type locality the Dalichai Fm. consists of about 107 m of light-grey to bluish-grey limestones with thin marly intercalations. According to Steiger (1966) the thickness of the Dalichai Fm. is about 50 to 120 m, averaging 100 m, but reaches more than 300 m in the eastern Alborz. The lower part of the Dalichai Fm. is Bajocian in age in most of the outcrops of the Alborz Mountains, and its dominant lithology consists of marls, marly limestones and green to gray marly shales (Aghanabati 2004). The Dalichai Fm. is thicker in the eastern Alborz than in the Central and western Alborz (Shafeizad & Seyed-Emami 2005).

Brief description of the section

The outcrops of the Dalichai Fm. at Telma-Dareh are covered in many parts, so that it could be observed only partially, by which the studied section could not be subdivided in detail. Thus, the subdivision of the sampled interval was done in terms of thick transects of rocks designated as units I-V (Fig. 2) within which are located the fossiliferous horizons. The succession, from below, is as follows:

Shemshak Group. The lowermost beds observed consist of about 60 m of pale sandstones, apparently not fossiliferous. The passage to the overlying Dalichai Fm. is rather continuous with no more discontinuity than that of the change of lithology. The age of this part of the section could be early Aalenian or older.

Dalichai Fm. The main part of the studied section consists of a succession dominated by marly limestones, marls and limestones in the upper part. The total thickness is 114 m. The age of this part of the column is Aalenian to, at least, Bajocian as indicated by ammonites described below and supported by the belemnites. It can be subdivided on the basis of lithological criteria in five units, from below:

- *Unit I*: 7.5 m of pale sandy limestones. Fossils are scarce; only a single specimen of *Ludwigia* cf. *murchisonae* has been recorded. Faunal levels: FL-1.
- *Unit II*: about 30 m of marly limestone with gypsum and calcareous sideritic concretions showing weathered limonitic surface. Fossils: trigoniid and pleuromyid bivalves and oysters, belemnites (*Brevibelus breviformis*, *Holcobelus* cf. *munieri*) and ammonites (*Ludwigia* cf. *murchisonae*, *Leioceras* cf. *comptum*, *Tmetoceras scissum* and *Onychoceras*? sp.). Faunal levels: FL-2-6.
- *Unit III*: 29 m of grey to greenish marls with gypsum and calcareous sideritic concretions. Fossils: belemnites (*Brevibelus breviformis*, *Holcobelus* cf. *munieri*). Faunal levels: FL-7-9.
- *Unit IV*: 16 m of grey to greenish-brown marly limestones. Fossils: *Zoophycos* at the top, ammonites (*Leptosphinctes* sp.). Faunal levels: FL-10.
- *Unit V*: 31.5 m of pale limestones with calcareous concretions abundant throughout. Fossils were not recorded.

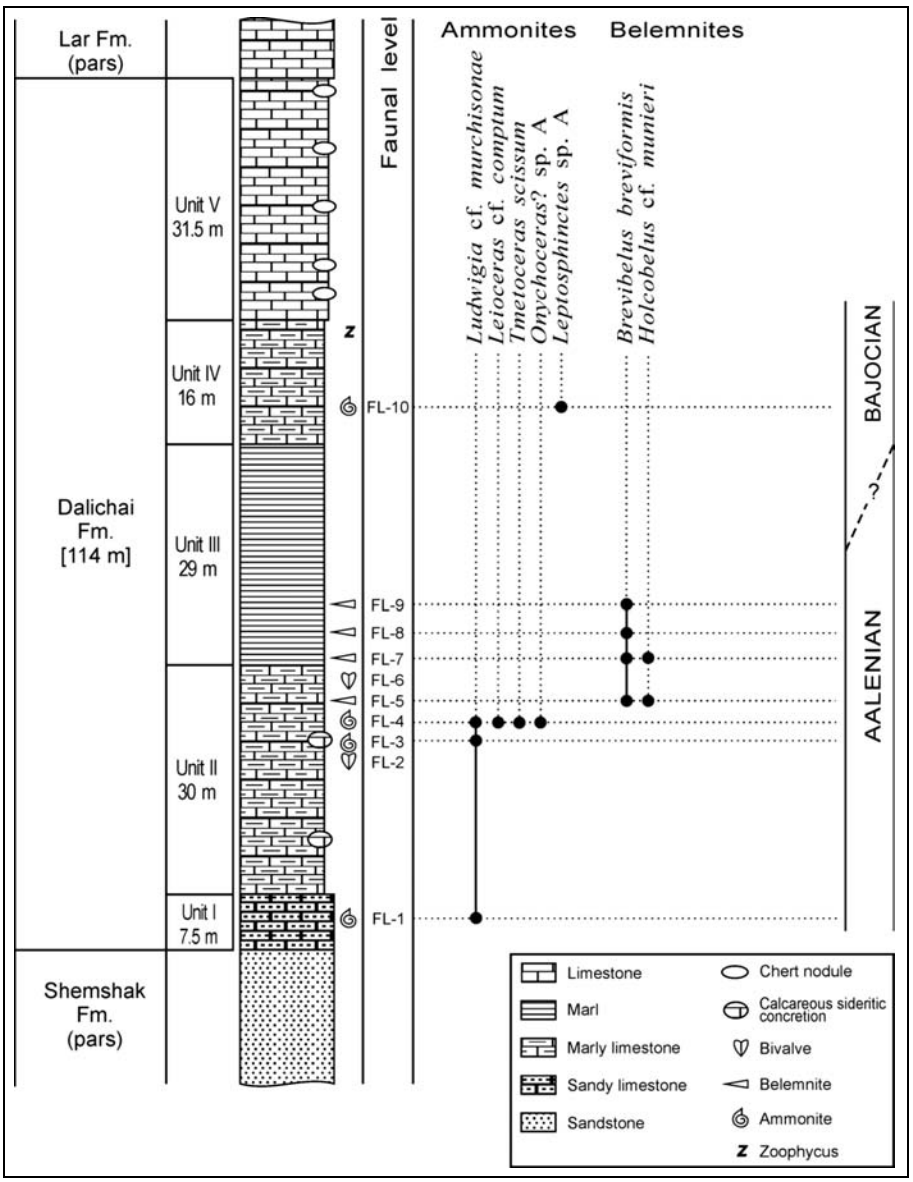

Fig. 2 - Log-section of the studied outcrop at Telma-Dareh with indication of the faunal levels detected and distribution of the cephalopods (ammonites and belemnites) studied. The Aalenian/Bajocian boundary is arbitrary for the lack of ammonites in the upper part of the unit III.

Lar Fm. This formation, not measured, may reach up to 300 m in thickness. The top of the studied section belongs to this formation, and is made up of a calcareous bank of about 10 m in thickness from which no fossils have been recorded. Thus, the age of this bank cannot be established.

Systematic palaeontology

The described material comes from Telma-Dareh, Dalichai Fm. and is housed in the collections of the Musée national d'histoire naturelle Luxembourg (MnhnL). The systematics of the belemnites used herein follows Riegraf et al. (1998); for terminology and dimensional adjectives see Doyle & Kelly (1988); the terms small, medium and large, related to the length of the rostrum (L), are respectively referred to L < 80 mm, L between 80 and 110 mm and L > 110 mm. For the ammonites the dimensions considered are the diameter (*D*), umbilical width (*U*), whorl width (*W*), whorl height (H_1), and whorl ventral (or apertural) height (H_2), all given in millimeters [mm]; biometric features of shell shape are reported in the form of dimensionless numbers or "indexes" which give direct reference to the relative morphology, allowing comparisons of shape in a range of comparable sizes. Open nomenclature follows Bengtson (1988).

The chronostratigraphical scale used for time-correlation is that of Callomon (2003: fig. 3).

Class **Cephalopoda** Cuvier, 1797

Order **Belemnitida** MacGillivray, 1840

Suborder **Belemnitina** MacGillivray, 1840

Family Megateuthididae Sachs & Nalnjaeva, 1967

Genus *Brevibelus* Doyle, 1992

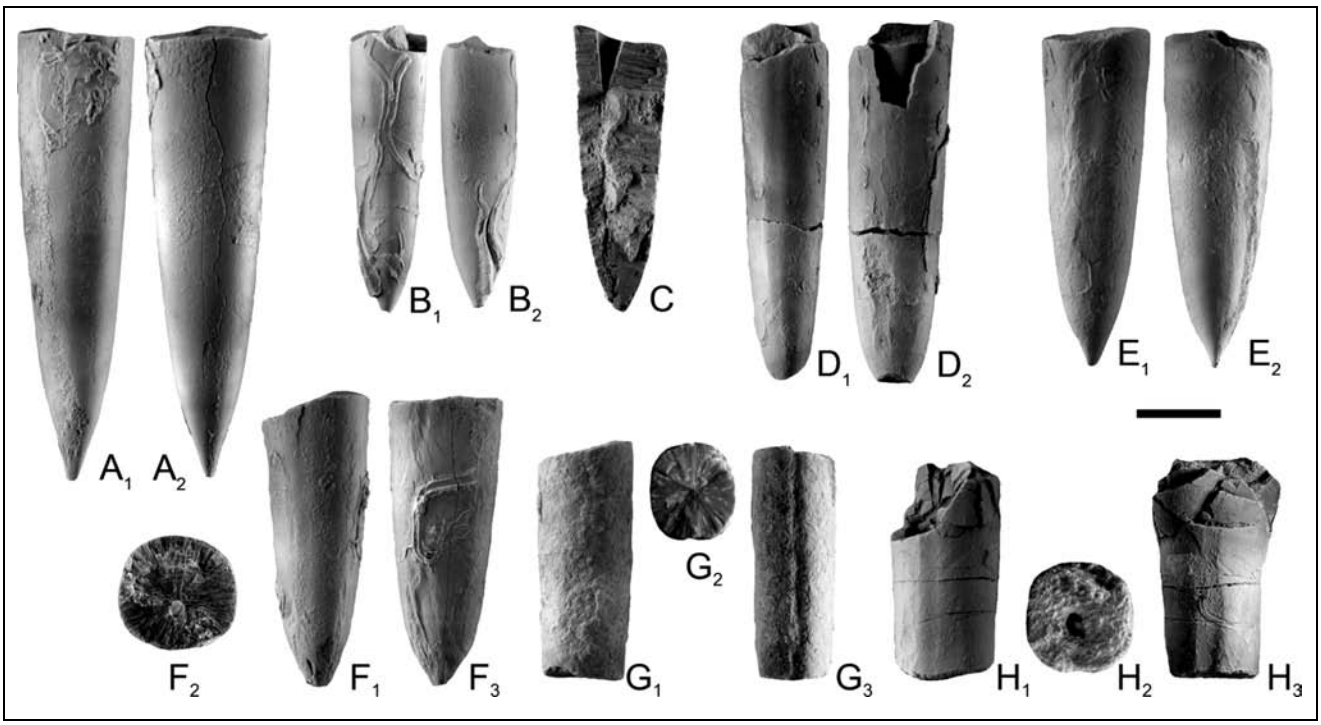

Fig. 3 - A-G - *Brevibelus breviformis* (Voltz, 1830), Aalenian, Telma-Dareh, Dalichai Fm. A) complete adult specimen; A_1: lateral view; A_2: ventral view; Unit II, FL-5; MnhnL QC380. B) juvenile specimen, covered with serpulids; B_1: lateral view; B_2: ventral view; Unit II, FL-5; MnhnL QC378. C) longitudinal section, venter on the left; Unit II, FL-5; MnhnL QC379. D) strongly depressed specimen, apex broken. D_1: lateral view; D_2: ventral view; Unit III, FL-7; MnhnL QC382. E) adult specimen with missing alveolar part; E_1: lateral view; E_2: ventral view; E_3: longitudinal thin section; Unit III, FL-8; MnhnL QC377. F) EM picture of the protoconch; Unit II, FL-5. MnhnL QC374. G) adult specimen with missing alveolar part; G_1: lateral view; G_2: transverse section close to the protoconch; G_3: lateral view; Unit III, FL-9; MnhnL QC381.
H - *Holcobelus* cf. *munieri* (Eudes-Deslongchamps, 1878), Aalenian, Telma-Dareh, Dalichai Fm., Unit II, FL-5. H) stem-fragment; H_1: lateral view; H_2: transverse section; H_3: supposed ventral view; MnhnL QC371.

Type species: *Belemnites breviformis* Voltz, 1830.

Diagnosis: Small, short and robust, conical to cylindriconical Megateuthidinae. Outline symmetrical and conical to cylindriconical, profile nearly symmetrical, otherwise similar to the outline. Apex obtuse to moderately acute, often mucronate. Venter inflated in some species. Transverse sections quadrate, compressed in some species, depressed in others. Apex lacking grooves or striae. Lateral lines may be well-developed, consisting of two weak and parallel depressions separated by a relatively well-developed ridge. Phragmocone ventrally displaced, penetrating one half of the rostrum. Apical line strongly cyrtolineate, apical angle approximately 27° (Doyle 1992).

Brevibelus breviformis (Voltz, 1830)

Fig. 3A-G

1992 *Brevibelus breviformis* (Voltz) - Doyle, p. 62, pl. 23 fig. 6, 10-11; pl. 24 fig. 1-2 (cum syn.)

1999 *Brevibelus breviformis* (Voltz) - Weis, p.222, fig. 4-5, 27-29

2007 *Brevibelus breviformis* (Voltz) - Weis & Mariotti, p. 158, pl. 3, figs. 3-4, 7

2010 *Brevibelus breviformis* (Voltz) - Arp, pl. 4, figs. 27-28

Material: 40 subcomplete rostra (MnhnL QC366; QC374-383). Lower Dalichai Fm. (Units II and III, FL-5, 7, 8-9), Aalenian.

Description. Small-sized, stout and conical rostrum. Outline and profile almost symmetrical and conical. The apex is acute, mucronate in the better preserved specimens. No traces of apical or alveolar grooves present, but broad and shallow lateral lines are distinguishable. Transverse sections are subquadrate, and slightly compressed to depressed. Venter flattened in most specimens. Phragmocone penetrates up to one half of the rostrum and strongly ventrally eccentric.

Remarks. The specimens from the Dalichai Fm. are typical representatives of this rather variable species, which was well characterised by Doyle (1992). The distinct and in some cases rather extreme depression of the present rostra (e.g., Fig. 3D) has been found also in specimens from the Murchisonae and Concavum zones of Luxembourg (Weis & Mariotti 2007; Weis, personal observation).

Distribution. Upper Toarcian to Aalenian (Doyle 1992) or lowermost Bajocian (Riegraf 1980) of Europe, Aalenian of the Caucasus (Krimholz 1931), and northern Iran (this report).

Suborder **Pachybelemnopseina** Riegraf
(in Riegraf et al., 1998)
(= Belemnopseina Jeletzky, 1966)
Family Holcobelidae Gustomesov, 1977
(emend. Riegraf 1980)
Genus *Holcobelus* Stolley, 1927

Type species: *Belemnites munieri* Eudes-Deslongchamps, 1878.

Diagnosis: Small to large-sized, conical to cylindriconical Holcobelidae, with usually elongated apical region and compressed transverse sections. A more or less long narrow intermediate ventral groove is present. Splitting surface rudimentary developed. Alveolus penetrates deeply, one third to three quarters of the rostrum. Earliest juvenile rostrum conirostrid, short to elongate conical. Epirostrum commonly developed. Alveolar angle 20-24º (Weis et al. 2012).

Holcobelus cf. **munieri** (Eudes-Deslongchamps, 1878)
Fig. 3H

cf. 1931 *Cylindroteuthis blainvillei* Voltz - Krimholz, p. 40, pl. 2, figs. 33-35, 39
cf. 1994 *Holcobelus munieri* (Deslongchamps) - Combémorel et al., p. 15, pl. 2, figs. 7-8
cf. 2007 *Holcobelus munieri* (Eudes-Deslongchamps) - Mariotti et al., p. 9, pl. 1, figs. 2, 5
cf. 2012 *Holcobelus munieri* (Eudes-Deslongchamps) - Mariotti et al., p. 104, figs. 4(3-7), 5(5-6)
cf. 2012 *Holcobelus munieri* (Eudes-Deslongchamps) - Weis et al., pl. 2, figs. 8-16; pl. 3, figs. 1-12 (cum syn.)

Material: 5 fragmentary rostra (MnhnL QC368-372). Lower Dalichai Fm. (Units II and III, FL-5, 7), Aalenian.

Description. The cylindriconical alveolar and stem fragments show a long and narrow ventral groove, fading out on the alveolar region. The transverse sections are elliptical to slightly subquadrate and compressed.

Remarks. The fragmentary state of the material makes it difficult to give a definitive specific determination. However, the compressed transverse sections and the narrow, long ventral groove, which fades out before reaching the alveolar border, allows to assign them not only to the genus *Holcobelus* but also to compare them to *H. munieri*.

Distribution. Middle Aalenian (Murchisonae Zone) to Lower Bajocian (Humphriesianum Zone) of northern Africa (Maghreb; Weis et al. 2012), southern and western Europe (Weis et al. 2012), the Caucasus (Krimholz 1931), and northern Iran (this report).

Order **Ammonitida** Fischer, 1882
Suborder **Ammonitina** Fischer, 1882
Superfamily Hildoceratoidea Hyatt, 1867
Family Hildoceratidae Hyatt, 1867
Subfamily Tmetoceratinae Spath, 1936
Genus *Tmetoceras* Buckman, 1892

Type species: *Ammonites scissus* Benecke, 1865, by original designation.

Tmetoceras scissum (Benecke, 1865)
Fig. 4R

1993 *Tmetoceras scissum* (Benecke, 1865) - Seyed-Emami et al., p. 16, pl. 1: 3, 4?
1994 *Tmetoceras scissum* (Benecke, 1865) - Callomon & Chandler, p. 27, pls. 5: 2-3, 6: 3, 8: 2-4. With complete synonymy.

Material: A single specimen (MnhnL QC348). Lower Dalichai Fm., FL-4, Aalenian, upper Scissum-lower Murchisonae zones.

Description. Small serpenticone, maximum D = 25 mm, last septum at D = 18 mm. Innermost whorls (D < 10 mm) evolute, with rounded whorl section. Ribbing composed of closely spaced, acute, slightly prosocline to radial primaries. Outer whorls of phragmocone and bodychamber very evolute and widely umbilicate (U/D = 0.46), with suboval whorl section, slightly higher than wide (W/H_1 = 0.92). Ribbing of outer whorls is composed by about 15-20 primary ribs per half whorl, almost radial, undivided, interrupted on the venter forming a well-marked narrow groove.

Remarks. The specimen described could be an adult microconch, but this extremely evolute form does not develop a perceptible terminal, adult uncoiling, thus preventing the recognition of adulthood from scarce or poorly preserved material without preserved peristome and not visible sutures. The closest resemblance of the present specimen is with those from the lower Scissum Zone figured by Callomon & Chandler (1994: pl. 8: 2, 4) of southern England. The specimen from North Kerman, Central Iran described by Seyed-Emami et al. (1993: pl. 1: 4), although poorly preserved, is indistinguishable from the present specimen and must come from a similar or identical stratigraphic position.

Distribution. *T. scissum* is a conspicuous, slightly sexually dimorphic ammonite because of its simple shell shape, strongly evolute coiling and very simple and isocostate, acute ribbing. Its palaeogeographical distribution is quasi-pandemic (see Fernández-López et al. 1999). In Great Britain, where the record of this species seems to be the most complete of Europe, it ranges through the Scissum to the lower Concavum zones (Callomon & Chandler 1994).

Family Graphoceratidae Buckman, 1905
Subfamily Graphoceratinae Buckman, 1905

Remarks. Following Contini (1989) and Chandler & Callomon (2009) we assume that the family Graphoceratidae consists of a main evolutionary lineage,

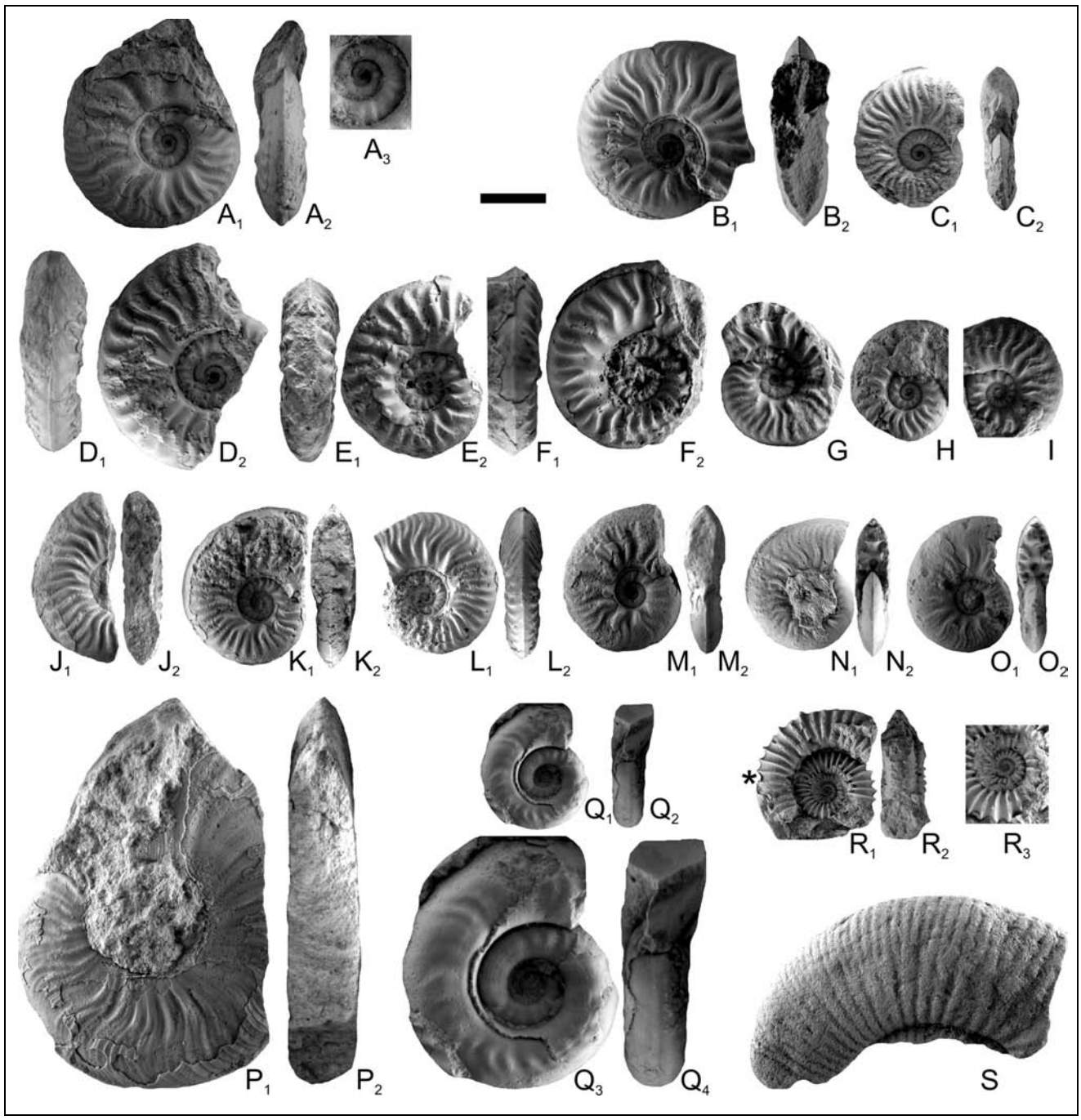

Fig. 4 - A-L – *Ludwigia* cf. *murchisonae* (Sowerby, 1829), Aalenian, Telma-Dareh, Dalichai Fm. A) phragmocone (MnhnL QC345), FL-1; A_3: inner whorls shown in double size (x2). B) phragmocone (MnhnL QC346), FL-3. C) phragmocone (MnhnL QC352), FL-3. D) phragmocone (MnhnL QC364), FL-4. E) phragmocone (MnhnL QC362), FL-4. F) phragmocone (MnhnL QC363), FL-4. G) phragmocone (MnhnL QC355), FL-4. H) phragmocone (MnhnL QC360), FL-4. I) phragmocone (MnhnL QC359), FL-4. J) phragmocone (MnhnL QC356), FL-4. K) phragmocone (MnhnL QC358), FL-4. L) phragmocone (MnhnL QC361), FL-4.
M-P - *Leioceras* cf. *comptum* sensu Rieber, 1963 (non Reinecke, 1818), Aalenian, Telma-Dareh, Dalichai Fm. M) phragmocone (MnhnL QC357), FL-4. N) phragmocone (MnhnL QC351), FL-4. O) phragmocone (MnhnL QC347), FL-4. P) adult? phragmocone with beginning of bodychamber (MnhnL QC365), FL-4.
Q - *Onychoceras*? sp., phragmocone (MnhnL QC349), FL-4; Q1-Q2) natural size (x1), Q3-Q4) double size (x2).
R - *Tmetoceras scissum* (Benecke, 1865), Aalenian, Telma-Dareh, Dalichai Fm., FL-4; R1-R2) adult? phragmocone with part of bodychamber (MnhnL QC348); R3) inner whorls shown in enlarged (x2).
S - *Leptosphinctes* sp., Bajocian, Telma-Dareh, Dalichai Fm., FL-10; fragment of phragmocone (MnhnL QC350).
All natural size (x1) except A3, Q3-Q4 and R3 (x2). The bar represents 10 mm for natural size (x1) specimens. The asterisks indicate the last septum.

the Graphoceratinae (including Leioceratinae Spath, 1936) and a short, specialized offshoot lineage, the Staufeniinae Maubeuge, 1950. We have preferred this simple classification which does not support the separation of the group that Howarth (2013: 93) considers as the subfamily Leioceratinae Spath, 1936.

Genus *Leioceras* Hyatt, 1867

Type species: *Nautilus opalinus* Reinecke, 1818 by subsequent designation of Buckman (1887)

Leioceras cf. **comptum** sensu Rieber, 1963 (non Reinecke, 1818)

Fig. 4M-P

Material: Six well-preserved but incomplete phragmocones (MnhnL QC347; 351; 353a-b; 354a-b), and one specimen apparently adult with part of its bodychamber (MnhnL QC365). Lower Dalichai Fm., FL-4, Aalenian, upper Scissum-lower Murchisonae zones.

Description. Suboxyconic, narrowly umbilicate, compressed, whorl section lanceolate, much higher than wide with a well defined acute ventral keel. Inner whorls, up to about D = 25 mm, covered by strong, flexuous primary ribs which bi- or trifurcate irregularly around mid-flank; secondary ribs, and abundant intercalatories in some specimens, fade-off gradually towards the venter (inner mould).

The largest specimen (Fig. 4P) preserves apparently a part of the bodychamber. The last whorl remains very compressed but more densely and finely ribbed. Primary ribs are flexuous with the furcation point on the lower half of the flank; some of them, especially towards the end, divide in sheaves of very fine secondaries. Some portions of the preserved test show that the fine ventral ribs reach the ventral keel. In the terminal part an incipient periumbilical depression can be observed which forms a lip on the umbilical shoulder besides a depressed area.

Remarks. Within the huge number of illustrated specimens classified in a large number of morpho-genera and/or morpho-subgenera (see Chandler & Callomon 2009 for reference and the discussion in Westermann 2010), our largest specimen (Fig. 4P) is identical to those figured by Contini (1969: pl. 8: 7-9) as *Leioceras comptum evolutum*. Identical specimens from western Jajarm (East Alborz) have been described as *L. comptum* by Seyed-Emami et al. (2005: fig. 7D, J); these specimens are associated with *T. scissum* and their age was considered Opalinum Zone.

Considering that our material is scarce and the inner whorls of the best preserved specimen are not visible, we have not adopted for the time being a definitive identification. Moreover, the specimen from the faunal level FL-1 which is morphologically indistinguishable is included in this group although its stratigraphic position suggests it could belong to an older transient.

Recently the restudy of the type of Reinecke's *Nautilus comptus* revealed that it is a *Pleydellia* from the late Toarcian (Chandler & Callomon 2009). Since the complex nomenclature of leioceratids is not yet resolved with content, we here use *Leioceras comptum* in the interpretation of Rieber (1963).

Distribution. The ammonites commonly attributed to *L. comptum* are typical in assemblages including T. scissum in the Scissum Zone.

Genus *Ludwigia* Bayle, 1878

Type species: *Ammonites murchisonae* Sowerby, 1827, by subsequent designation of H. Douvillé (1879)

Ludwigia cf. **murchisonae** (Sowerby, 1827)

Fig. 4A-L

Material: 15 specimens, well preserved but incomplete phragmocones (MnhnL QC345-346; 352; 353c-d; 354c; 355-364). Lower Dalichai Fm., FL-1, 3-4, Aalenian.

Description. The material available comprises a widely variable, perfectly intergrading series of phragmocones within a range of sizes D = 20-35 mm. In one extreme of the range stand stout (W/D = 0.28-0.31) and widely umbilicate (U/D = 0.31-0.38) platyconic shells with heavy sculpture composed by flexuous undivided or bifurcated primary ribs which fade-off on a ventral keel (Fig. 4D-F). In the opposite end of the range stand compressed (W/D = 0.26-0.28) and narrowly umblicate (U/D = 0.25-0.27) suboxyconic shells with finer sculpture composed by flexuous, bi- or trifurcated primary ribs which fade-off against the ventral keel (Fig. 4J-L). All the intermediate forms in shell shape and sculpture are also represented (Fig. 4G-I, A-C).

Remarks. The specimens shown in Fig. 4D-F perfectly match at comparable diameter with the holotype of *L. murchisonae* (see Howarth 2013: fig. 66, 1). The variation described corresponds to the juvenil stage of the species and could appear excessive for a single species, especially for a morphotypic classification. Nevertheless, the complete and gradual variation observed in the sample from the horizon FL-4 (Fig. 4D-L) strongly suggests that they belong to a single species. It could be argued that pre-adult individuals most likely lived along different environments developed through a continuum of depths/biotopes, so that the wide morphological variation should be eco-phenotypic, originated as a response to the different environmental conditions.

Furthermore, the specimens described above as *Leioceras* cf. *comptum* could also be included herein as an extension of the compressed-finely ribbed end of the described range. This interpretation is well supported by the detailed study based on complete adult macro- and microconch specimens by Chandler & Callomon (2009). These latter authors have shown a large series of specimens from a single horizon within the Scissum Zone of southern England with which all our morphotypes can be matched. Nevertheless, because of the persistent chaotic classification within the family we have followed a simple, rather morphotypic approach.

Distribution. The index zone species *L. murchisonae* is said to be confined to the *murchisonae* horizon in the middle part of the Murchisonae Zone (*sensu* Contini 1969: 4) or in the uppermost part of the Murchisonae Zone in England (*sensu* Callomon & Chandler 1994: fig. 1).

Family Strigoceratidae Buckman, 1924

Subfamily Phlycticeratinae Spath, 1925

Genus *Onychoceras* Wunstorf, 1905

Type species: *Onychoceras differens* Wunstorf, 1905, by monotypy

Onychoceras? sp.

Fig. 4Q

Material: A single, well-preserved, almost complete specimen (MnhnL QC349). Lower Dalichai Fm., FL-4, Aalenian.

Description. Stout serpenticone, maximum D = 19 mm. The two outermost whorls are preserved. Evolute with wide umbilicus (U/D = 0.39). Whorl section rounded, slightly higher than wide. Sculpture consists of gross and densely spaced primary ribs, undivided and rursiradiate, about 10-12 per half whorl. In the portions where the test is preserved there can be observed a well defined spiral sculpture, especially evident in the penultimate whorl.

Remarks. The spiral sculpture strongly suggests the specimen belongs to the Strigoceratidae. The shell shape ornamented with gross rursiradiate, undivided primary ribs points to the genus *Onychoceras*, which includes the microconchs (males) of *Csernyeiceras* Geczy, 1963 (Schweigert et al. 2000). The size of the present specimen is rather large for the genus. However, our specimen could certainly belong to an undescribed species, big-sized and with some female features. Another very similar ammonite, in shell shape and partially in sculpture, is the Aalenian hammatoceratid *Shahrudites asseretoi* Seyed-Emami, 2006. Nevertheless, a spiral sculpture has never been recorded in *Shahrudites*.

Distribution. The stratigraphic range of *Onychoceras* is from the Toarcian up to the Lower Aalenian (Schweigert et al. 2000). However, the present specimen belongs to an assemblage which is herein assigned to the upper Scissum-lower Murchisonae interval. The present specimen could indicate an extension into the Middle Aalenian, at least locally in the northeastern Tethys.

Superfamily Perisphinctoidea Steinmann, 1890

Family Perisphinctidae Steinmann, 1890

Subfamily Leptosphinctinae Arkell, 1950

Genus *Leptosphinctes* Buckman, 1920

Type species: *Leptosphinctes leptus* Buckman, 1920 by original designation

Leptosphinctes sp.

Fig. 4S

Material: Two fragmentary specimens (MnhnL QC350; QC354d). Upper Dalichai Fm., FL-10, Bajocian.

Description and remarks. The best preserved specimen shown in Fig. 4S is a portion of phragmocone with rounded subrectangular whorl section, higher than wide. Densely spaced primary ribs which start at the umbilical wall and bi- or trifurcate indistinctly on the upper half of the flank; the secondary ribs are slightly finer than the primaries. A very similar ammonite at comparable size is *Leptosphinctes* aff. *leptus* Buckman (in Dietl 1980: pl. 3: 3) from the Subfurcatum Zone of Germany.

Discussion and conclusion

Biostratigraphy and time-correlation

The unequivocal occurrence of *Tmetoceras* in the horizon FL-4 indicates the Aalenian. The strongest evidence for time-correlation at zonal level in the studied succession is the assemblage of the horizon FL-4. The association of *Leioceras* with *Ludwigia* and *T. scissum* constrains the Aalenian age to an interval within the Scissum-Murchisonae zones. The most complete graphoceratid available is identical with those figured as *L. comptum* from the '*murchisonae* horizon' by Contini (1969). Additionally, the present morphotype of *T. scissum* is identical to those of the lower Scissum Zone of southern England as indicated above. As a compromise from the consideration of these evidences we conclude that the interval FL-1-4 correlates with the upper Scissum-lower Murchisonae zones. An assemblage including *T. scissum*, *Leioceras* "*comptum*" and coarsely ribbed, evolute leioceratids was described from the Jajarm area (south of Koppeh Dagh) by Seyed-Emami et al. (2005)

and assigned to the Comptum Zone, nearly equivalent to the upper Scissum Zone used in this study. That assemblage is practically identical to the present assemblage of the horizon FL-4.

It is interesting to note that in the palaeogeographically close area of Saaalazan Kakheti in southern Georgia the same association of *T. scissum* occurs with almost identical leioceratids (Topchischvili 1975: pl. 2: 1-5, 7) in Lower to Middle Aalenian beds of the local succession.

The horizon FL-10 with *Leptosphinctes* sp. may be assigned to the Bajocian, most probably upper Bajocian considering the stratigraphical distribution of the genus (see Galacz 2012 and Pavia & Zunino 2012).

Concerning the studied belemnites, *Brevibelus breviformis* has a range from the Upper Toarcian (Dispansum Zone) to Upper Aalenian in Great Britain and mainland Europe according to Doyle (1992), whereas Riegraf (1980) and Weis & Mariotti (2007) give an Upper Toarcian (Dispansum Zone) to lowermost Bajocian (Propinquans Zone, nearly equivalent to the Sauzei Zone of the adopted scale) range for SW Germany and Luxembourg. Furthermore, *Holcobelus munieri* occurs from the lower Aalenian (Murchisonae Zone) to the Lower Bajocian (Humphriesianum Zone, Weis et al. 2012). Given the absence of characteristic Bajocian taxa, such as *Brevibelus gingensis*, *Megateuthis*, *Pachybelemnopsis* and *Hibolithes*, it seems therefore reasonable to assume a Murchisonae-Concavum zones, Aalenian age for the *Brevibelus-Holcobelus* assemblage of the interval FL-5-9 of the Dalichai Fm. This concurs with the slightly older age indicated by the ammonite fauna for the lower horizons FL-1-4, and the younger age (Bajocian) in the uppermost horizon FL-10.

Palaeobiogeography

Mariotti et al. (2010, 2012) and Weis et al. (2012) have summarized the distribution of belemnoids at the Aalenian/Bajocian boundary (Murchisonae-Laeviuscula zones) as follows:

– a Subboreal fauna, composed mainly by Belemnitina (*Homaloteuthis*, *Brevibelus*, *Eocylindroteuthis*, *Megateuthis)*, in some cases associated with a single species of Pachybelemnopseina (*Holcobelus blainvillii*). This fauna was recorded from Luxembourg, central and eastern France, north-western Switzerland and southern Germany (Weis & Mariotti 2007);

– a Submediterranean fauna, characterized by Pachybelemnopseina, mainly holcobelids (*Holcobelus munieri, H. trauthi, Calabribelus pallinii, C.* aff. *pallinii*) associated with the first *Pachybelemnopsis* and *Hibolithes*. This association has been recorded from Calabria (southern Italy, Mariotti et al. 2007) and the Digne-Castellane area (south-eastern France, Mariotti et al. 2012). A similar fauna has also been recorded from the Upper Aalenian (Concavum Zone) to the Lower Bajocian (Sauzei Zone) of Morocco (Sadki 1997 and unpublished data) and from the Lower Bajocian of Algeria (Elmi collection, in Weis et al. 2012).

– a 'mixed fauna', composed by some distinctive representatives of Subboreal and Submediterranean associations. It has been evidenced in western France (Normandy, Aquitaine, Eudes-Deslongchamps 1878, Mariotti et al. 2010) and south-western England (Dorset, Phillips 1869). This fauna is composed of representatives of the genera *Holcobelus*, *Brevibelus, Megateuthis* at the Aalenian/Bajocian boundary and, from the Early Bajocian onwards, occur *Pachybelemnopsis* and *Hibolithes*. Similarly composed faunas have also been reported from Romania (Preda 1975), Bulgaria (Stoyanova-Vergilova 1982, 1985, 1990) and from the Caucasus (Krimholz 1931, Nutsubidze 1966).

The belemnite fauna from Iran, characterized by the predominance of *Brevibelus breviformis,* with few specimens referred to *Holcobelus* cf. *munieri*, fits well the 'mixed fauna' described above. This pattern of distribution, based on the new material described herein, indicates that there has been interaction between the Subboreal and Submediterranean belemnite faunas all along the European margins of the Tethys Ocean.

The ammonites are typical of the Tethys and Submediterranean provinces. This is clearly in accord with the most recent palaeogeographic reconstructions (Thierry 2000, Golonka 2002, Wilmsen et al. 2009) with the Iran Plate in the northeastern Tethys, South of the Russian Platform during the Middle Jurassic.

The studied section at Telma-Dareh, not palaeontologically studied previously (Fig. 1), is part of the Jurassic outcrops of the eastern Central Alborz Mountains. It consists of an Aalenian-Bajocian succession of calcareous rocks (mainly marls and limestones) which we assign to the Dalichai Fm. (Fig. 2). This succession overlies conformably a poorly exposed succession of sandstones typical of the Shemshak Fm. However, the detailed studies of Fürsich et al. (2009a, b) and Wilmsen et al. (2009 and references therein) indicate the Dalichai Fm. is Bajocian or Bathonian to Callovian in age, separated by the Mid-Cimmerian unconformity from the underlying Shemshak or Dansirit formations, the latter containing Aalenian ammonites. In our section we have not observed any evidence of the Mid-Cimmerian unconformity. An explanation of the important difference in the age of the rocks which we consider to represent the Dalichai Fm. is impossible to advance with certainty from our local data. At first glance there could be a difference in the lithostratigraphical criteria for the recognition of the Dalichai Fm. in the field, although a significant heterochrony between close sections cannot be disregarded. Indeed, the succession of the Dalichai

Fm. at Parvar (Fürsich et al. 2009a), about 55 km southwest of Telma-Dareh, shows a very similar lithology, including the occurrence of *Pleuromya* in the uppermost beds of the underlying unit that these authors identified as the Dansirit Fm. Moreover, the lower part of the Dalichai Fm. at Parvar consists of silty and sandy calcareous rocks (Fürsich et al 2009a: 197, fig. 7). These features are closely similar to those observed in the lower part of the Dalichai Fm (FL-1-2) of the studied section. Anyway, the differences discussed in the context of a complex regional tectonical dynamics are an interesting issue for future research.

Acknowledgements. Gerhard Schairer (†, München), Markus Wilmsen (Dresden), Theodor Fürsich (Erlangen), Kazem Seyed-Emami (Tehran), András Galácz (Budapest) and Robert Chandler (Surrey) for discussion and literature. Vasili Mitta (Moscow) for his help with translations. Giulio Pavia and Sixto Fernández-López made valuable suggestions for enhancing this paper acting as reviewers of the journal.

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