OXFORDIAN BELEMNITES AND AMMONITES FROM ROSTAM KOLA, NORTHERN EAST ALBORZ, NORTH IRAN

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Abstract.- A Middle Oxfordian Jurassic belemnite fauna, associated with ammonites, from the Lar Formation at Rostam Kola (North Iran) is described for the first time. The specimens have been assigned to the following taxa: *Hibolithes hastatus*, *Hibolithes* aff. *beyrichi*, *Pachybelemnopsis latesulcatus*, *Duvalia didayana*, *Duvalia monsalvensis*, *Rhopaloteuthis* cf. *argoviana* and *Rhopaloteuthis sauvanausa*. Ammonites collected from the same belemnite bearing levels allow to refer the belemnite fauna to the Middle Oxfordian Transversarium Zone. Only a few Tethyan belemnite assemblages are recorded in the Middle Oxfordian, but it is possible to establish a close affinity with the taxa of the Mediterranean Province. The ammonites associated with the belemnites as also those from the upper levels of the section show clear Submediterranean affinities. All the ammonites known from previous and present surveys in the study area belong to the families Perisphinctidae and Ataxioceratidae. The species in new samples are *Perisphinctes* cf. *parandieri*, *Perisphinctes* (*Subdiscosphinctes*) sp. A, *Orthosphinctes* sp. A, *Orthosphinctes* sp. B, *Lithacosphinctes*? sp. A and *Passendorferia* cf. *gygii*.
Key-words: Belemnites, Ammonites, Lar Formation, Oxfordian, East Alborz, Iran.

Resumen.- ***Belemnites y amonites oxfordianos de Rostam Kola, NE de Alborz, N de Iran.*** Por primera vez se describe una fauna de belemnites asociada con amonites del Oxfordiano Medio provenientes de la Formación Lar en Rostam Kola (Norte de Irán). Los belemnites han sido asignados a las siguientes especies: *Hibolithes hastatus*, *Hibolithes* aff. *beyrichi*, *Pachybelemnopsis latesulcatus*, *Duvalia didayana*, *Duvalia monsalvensis*, *Rhopaloteuthis* cf. *argoviana* y *Rhopaloteuthis sauvanausa*. Los amonites colectados en los mismos niveles permiten referir la fauna de belemnites a la Zona Transversarium del Oxfordiano Medio. Aún cuando sólo unas pocas faunas de belemnites has sido registradas en el Oxfordiano Medio del Tethys, es posible establecer fuertes afinidades con taxa de la Provincia Mediterránea. Los amonites asociados con los belemnites, así como también los de niveles mas altos de la sección estudiada, muestran claras afinidades submediterráneas. Todos los amonites del area de estudio descriptos en trabajos anteriores y el presente corresponden a las familias Perisphinctinae y Ataxioceratidae. Las especies identificadas en las nuevas muestras son: *Perisphinctes* cf. *parandieri*, *Perisphinctes* (*Subdiscosphinctes*) sp. A, *Orthosphinctes* sp. A, *Orthosphinctes* sp. B, *Lithacosphinctes*? sp. A and *Passendorferia* cf. *gygii*.
Palabras clave: Belemnites, Amonites, Formación Lar, Oxfordiano, Alborz oriental, Irán.

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INTRODUCTION

Rostam Kola (East Alborz Mountains, N Iran) is the northernmost outcrop known of the Lar Formation in the East Alborz Mountains (Fig. 1). The age of these outcrop is Middle to Late Oxfordian. The strata consist of carbonates containing ammonites, belemnites and brachiopods at several levels (see Parent et al. 2012). The palaeogeographic reconstructions of Thierry (*in* Dercourt et al. 2000) and Wilmsen et al. (2009: fig. 2) indicate that Rostam Kola was located along the northern border of the Alborz Block, as part of the carbonate platforms of the south Caspian Basin. The palaeobiogeographic affinities of stratigraphically well controlled ammonite levels in this area are of importance in establishing the faunal relationships between western and eastern Tethyan domains, and for palaeogeographic modelling and geodynamics of the South Caspian Basin.

Oxfordian ammonites from the East Alborz Mountains have been described from several localities as summarized by Seyed-Emami & Schairer (2010). A first report of the ammonite fauna of Rostam Kola (Parent et al. 2012) has shown Submediterranean affinities and differences from surrounding areas. On the other hand, Jurassic belemnites from Iran have been largely unknown for many years, with a few exceptions (*e.g.* Weithofer 1890), although belemnites have been reported and figured from adjacent areas such as the Caucasus (Krimholz 1931) and Turkmenistan (Krimholz 1962). Recently, an early Middle Jurassic belemnite assemblage from Telma-Dareh, Northern Iran has been reported by us (Parent et al. 2013).

The objective of the present paper is to describe an Oxfordian belemnite fauna and selected ammonites recently collected by two of the authors (MF, MJ) in the section of the Lar Fm. at Rostam Kola (Fig. 1) described in Parent et al. (2012). The belemnites available are moderately well preserved and abundant, albeit mostly in a fragmentary state. The new ammonites are rather abundant but mostly poorly preserved; most of them can be assigned to the species already described in Parent et al. (2012). Only a few of the new ammonites, which belong to species that are recorded for first time in the present locality, are described below. These newly recorded species lead us to the re-interpretation of the time-correlation of the lower part of the section as being older than previously assumed. The complete list of the ammonites recorded in our former and new collections is given in the biostratigraphic discussion below and listed in the Fig. 2.

STRATIGRAPHIC FRAMEWORK

The local stratigraphic framework and the section were already described in detail in our previous study (Parent et al. 2012) to which we refer all the new observations. The log-section in Fig. 2 includes former and new records of ammonites and also the belemnite fauna described below.

SYSTEMATIC PALAEONTOLOGY

The belemnite systematic arrangement adopted is based on those proposed by Doyle et al. (1994) and Riegraf et al. (1998). Thirty belemnite rostra from Rostam Kola have been determined at species or genus level; they are stored at the palaeontological collections of the National Museum of Natural History, Luxembourg (MNHNL). The specimens described were collected from level RK-03, only two fragments (QC417 and QC418) come from level RK-08. Few belemnites collected from level RK-06 are too poorly preserved for identification. The ammonites are stored at the Department of Geology of the Payame Noor University, Shiraz, Iran (MF).

Order Belemnitida Zittel, 1895
Suborder Pachybelemnopseina Riegraf *in* Riegraf et al., 1998
Family Mesohibolithidae Nerodenko, 1983

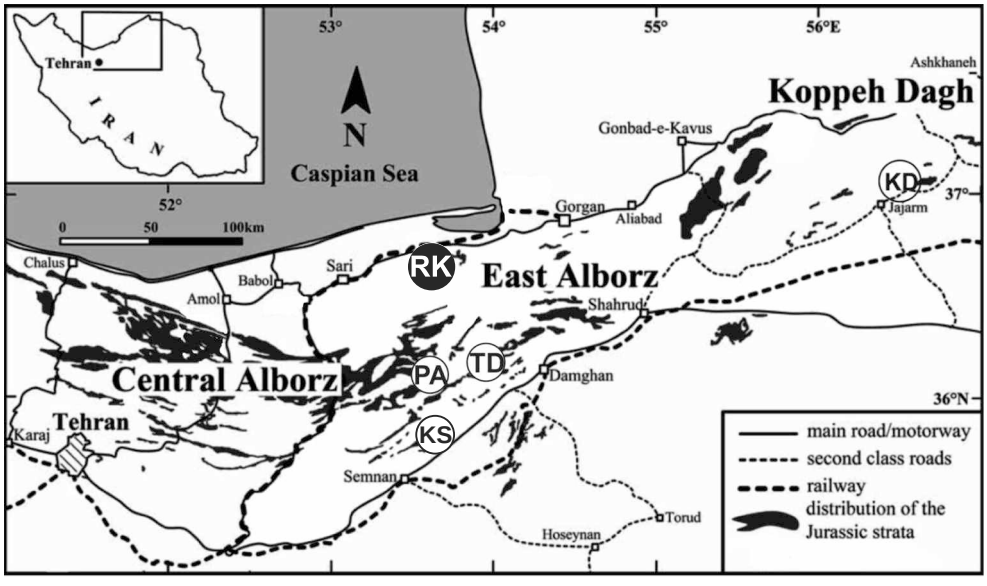

Figure 1. Location of the studied section at Rostam Kola (RK) in North Iran. Modified from Seyed-Emami & Schairer (2011) and Parent et al. (2012). Other localities of reference and/or cited in text: KS: Kuhe Sharaf, PA: Parvar Area, TD: Telma-Dareh, KD: Koppeh-Dagh.

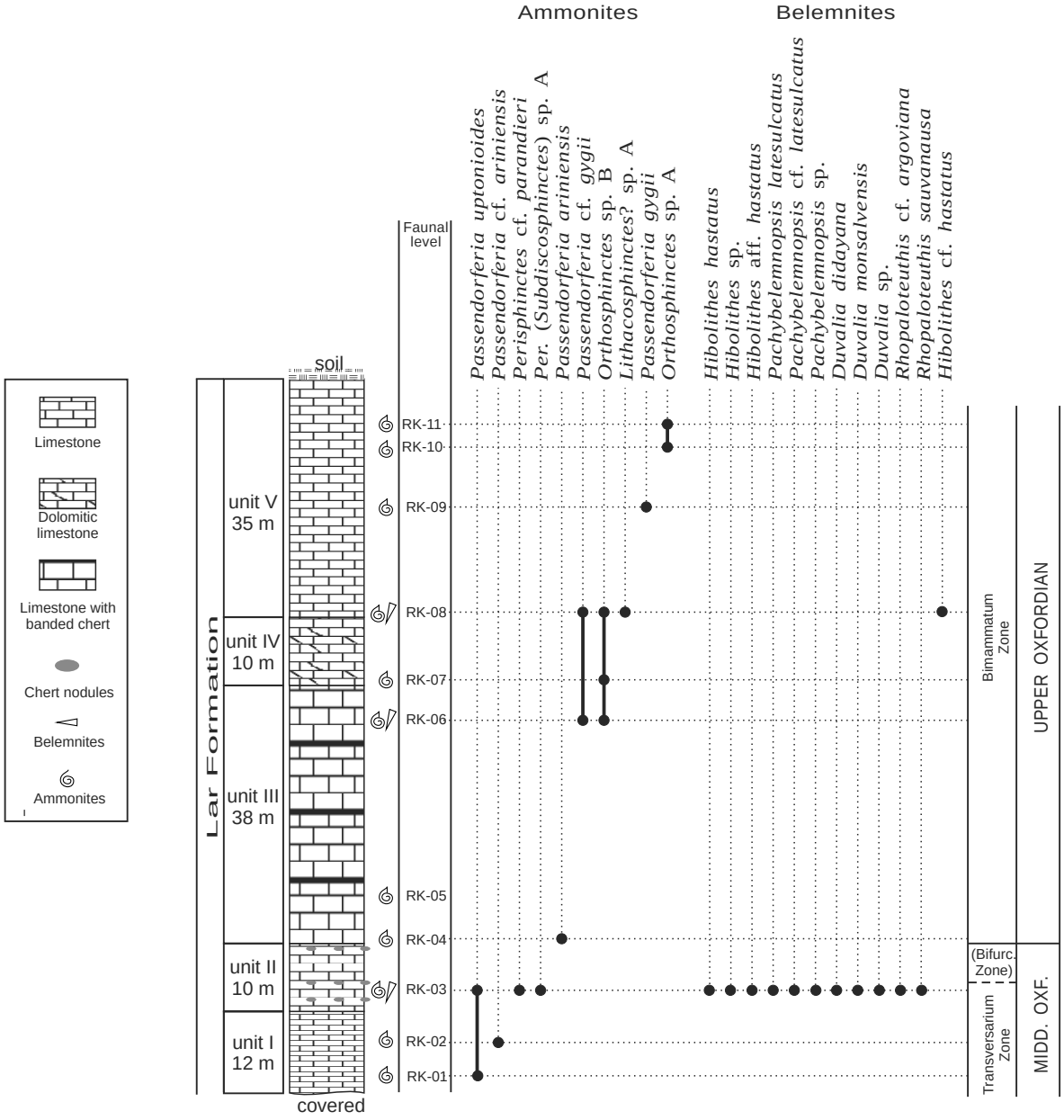

Figure 2. Log-section of Rostam Kola with indication of faunal levels RK-01-RK-11 and the succession of cephalopods (belemnites and ammonites). The chronostratigraphic classification is modified from Parent et al. (2012) based on the results presented in this report.

Genus *Hibolithes* Montfort, 1808

Type species.- *Hibolithes hastatus* Montfort, 1808.

***Hibolithes hastatus* Montfort, 1808**

Fig. 3H

1808 *Hibolithes hastatus* n.sp.- Montfort: 387.
1827 *Hibolithes hastatus*.- de Blainville: 71, pl. 2: 4-5, pl. 5: 3.
1981 *Hibolithes (Hibolithes) hastatus hastatus* (Montfort).- Riegraf: 81, pl. 6: 45-47 (*cum syn.)*.
1998 *Hibolithes semisulcatus* (Münster).- Schlegelmilch: pl. 18: 3-5.
2002 *Hibolithes hastatus* (Montfort).- Mariotti: pl. 1: 1-6.

Material.- One juvenile specimen lacking the alveolar region (MNHNL QC413), level RK-03.

Description.- A hastate and slender rostrum with a typical inflation in its posterior portion (maximum diameter). The outline and profile are symmetrical and hastate. The transverse section is slightly depressed in the stem and apical regions. A ventral groove extends up to the beginning of the apical region. Lateral lines run on each flank. The apex is acute.

Remarks.- The investigated specimen is similar to those described by de Blainville (1827), Favre (1876), Lissajous (1925), Pugaczewska (1961), Riegraf (1981). Schlegelmilch (1998) proposed *Belemnites semisulcatus* v. Münster, 1830 as new type species of *Hibolithes* instead of *Hibolithes hastatus* (a possible *nomen dubium*). The former is a possible junior synonym of the latter, according to Schlegelmilch (1998). This question needs further investigation.

Occurrence.- Transversarium Zone, Middle Oxfordian of

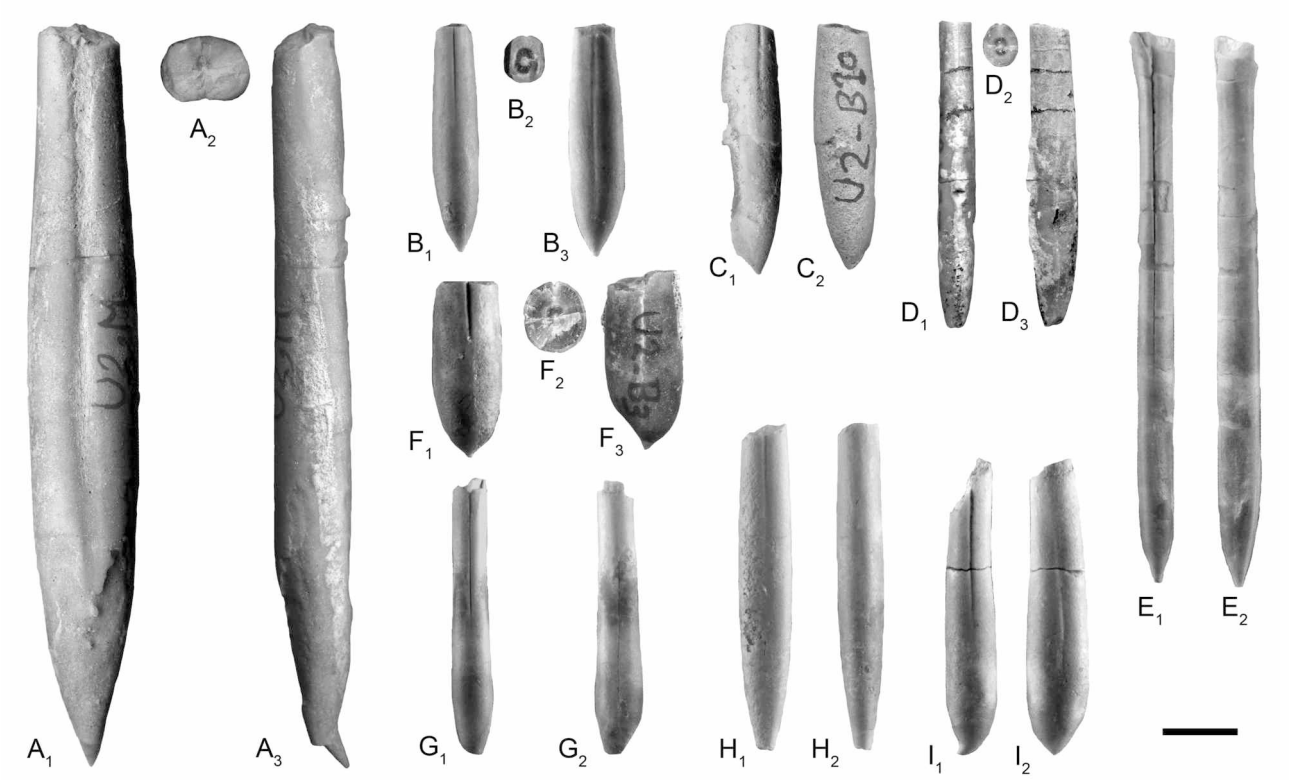

Figure 3. Oxfordian belemnites from Rostam Kola, North Iran. **A:** *Pachybelemnopsis latesulcatus* (Voltz *in* Thurmann, 1832), alveolar part missing, level RK-03. **A_1:** ventral view; **A_2:** transverse section; **A_3:** lateral view, ventral side left. **B:** *Duvalia monsalvensis* (Gilliéron, 1873), alveolar part missing, level RK-03. **B_1:** dorsal view; **B_2:** transverse section at broken end; **B_3:** lateral view, dorsal side left. **C:** *Rhopaloteuthis* cf. *argoviana* (Mayer, 1863), alveolar part missing, level RK-03. **C_1:** dorsal view; **C_2:** lateral view, dorsal side left. **D:** *Duvalia didayana* (d'Orbigny, 1842), alveolar part missing, level RK-03. **D_1:** dorsal view; **D_2:** transverse section at broken end; **D_3:** lateral view, dorsal side left. **E:** *Hibolithes* aff. *beyrichi* (Oppel, 1857), level RK-03. **E_1:** ventral view; **E_2:** lateral view, ventral side right. **F:** *Rhopaloteuthis sauvanausa* (d'Orbigny, 1842), apical part, level RK-03. **F_1:** dorsal view; **F_2:** transverse section at broken end; **F_3:** lateral view, dorsal side right. **G:** *Duvalia monsalvensis* (Gilliéron, 1873), apex broken, bed level RK-03. **G_1:** dorsal view; **G_2:** lateral view, dorsal side left. **H:** *Hibolithes hastatus* Montfort, 1808, alveolar part missing, level RK-03. **H_1:** ventral view; **H_2:** lateral view, ventral side left. **I:** *Duvalia monsalvensis* (Gilliéron, 1873), level RK-03. **I_1:** dorsal view; **I_2:** lateral view, dorsal side left. All natural size. Scale bar 10 mm.

Rostam Kola (Northern Iran). Furthermore this species is recorded from Late Callovian to Middle Oxfordian beds at Monte Kumeta (Sicily, Italy; Mariotti 2002), and considered as the most widespread species in the Callovian-Oxfordian Swiss rocks (Favre 1876) and the most characteristic of Early Oxfordian layers in France (d'Orbigny 1842-49). Riegraf (1981) collected it in Oxfordian to Early Tithonian sediments of Southwest Germany. Pugaczewska (1961) recorded it as a widespread species in the Bathonian - Oxfordian of Poland, furthermore she reported it from Germany, France, England, Switzerland, Austria, Portugal, Spain, Algeria, Caucasus, Russia, Arabia, India and Madagascar.

Hibolithes cf. *hastatus* Montfort, 1808

Material.- One fragment of alveolar region (MNHNL QC417) and one fragment of the apical portion (MNHNL QC418), from level RK-08.
Description.- Presumably a large sized rostrum with transverse alveolar and apical sections rounded, a groove is present in the alveolar region, two lateral lines run on the flanks of the alveolar region. The apex is acute. The apical line is centrally placed.
Remarks.- The only observable characters are the rounded transverse sections, the presence of a groove, two lateral lines and the large size. Unfortunately the lack of stem precludes any attempt for a more conclusive specific attribution.
Occurrence.- Early Late Oxfordian Bimammatum Zone of Rostam Kola (Northern Iran).

Hibolithes sp.

Material.- Two fragments of the alveolar region (MNHNL QC410, QC389), level RK-03.
Description.- Rounded cross section, two lateral lines on the flanks and a shallow groove with angular edges.
Remarks.- All the characters are typical of the genus *Hibolithes*, but a specific attribution is not possible.
Occurrence.- Transversarium Zone, Middle Oxfordian of Rostam Kola (Northern Iran).

Hibolithes aff. *beyrichi* (Oppel, 1857)

Fig. 3E

2002 *Hibolithes* sp. aff. *H. beyrichi*.- Mariotti: 18, pl. 2: 1-2.

Material.- One almost complete rostrum (MNHNL QC415) and six fragmentary specimens: two specimens lacking the alveolar region and partially stem (MNHNL QC388, QC402), two fragments of alveolar region (MNHNL QC401, QC407), a specimen lacking the apical region (MNHNL QC403), a long stem fragment (MNHNL QC409); all from level RK-03.
Description.- The rostrum is very slender with a symmetrical outline and only weakly hastate. The profile is symmetrical, cylindrical to slightly hastate. Two lateral lines run on every

flank close towards the apex. The transverse section is circular to weakly compressed. A narrow and shallow ventral groove fades out somewhat beyond the mid-length of the rostrum. The slender apical region is sharply pointed.
Remarks.- Similar specimens were recorded by Mariotti (2002) in Late Callovian-Middle Oxfordian beds at Monte Kumeta (Sicily, Southern Italy). These rostra show the same morphological characters (long and slender rostrum with a circular transverse section). The closest species is *Hibolithes beyrichi*, defined by Pugaczewska (1961), and successively described by Riegraf (1980) as *Belemnopsis* (*Longibelemnopsis*) *beyrichi* and subsequentely ascribed to *Longibelemnopsis* by Riegraf et al. (1998). The studied specimens, though very similar to the specimens figured by Pugaczewska (1961), differ by a more marked hastation of the apical region and in a clearly longer groove. The collected material is however too poor for considering the differentiation of a new species.
Occurrence.- Transversarium Zone, Middle Oxfordian of Rostam Kola (Northern Iran) and Late Callovian-Middle Oxfordian of Monte Kumeta (Sicily, Italy; Mariotti 2002).

Genus *Pachybelemnopsis* Bayle, 1878
Type species.- *Belemnites canaliculatus* Schlotheim, 1820.

***Pachybelemnopsis latesulcatus* (Voltz *in* Thurmann, 1832)**
Fig. 3A

1832 *Belemnites latesulcatus* (Voltz).- Thurmann: 27.
1845 *Belemnites latesulcatus*.- d'Orbigny: 301, pl. 50: 3-8.
1846-9 *Belemnites semihastatus depressus* n. sp.- Quenstedt: 440, pl. 29: 12-19.
1893 *Belemnites (Hibolites) latesulcatus* (Voltz).- Riche: 327-328, pl. 2: 13-17.
1902 *Belemnites (Hibolites) latesulcatus* (d'Orbigny).- de Loriol: 8-9, pl. 1: 8-11.
1910 *Belemnites latesulcatus* (Voltz).- Benecke: 129-132, text-fig. 1.
1912 *Belemnites (Hibolites) latesulcatus* (d'Orbigny).- Lissajous: 15, pl. 2: 7-8.
1920 *Hibolithes latesulcatus* (Voltz).- Bülow-Trummer: 145.
1925 *Belemnopsis latesulcatus* (d'Orbigny).- Lissajous: 105.
1961 *Belemnopsis latesulcatus* (d'Orbigny).- Pugaczewska: 150-153, pl. 11, pl. 12:1.
2002 *Belemnopsis latesulcatus* Voltz in Thurmann.- Mariotti: 20, pl. 2: 3-6.

Material.- Three specimens, a complete rostrum (MNHNL QC416), a juvenile (MNHNL QC395) and a juvenile lacking the alveolar region (MNHNL QC414), all from level RK-03.
Description.- The medium sized rostrum is slender and slightly hastate. The outline is symmetrical and hastate, the profile is symmetrical, cylindrical to subhastate. The ventral surface is flattened, the maximum diameter is about the half of the rostrum. The transverse section is clearly depressed in the stem and apical regions. Two weak lateral lines run along each flank. A ventral large and shallow groove starts at the alveolar region and ends at the beginning of the apical region. The apex is acute and pointed.
Remarks.- The peculiar history of the name of this species is discussed in Mariotti (2002). The weak hastation, the long groove and the always depressed transverse section enable to distinguish this species.
Occurrence.- Transversarium Zone, Middle Oxfordian of Rostam Kola (Northern Iran). This species is also recorded in Late Callovian-Middle Oxfordian sediments of Monte Kumeta (Sicily, Italy; Mariotti 2002), in Late Callovian beds ("*Quenstedtoceras lamberti* Zone") at Lupieu (Ain), Montrevel (Jura) and Valfin-sur-Valouze, Jura (Riche 1893), in the Early Oxfordian of the Jura bernois (d'Orbigny 1845), in the "*Pholadomya exaltata* beds" at Andelot-en-Montagne, Gevingey, Arc-sous-Montenot, Dramelay, la Billode (de Loriol 1902), in the Oxfordian beds of Monte Terrible (Benecke 1910), in the Late Callovian "*Quenstedtoceras lamberti* Zone" of the "Jurassique macônnais" (Lissajous 1912) and in Bathonian and Callovian horizons in Poland (Pugaczewska 1961).

***Pachybelemnopsis* cf. *latesulcatus* (Voltz *in* Thurmann, 1832)**

Material.- A fragment of the apical region (MNHNL QC397), from level RK-03.
Description.- An apical region with a depressed transversal section and the terminal part of a large and very feeble groove.
Remarks.- The depressed cross section and the presence of the final portion of a large and shallow groove allow to ascribe this fragment to *Pachybelemnopsis* and to compare it to *P. latesulcatus*, as the lack of stem does not permit a closer specific attribution.
Occurrence.- Transversarium Zone, Middle Oxfordian of Rostam Kola (Northern Iran).

***Pachybelemnopsis* sp.**

Material.- Two fragments of the apical region (MNHNL QC400, QC408), level RK-03.
Description.- The transverse section is depressed, a large and shallow groove ends right after the beginning of the apical region. The apex is acute.
Remarks.- The few observable characters, such as depression of the rostrum and large shallow alveolar groove, allow to assign these fragments to *Pachybelemnopsis*.
Occurrence.- Transversarium Zone, Middle Oxfordian of Rostam Kola (Northern Iran).

Family Duvaliidae Pavlow, 1914
Genus *Duvalia* Bayle, 1878
Type species.- *Belemnites dilatatus* de Blainville, 1827, by SD of Douvillé (1879)

***Duvalia didayana* (d'Orbigny, 1842)**
Fig. 3D

1842 *Belemnites Didayanus* n.sp.- d'Orbigny: 126-127, pl. 20: 1-5.
1863 *Belemnites Didayanus* d'Orbigny.- Vilanova & Piera : pl. 9: 9 [*fide* Lissajous 1925].
1994 *Duvalia didayana* (d'Orbigny).- Combémorel & Fischer *in* Fischer: 19-20, pl. 4: 4-5.
2002 *Duvalia didayana* (d'Orbigny, 1842).- Mariotti: 22, pl. 2: 8.

Material.- One specimen lacking the alveolar region (MNHNL QC405), level RK-03.
Description.- The rostrum is slender and compressed. The outline is symmetrical and slightly hastate. The profile is hastate and asymmetrical for a more accentuated ventral side in

the apical region. The maximum lateral diameter is placed at the posterior portion of the rostrum. Lateral lines run along the flanks. A dorsal alveolar groove extends up to the beginning of the short apical region. The cross section is compressed with rounded edges and a more developed ventral side.
Remarks.- The extreme thinness and the long dorsal groove distinguish *Duvalia didayana* from *D. monsalvensis*.
Occurrence.- Transversarium Zone, Middle Oxfordian of Rostam Kola (Northern Iran). Mariotti (2002) collected material of this species from Late Callovian-Middle Oxfordian beds cropping out at Monte Kumeta (Sicily, Italy). D'Orbigny (1842-49) reported this species from Oxfordian beds at Rians and Châtillon-sur-Seine (France).

Duvalia monsalvensis (Gilliéron, 1873)
Fig. 3B, G, I

1873 *Belemnites monsalvensis* Gilliéron: 202, pl. 8: 5-7.
2002 *Duvalia monsalvensis* (Gilliéron, 1873).- Mariotti: 24, pl. 3: 3-4, 6-7 (*cum syn*.).

Material.- Four specimens, two juveniles (MNHNL QC391, QC394) and two subadults (MNHNL QC404, QC412), all from level RK-03.
Description.- The robust, compressed, medium sized rostrum shows a symmetrical and weakly hastate outline, a hastate and asymmetrical profile with a more convex ventral side. This convexity is well marked in the apical region leading, in some cases, to a club-shaped profile. A narrow dorsal alveolar groove extends up to the mid-point of the rostrum. The flattened flanks show a slight depression that, especially in the sub-adult specimens, changes into a flattened area in the apical region. The cross section is elliptical in the alveolar region and rectangular with rounded angles in the back. The phragmocone penetrates, more or less, for one quarter into the rostrum. The apical line is almost central.
Remarks.- The attribution of this species to the genus *Duvalia* is preliminar, as it is also the type species of *Produvalia* Riegraf, 1981, a genus with an unstable taxonomic status (Riegraf et al. 1998). A request to ICZN is still pending (see Riegraf et al. 1998: 264). Here we use the genus *Duvalia*, waiting for a resolution by the International Commission on Zoological Nomenclature.

The most similar species are *Duvalia dumortieri* and *D. neyrivensis*; *D. dumortieri* possesses a shorter and stouter rostrum and a clearly shorter groove, while *D. neyrivensis* shows a longer, slender and clavate rostrum with a shorter groove.
Occurrence.- Transversarium Zone, Middle Oxfordian of Rostam Kola (Northern Iran). Mariotti (2002) collected this species from the Late Callovian-Middle Oxfordian of Monte Kumeta (Sicily, Southern Italy). Gilliéron (1873) and Favre (1876) recorded it in the sediments of the "*Gregoryceras transversarius* Zone" in Monsalvens (Alps of Fribourg). Favre (1876) reported it from Plagnère, Prayouds, Riondanaire, vie de Neyrive (Switzerland), and (Favre, 1875) from the Oxfordian beds at Voirons (Savoie, France). Dumortier & Fontannes (1876) collected this species from Crussol, Bouchard (Ardèche, France) and les Pènes (Ain, France). Some specimens of the Lissajous collection, housed at the Museum of the Claude-Bernard University, Lyon-Villeurbanne come from Oxfordian marls of Crussol (Ardèche, SE France). Finally, Riegraf (1981) reported this species from the middle part of Early Oxfordian at Stoberg near Blumberg/Wutach and Early Oxfordian of Reichenbach near Nusplingen (southwestern Germany).

Duvalia sp.

Material.- Three juvenile specimens lacking the alveolar region (MNHNL QC390, QC393, QC411), level RK-03.
Description.- Compressed rostrum with a symmetric outline and a slightly asymmetrical profile. The asymmetry is caused by a more convex ventral side. A narrow groove is present on the dorsal side. A soft depression runs on every flank. The transverse section is rectangular with rounded borders and a more developed ventral side.
Remarks.- Even if the specimens are fragmentary, some characters as compression, lateral depression and the presence of a groove allow to ascribe them to the genus *Duvalia*.
Occurrence.- Transversarium Zone, Middle Oxfordian of Rostam Kola (Northern Iran).

Genus *Rhopaloteuthis* Lissajous, 1915
Type species.- *Belemnites sauvanausus* d'Orbigny, 1842.

Rhopaloteuthis cf. *argoviana* (Mayer, 1863)
Fig. 3C

1849 *Belemnites hastatus impressae* n. sp.- Quenstedt: 447, pl. 29: 36-37, *non* 38-39.
1863 *Belemnites argovianus* n. sp.- Mayer: 193.
2002 *Rhopaloteuthis argoviana* (Mayer, 1863).- Mariotti: 26, pl. 4: 2-3 (*cum syn*.).

Material.- One specimen lacking the alveolar region (MNHNL QC398), level RK-03.
Description.- Small sized rostrum with a symmetrical, cylindrical outline and slightly asymmetrical hastate profile. The cross section is sub-circular. Lateral lines, sometimes changing into a very shallow depression, run on each flank. The apical region is short, ending with an acute apex.
Remarks.- Even if all the morphological characters would allow attribution to *Rhopaloteuthis argoviana*, the lack of the alveolar region and the partially eroded rostrum recommends the comparison.
Occurrence.- Beyond the occurence in the Middle Oxfordian (Transversarium Z.) of Rostam Kola (Northern Iran), the species was reported from Late Callovian - Middle Oxfordian sediments at Monte Kumeta (Sicily, Italy; Mariotti 2002), from the "*Epipeltoceras bimammatum* Zone" at Birmensdorf and Voirons, "*Streblites tenuilobatus* Zone" at Lémenc and Monsalvens, Oxfordian at the Hongrin Valley (Favre 1875, 1876), the "*Ammonites arolicus"* Zone at St. Sorlin (de Loriol 1902), from the Early Oxfordian in Poland (Pugaczewska 1961) and from the Middle Oxfordian ("*cautisnigrae*-Zone, *transversarium*-Schichten") in South Germany (Riegraf 1981). Some specimens of the Lissajous collection, stored at the Musem of Earth Sciences Department, Claude-Bernard University, Lyon, come from Early Oxfordian beds at Crussol (Ardèche) and from Oxfordian beds at Authoison (Haute Saône, France).

Rhopaloteuthis sauvanausa (d'Orbigny, 1842)
Fig. 3F

1842 *Belemnites sauvanausus* n. sp.- d'Orbigny: 128, pl. 21: 1-10.
2002 *Rhopaloteuthis sauvanausa* (d'Orbigny, 1842).- Mariotti: 27, pl. 4: 4, 7 (*cum syn*.).

Material.- Two specimens lacking the alveolar region

(MNHNL QC392, QC396), level RK-03.
Description.- The small sized, stout and hastate rostrum shows an symmetrical and hastate outline and a slightly asymmetrical and hastate profile. The asymmetry is caused by a more rounded dorsal side in the apical region. The cross section is circular, at the end of alveolar region, to sub-quadrate in the stem and apical regions. A deep dorsal alveolar groove runs as far as the maximum diameter of the rostrum. Weak lateral lines are present on each flank. The apex is mucronate and clearly dorsally eccentric.
Remarks.- The closest species to our material is *R. argoviana* but this latter has a markedly longer rostrum and a less hastate outline and profile.
Occurrence.- This is the best known and widespread species of the genus *Rhopaloteuthis* in the Oxfordian Tethyan successions. It was found in Late Callovian-Middle Oxfordian beds at Monte Kumeta (Sicily, Italy; Mariotti 2002), in Early Oxfordian beds of Germany, France, Switzerland, Portugal, Algeria, India, Madagascar and Late Callovian-Early Oxfordian of Poland (Pugaczewska 1961), in Early Oxfordian beds in Madagascar associated with *Putealiceras* which indicates the lower Mariae Zone of Tethyan Europe (Combémorel 1988), in Oxfordian rocks of Northwest Anatolia (Turkey; Doyle & Mariotti 1991) and finally, present report, in the Transversarium Zone, Middle Oxfordian of Rostam Kola (Northern Iran).

Order Ammonitida Fischer, 1882
Suborder Ammonitina Fischer, 1882
Superfamily Perisphinctoidea Steinmann, 1890
Family Perisphinctidae Steinmann, 1890
Subfamily Perisphinctinae Steinmann, 1890

Genus *Perisphinctes* Waagen, 1869
Subgenus *Perisphinctes* Waagen, 1869
Type species.- *Ammonites variocostatus* Buckland, 1836; SD Arkell (1951)

Remarks.- The use of subgenera adopted herein is merely morphotypic, like groups of morpho-species with their characteristic morpho-ornamental configurations. Most of the subgenera likely represent nothing but sexual dimorphism and the range of variation of the single genus (lineage or phylo-genus) *Perisphinctes*.

***Perisphinctes* (*Perisphinctes*) cf. *parandieri* De Loriol, 1903**
Fig. 4A-B

Material.- A large macroconch (AM-MF U2A) and three fragmentary septate specimens (AM-MF U2B4) from level RK-03.
Description.- The largest and best preserved specimen (Fig. 4A) consists of an almost complete adult macroconch (max preserved *D* = 284 mm) with a short portion of the adult phragmocone; the juvenile phragmocone seems not to be preserved. The terminal phragmocone and the bodychamber are serpenticonic, evolute with subrectangular, wider than high, whorl section with flat flanks that become rounded through the terminal bodychamber. The sculpture on the phragmocone and first half of the bodychamber consists of strong radial primary ribs which fade out abruptly on the ventro-lateral shoulder. The venter is smooth. Along the last half of the bodychamber the ribs are more prosocline and slightly curved forward fading out on the venter; towards the peristome they are gradually subdued. The peristome is not preserved. The sutures are not preserved well enough for description.

The smaller specimen (Fig. 4B) is part of a phragmocone. It is evolute and widely umbilicate with higher than wide subrectangular whorl section. The flanks are densely ribbed by prosocline primary ribs which born on the umbilical wall and regularly bifurcate on the uppermost part of the flanks. Secondary ribs are narrowly splayed and projected forwardly. In the two whorls preserved the density (number of ribs respect to a defined fraction of whorl) of the primary ribbing is identical.

Remarks.- This ammonite is the most abundant in the new samples from level RK-03, mostly occurring as small specimens (Fig. 4B) which could represent inner whorls of macroconchs or microconchs. At comparable diameter our specimens perfectly match with *P. parandieri*, especially with the specimens figured by De Loriol (1903: pl. 7) and Enay (1966: fig. 98 and pl. 6). The available material is insufficient for a definitive assignation. Our specimens are also very similar in morphology and scultpure to *Perisphinctes andelotensis* Enay, 1966. *P. parandieri* is characteristic of the Parandieri Subzone of the Transversarium Zone (Enay 1966, Callomon 1988), whereas *P. andelotensis* ranges somewhat higher up, into the lower Bifurcatus Zone (Enay 1966). As indicated by Glowniak & Wierzbowski (2007) and already well documented with exceptional material by Enay (1966), from the Bifurcatus Zone upwards the representatives of *Perisphinctes* change its mean morphology and sculpture. The representatives of the Bifurcatus Zone show a shorter and abrupt variocostation with respect to those of the Transversarium Zone, and develop more narrowly spaced cuneiform ribs on the flanks. Typical representatives of this change in the main lineage are the lower Bifurcatus *Perisphinctes panthieri* Enay, 1966 and *Perisphinctes cuneicostatus* Arkell, 1956 (see Klebelsberg 1912: pl. 18: 2, holotype), as also the specimen of *Perisphinctes cautisnigrae* Arkell, 1935 figured by Glowniak (2006: fig. 6). Our large macroconch shows a rather longer stage of coarse ribs, which develop gradually along more than a complete whorl, suggesting, in accord with the above comparisons, correlation with the Transversarium Zone.

Subgenus *Subdiscosphinctes* Malinowska, 1972
Type species.- *Perisphinctes kreutzi* Siemiradzki, 1891 by OD

***Perisphinctes* (*Subdiscosphinctes*) sp. A**
Fig. 4C

Material.- A single, well preserved phragmocone (AM-MF U2D) and two fragmentary specimens from level RK-03.
Description.- The best preserved specimen of the sample consists of an incomplete phragmocone, slightly crushed (*D* = 63 mm), moderately involute (*U/D* about 0.41); whorl section subrectangular, higher than wide with moderately high umbilical wall and well rounded shoulder, venter narrow and slightly rounded. Ribbing dense, composed by fine primary ribs which begin on the umbilical wall and cross the flank slightly prorsiradiate; most of them bifurcate producing two narrowly splayed secondaries, slightly finer than the primary and all of them with the undivided primaries cross the venter unchanged. Some few primaries bifurcate near the mid-flank and one of the secondaries bifurcates again on the upper third of

the flank. There are one to two narrow and shallow constrictions per whorl for $D < 40$-45 mm. Sutures are not preserved.

Remarks.- The platyconic shell shape and the style of ribbing allow to attribute our specimens to the morpho-subgenus *P.* (*Subdiscosphinctes*). Within the several species usually included in *P.* (*Subdiscosphinctes*) the present specimen is very similar to the specimens figured by Enay (1966: pl. 37: 7-10) and the inner whorls of the lectotype of *P.* (*S.*) *kreutzi* (refigured by Glowniak & Wierzbowski 2007: fig. 7). *P.* (*S.*) *kreutzi* (and probably most of the nominal species of the subgenus) occur mainly in the middle Transversarium Zone (Callomon 1988, Glowniak & Wierzbowski 2007).

BIOSTRATIGRAPHY AND PALAEOGEOGRAPHY

Rostma Kola is the northernmost Upper Jurassic outcrop known in the Alborz Mountains (Fig. 1). The study area was located, at least during the Callovian-Oxfordian interval, along the northern border of the Alborz Block (Thierry *in* Dercourt et al. 2000, Wilmsen et al. 2009, Seyed-Emami & Schairer 2011), rather isolated from the European platforms by deep waters, perhaps narrowly connected via the narrow southern platforms of the Caspian-Caucasus Corridor (the Great Caucasus Through of Thierry *in* Dercourt et al. 2000).

The new ammonite samples together with the material from the same section and levels described formerly in Parent et al. (2012) suggest a slightly different interpretation of the chronostratigraphic classification proposed in this latter paper for the lower part of the Lar Formation as exposed at Rostam Kola. The complete list of the ammonites collected in our former and present surveys is given in Fig. 2. The new samples include the following ammonites, from top:

Level RK-08: *Passendorferia* cf. *gygii* (Brochwicz-Lewinski & Rozak, 1976) [1 specimen], *Orthosphinctes* sp. B (*in* Parent et al. 2012) [1 specimen], and *Lithacosphinctes*? sp. A: a fragmentary specimen (Fig. 4D) densely ribbed with apparently a short lappet, which could be partially compared with *Litacosphinctes gidoni* (Atrops 1982, cf. pls. 30: 2 and 31: 2) [1 specimen].

Level RK-06: *Orthosphinctes* sp. B (*in* Parent et al. 2012) [1 specimen] and *P.* cf. *gygii* [1 specimen].

Level RK-03: *Passendorferia uptonioides* (Enay, 1966) a large macroconch with bodychamber (diameter about 400 mm, observed in the field but not collected), *P.* cf. *parandieri* [described above, 4 specimens], *P.* (*Subdiscosphinctes*.) sp. A [described above, 3 specimens].

The assemblage of level RK-08 seems rather heterogenous in a chronostratigraphic sense but could be attributed to the upper Bimammatum Zone. This correlation indicates a slightly younger age assignment than previously assumed. (Parent et al. 2012).It is based on the occurrence of better preserved specimens of *Passendorferia* which allow a close comparison with *P. gygii*.

The ammonites of level RK-06 suggest middle-upper Bimammatum Zone.

The new samples from level RK-03 include perisphinctids typical of the Submediterranean Province. *P.* cf. *parandieri* and *P.* (*Subdiscosphinctes*) sp. A strongly suggest that the stratum belongs to the Transversarium Zone. *P. parandieri*, *P. andelotensis* and the species included in *P.* (*Subdiscosphinctes*) are known to occur associated with them and ranging throughout the Transversarium Zone. (Enay 1966, Callomon 1988, Cariou et al. 1997). The level RK-03 was attributed to the Bifurcatus Z. in Parent et al. (2012) based on the occurrence of *Passendorferia uptonioides* (Enay, 1966). Nevertheless, this latter species ranges from the lower Transversarium to the lower Bifurcatus Zones according to Enay (1966). Thus, considering the now more completely known assemblage, it can be assumed that level RK-03 belongs to the Transversarium Zone, somewhat older than the previous time-correlation proposed.

The Submediterranean affinities of the ammonites of Rostam Kola was already established by Parent et al. (2012) and the new samples confirm it.

Distribution of the belemnite fauna

Except earlier authors (de Blainville 1827, d'Orbigny 1842-49, Favre 1875, 1876, Gilliéron 1873, de Loriol 1900, 1902, Lissajous 1912, 1915, 1925), Oxfordian belemnite faunas from the Peri Mediterranean Tethys have been poorly documented. Pugaczewska (1961) recorded belemnites from Bathonian-Callovian of Poland, meanwhileRiegraf (1980, 1981), carrying on the belemnite revision initiated by Schwegler (1965), completed the biostratigraphical, evolutionary and palaeobiogeographical study of Jurassic belemnites of southwestern Germany; lately, Mariotti (2002) described a Late Callovian-Middle Oxfordian fauna from Sicily (Italy).

The Iranian ammonite fauna, coming from the belemnite bearing level RK-03, indicates a stratigraphic position in the Middle Oxfordian Transversarium Zone (slightly older than assumed formerly in Parent et al. 2012). The Iranian belemnite species have a Late Callovian-Middle Oxfordian stratigraphic distribution in the Peri-Mediterranean Tethys. Only in Poland some of the taxa considered here occur in the Bathonian-Callovian (Pugaczewska 1961); all the others species are only present in the Oxfordian in other localities.

Two fragmentary specimens from level RK-08, referable to the Late Oxfordian Bimammatum Zone (Fig. 2), are comparable with *Hibolithes hastatus* which has a stratigraphic distribution covering all of the Oxfordian.

Beginning in the Late Callovian, the Late Jurassic marks a clear change, regarding the composition of the belemnite fauna of the Peri-Mediterranean Tethys. It is the origin of the deep faunistic renewal from the Late Jurassic onwards, and during this last time interval it is possible to recognize more and more clearly a typical Submediterranean province (sensu Parent et al. 2012). The Mediterranean character of the belemnites is present since the Middle Jurassic with the significant development of the genera *Pachybelemnopsis* and *Hibolithes*, with the successive addition of *Rhopaloteuthis* and *Duvalia*.

As indicated above, Mariotti (2002) reported a Late Callovian-Middle Oxfordian fauna from layers cropping out at Kumeta Mount (Sicily, Italy). The same genera of the Iranian fauna are present in the Italian locality, with the exception of *Pseudobelus* not yet identified in Iran. The specific association differs from the Iranian fauna only in a few species: *Duvalia dumortieri*, *D. neyrivensis* and *Pseudobelus coquandus*. For a better understanding of the belemnite faunal changes during Late Jurassic, two more belemnite assemblages, coming from the Early Kimmeridgian (Mariotti 2003) and the Early Tithonian (Combémorel & Mariotti 1986) outcrops located in the Central Apennines (Italy), are here discussed. These faunas are the only ones known from the Late Jurassic of the Peri-Mediterranean Tethys region. The following remarks on the composition of these assemblages may clarify the stratigraphic

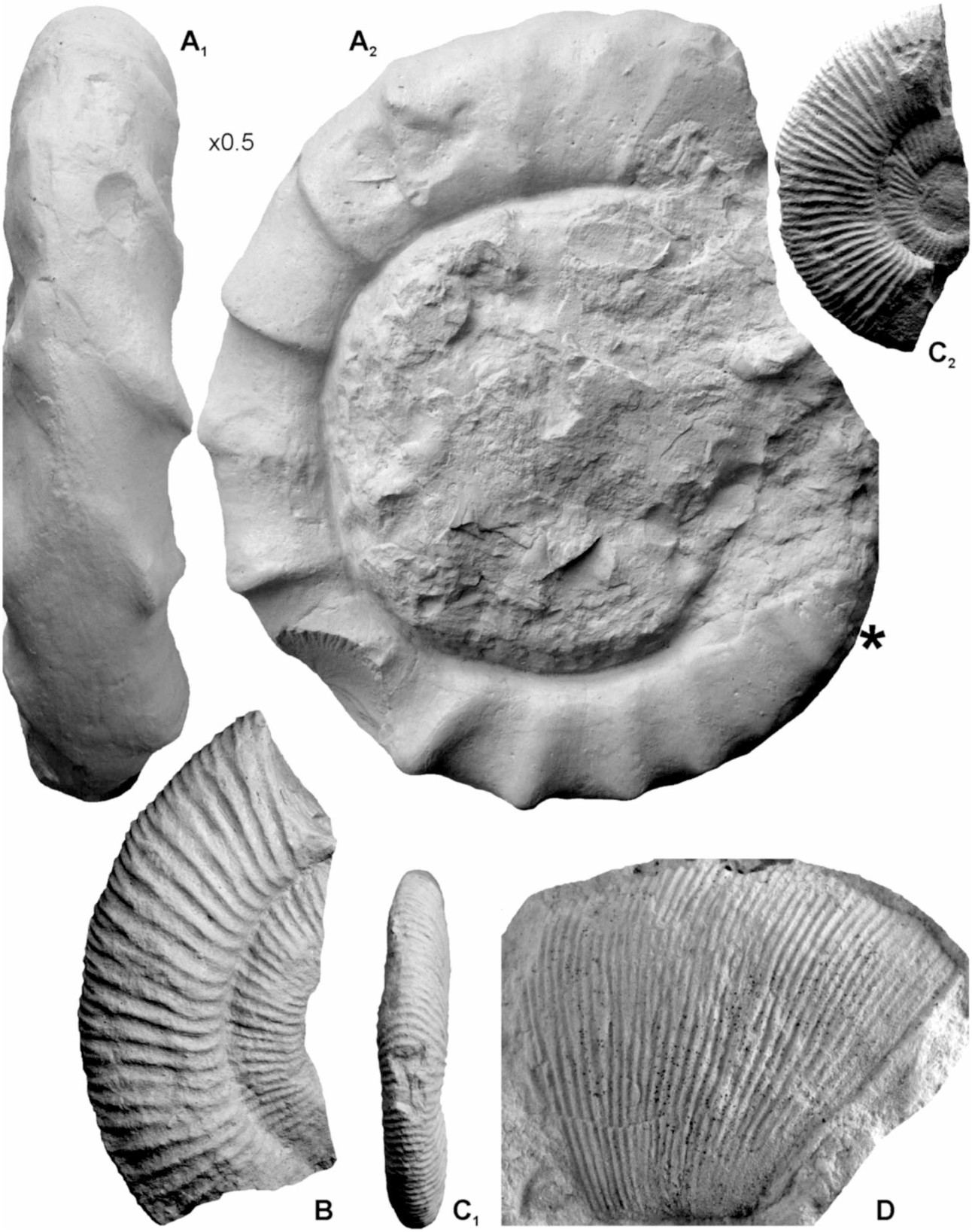

Figure 4. A-B: *Perisphinctes* (*Perisphinctes*) cf. *parandieri* (de Loriol, 1903); Rostam Kola, level RK-03, Transversarium Zone; **A:** Almost complete adult macroconch (MF-U2A), scale: x0.5; **B**: portion of phragmocone, probably macroconch (MF-U2B4). **C:** *Perisphinctes* (*Subdiscosphinctes*) sp. A, phragmocone (MF-U2D); Rostam Kola, level RK-03, Transversarium Zone. **D:** *Lithacosphinctes*? sp. A, portion of the end of a microconch bodychamber showing a short lappet (MF-U4B); Rostam Kola, level RK-08, Bimammatum Zone. All natural size except A (x0.5). The asterisk indicates the last adult septum.

and specific belemnite distribution in the Middle-Late Jurassic interval. Mariotti (2003) described an Early Kimmeridgian fauna, coming from outcrops at the top of Monte Nerone (Central Apennines, Italy), characterized by the same Iranian genera (*Hibolithes, Pachybelemnopsis, Duvalia* and *Rhopaloteuthis*) except *Acutibelus*, but by completely different species. This emphasizes overall the specific renewal of the belemnites. Another interesting fauna, collected from Tithonian beds (Ponti Zone) exposed in a quarry located near the Serra San Quirico village (Central Apennines; Ancona; Combémorel & Mariotti 1986), is composed of the genera *Hibolithes, Duvalia, Rhopaloteuthis, Pseudobelus* and *Quiricobelus*. The first three taxa are present in the Iranian Oxfordian fauna and Italian Early Kimmeridgian and Early Tithonian associations; in this case the species are also completely different. It is clear that the genera *Duvalia, Rhopaloteuthis, Pachybelemnopsis* and *Pseudobelus* characterize chronostratigraphic intervals at the end of the Jurassic.

CONCLUSION

The ammonites in the studied samples are typical of the successions of the Submediterranean Province which is in accordance with the previous study of this section (Parent et al. 2012). The palaeobiogeographic character of the belemnite fauna is Mediterranean, composed of genera which are characteristic of the Late Jurassic. This faunal affinity is well supported by the ammonite fauna which has in its composition a high proportion of ammonites of the subfamily Passendorferiinae, which are well represented in the Mediterranean domain.

The level RK-03 was formerly assigned to the Bifurcatus Zone (Parent et al. 2012) but the new ammonites allow to compose a more complete assemblage which lead us to re-assign this level to the Transversarium Zone. The belemnite assemblage of this level is composed of species known to range up to the Transversarium Zone (with the exception of *Rhopaloteuthis* cf. *argoviana* which could range up into the Bimammatum Zone or upper, see above), giving additional support to the time-correlation proposed. The next overlying level RK-04 (base of Unit III) has been assigned to the lower Bimammatum Zone. The Bifurcatus Zone seems to be not represented or reduced to the uppermost part of the Unit II (Fig. 2).

An outstanding feature of the local ammonite fauna is that it is composed exclusively of perisphinctids of the subfamilies Perisphinctinae and Passendorferiinae in similar proportions, and Ataxioceratinae. Oppeliids, aulacostephanids, aspidoceratids, phylloceratids and lytoceratids have never been recorded in the studied locality. This limited or poorly diverse fauna strongly differs from those of coeval deposits of surrounding areas which are much more diverse (cf. Seyed-Emami & Schairer 2011, Parent et al. 2012 and references therein). These latter comprise the typical spectrum seen in Oxfordian Tethyan faunas: oppeliids, perisphinctids, (?)aulacostephanids, aspidoceratids as also phylloceratids and lytoceratids. For instance, in Kuhe Sharaf (Fig. 1), about 100 km south of Rostam Kola, Seyed-Emami et al. (1998) have recorded aspidoceratids throughout the Oxfordian: *Euaspidoceras douvillei* (Collot; Cordatum Z.), *Mirosphinctes hiemeri* (Oppel; Plicatilis-Transversarium zones) and *Epipeltoceras* sp. (Bimammatum Z.). Cardioceratids or other Sub-boreal or Boreal ammonites are not known.

Currently Rostam Kola is the only locality in the East Alborz where ammonites of the subfamily Passendorferiinae have been recorded, and moreover these records include rather abundant representatives at several levels of the local succession, covering as a whole the Middle and Upper Oxfordian. The ammonites of the subfamily Passendorferiinae have a marked southern trend of expansion from at least the early Middle Oxfordian onwards covering the southern west Tethys. Moreover, representatives of the subfamily have been described from the Middle Oxfordian Passendorferia Zone of the Andean Neuquén-Mendoza Basin (Parent 2006).

The intriguing differences of palaeobiogeographical character or affinities between the Oxfordian ammonite faunas of Rostam Kola and those of more or less closely situated localities like Kuhe Sharaf or Koppeh Dagh is hard to explain from the available data. Unfortunately, there are no belemnites described from Koppeh Dagh or close localities which could contribute to shed light on the origin of these differences, which most likely were produced by the complex geological setting of the southern platforms (and local basins) of the South Caspian Basin (Wilmsen et al. 2009: fig. 2).

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