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Systematics and taphonomy of an Early Kimmeridgian belemnite fauna from the Mediterranean Tethys (Monte Nerone, Central Apennines, Italy)

Systématique et taphonomie d'une faune de bélemnites du Kimméridgien inférieur de la Téthys Méditerranéenne (Monte Nerone, Apennin central, Italie)

Circa trecento rostri di belemniti sono stati raccolti da un livello di età Kimmeridgiano inferiore di una sequenza tipica di alto strutturale affiorante a Monte Nerone (Appennino centrale, provincia di Pesaro)

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Abstract

About three hundred belemnite rostra were collected from Lower Kimmeridgian beds of a structural high sequence cropping out at Mt. Nerone (central Apennines, Pesaro Province, Italy). The belemnite fauna is composed mainly of new species. Nine species were recognised, ascribed to five genera, which include *Hibolithes semisulcatus* Münster, 1830; *H. pignattii* nov. sp.; *Acutibelu0s* sp. cf. *acuariformis* Riegraf, 1981; *Belemnopsis neronensis* nov. sp., *Duvalia matteuccii* nov. sp., *D. nicosiai* nov. sp., *D. pallinii* nov. sp., *D. raymondi* nov. sp. and *Rhopaloteuthis massimoi* nov. sp.; moreover a single specimen is treated in open nomenclature as Belemnopseidae incertae sedis. The stratigraphic and palaeobiogeographic significance of the new fauna is discussed. The taphonomy of the belemnite-rich level is described, with reference to borings found on the belemnite rostra. © 2002 Éditions scientifiques et médicales Elsevier SAS. All rights reserved.

Résumé

Dans une série de couches du Kimméridgien inférieur affleurant au Monte Nerone (Apennin central, province de Pesaro, Italie), une importante faune de bélemnites (300 rostres) a été récoltée. Cette faune, où neuf espèces ont été reconnues attribuées à cinq genres, est surtout composée d'espèces nouvelles. Ce sont: *Hibolithes semisulcatus* Münster, 1830 ; *H. pignattii* nov. sp. ; *Acutibelus* sp. cf. *acuariformis* Riegraf, 1981 ; *Belemnopsis neronensis* nov. sp. ; *Duvalia matteuccii* nov. sp. ; *D. nicosiai* nov. sp.; *D. pallinii* nov. sp. ; *D. raymondi* nov. sp. et *Rhopaloteuthis massimoi* nov sp. En outre, un rostre est laissé en nomenclature ouverte: Belemnopseidae incertae sedis. L'importance stratigraphique et paléogéographie de cette faune nouvelle est mise en évidence. Enfin, dans un niveau particulièrement riche en rostres, la taphonomie a pu être envisagée d'après les perforations rencontrées sur les rostres. © 2002 Éditions scientifiques et médicales Elsevier SAS. Tous droits réservés.

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Riassunto

La fauna a belemniti risulta composta quasi esclusivamente da specie nuove. Sono state riconosciute le seguenti specie: *Hibolithes semisulcatus* Münster, 1830; *H. pignattii* nov. sp.; *Acutibelus* sp. cf. *acuariformis* Riegraf, 1981, *Belemnopsis neronensis* nov. sp., *Duvalia matteuccii* nov. sp., *D. nicosiai* nov. sp., *D. pallinii* nov. sp., *D. raymondi* nov. sp. and *Rhopaloteuthis massimoi* nov. sp. Inoltre un esemplare è stato discusso con nomenclatura aperta come Belemnopseidae incertae sedis. Alcuni nuovi dati stratigrafici e paleobiogeografici sono stati analizzati ed integrati con i dati della letteratura. E' stata anche esaminata la tafonomia del livello a belemniti e le perforazioni presenti sulla superficie dei rostri.

Keywords: Belemnites; Jurassic; Central Italy; Systematics; Mediterranean tethys; Taphonomy

Mots clés: Bélemnites; Jurassique; Italie centrale; Systématique; Téthys méditerranéenne; Taphonomie

Palabras claves: Belemniti; Giurassico; Italia centrale; Sistematica; Tetide mediterranea; Tafonomia

1. Introduction

The purpose of this paper is to describe in detail both the systematics and taphonomy of an Early Kimmeridgian belemnite fauna. The biostratigraphic and paleobiogeographic significance of the fauna is also briefly discussed.

The studied belemnites were collected from a single site, near the top of Mt. Nerone, SE of the village of Piobbico (Pesaro Province), in the central Apennines (Fig. 1). The assemblage is important because, due to both the number of specimens and the high number of species, it can be considered as a reliable sample of the original living fauna, also considering that stratigraphy and taphonomy suggest it was formed in a short lapse of time. These characteristics make it the first described Kimmeridgian belemnite assemblage coming from a well-defined and short interval and from a single site in the whole western Tethys.

2. Geological setting

The investigated fauna was collected between 1992 and 2000 in a small outcrop on the eastern side of Mt. Nerone (Pesaro, central Italy), a few hundred metres NE of its peak. A larger area is named on the 1:25,000 map as 'Campo al Bello', and under that name the site is already well known in the geological literature (Centamore et al., 1971; Farinacci et al., 1981; Cecca et al., 1990).

Details on the geology of the site are given in the sheet 290 'Cagli' of the 1:50,000 Geological Map of Italy (Servizio Geologico d'Italia, 1972), and in Centamore et al. (1971), Farinacci et al. (1981), Cecca et al. (1990) and Cresta et al. (1989); palaeontological investigations over the years have included ammonites (Cecca and Santantonio, 1988; Cresta et al., 1988), radiolarians (Baumgartner, 1984, 1990), bivalves (Monari, 1994), and crinoids (Manni and Tinozzi, in press).

In Earliest Jurassic time, the area of the central Tethys that today constitutes the Umbria–Marche Apennines was

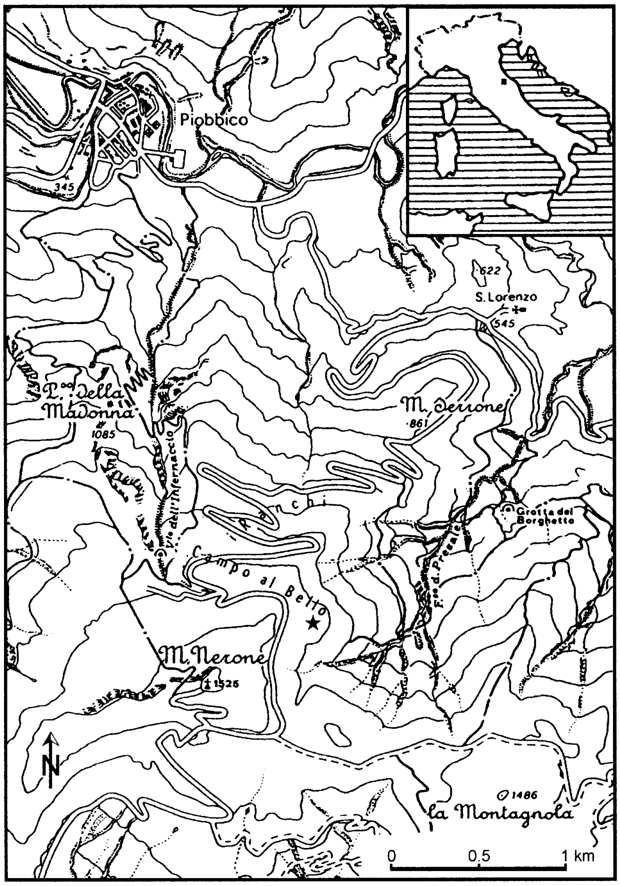

Fig. 1. Location map of Campo al Bello section.
Carte de localisation de la coupe de Campo al Bello.

part of a larger carbonate shelf. Following a Sinemurian–Early Pliensbachian extensional tectonic phase, the carbonate platform was dismembered into a complex system of more or less lowered areas and of structural highs with contrasting stratigraphic and sedimentological features (Centamore et al., 1971; Centamore and Deiana, 1986; Colacicchi et al., 1970, 1988; Bernoulli, 1971; Farinacci et al., 1981; Santantonio, 1993, 1994). The successions deposited in basins are thicker and probably continuous, while those found on the structural highs (Pelagic Carbonate

Platforms sensu Santantonio, 1993) are thin, condensed, and discontinuos. As a result, the Jurassic lithostratigraphy of the Umbria–Marche Apennines is traditionally subdivided into two end-member successions for each of these palaeostructural settings (see on this topic Cresta et al., 1988).

The Campo al Bello section epitomises the Pelagic Carbonate Platform depositional environment. The thick carbonate platform deposits of the Calcare Massiccio di Monte Nerone Formation are conformably overlain by a sequence made by a pellicular Jurassic cover and by a thicker Cretaceous–Tertiary sequence.

The Jurassic portion of the succession was ascribed to the Fosso Bugarone Formation by Jacobacci et al. (1974) and Centamore et al. (1971), in turn subdivided into four members. The oldest member ('Calcari stratificati grigi', 7 m) is Pliensbachian age; the second member ('Calcari nodulari e marne verdi') is 8 m thick and Toarcian in age; the third 'Calcari dolomitizzati nocciola member' is 10 m thick and Aalenian–Early Bajocian in age. This layer is overlain a 2 m thick interval of very thinly bedded, partially silicified, marly limestone (Early Kimmeridgian in age according to Baumgartner, 1990). It represents a wedge of a basinal formation (Calcari Diasprigni Formation), that pinches out and onlaps a low-angle slope (Cecca et al., 1990; Santantonio, 1993). It is followed by a 3.5 m thick condensed fossiliferous limestone, representing the last member of the Bugarone Formation (Early Kimmeridgian –Early Tithonian 'Calcari nodulari ad aptici'). The lowermost part of the Late Tithonian–Aptian, Maiolica Formation ends the measured section (Fig. 2).

The studied specimens come from a thin limy-argillaceous intercalation at the base of the Calcari Diasprigni Formation.

The first levels of the Kimmeridgian apparently lie paraconformably on the Lower Bajocian dolomitized limestone. The lack of Middle Bajocian–Earliest Kimmeridgian sediments evidences a 20 Ma region-wide gap recognised in many other localities of the Umbria–Marche Apennines (Farinacci et al., 1981; Farinacci, 1988; Cecca et al., 1990; Santantonio, 1993; Bartolini and Cecca, 1999).

At the centimetric scale, the fossiliferous beds (Fig. 3B) can be described as follows (top to bottom):

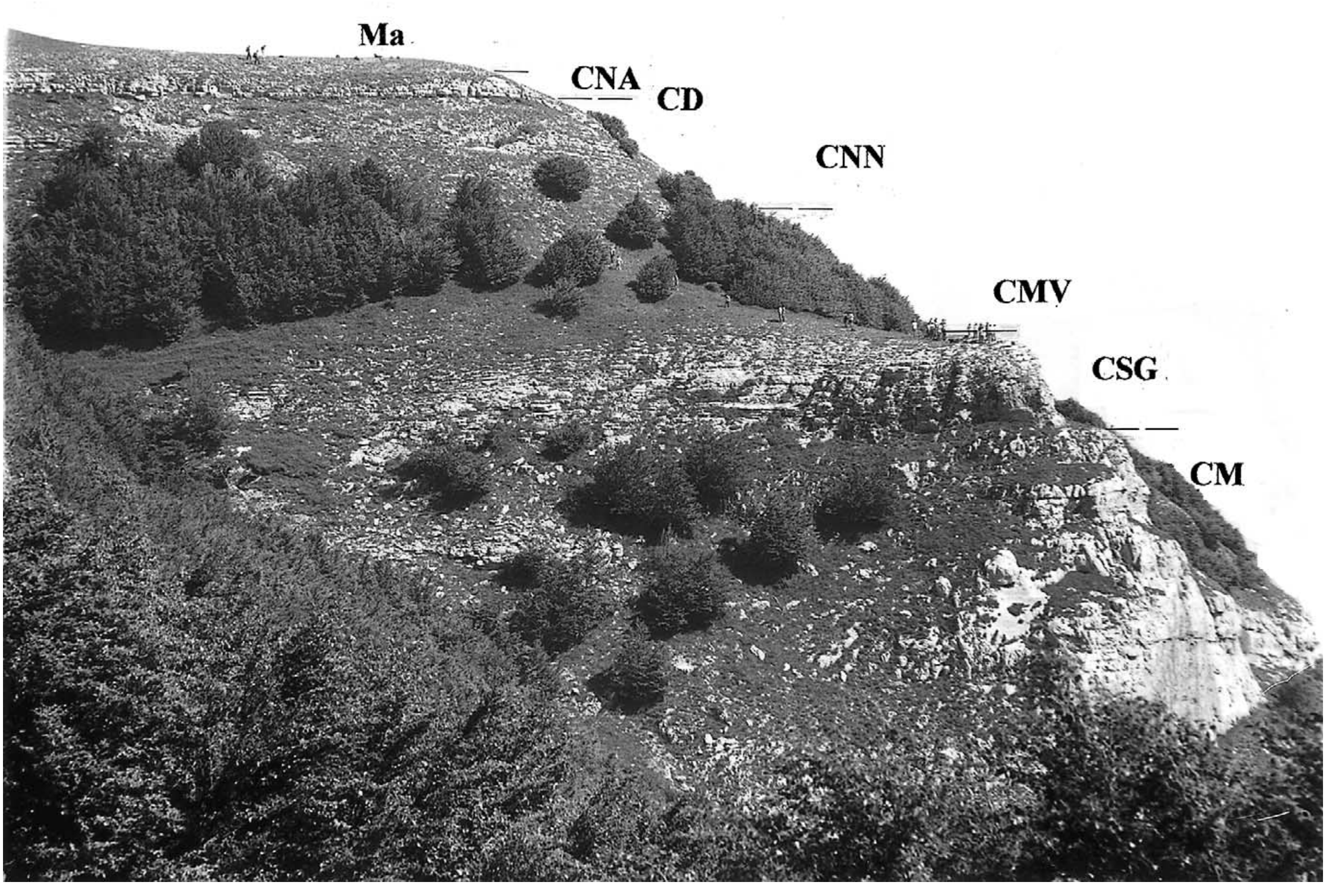

Fig. 2. General view of the Campo al Bello section. CM, Calcare Massiccio Formation; CSG, Calcari stratificati grigi member; CMV, Calcari nodulari e marne verdi member; CNN, Calcari nodulari nocciola member; CD, Calcari Diasprigni Formation; CNA, Calcari nodulari ad aptici member; Ma, Maiolica Formation.

Vue d'ensemble de la séquence de Campo al Bello. CM, Calcare Massiccio Formation; CSG, Calcari stratificati grigi member; CMV, Calcari nodulari e marne verdi member; CNN, Calcari nodulari nocciola member; CD, Calcari Diasprigni Formation; CNA, Calcari nodulari ad aptici member; Ma, Maiolica Formation.

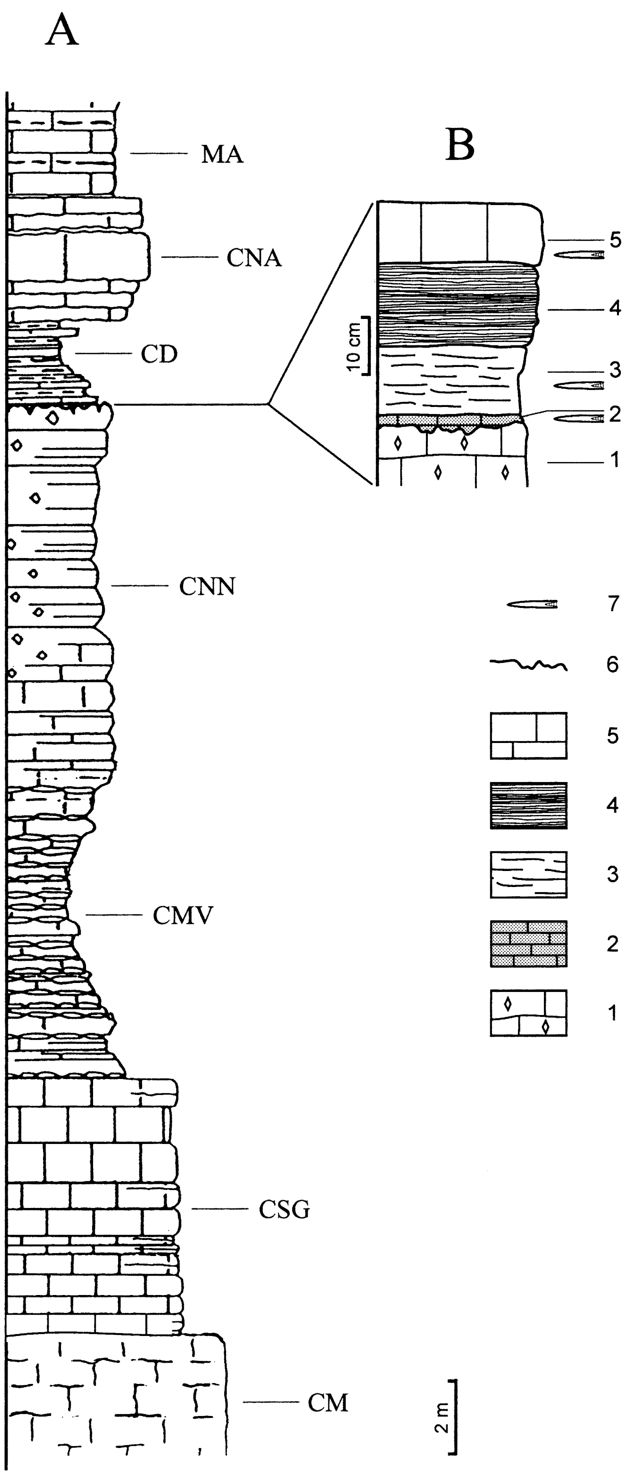

Fig. 3. The Jurassic succession at Campo al Bello. A. lithostratigraphic units (see Fig. 2 for abbreviations); B. Close up of the belemnite-bearing interval. 1, dolomitic limestone of the Lower Bajocian; 2, 2-cm-thick white limestone of the Lower Kimmeridgian; 3, 12-cm-thick shaly laminated bed; 4, 15-cm-thick marly siliceous interval; 5, 10-cm-thick calcareous level; 6, hard ground; 7, belemnites.

La succession Jurassique de Campo al Bello. A. Unités lithostratigraphiques, abréviations comme dans la Fig. 2. B. Détail agrandi des niveaux riches en bélemnites. 1, calcaire dolomitique du Bajocien inférieur; 2, 2 cm de calcaire blanc, Kimméridgien inférieur; 3, niveau épais de 12 cm d'argile laminée; 4, niveau marneux, siliceux de 15 cm d'épaisseur; 5, niveau calcaire de 10 cm; 6, hard ground; 7, bélemnites.

(5) a 10-cm-thick calcareous bed, with aptychi, rhyncholites, and an ammonite fauna referred to the Early Kimmeridgian age (Divisum Zone) by Cecca et al. (1990, p. 90);

(4) a 15-cm-thick marly-siliceous bed, ascribed to the Early Kimmeridgian (Cresta et al., 1988);

(3) a 12-cm-thick shaly laminated bed, rich in fossils. This is where most of the belemnite fauna described below comes from. The fauna as a whole also includes terebratulid brachiopods, small solitary corals, rare bivalves, fragmentary ammonite inner moulds, rhyncholites, aptychi, isocrinid and cyrtocrininid crinoids, and fish teeth. A fragment of a probable ichthyosaur rib was also found. This is the lateral equivalent of a bed that yielded a Kimmeridgian *Taramelliceras* just few hundred meters to the north.

(2) a 2-cm-thick white limestone layer containing badly worn Late Jurassic crinoids and bioeroded belemnites, filling the depressions of an eroded surface;

(1) a 20-cm-thick dolomitic limestone, rich in 'protoglobigerinid' forams, topped by a hardground. The age of the hardground is established on the basis of the presence of eroded ammonites at the bed top. These belong to *Skirroceras* and *Praestrigites*, indicating an Early Bajocian age (Humphriesianum Zone) (Cresta, 1988; Cecca et al., 1990).

The age of the belemnite-bearing bed is thus constrained by the Early Bajocian ammonites at the base and by an Early Kimmeridgian ammonite 20 cm above.

3. Systematic palaeontology

Jeletzky (1966) was the first to attempt a modern revision of the subclass Coleoidea, which he subdivided into six orders. Among them, the order Belemnitida was subdivided into three suborders: Belemnitina, characterised by forms with one or more apical grooves; Belemnopseina, with forms possessing alveolar grooves; Diplobelina, including taxa characterised by a reduced rostrum.

Engeser and Bandel (1988) proposed a new classification of the subclass Coleoidea, based on phylogenetic systematics, distinguishing two evolutionary lines: the extinct mono phylum Belemnoidea, and the Vampyromorphoidea and Decapoda, both characterised by fossil and living forms. In their classification scheme the Coleoidea are constituted by the following super orders: Belemnoidea, Vampyromorphoidea and Decapoda. Belemnoidea is subdivided into four orders: Aulacocerida, Phragmoteuthida, Belemnitida and Diplobelida.

Engeser (1990) suggested a systematization of the fossil Coleoidea, in which the Belemnoidea are considered as a sister-group of the Dibranchiata.

Doyle et al. (1994) based the phylogeny of coleoids on three natural groups at superorder level: Belemnoidea, Decabrachia and Octobrachia. The authors proposed a classification of the Coleoidea, in which the order Belemnitida was subdivided into the suborders Belemnitina, Belemnopseina and Belemnotheutidina.

Recently Riegraf (1995), in the Fossilium Catalogus I, and Riegraf et al. (1998) in the Fossilium Catalogus II, proposed a nomenclature and systematics revision. Riegraf et al. (1998) subdivided the subclass Coleoidea into the following superorders: Belemnophora and Decacera, the former including the orders Aulacoceratida, Phragmoteuthida, Belemnitida, Belemnoteuthida and Diplobelida. The order Belemnitida was subdivided in two suborders: Belemnitina and Pachybelemnopseina.

The classification here adopted is mainly based on that proposed by Doyle et al. (1994), although the more recent work of Riegraf et al. (1998) opens some systematic problems that will need some time to be solved.

The terminology herein used is derived from Spath (1963), Doyle and Kelly (1988) and Combémorel (1988), and it is summarised in Fig. 4. Individual descriptions also include size measurements in case of complete or almost complete specimens. All measures are in millimetres. Estimated values for incomplete specimens are marked by a (*). 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.

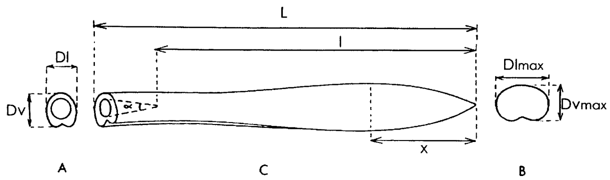

Fig. 4. Principal measures of the belemnite rostrum. A, at the level of the alveolar opening; B, at the level of the maximum diameter; C, along the rostrum L, total preserved length l, length of the post-alveolar portion; Dv, dorso-ventral diameter at the alveolar opening; Dl, lateral diameter at the alveolar opening; Dvmax, maximum dorso-ventral diameter; Dlmax, maximum lateral diameter; x, length from apex to Dmax. α, alveolar angle; Ic, compression index. It is used for the Duvaliidae, which usually are compressed. It is the ratio between dorso-ventral diameter and lateral diameter, that can be calculated at different levels: Ica, at the level of the alveolar opening, and Icm, at the level of the maximum dorso-ventral diameter; Id, depression index. It is used for the Belemnopseidae, which usually are depressed. It is the ratio between lateral diameter and dorso-ventral diameter calculated at different levels: Ida, at the level of the alveolar opening, and Idm, at the level of the maximum lateral diameter. * estimated value.

Principales mesures effectuées sur le rostres de bélemnites. A, au niveau de l'ouverture alvéolaire; B, au niveau du diamètre maximal; C, sur la longueur du rostre L, longueur du rostre; l, longueur de la région post-alvéolaire; Dv, diamètre dorso-ventral au niveau de l'ouverture alvéolaire; Dl, diamètre latéral au niveau de l'ouverture alvéolaire; Dvmax, diamètre dorso-ventral maximal du rostre; Dlmax, diamètre latéral maximal du rostre; x, longueur de la région apicale; α, angle alvéolaire. Ic, indice de compression. Il est utilisé chez les Duvaliidae, qui sont généralement comprimées. C'est le rapport diamètre dorso-ventral/diamètre lateral, que l'on peut calculer à différents niveaux: Ica, au niveau de l'ouverture alvéolaire, Icm, au niveau du diamètre dorso-ventral maximal. Id, indice de dépression. Il est utilisé chez les Belemnopseidae, qui sont généralement déprimées. C'est le rapport diamètre latéral/diamètre dorso-ventral, que l'on peut calculer lui aussi à différents niveaux: Ida, au niveau de l'ouverture alvéolaire, Idm, au niveau du diamètre latéral maximal. * valeur estimée.

All the collected specimens are housed at the Palaeontological Museum of the Dipartimento di Scienze della Terra of the University 'La Sapienza' of Rome, and are stored with the collection number NS 20/92-198, /225-299, /1001-1153.

3.1. Previous works

Before discussing the fauna of Campo al Bello, a brief historical review of the main papers on Kimmeridgian Tethyan belemnites is needed.

Del Campana (1903, 1905) and Pasquaré (1965) recorded the presence of *Hibolithes semisulcatus* (Münster, 1830) in northern Italy.

Riegraf (1981), in his revision of the Swabian Jurassic belemnites, described many representatives (in many cases new taxa) of the genera *Hibolithes* MONTFORT, *Suebibelus* RIEGRAF, *Subulibelus* RIEGRAF, *Rhaphibelus* NAEF, *Produvalia* RIEGRAF, *Conobelus* STOLLEY, *Diplobelus* NAEF, and discussed their biostratigraphical, palaeoecological and palaeobiogeographical characteristics. The following forms were recorded from Kimmeridgian deposits: *Hibolithes (Hibolithes) hastatus hastatus* MONTFORT, *H. (H.) hastatus elegans* RIEGRAF, *H. (H.) hastatus semisulcatus* MONTFORT, *H. (H.) hastatus crassirostris* RIEGRAF, *H. (H.) planoclava* RIEGRAF (Upper Oxfordian or lowermost Kimmeridgian), *H. (Acutibelus) acuariformis* RIEGRAF, *Subulibelus problematicus* RIEGRAF, *Produvalia (Pachyduvalia) pinguis* RIEGRAF (the species are here listed with their original nomenclature).

Mariotti (1994) reported specimens collected from Mt. Ginguno (Central Apennines, Pesaro province) belonging to *Hibolithes semisulcatus* and *Duvalia* sp.

Riegraf et al. (1998) remark that the Kimmeridgian age ascribed to the genus *Produvalia* (in Riegraf, 1981), is erroneous, due to wrong old collection labels.

Further documentation on Kimmeridgian Tethyan belemnites can be obtained from the extra-european regions, mainly eastern Tethyan and peri-Gondwanian. Other European sites are in fact only known for Oxfordian and Early Tithonian faunas (genera *Hibolithes* and *Belemnopsis*, and family Duvaliidae).

Waagen (1875), in his study on Jurassic cephalopods of Cutch, described for the first time *Belemnites kuntkotensis* from the Upper Oxfordian to Lower Tithonian levels, and *B. claviger* from the Upper Oxfordian to the Kimmeridgian.

Spath (1927), in his revision of the Jurassic cephalopod fauna of Cutch, recorded from Kimmeridgian beds the following taxa: *Belemnopsis kuntkotensis* (WAAGEN), *B. tanganensis* (FUTTERER), *Hibolithes* sp. nov. cf. *hastatus* (BLAINVILLE), *H.* cf. *semisulcatus* (MÜNSTER), *H. katrolensis* (WAAGEN), *H. (Hastites?) claviger* (WAAGEN).

Spath (1967), Stevens (1965, 1967, 1973, 1977, 1977, 1980a, b) studied the systematics, taxonomy, biostratigraphy and palaeobiogeography of the Mesozoic coleoids from the Indo-Pacific region, and from New Zealand in particular. He reached interesting conclusions on migration routes, faunal differentiation, palaeoclimates and palaeogeography. He also attempted a belemnite biostratigraphy for the Kimmeridgian of New Zealand. In particular he proposed the following belemnite zones: *Conodicoelites* in the Lower Kimmeridgian, *Belemnopsis keari* (Lower to Middle Kimmeridgian), *B. alfurica* (Middle Kimmeridgian), and *B. aucklandica trechmanni* (late Middle Kimmeridgian). This biostratigraphy was calibrated against biostratigraphy of other taxonomic groups, such as *Buchia*, *Inoceramus* and ammonites.

Combémorel (1988) described and figured several species from the Kimmeridgian of Madagascar. These include: *Belemnopsis casterasi* BESAIRIE, *B. alfuricus* (BOEHM), *Belemnopsis sikilyensis* COMBÉMOREL, *Hibolithes savornini* NICOLAI, *H. antsoaensis* COMBÉMOREL, *H. claviger* (WAAGEN) (this latter being very common in the Lower Kimmeridgian–Upper Tithonian), *H. flemingi* SPATH and *Duvalia* sp. B.

In a series of papers, Challinor (1972, 1980, 1990, 1991), Challinor and Swarko (1982), and Challinor and Grant-Mackie (1989) recorded Kimmeridgian belemnites from New Zealand, New Caledonia, Papua New Guinea, Indonesia, and Gondwana. They discussed various species of *Belemnopsis*, *Dicoelites* and *Hibolithes* from Kimmeridgian beds. Particularly important, for stratigraphical purpose, is the *moluccana*-lineage zone spanning the Earliest Oxfordian to the Latest Tithonian.

3.2. Systematics

For descriptive and reference use more than 300 collected specimens, either complete or fragmentary, were considered. Some specimens were photographed and subsequently polished to examine transverse and longitudinal sections; moulds were obtained before any destructive procedure.

Class CEPHALOPODA Cuvier, 1794
Subclass COLEOIDEA Bather, 1888
Order BELEMNITIDA Gray, 1849
Suborder BELEMNOPSEINA Jeletzky, 1965
Family BELEMNOPSEIDAE Naef, 1922
Genus ***Hibolithes*** MONTFORT, 1808

Type species: *Hibolithes hastatus* MONTFORT, 1808. According to Riegraf et al. (1998): 'Type species is a nom. dub.; ICZN pending: validation with type species *Belemnites semisulcatus* v. Münster, 1830 (Belemniten)'. Until the question is officially settled it seems useful to consider *Hibolithes hastatus* MONTFORT, 1808 as the type species.

Diagnosis: Elongated, slender, usually hastate rostrum. Symmetrical outline and profile. Maximum transverse diameter usually at the posterior region, near the apex. Transverse section generally circular, sometimes depressed in the posterior region and at the mid point of the rostrum, some others compressed in the alveolar region. Shallow ventral groove limited at the anterior half of rostrum. Well evident lateral lines (Doppellinien). Central apical line.

Stratigraphical range and geographical distribution: Bajocian to Aptian; Europe, Africa, Madagascar, Pakistan, India, Tibet, south-eastern Asia, New Zealand, Australia, western Antarctica, South and North America.

Remarks: The genus, characterised by its regularly hastate form, is widespread in most Tethyan and some Boreal regions. Riegraf (1981) subdivided the genus into three subgenera: *Hibolithes (Hibolithes*) MONTFORT, 1808, *H. (Acutibelus)* RIEGRAF, 1981 and *H.* (Rhopaloteuthis) LISSAJOUS, 1915. Subsequently Riegraf et al. (1998) considered *Acutibelus* as a separate genus, and *Rhopaloteuthis* as a member of the family Duvaliidae.

Hibolithes semisulcatus Münster, 1830
Fig. 5.1–4

Type specimen: *Belemnites semisulcatus* - Münster, 1830.

1830 *Belemnites semisulcatus* MÜNSTER, p. 6, pl. 1, figs. 1–8.

1865 *Belemnites semisulcatus* MÜNSTER - Oppel, p. 545.

v 1868 *Belemnites semisulcatus* MÜNSTER - Zittel, p. 37, pl. 1, fig. 8 a–c.

1875 *Belemnites semisulcatus* MÜNSTER - Pillet and Fromentel, p. 12, 39, 63, pl. 10, figs. 1–3, pl. 5, figs. 1–2, pl. 8, figs. 12–15.

1877 *Belemnites semisulcatus* MÜNSTER - Favre, p. 10, pl. 1, figs. 3–6.

1880 *Belemnites semisulcatus* MÜNSTER - Favre, p. 21, pl. 2, figs. 1–3.

1981 *Hibolithes (Hibolithes) hastatus semisulcatus* (MÜNSTER) - Riegraf, p. 85, text-figs. 202–203, pl. 6, figs. 48–49.

v 1986a *Hibolites semisulcatus* (MÜNSTER) - Combémorel & Mariotti, p. 312, pl. 2, figs. 14–16.

Material: Five almost complete rostra of adult specimens (NS 20/129, /135, /133, /117, /291); seven juvenile specimens (NS 20/154, /1009, /1072, /1035, /158, /108, /1065) and two at neanic stadium (NS 20 /1054, /148); four adult specimens partially lacking the alveolar region (NS 20/104, /132, /134, /147) and one juvenile specimen (NS 20/95); four specimens lacking the apical region, three adult before NS = before NS = (NS 20/107, /1132, /118) and one young NS 20/1046): three rostra lacking the alveolar region and a portion of the stem (NS 20/264, /1096, /1108); four complete but partially eroded specimens (NS 20/110, /1014, /1022, /1026); many fragments of alveolar or apical region. All specimens were collected from the shaly laminated bed 3, with the exception of NS 20/107, /132, /133, /134, 135, which were found at the base of bed 5, Lower Kimmeridgian (Divisum Zone) at Campo al Bello (Mt. Nerone, Central Apennines, Pesaro Province).

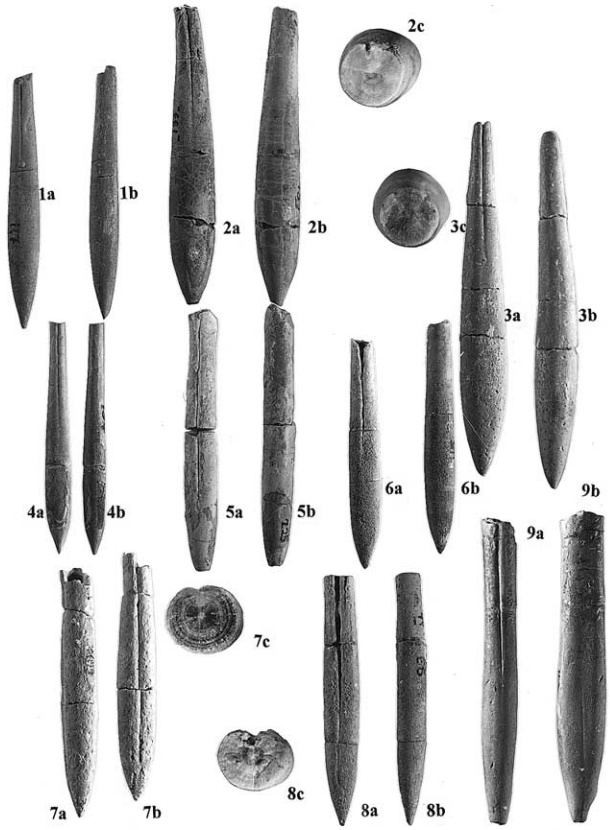

Fig. 5. 1–4. *Hibolithes semisulcatus* Münster, 1830. 1a, ventral view, ×1, 1b, left view, ×1, (NS 20/117); 2a, ventral view, ×1, ×1, 2b, left view, ×1, 2c, transverse section, ×2, (NS 20/133); 3a, ventral view, ×1, ×1, 3b, left view, ×1, 3c, transverse section, ×2, (NS 20/129); 4a, ventral view, ×1, 4b, left view, ×1, (NS 20/154); 5–6. *Hibolithes pignattii* nov. sp.; 5a, ventral view, ×1, 5b, left view, ×1, holotype (NS 20/225); 6a, ventral view, ×1, 6b, left view, ×1, paratype (NS 20/115); 7–8. *Belemnopsis neronensis* nov. sp., 7a, left view, ×1, 7b, ventral view, ×1, 7c, transversal section, ×2, holotype (NS 20/1109); 8a, ventral view, ×1, 8b, left view, ×1, 8c transversal section, ×2, ×2, paratype, (NS 20/99); 9. *Duvalia matteuccii* nov. sp., 9a, dorsal view, ×1, 9b, left view, ×1, holotype (NS 20/143).

1–4. *Hibolithes semisulcatus* Münster, 1830. 1a, vue ventrale, ×1, 1b, vue latérale gauche, ×1, (NS 20/117); 2a, vue ventrale, ×1, ×1, 2b, vue latérale gauche, ×1, 2c, section transversale, ×2, (NS 20/133); 3a, vue ventrale, ×1, ×1, 3b, vue latérale gauche, ×1, 3c, section transversale, ×2, (NS 20/129); 4a, vue ventrale, ×1, 4b, vue latérale gauche, ×1, (NS 20/154); 5–6. *Hibolithes pignattii* nov. sp., 5a, vue ventrale, ×1, 5b, vue latérale gauche, ×1, holotype (NS 20/225) ; 6a, vue ventrale, ×1, 6b, vue latérale gauche, ×1, paratype (NS 20/115); 7–8. *Belemnopsis neronensis* nov. sp., 7a, vue latérale gauche, ×1, 7b, vue ventrale, × 1, 7c, section transversale, ×2, holotype (NS 20/1109); 8a, vue ventrale, ×1, 8b, vue latérale gauche, ×1, 8c, section transversale, ×2, ×2, paratype, (NS 20/99); 9. *Duvalia matteuccii* nov. sp., 9a, vue dorsale, ×1, 9b, vue latérale gauche, ×1, holotype (NS 20/143).

Diagnosis: Slender, medium-sized rostrum. Outline and profile symmetrical and hastate. Almost circular transverse section. Maximum inflation point in the apical third. Acuminate apex. A ventral alveolar groove extending up to the half of the rostrum.

Description: The rostrum is medium-sized and slender. The profile is symmetrical and hastate. The outline is symmetrical and hastate with its maximum diameter (Dvmax) about one third of the length from the apex. The lateral sides, after the maximum inflation point, converge towards the point of minimum inflation, usually located at the tip of the alveolus, defining an evident reduction of the stem. The transverse section is circular to slightly depressed at the alveolar region, and slightly depressed at the maximum diameter point. A ventral alveolar groove extends to the stem region not surpassing the half of the rostrum. Weak lateral lines are present on the flanks, mainly in the juvenile specimens. The apex is acute, slightly mucronate; the apical line is central.

Dimensions: See Table 1.

Remarks: Münster (1830) recognised several morphotypes of this species: all are hastate, bulging to some degree in the last half, near the apical region, and more rarely at the mid point of the rostrum. Also Lissajous (1925) observed that the forms described and figured by Zittel (1868) and Favre (1877) are similar to those studied by Münster (1830) but are more markedly hastate. All the specimens examined by the above mentioned authors are Early Tithonian in age. Specimens collected from Lower Tithonian strata of both Sicily and the central Apennines (Combémorel and Mariotti, 1986a, 1990) show the same morphological features. These forms might represents a 'morphologic group' varying from more bulging Late Oxfordian–Early Kimmeridgian specimens to more hastate Early Tithonian morphotypes.

Occurrence: This species is very common in the studied outcrop. Elsewhere it has been recorded (Combémorel and Mariotti, 1986a) from Kimmeridgian and Lower Tithonian sediments in Italy, France, Switzerland, Czech Republic, Poland, Southern Germany, Austria, Romania, south-east of southern Carpathians and Iran.

Hibolithes pignattii nov. sp.

Fig. 5.5,6

Derivatio nominis: Named after my friend and colleague Dr. Johannes Pignatti, specialist in macroforaminifers and coleoids.

Locus typicus: Campo al Bello, Mt. Nerone (Central Apennines, Pesaro Province).

Stratum typicum: From the shaly laminated bed 3 of Lower Kimmeridgian (Divisum Zone).

Holotype: NS 20/225. Fig. 5.5.

Paratypes: Three almost complete specimens (NS 20/115, /1101, /1057).

Diagnosis: Small-sized rostrum. Outline and profile symmetrical and hastate. Long ventral alveolar groove. Circular to very slightly depressed transverse section.

Description: Small-sized, slender rostrum. The outline is symmetrical and hastate. The maximum inflation (Dlmax), not particularly evident, is located at the posterior half of the rostrum. The profile is symmetrical and not so markedly hastate as the outline because the dorsal and ventral sides do not converge so strongly as the flanks. In transverse section the stem and the apical region are slightly depressed, and the alveolar region is nearly circular. A ventral groove starts from the alveolar opening, persists into the posterior portion

Table 1
Hibolithes semisulcatus MÜNSTER, 1830

NS 20/	*L*	Dlmax	Dvmax	Dl	Dv	*x*	Idm	Ida
95	52.2*	6.2	5.8	–	–	–	1.07	–
104	67.0*	10.3	9.8	–	–	32.6	1.05	–
117	70.6	9.2	8.8	5.0	5.5	26.4	1.04	0.91
129	98.0	12.9	11.5	5.0	4.8	28.0	1.12	1.04
132	74.0	11.0	10.5	6.2	6.8	31.0	1.05	0.91
133	83.0	13.0	12.6	6.8	6.7	25.0	1.03	1.01
134	82.0*	11.7	11.0	–	–	36.0	1.06	–
135	85.6	11.3	11.3	5.7	6.2	27.0	1.00	0.92
154	64.6	7.2	6.5	4.0	3.9	20.0	1.11	1.02
158	52.0	7.3	6.7	4.3	4.3	16.7	1.09	1.00
291	62.0	8.6	7.9	4.9	5.1	21.0	1.09	0.96
1009	67.4	7.6	6.7	3.1	3.4	20.5	1.13	0.91
1035	52.3	7.2	6.2	4.3	4.3	19.0	1.16	1.00
1054	40.3	3.3	3.2	1.7	1.6	13.6	1.03	1.06
1072	62.0	7.2	6.4	4.1	3.9	21.0	1.12	1.05

Table 2
Hibolithes pignattii nov. sp.

NS 20/	*L*	Dlmax	Dvmax	Dl	Dv	*x*	Idm	Ida
225	72.3	9.4	9.0	7.7	8.0	22.0	1.04	0.96
115	64.4	8.7	8.1	6.3	6.4	18.0	1.07	0.98
1057	56.0	8.1	7.6	5.3	5.4	16.5	1.06	0.98
1101	65.6	9.0	8.4	6.6	6.4	22.8	1.04	0.96

of the stem region, and disappears at the maximum inflation point. The apical region is acute with a central apex.

Dimensions: See Table 2.

Remarks: The only taxa comparable to *Hibolithes pignattii* are *H. (H.) hastatus hundsrueckenensis* Riegraf 1998 in Riegraf et al. 1998 (= *H. (H.) hastatus elegans* Riegraf 1981) and *H. flemingi* Spath, 1927. The former, described by Riegraf (1981) from Upper Oxfordian–Lower Kimmeridgian sediments of the Swabian Alb (SW Germany), appears to be more slender with a more acute apex. The latter, recorded by Combémorel (1988) in Madagascar, is characterised by a greater specific variability, and shows some characters similar to the new species (e.g. the shape, the position of maximum inflation point and the shape of the apical region), but differs from it in having a shorter groove, in larger size, and in the more depressed rostrum.

Occurrence: Lower Kimmeridgian of Campo al Bello (Mt. Nerone area, Pesaro Province).

Genus ***Acutibelus*** Riegraf, 1981

Type species: *Hibolithes (Acutibelus) acuariformis* Riegraf, 1981.

Diagnosis: Large-sized, very slender, weakly hastate rostrum. Long ventral groove. Slender apical region ending with a sharp apex. Rounded, little depressed transversal section.

Stratigraphical range and geographical distribution: Lower Kimmeridgian, SW Germany and Central Italy.

Remarks: The subgenus *Hibolites (Acutibelus)* was instituted by Riegraf (1981); later Riegraf et al. (1998) considered this taxon as a genus.

Acutibelus sp. cf. *acuariformis* Riegraf, 1981

Material: One specimen lacking the apex and alveolar region (NS 20/280).

Description: The middle-sized (estimated) rostrum is characteristically very slender. The outline is symmetrical and hastate. The profile is slightly hastate and asymmetrical because the venter is more flattened than the dorsum. A long ventral long groove extends up to the apical region. Longitudinal depressions on the flanks correspond to lateral lines. The transverse section is subcircular and slightly ventrally depressed.

Remarks: The very characteristic morphological features of the considered rostrum are very close to those in *Acutibelus acuariformis*, but because of the fragmentary status of the examined specimen it is not possible to ascribe it to this species with certainty.

Occurrence: Lower Kimmeridgian (Divisum Zone) of Campo al Bello (Mt. Nerone area, Pesaro Province).

Genus ***Belemnopsis*** BAYLE, 1878

Type species: *Belemnites sulcatus* MILLER, 1823, by subsequent designation (Douvillé , 1879). Recently Riegraf et al. (1998) questioned the validity of the genus *Belemnopsis* and its type species *Belemnites sulcatus* MILLER. However, it was maintained in this paper to follow mainly the classification of Doyle et al. (1994)—contra, see Riegraf (1980), Riegraf et al. (1998) and Howlett (1989).

Diagnosis, Cylindrical to hastate, elongate rostrum. Outline symmetrical. Profile asymmetrical. Acute apex. Transverse section usually depressed in the apical and stem regions. Broad, ventral alveolar groove extending up to the apex. Apical line ventrally eccentric. Lateral lines rarely present.

Stratigraphical range and geographical distribution: Bajocian to lowermost Hauterivian; Europe, Africa, Madagascar, Pakistan, India, Tibet, South East Asia, Australia, New Zealand, western Antarctica and South America. In Italy the genus is known from the Oxfordian (western

Sicily; unpublished data) and the Early Kimmeridgian (Campo al Bello, Central Apennines).

Belemnopsis neronensis nov. sp.
Figs. 5.7,8

Derivatio nominis: Named after Mt. Nerone, the type area of the present belemnite fauna.

Locus typicus: Campo al Bello, Mt. Nerone (Central Apennines, Pesaro Province).

Stratum typicum: From the shaly laminated bed 3 of Lower Kimmeridgian (Divisum Zone).

Holotype: NS 20/1109. Fig. 5.7.

Paratypes: An almost complete specimen (NS 20/1060); a specimen lacking part of the alveolar region (NS 20/99); two apical region fragments (NS 20/1070, /1186).

Diagnosis: Middle-sized, hastate, depressed rostrum. Outline symmetrical and hastate, profile asymmetrical and hastate. Prominent and broad ventral alveolar groove, ending near the apex. Depressed cross section in the stem and apical regions.

Description: The moderately robust rostrum, small to medium in length, is typically depressed. The outline is hastate, with Dlmax located slightly posterior of the midpoint. The profile is slightly hastate to hastate, and asymmetrical with the ventral side inflated. The alveolar opening has a circular cross section (Ida 0.99), just after the rostrum becomes characteristically depressed (Idm 1.10 and 1.23) throughout its length. The alveolus penetrates for one third into the rostrum. A deep, broad, ventral groove extends from the alveolar region nearly up to the acute apex. The apical region is short. Two weak lateral lines, developed as flattening depressions, occur on each flank, ending near the apex.

Dimensions: See Table 3.

Remarks: In the western Tethys no Kimmeridgian species ascribed to *Belemnopsis* are known. The only species, that have some morphological similarities are *Belemnopsis alfuricus* (BOEHM), from the Oxfordian of India, Indonesia and Australia and from the Lower Kimmeridgian of New Zealand and Madagascar, and *B. casterasi* BESAIRIE from the Lower Kimmeridgian–Hauterivian of Madagascar (Combémorel, 1988).

B. alfuricus differs for a less hastate rostrum and a more acute apical region. *B. casterasi* appears to be less hastate with a long acute apical region and a narrower groove.

Occurrence: Lower Kimmeridgian (Divisum Zone) of Campo al Bello (Mt. Nerone area, Pesaro Province).

Table 3
Belemnopsis neronensis nov. sp.

NS 20/	*L*	Dlmax	Dvmax	Dl	Dv	*x*	Idm	Ida
1109	70.0	10.8	9.8	7.9	8,0	20.6	1.10	0.99
99	69.1*	10.1	8.2	8.3	6.7	26.0	1.23	1.24
1060	87.4	9.0	7.6	3.5	3.0	28.0	1.18	1.17

Belemnopseidae incertae sedis
Fig. 7.8

Material: One specimen (NS 20/160), lacking the alveolar region.

Description: Very slender and large-sized rostrum. The outline is symmetrical and hastate. The profile is hastate and slightly asymmetrical for a straight ventral side, while the dorsal side is slightly convex. A well-marked ventral groove extends from the alveolar region almost up the apex. The long and slender apical region ends with a sharp apex. Two evident lateral lines (Doppellinien) run along the flanks up to the apex. The transverse section is rounded with a flattened ventral side.

Remarks: This very characteristic specimen could belong to *Belemnopsis*, because of its broad long groove, but the depression is not so accentuated and the rostrum is too narrow and long. It might be compared to *Acutibelus acuariformis* but it seems to differ in being less hastate and in having a relatively large ventral groove.

Occurrence: Lower Kimmeridgian (Divisum Zone) from Campo al Bello (Mt. Nerone area, Pesaro Province).

Family DUVALIIDAE Pavlow, 1914
Genus ***Duvalia*** BAYLE, 1878

Type species: *Belemnites dilatatus* DE BLAINVILLE, 1827, by subsequent designation (Douvillé, 1879).

Diagnosis: Small- to large-sized, more or less strongly compressed rostrum. Alveolar dorsal groove. Outline symmetrical. Profile asymmetrical. Two lateral lines (Doppellinien) on each flank. Apex short, sometimes mucronate or rounded.

Stratigraphical range and geographical distribution: *Duvalia* is a widespread Tethyan genus in Kimmeridgian–Early Aptian times, rarer in the Middle Jurassic; the only known Bathonian occurrences, *Duvalia disputabilis* (NEUMAYR) and *D. rhopaliformis* COMBÉMOREL, are recorded from Poland (Pugaczewska, 1961) and Madagascar (Combémorel, 1988), respectively. The youngest species, *D. rafarae* COMBÉMOREL, was collected from the Turonian of Madagascar (Combémorel, 1988). The only species recorded outside the Tethyan Realm is *D. grasiana* (DUVAL-JOUVE) from the middle Late Aptian of NW Germany (Mutterlose, 1988, 1990, 1992, 1998).

Duvalia matteuccii nov. sp.
Fig. 5.9; Fig. 6.1,2

Derivatio nominis: Named after my friend and colleague Professor Ruggero Matteucci, specialist in larger foraminifera.

Locus typicus: Campo al Bello, Mt. Nerone (Central Apennines, Pesaro Province).

Stratum typicum: From the shaly laminated bed 3 of Lower Kimmeridgian (Divisum Zone).

Holotype: NS 20/143.

Paratypes: Four almost complete specimens (NS 20/92, /146, /155, /1126); one specimen lacking the apex

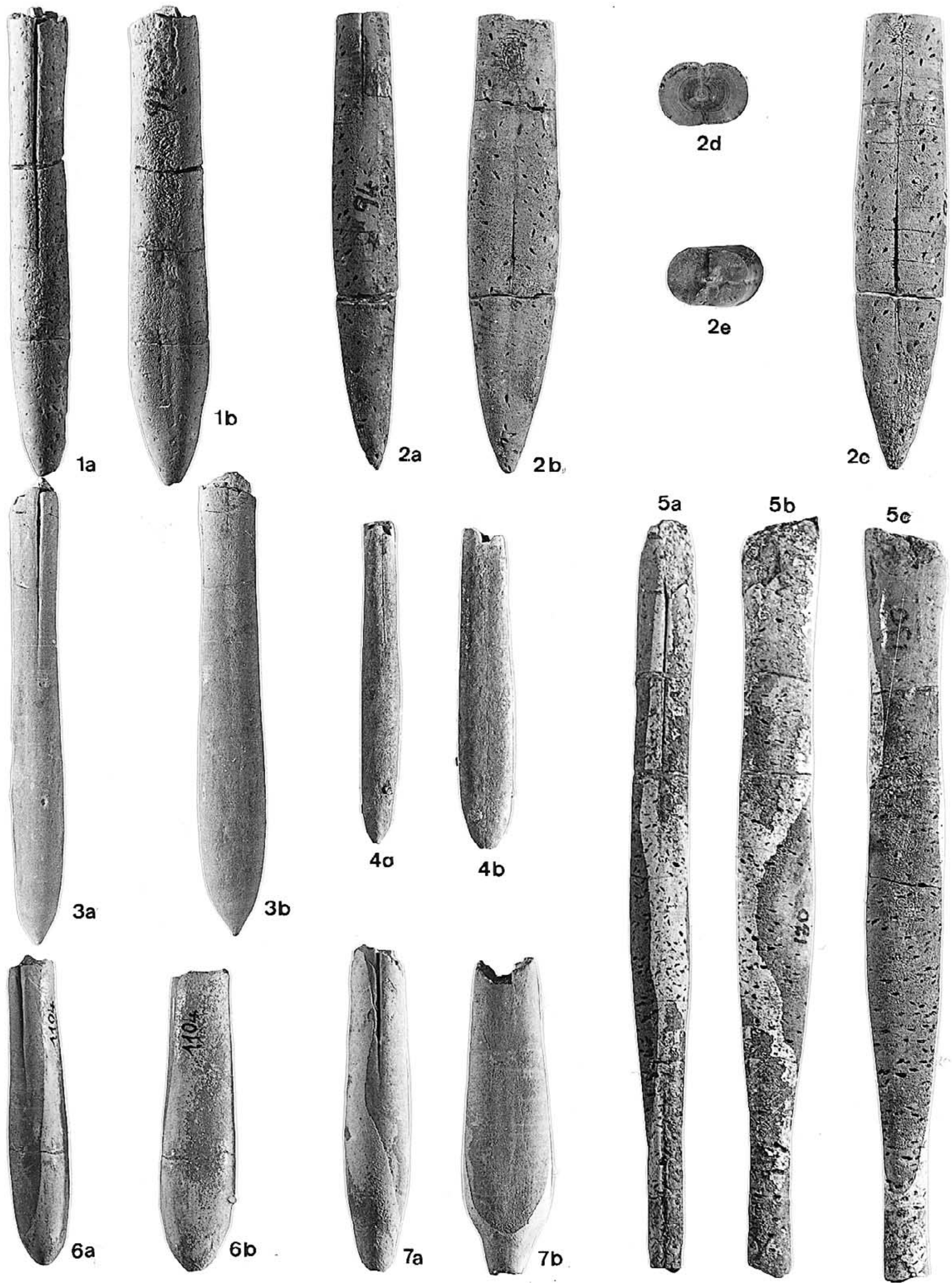

Fig. 6. 1–2. *Duvalia matteucii* nov. sp., 1a, dorsal view, ×1, 1b, left view, ×1, paratype, (NS 20/92); 2a, dorsal view, ×1, 2b, right view, ×1, 2c, left view, ×1, 2d–e, transverse sections, ×1, paratype (NS 20/94); 3–5. *Duvalia nicosiai* nov. sp., 3a, dorsal view, ×1, 3b, right view, ×1, holotype (NS 20/145); 4a, dorsal view, ×1, 4b, left view, ×1, paratype (NS 20/1107); 5a, dorsal view, ×1, 5b, left view, ×1, 5c, right view, ×1, paratype (NS 20 /130); 6–7. *Duvalia raymondi* nov. sp., 6a, dorsal view, ×1, 6b right view, ×1, ×1, holotype (NS 20/1104); 7a, dorsal view, ×1, 7b, right view, ×1, paratype (NS 20 1016).

1–2. *Duvalia matteucii* nov. sp., 1a, vue dorsale, ×1, 1b, vue latérale gauche, ×1, paratype, (NS 20/92); 2a, vue dorsale, ×1, 2b, vue latérale droite, ×1, 2c, vue latérale gauche, ×1, 2d–e, coupes transversales, ×1, paratype (NS 20/94); 3–5. *Duvalia nicosiai* nov. sp., 3a, vue dorsale, ×1, 3b, vue latérale droite, ×1, holotype (NS 20/145); 4a, vue dorsale, ×1, 4b, vue latérale gauche, ×1, paratype (NS 20/1107); 5a, vue dorsale, ×1, 5b, vue latérale gauche, ×1, 5c, vue latérale droite, ×1, paratype (NS 20/130); 6–7. *Duvalia raymondi* nov. sp., 6a, vue dorsale, ×1, 6b, vue latérale droite, ×1, ×1, holotype (NS 20/1104); 7a vue dorsale, ×1, 7b, vue latérale droite, ×1, paratype (NS 20/1016).

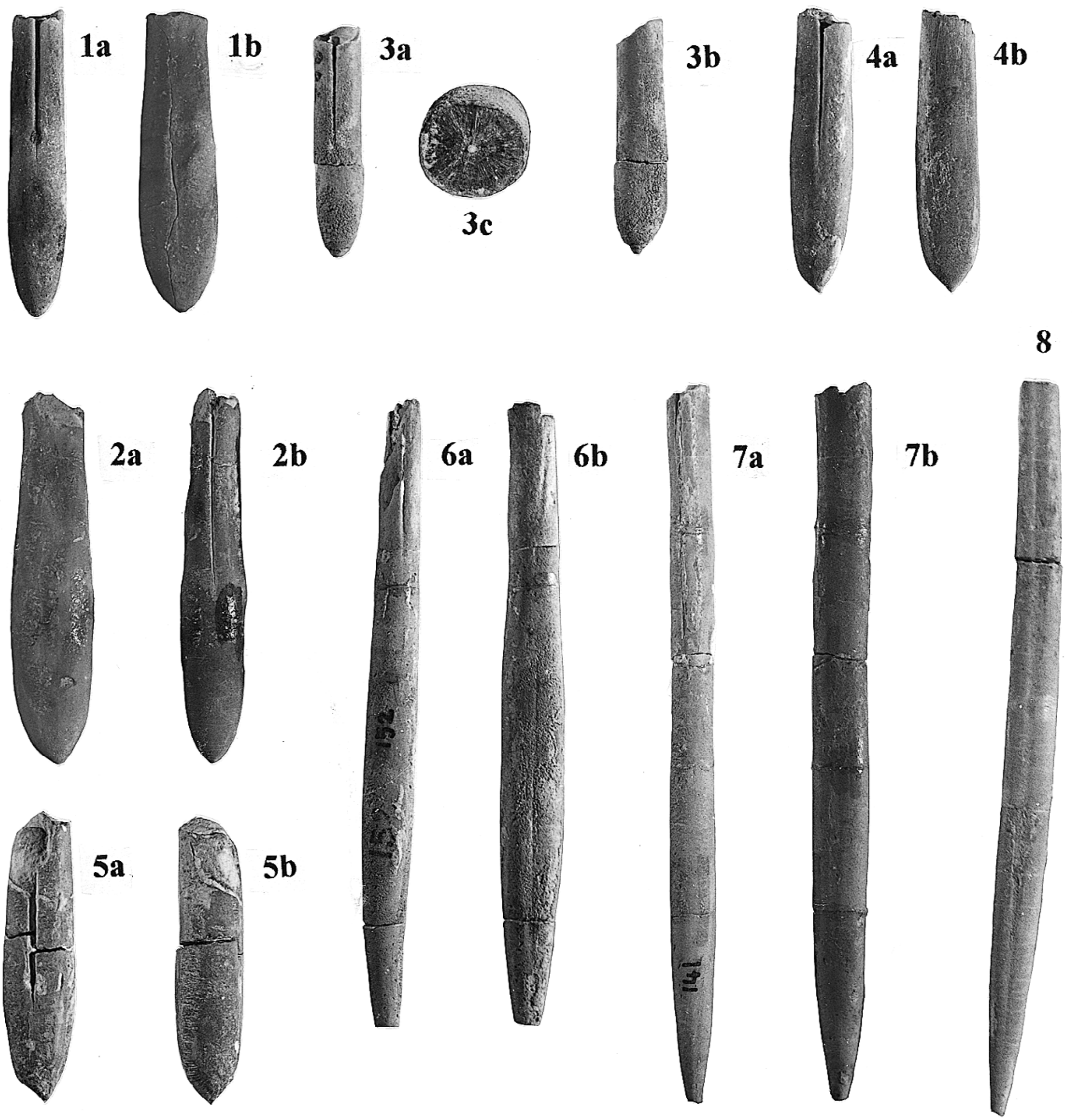

Fig. 7. 1–2. *Duvalia raymondi* nov. sp., 1a, dorsal view, ×1, 1b, left view, ×1, paratype (NS 20/128); 2a, left view, ×1, 2b, dorsal view, ×1, paratype (NS 20/1067); 3–5. *Rhopaloteuthis massimoi* nov. sp., 3a, dorsal view, ×1, 3b, right view, ×1, 3c, transverse section, ×3, paratype (NS 20/226); 4a, dorsal view, ×1, 4b, left view, ×1, holotype (NS 20/1029); 5a, dorsal view, 5b, left view, ×1, paratype (NS 20/1017); 6–7. *Duvalia pallinii* nov. sp., 6a, dorsal view, ×1, 6b, right view, ×1, paratype (NS 20/152); 7a, dorsal view, ×1, 7b, right view, ×1, holotype (NS 20/141); 8. Belemnopseidae incertae sedis. Ventral view, ×1 (NS 20/160).

1–2. *Duvalia raymondi* nov. sp., 1a, vue dorsale, ×1, 1b, vue latérale gauche, ×1, paratype (NS 20/128); 2a, vue latérale gauche, ×1, 2b, vue dorsale, ×1, paratype (NS 20/1067); 3–5. *Rhopaloteuthis massimoi* nov. sp., 3a, vue dorsale, ×1, 3b, vue latérale droite, ×1, 3c, section transversale, ×3, paratype (NS 20/226); 4a, vue dorsale, ×1, 4b, vue latérale gauche, ×1, holotype (NS 20/1029); 5a, vue dorsale, ×1, 5b, vue latérale gauche, ×1, paratype (NS 20/1017); 6–7. *Duvalia pallinii* nov. sp., 6a, vue dorsale, ×1, 6b vue latérale droite, ×1, paratype (NS 20/152); 7a vue dorsale, ×1, 7b, vue latérale droite, ×1, holotype (NS 20/141); 8. Belemnopseidae incertae sedis, vue ventrale, ×1 (NS 20 160).

(NS 20/103); five specimens lacking the alveolar region (NS 20/122, /156, /153, /94, /1129); two apical region fragments (NS 20/292, /173).

Diagnosis: Medium-sized, compressed rostrum. Outline symmetrical. Profile hastate and symmetrical to very slightly asymmetrical. Well incised dorsal alveolar groove.

Table 4
Duvalia matteuccii nov. sp.

NS 20/	*L*	Dlmax	Dvmax	Dl	Dv	*x*	Icm	Ica
143	86.2	9.8	13.3	9.7	11.7	25.0	1.36	1.21
146	76.6	9.8	12.4	7.8	9.7	20.5	1.26	1.24
153	77.3*	11.4*	9.8	9.8	11.3	30.8	–	–
155	70.6	8.5	12.6	8.8	9.7	21.8	1.48	1.10
103	75.3*	10.6	13.5	8.5	10.3	–	1.27	1.21
156	70.0*	9.1	11.8	–	–	27.2	1.30	–
92	82.3	10.0	13.8	9.8	11.7	24.0	1.38	1.19
94	79.0*	11.0	15.7	–	–	37.4	1.43	–
1126	98.3	8.3	11.3	7.1	9.0	46.0	1.36	1.27

Apex acute. Compressed transverse section. Lateral lines on each flank.

Description: The medium-sized rostrum is compressed (Icm 1.26 to 1.48; Ica 1.10 to 1.24). The outline is symmetrical and hastate with the maximum lateral diameter (Dlmax) occurring posterior of the mid-point. The profile is hastate and symmetrical to slightly asymmetrical with the venter slightly more convex than the dorsum. The transverse section is subrectangular with the ventral side slightly more developed. In lateral view the venter and dorsum are parallel in the alveolar region, hence they diverge slowly but continuously up to the maximum inflation diameter (Dvmax), corresponding to one third of the length from the apex. They converge markedly up to the apex. An incised depression, corresponding to lateral lines, runs on each flank ending near the acute apex. An alveolar incised groove runs along the dorsum up to the mid-point of its length.

Dimensions: See Table 4.

Remarks: The characteristic shape of the rostrum, with an acute apical region, makes this species comparable only to *Duvalia dionysii* (FAVRE) from the Oxfordian of the Fribourg Alps in Switzerland (Favre, 1876). The latter species differs in a more marked asymmetry in lateral view, and in a more inflate apical region.

Occurrence: Lower Kimmeridgian (Divisum Zone) of Campo al Bello (Mt. Nerone area, Pesaro Province).

Duvalia nicosiai nov. sp.

Fig. 6.3–5

Derivatio nominis: Named after my friend and colleague Professor Umberto Nicosia, specialist in crinoids and tetrapod footprints.

Locus typicus: Campo al Bello, Mt. Nerone (Central Apennines, Pesaro Province).

Stratum typicum: From the shaly laminated bed 3, Lower Kimmeridgian (Divisum Zone).

Holotype: NS 20/145. Fig. 6.3.

Paratypes: Four complete specimens (NS 20/101, /1107, /98, /265); two juvenile specimens lacking the alveolar region (NS 20/93, /294); one specimen lacking the apical region (NS 20/142); a stem region of an adult specimen (NS 20/1027); one senile specimen with a well developed epirostrum (NS 20/130).

Table 5
Duvalia nicosiai nov.sp.

NS 20/	*L*	Dlmax	Dvmax	Dl	Dv	*x*	Icm	Ica
145	81.2	9.2	11.5	8.4	10.2	21.7	1.25	1.21
101	65.0	9.3	12.0	5.8	9.0	18.5	1.29	1.55
98	58.0	6.7	9.5	5.3	6.5	11.0	1.42	1.23
1107	55.2	6.4	9.6	5.5	7.8	10.4	1.50	1.42
265	56.2	7.8	10.2	6.1	8.0	12.3	1.31	1.31
93	53.8*	6.3	7.4	–	–	10.7	1.17	–
294	45.8*	6.0	8.2	–	–	11.4	1.37	–

Diagnosis: Small- to medium-sized compressed rostrum. Outline symmetrical and very slightly hastate. Profile asymmetrical. Apex obtuse and mucronate. Well incised dorsal groove. Subrectangular to subquadrate transverse section. Lateral lines developed as a shallow depression on each flank.

Description: The rostrum is elongated and compressed (Icm 1.17 to 1.50, Ica 1.21 to 1.55). The outline is symmetrical and weakly hastate. The widest point (Dlmax) is placed at the posterior portion of the rostrum. The hastatation is caused by the very gradual widening of the sides, starting from the anterior region, till about the three fourths of the total length, then they converge rapidly in the apical fourth. The profile is slightly hastate and asymmetrical. The asymmetry is due to the more accentuated ventral side in the apical region. The lateral sides possess a weak and narrow depression running from the alveolar region nearly to the apex. A narrow dorsal, alveolar groove extends for all the alveolar region. The apical region is short and ends with an obtuse and mucronate apex. The transverse section is compressed throughout the length of the rostrum.

Dimensions: See Table 5.

Remarks: The Oxfordian species *Duvalia monsalvensis* (GILLIERON) and *D. dionysii* (FAVRE) weakly resemble *D. nicosiai*. The former differs in a much more hastate outline and profile and in a less slender shape, the latter has a more acute apical region and a more rounded compressed cross section.

Occurrence: Lower Kimmeridgian (Divisum Zone) of Campo al Bello (Mt. Nerone area, Pesaro Province).

Duvalia raymondi nov. sp.

Fig. 6.6,7; Fig. 7.1,2

Derivatio nominis: Named after my friend and colleague Professor Raymond Combémorel, belemnite specialist.

Locus typicus: Campo al Bello, Mt. Nerone (Central Apennines, Pesaro Province).

Stratum typicum: From the shaly laminated bed 3 of Lower Kimmeridgian (Divisum Zone).

Holotype: NS 20/1104. Fig. 6.6.

Paratypes: Twelve nearly complete specimens (NS 20/1067, /1100, /128, /1016, /1111, /100, /1106, /105, /125, /1038, /1045, /1037); six specimens lacking the apex (NS 20/195, /1033, /1034, /1058, /1082, /123); eight specimens lacking part of alveolar region (NS 20/172, /293, /296,

/1023, /1040, /1069, /1113, /1120); four fragments of the apical and stem regions (NS 20/1098, /1114, /1121, /1187); one deeply bioeroded specimen (NS 20/1062).

Diagnosis: Small-sized, massive and compressed rostrum. Symmetrical outline and slightly asymmetrical profile. Dorsal, alveolar groove. Short and dorsally eccentric apex. Lateral lines on each flank.

Description: The small-sized rostrum is moderately robust and markedly compressed throughout its length, with compression index at maximum diameter (Icm) 1.10 to 1.38 and at the alveolar opening (Ica) 1.15 to 1.42. The outline is symmetrical and weakly hastate, the maximum lateral diameter (Dlmax) occurs at one third of the total length from the apex. The profile is slightly but clearly asymmetrical. The asymmetry is due to an almost straight dorsum in contrast to the more convex venter. A narrow, dorsal, alveolar groove usually extends to the mid-point of the rostrum. Two lateral lines (Doppellinien) occur along the flanks; they are very clear in the juvenile specimens, often in the adult specimens they merge in a single central depression. The transverse section is compressed, with the ventral side slightly more developed than the dorsum. The apical region is short and blunt with a mucronate ventrally eccentric apex. The phragmocone penetrates approximately for one third into the rostrum. The alveolar angle is about 34°. In a mature specimen it is possible to observe the incipient development of an epirostrum.

Dimensions: See Table 6.

Remarks: Because of its characteristic shapes *Duvalia raymondi* cannot be compared to any Kimmeridgian species. Some similarities exist with Early Tithonian *Duvalia ensifer* (OPPEL) and the Oxfordian *Produvalia monsalvensis* (GILLIERON). The former differs in having the venter and the dorsum parallel in lateral view, a longer groove, a more compressed dorsum and a more penetrating phragmocone. The latter possesses a characteristically longer rostrum, a more hastate profile and a less compressed transversal cross section.

Occurrence: Lower Kimmeridgian (Divisum Zone) of Campo al Bello (Mt. Nerone area, Pesaro Province).

Table 6
Duvalia raymondi nov. sp.

NS 20/	*L*	Dlmax	Dvmax	Dl	Dv	*x*	Icm	Ica
1037	44.5	9.5	10.5	5.8	10.2	29.8	1.10	1.75
1038	52.8	8.1	10.7	7.0	8.9	20.1	1.32	1.27
100	58.0	9.8	12.2	7.6	10.0	18.2	1.24	1.31
1106	46.7	8.9	12.3	7.3	9.1	18.6	1.38	1.24
1016	56.2	11.4	15.7	9.3	11.4	18.4	1.37	1.22
1033	54.0*	8.0	10.2	8.3	10.2	18.1	1.27	1.22
1104	54.5	9.8	13.4	8.9	10.3	18.1	1.36	1.15
1111	43.0	7.4	9.3	4.9	6.4	12.3	1.25	1.30
105	48.7	7.9	10.5	7.2	9.0	22.0	1.32	1.25
125	39.5	7.3	9.7	5.4	7.7	16.4	1.32	1.42
293	41.9*	8.6	11.0	6.6	8.5	16.6	1.27	1.28
1067	55.5	9.4	12.2	7.2	9.5	19.6	1.29	1.31
128	45.8	8.7	11.9	7.4	9.2	18.2	1.36	1.24
123	37.7*	6.4	8.6	5.7	7.9	15.5	1.34	1.38
1069	36.4*	7.1	9.8	6.6	8.8	–	1.38	1.33
1058	50.4*	9.1	10.4	7.4	8.8	19.6	1.14	1.18
1100	49.7	8.7	10.9	7.8	9.6	20.3	1.25	1.23
1045	33.6	5.5	6.6	9.8	5.8	12.5	1.20	1.20

Duvalia pallinii nov. sp.
Fig. 7.6,7

Derivatio nominis: Named after my friend and colleague Professor Giovanni Pallini, ammonite specialist.

Locus typicus: Campo al Bello, Mt. Nerone (Central Apennines, Pesaro Province).

Stratum typicum: From the shaly laminated bed 3, Lower Kimmeridgian (Divisum Zone).

Holotype: NS 20/141. Fig. 7.7.

Paratypes: Two nearly complete specimens (NS 20/152, /1131); one specimens lacking the apical region (NS 20/1090).

Diagnosis: Large-sized, compressed, slender rostrum. Long apical region and very acute apex. Outline and profile symmetrical. Short, dorsal, alveolar groove. Lateral lines as depressions on each flank.

Description: The large-sized rostrum is characteristically very slender, narrow and compressed (Icm 1.22–1.36; Ida 1.18–1.52). The outline is symmetrical, cylindrical to hastate. The profile is hastate and symmetrical to slightly asymmetrical. The hastate shape is caused by an inflation of the ventral and dorsal sides at one third of the length from the apex, and the asymmetry by a slightly greater convexity of the venter than the dorsum. The lateral sides show a longitudinal depression, corresponding to lateral lines, extending from the end of the alveolar region nearly up to the apex. The transverse section is subrectangular with the dorsal side a little more developed than the ventral side. A dorsal groove is present in the alveolar region. The apical region is slender and acute.

Dimensions: See Table 7.

Remarks: No similar species is known in the literature.

Occurrence: Lower Kimmeridgian (Divisum Zone) of Campo al Bello (Mt. Nerone area, Pesaro Province).

Genus ***Rhopaloteuthis*** Lissajous, 1925

Type species: *Belemnites sauvanausus* D'ORBIGNY, 1842.

Diagnosis: Small-sized hastate rostrum. Symmetrical and hastate outline. Symmetrical to very slightly asymmetrical hastate profile. Circular to subquadrate transverse section. Dorsal alveolar groove present. Apical line slightly eccentric, alveolus penetrating 1/4 to 1/2 of the total length. Weak lateral lines on each flank.

Table 7
Duvalia pallinii nov. sp.

NS20/	*L*	Dlmax	Dvmax	Dl	Dv	*x*	Icm	Ica
141	111.0	6.8	8.6	6.2	7.3	31.3	1.26	1.18
152	95.6	8.0	9.8	5.0*	7.4	36.2	1.22	1.48
1131	84.0	5.0	6.8	2.9	4.4	21.5	1.36	1.52

Stratigraphical range and geographical distribution: Bathonian to Tithonian of the Mediterranean area and southern Europe.

Rhopaloteuthis massimoi nov. sp.
Fig. 7.3–5

Derivatio nominis: Named after my friend and colleague Professor Massimo Santantonio, sedimentary geologist.

Locus typicus: Campo al Bello, Mt. Nerone (Central Apennines, Pesaro Province).

Stratum typicum: From the shaly laminated bed 3, Lower Kimmeridgian (Divisum Zone).

Holotype: NS 20/1029. Fig. 7.4.

Paratypes: Seven almost complete specimens (NS 20/1017, /1102, /1013, /1019, /1021, /226, /1018); one fragment of the alveolar region (NS 20/1125); one deeply bioeroded specimen (NS 20/1142).

Diagnosis: Small-sized and slightly hastate rostrum. Symmetrical and hastate outline. Asymmetrical and hastate profile. Circular to subquadrate transverse section. Dorsal alveolar groove present. Short apical region with a mucronate apex. Weak lateral lines on each flank.

Description: The small-sized and blunt rostrum tends to enlarge slowly towards the back up to the maximum inflation point, situated at one third of the length from the apex. Then it tapers very rapidly to end with a slightly eccentric mucronate apex. The outline is very slightly hastate. The profile is asymmetrical because of the stronger convexity of the venter respect to the dorsum. The juvenile specimens are more hastate. The transverse section is circular to slightly subquadrate. A dorsal alveolar groove extends to the mid-point of the rostrum disappearing abruptly. Very weak lateral lines are visible in some specimens.

Dimensions: See Table 8.

Remarks: The closest species to *Rhopaloteuthis massimoi* are: *R. argovianus* (MAYER), recorded from the Oxfordian of SW Germany (Riegraf 1981), from the Fribourg Alps (Favre, 1876) and the 'Jura lédonien' (de Loriol, 1902); *R. mulleri* (GILLIERON) from the Oxfordian of SW Germany (Riegraf 1981) and *R. siciliensis* COMBÉMOREL & MARIOTTI from the Early Tithonian of central and southern Italy (Combémorel and Mariotti, 1986a, 1990). In comparison to all these species, *R. massimoi* shows a characteristic inflation placed nearer to the apex, a more evident asymmetry, a shorter apical region and a more obtuse apex.

Table 8
Rhopaloteuthis massimoi nov. sp.

NS 20/	*L*	Dlmax	Dvmax	Dl	Dv	*x*	Icm	Ica
1029	43.7	9.7	9.6	8.2	8.0	14.7	0.99	0.97
1013	34.4	7.2	6.6	5.8	6.7	20.1	1.09	1.15
1102	33.7	7.4	7.4	7.1	7.1	11.5	1.00	1.00
1018	49.0	8.9	8.9	7.8	7.4	11.2	1.00	0.95
1021	27.3	6.9	7.6	5.2	5.4	9.2	1.10	1.04
1019	30.1	6.1	6.7	4.8	5.1	10.2	1.09	1.06
226	35.7	8.4	8.2	7.1	7.0	10.5	0.98	0.98
1125	27.9*	7.4	7.9	–	–	10.3	–	–
1017	43.8	11.2	10.0	9.8	9.5	16.7	0.89	0.97

Occurrence: Lower Kimmeridgian (Divisum Zone) of Campo al Bello (Mt. Nerone area, Pesaro Province).

3.3. *Kimmeridgian stratigraphy and palaeobiogeography, based on new data on the Campo al Bello outcrop*

Before we discuss our dataset, a summary of the known occurrences for the Mediterranean Tethys in the Kimmeridgian is necessary.

Stevens (1965, 1967, 1973), in a review of pre-late Oxfordian Tethyan assemblages, recognised three Tethyan belemnite provinces:

- the Mediterranean Province, characterised by a *Hibolithes* assemblage (e.g. *H. semisulcatus*) and rare representatives of *Belemnopsis*;
- the Ethiopian Province, with abundant *Belemnopsis*;
- the Indo-Pacific Province, with *Belemnopsis* and dicoelitids.

In LoLower Kimmeridgian times the Ethiopian Province (Madagascar, East Africa and Cutch) was characterised by the occurrence of *Belemnopsis orientalis-gerardi* group and *B. tanganensis*. The author remarked that migration along the Tethys towards the east was discontinued during the Late Oxfordian and Kimmeridgian.

Combémorel (1988) observed that in Madagascar the genus *Rhopaloteuthis* is absent from the Middle Oxfordian to Early Tithonian, and that from the Kimmeridgian to Early Valanginian duvaliids are extremely rare, while belemnopseids, with species that are endemic or with an Indonesian or Australian affinity, are abundant. Relations between European Tethys and Madagascar were therefore virtually non-existent, and the 'malagasian' faunas spread to Tanzania, Kenya, Somaliland, Ethiopia and Cutch, thus defining an Ethiopian Province.

Mutterlose (1988, 1992) gave a more accurate definition of certain terms commonly used in literature, such as realm, province, and subprovince. In his opinion, the term *realm* defines a particular area characterised by the presence of belemnite families which evolved independently; *provinces* are areas in which the same belemnite families occur, but are characterised by faunal differentiation at generic and specific level (endemic faunas); *subprovinces* are areas populated by species and subspecies having only minor local differences.

The author recognised in the Tethyan Realm two different belemnite Provinces from the Kimmeridgian onwards: the Mediterranean Province and the Indo-Pacific Province. The former is characterised by the absence of *Belemnopsis* and the latter by endemic *Belemnopsis*, while *Hibolithes* occurred in both provinces. In the Late Jurassic, owing to the geographic isolation of *Belemnopsis* and *Hibolithes* in the Indo-Pacific Province, a regional differentiation into two

Subprovinces arose: Ethiopian and Indo-Pacific. A similar paleobiogeographical figure was envisaged also by Doyle and Howlett (1989).

Challinor (1991) recognised two different belemnite assemblages along the coasts of Gondwana in the Middle–Late Jurassic and Early Cretaceous. One group populated the Tethyan coast from East Africa eastwards, the other extended along the south Pacific region. He regarded these two regions as different biogeographic Provinces: the South Pacific Province (Middle and Late Jurassic, Early Cretaceous), and the Tethyan Province (Bajocian–Early Oxfordian). The same author subdivided the Tethyan Province into three Subprovinces: Mediterranean (Oxfordian–Tithonian), Ethiopian (Oxfordian–Valanginian), and Indo-Tethyan (Oxfordian–Tithonian). The Mediterranean Subprovince is characterised by the presence of relict *Belemnopsis* in the Kimmeridgian and abundant *Hibolithes* in the Oxfordian–Tithonian. Rare *Conodicoelites*, pre-early Oxfordian, also occurred. The element that characterised this Subprovince is the rarity of *Belemnopsis*. The Ethiopian Subprovince is characterised by very narrow-grooved *Belemnopsis* forming probably a lineage from the Middle Oxfordian to the Late Valanginian. Short-grooved *Hibolithes* forms were present, while *Duvalia* appeared in the Valanginian.

Within this palaeobiogeographic picture it is now possible to discuss our data from Campo al Bello outcrop.

The Early Kimmeridgian fauna from Campo al Bello is characterised by the presence of *Belemnopsis*, *Hibolithes*, *Rhopaloteuthis* and *Duvalia*, all characteristic forms of the Mediterranean Tethys.

Belemnopsis was already recorded from the Early Bajocian (*Humphriesianum* Zone) of the central Apennines (Mariotti, 1994); additional specimens, as yet unpublished, are part of a rich collection from the Oxfordian of western Sicily. All these specimens strongly differ from those collected at Campo al Bello.

Hibolithes is recorded from the Oxfordian of western Sicily, and the Kimmeridgian and the Early Tithonian of continental Italy (Combémorel and Mariotti, 1986a, 1990; Mariotti, 1994 and unpublished data).

Duvalia is common in the Oxfordian of western Sicily (unpublished data), and in the Kimmeridgian and Early and Late Tithonian of continental Italy (Combémorel and Mariotti, 1986a,b, 1990; Mariotti, 1994).

Rhopaloteuthis was recorded from several Oxfordian, Kimmeridgian and Lower Tithonian outcrops throughout Italy (Pasquaré, 1965; Combémorel and Mariotti, 1986a, 1990). It seems that no species younger than the Early Tithonian occurs in Italy.

The geographic and stratigraphical distribution of the above mentioned genera is in agreement with published data, perhaps with the exception of *Belemnopsis* in the Early Kimmeridgian of the western Tethys. At species level, however, differences do exist.

The species of the genera *Rhopaloteuthis* and *Duvalia* are new and probably restricted to the Kimmeridgian, as they were never found in the Tithonian.

Hibolithes is present with two species. The first is a well-known species in the western Tethys, *Hibolithes semisulcatus*, recorded in the Lower Tithonian of Italy and across the whole western Tethys (Combémorel and Mariotti, 1986a, 1990); the second is a new species. *Hibolithes semisulcatus* is represented by specimens of the neanic, nepionic and ephebic–gerontic stages, while *Hibolithes pignattii* nov. sp. is rarer. This latter taxon seems restricted to the Early Kimmeridgian.

The genus *Belemnopsis* is present with few specimens belonging to the new species *B. neronensis*. The genus is known from the Oxfordian of western Sicily, where it occurs with forms that differ markedly from those collected at Campo al Bello (unpublished data; paper in preparation). This is probably the youngest occurrence of this genus in the western Tethys.

All the new species apparently do not range into younger levels; this may be interpreted as the last diversification of a stock of species still in connection with the areas in which they were previously widespread. Their absence from younger levels, as well as from Madagascar and eastern Tethys in general may reflect the impossibility of a W–E migration (Stevens, 1965, 1973; Combémorel, 1988; Challinor, 1991).

From a stratigraphic perspective, our Late Jurassic faunas seem to provide the following indications:

- the Early Kimmeridgian records the disappearance of *Belemnopsis* and the appearance of the genera *Hibolithes*, *Duvalia* and *Rhopaloteuthis*. In the Early Kimmeridgian of Italy all the species are new, except *Hibolithes semisulcatus*;
- in the Early Tithonian faunas, the above mentioned genera, and *Pseudobelus*, are always represented by different species with respect to the Early Kimmeridgian. Very few Early Tithonian species are new, while the others are common throughout the western Tethys;
- in the Late Tithonian, only the genera *Pseudobelus* and *Duvalia* occur in central and southern Italy.

Consequently, it is possible to observe a diversification at generic and specific level of the belemnite faunas. Unfortunately, as already evidenced, in the Apennines the richest fossil-bearing layers are located on structural highs, that are characterised by discontinuous and thin sequences, so the vertical evolution of taxa cannot be examined continuously.

Nevertheless, it appears from the present study that our belemnite assemblages do have a biostratigraphic value. This can be summarised as follows, taking into account all the available data from central and southern Italy:

- the Oxfordian is characterised by the occurrence of *Belemnopsis* and *Duvalia* (unpublished data);
- the Early Kimmeridgian records the last occurrence of *Belemnopsis* and the presence of the genera *Hibolithes*, *Duvalia* and *Rhopaloteuthis*. All these genera are rep-

resented by new species, with the exception of *Hibolithes semisulcatus*, that do no longer occur in younger levels;
- the Early Tithonian assemblages are dominated by *Duvalia*, *Pseudobelus* (first occurrence), *Rhopaloteuthis*, and *Hibolithes*. Some of the species ascribed to these genera are new;
- in Late Tithonian–Early Cretaceous times the genus *Rhopaloteuthis* disappears, while *Duvalia*, with the species *D. tithonica* and *D. conica*, characterises the Late Tithonian–Berriasian.

4. Taphonomy

The above-described belemnite rostra were collected from a shale level, about 10 cm thick. The majority of the specimens was obtained by washing the sediment; only for 23 rostra was it possible to measure in place the azimuth; nevertheless some considerations are possible about the orientation and the taphonomy of the rostra. Moreover, observations were possible on borings found on several specimens. For this study 108 specimens were considered.

4.1. Depositional and biostratinomic data

The hardground surface separating the underlying sediments (Early Bajocian in age) (layer 1, Fig. 3B) from the Lower Kimmeridgian layer 2 (Fig. 3B) is markedly irregular. Rostra are sometimes oriented along the axes of shallow groves characterising this surface. Often the largest belemnites have their upper side almost completely bioeroded by cirripeds (Fig. 8), whereas the lower side has rarer borings as if the rostrum was initially exposed for short time on one side and later upturned. The smaller rostra have much rarer borings. This probably occurred as a result of more rapid burial by the bottom sediment.

4.2. Borings

Acrotoracic cirripeds were responsible for the borings that are frequently found on the surface of the rostra. These organisms are marine sessile crustaceans with a boring habitat in carbonate substrata: contrary to the majority of cirripeds, they possess a soft carapace (Mariotti and Matteucci, 1989). Acrotoracic cirripeds form in the substratum a sac-shaped cavity with a comma-shaped opening (with a round end and a sharp end), with a total length only rarely exceeding 2 mm. These organisms orient the cirri against the current flux from the rounded portion of the opening directing them towards the sharpened portion (Seilacher, 1968). As a result, by examining the orientation of the borings it is possible to obtain data about local sea-bottom palaeocurrents.

In addition, it is necessary to take into account the theory of Petriconi (1971), evidencing that for some forms of

8a 8b

Fig. 8. Specimen collected from the layer 2, just above the hardground surface (NS 20/1083), 8a, upper side almost completely bioerosed, 8b, lower, less bioeroded side, ×1.

Rostre récolté du niveau 2 au-dessus de la surface du hard-ground (NS 20/1083), 8a, la surface supérieure fortement bio-érodée du rostre, 8b surface inférieure du rostre moins bio-érodée, ×1.

cirripeds (*Cryptophialus*, *Alcyppe*) it is not necessary to colonise the substratum, as they are able to rotate the cirri of 180° or to pump the nutritive flux into their cavity simply by pulses of the muscular sac.

Data analysis: 108 rostra were analysed for the survey of boring orientations. Assuming that prevailing currents might result in a peculiar orientation both of the belemnite rostra and of the borings, the directions of both orientations were measured.

The bored specimens are 36 out of 108 (33.3%). Twelve rostra are bored on one side (33.3%): six with a round cross section and six with an elliptical cross section. The remaining 24 bored rostra show borings on both sides (66.7%): seven with a round cross section and 17 with an elliptical cross section.

The recorded orientations were plotted on a pie diagram. For 23 rostra it has been possible to measure the azimuth; these azimuth values indicate the angle, measured clockwise, that the maximum axis of the rostrum (the trend was chosen from the alveolus to the point) forms with the direction of the geographic north; the data are reported in the diagram of Fig. 9.

Six of the 23 oriented rostra were bored. For these rostra it was possible to measure the boring orientations with respect to the present N, and their azimuths are evidenced in black in the diagram of Fig. 9. On the same diagram the azimuth of the relevant borings is also shown, relative to the geographic north. This evidences a correspondence between the directions of the oriented belemnites and those of the borings.

Moreover, for the 36 bored rostra, the direction of the borings was measured with respect to the direction of the belemnites. The results and the dispersion of these values are represented in Fig. 10.

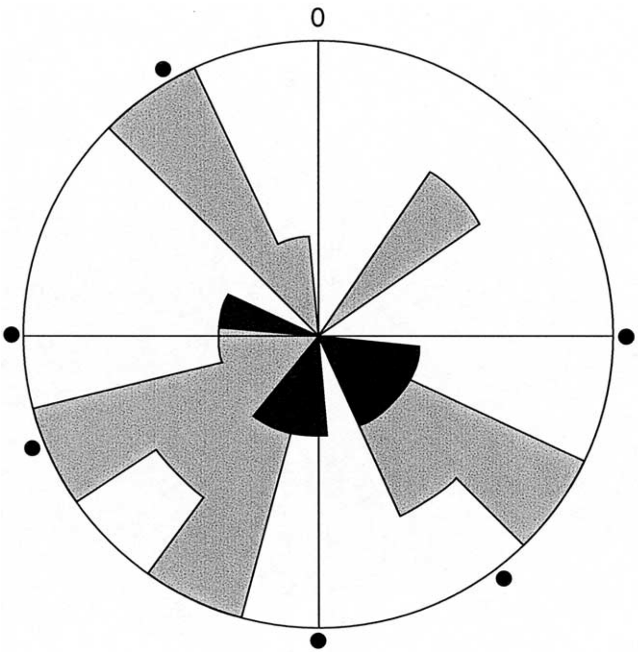

Fig. 9. Azimuth distribution of the 23 rostra in place; 6 are bored.
Distribution des azimuts des 23 rostres en place; 6 sont bio-érodés.

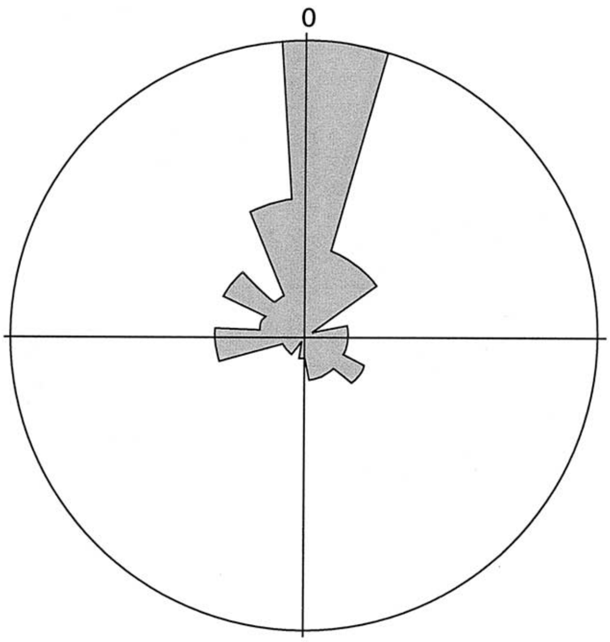

Fig. 10. Azimuth distribution of the borings of the 36 bored rostra assuming as north the longitudinal axes of the rostra.
Distribution des azimuts des perforations des 36 rostres bio-érodés en considérant comme nord les axes longitudinal des rostres.

4.3. Discussion

From a simple data analysis it appears clearly that the percentage of borings on both sides of rostra affects more the rostra with an elliptical cross section rather than those with a circular cross section. The cause for this phenomenon presumably lies in the fact that belemnites with an elliptical cross section, even if they cannot roll on the sea-bottom, can be overturned more easily even by weaker currents because, once they rise slightly along the longitudinal axis of the rostrum, they oppose a greater hydrodynamic resistance to the flux.

Moreover, assuming that borings by cirripeds occurred after the death of the belemnites and settlement of the rostrum on the bottom, it is conceivable that the relatively high percentage of bored rostra (33.3% versus 17.5% as cited by Mariotti and Matteucci (1989) in specimens collected from other areas of the central Apennines) was the result of sedimentation rates as slow as to permit the intense colonisation of rostra before they were covered by sediment.

The diagram analysis of rostra orientation (Fig. 9) shows the existence of a trend in the orientation of belemnite axes along two main suborthogonal directions: NW–SE and NE–SW. These orientations are consistent with the known behaviour of a long cylindrical body subjected to a current, which tends to arrange itself with its longer axis parallel or perpendicular to the flux; it is therefore possible to infer that the current direction had to be one of the two evidenced in the diagram, while no reliable hypothesis can be made on the versus. At Campo al Bello Cecca et al. (1990) describe, at the base and the top of the Calcari Diasprigni Formation, cross lamination, interpreted as the product of unidirectional bottom- or storm-currents. Also, these authors infer a shallow aphotic to deep-photic environment for the Upper Jurassic sediments of Mt. Nerone.

4.4. Taphonomic results

The data available lead to the following conclusions:

- belemnite rostra lying on the sea-bottom take an orientation that is parallel or perpendicular to current flux (the highest azimuth frequencies being at 90°);
- as the majority of the borings is also iso-oriented, this suggests that nearly the totality of the boring organisms are of the type that requires a proper orientation with respect to currents in order to receive the nutritive flux;
- the rostra orientations do not coincide with those of the borings; this was probably the result of changes in the direction of currents, and rostra re-orientation, following an early stage of colonisation by cirripeds;
- the rostra with an elliptical cross section are in their greater part bored on both sides. This suggests that they were more prone to overturning than the cylindrical forms;
- the relatively high percentage of bored rostra is an indication that sedimentation rates had to be low, or that

particular environmental conditions existed that favoured a rapid colonisation by cirripeds.

5. Conclusions

The Early Kimmeridgian fauna of Campo al Bello is characterised by the presence of the genera *Hibolithes*, *Acutibelus*, *Belemnopsis*, *Rhopaloteuthis* and *Duvalia*. All the species ascribed to these genera are new, with the exception of *Hibolithes semisulcatus* and *Acutibelus* sp. cf. *acuariformis*. The presence of *Belemnopsis* can be considered as the youngest occurrence of this genus in the western Tethys. The genera *Hibolithes*, *Duvalia* and *Rhopaloteuthis* occur in Early Tithonian assemblages (Combémorel and Mariotti, 1986a, 1990) with species completely different from the Early Kimmeridgian ones.

Although the possibility of some degree of endemism cannot be ruled out, these features may confirm that an eastward migration was no longer possible in the Early Kimmeridgian, as suggested by Spath (1963) and Combémorel (1988).

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