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RESEARCH PAPER

The lower/upper Bajocian boundary (Middle Jurassic) in the Casa Chimeneas section: Sierra de Ricote (Murcia Region), southern Spain

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Abstract
The Lower Bajocian/Upper Bajocian transition was analysed in the Casa Chimeneas section (JRi3), Sierra de Ricote (Murcia), which is located in the Median Subbetic paleogeographic domain. This stratigraphic section, consisting of an alternation of marls and marly limestones with radiolarians, finely shelled bivalves, *Zoophycos* and frequent ammonites, represents the best stratigraphic sequence of the Subbetic (Betic Range) and, also possibly, of the Mediterranean province (westernmost Tethyan Realm) to carry out this analysis. Ammonite have been sampled since the 90s increasing the collection available, which, together with the analysis of calcareous nannofossil assemblages and the carbon-isotope $\delta^{13}C$ curve, allows accurately modify the position of the Lower Bajocian/Upper Bajocian boundary in this stratigraphic reference section. Ammonite assemblages are dominated by Oppeliinae, Phylloceratoidea and Sphaeroceratidae, but other taxa with more biostratigraphical value (Stephanoceratinae, Cadomitinae, Frebolditinae, Leptosphinctinae and Parkinsoniidae) are also common. The absence of the typical *Teloceras* and the scarcity of *Caumonstisphinctes* make difficult to recognize the base of the Upper Bajocian. The appearance of the species *Leptosphinctes constrictus*, the last records of the genus *Paviceras*, and the species *Masckeites*? aff. *exilis* and *Subcollina ochoterenai* are the most significant bioevents marking this boundary. The first specimens, but not first occurrences, which would be recorded below the oldest studied sample, of the calcareous nannofossils *Cyclagelosphaera margerelii* and *Crepidolithus crassus* are identified in the base of the Blagdeni Subzone, and those of *Discorhabdus ignotus* and *Ethmorhabdus gallicus* within the upper part of the same subzone. The last occurrences (LOs) of *Hexalithus magharensis* and *Carinolithus superbus* are located within the Niortense Zone. Significant fluctuations are recorded in the $\delta^{13}C$ curve in the Lower Bajocian/Upper Bajocian transition coinciding with the turnover of ammonites and the increase in diversity of calcareous nannofossils. Some ammonite taxa with significant biostratigraphic value are herein described and illustrated for the first time in Sierra de Ricote.

Keywords Bajocian · Betic Cordillera · Sierra de Ricote · Ammonites · Calcareous nannofossils · Carbon-isotopes

Resumen
Se analiza la transición Bajociense Inferior/Bajociense Superior en la sección de Casa Chimeneas (JRi3), Sierra de Ricote, provincia de Murcia, situada en el dominio paleogeográfico Subbético Medio. Esta sección estratigráfica, constituida por una alternancia de margas y calizas margosas con radiolarios, bivalvos de concha fina, *Zoophycos* y frecuentes ammonites, representa la mejor secuencia estratigráfica para realizar este análisis de todo el Subbético (Cordillera Bética) y, posiblemente, también de toda la provincia Mediterránea (Tetis occidental). Los muestreos realizados desde los años 90 han incrementado

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las colecciones de ammonites disponibles, lo que, junto con el análisis de asociaciones de nanofósiles calcáreos y de cambios carbono-isotópicos del δ ^{13}C, permiten conocer mejor y modificar la posición del límite Bajociense Inferior/Bajociense Superior en esta sección estratigráfica de referencia. Las asociaciones de ammonites están dominadas por Oppeliinae, Phylloceratoidea y Sphaeroceratidae, pero también son comunes otros taxones con más valor bioestratigráfico (Stephanoceratinae, Cadomitinae, Frebolditinae, Leptosphinctinae y Parkinsoniidae). La ausencia de *Teloceras* típicos y la escasez de *Caumonstisphinctes* dificultan el reconocimiento de la base del Bajociense Superior. La aparición de *Leptosphinctes constrictus* y los últimos registros del género *Paviceras,* y de las especies *Masckeites*? aff. *exilis* y *Subcollina ochoterenai* constituyen los bioeventos más significativos que marcan este límite. Los primeros especímenes, pero no primeras apariciones, que estarían registradas por debajo de la muestra más antigua estudiada, de los nanofósiles calcáreos *Cyclagelosphaera margerelii* y *Crepidolithus crassus* se identifican en la parte inferior de la Subzona Blagdeni, y los de *Discorhabdus ignotus* y *Ethmorhabdus gallicus* en la parte superior de la misma. Las últimas apariciones (LOs) de *Hexalithus magharensis* y *Carinolithus superbus* se registran en la Zona Niortense. En la transición Bajociense Inferior/Bajociense Superior se producen fluctuaciones significativas en la curva de δ^{13}C coincidiendo con la renovación de ammonites y el aumento de diversidad de los nanofósiles calcáreos. Se describen e ilustran algunos taxones de ammonites con valor estratigráfico significativo, no incluidos en trabajos previos realizados en la Sierra de Ricote.

Palabras clave Bajociense · Cordillera Bética · Sierra de Ricote · Ammonites · Nanofósiles calcáreos · Isótopos de carbono

1 Introduction

The main objective of this paper is to carry out a detailed study of the Lower Bajocian/Upper Bajocian boundary in a section that can be a reference for the Betic Cordillera and for other areas of the Mediterranean province (Western Neo-Tethys realm). After sampling many stratigraphic sections throughout the Subbetic Basin (Sandoval, 1983), it has been shown that perhaps the Sierra de Ricote is the most appropriate place to develop this study.

The Jurassic successions of the Sierra de Ricote (eastern sector of the Betic Cordillera, southeastern Spain) are known since the nineteenth century for their impressive ammonite records (Almela & Ríos, 1954; Azema et al., 1971; de Verneuil & Collomb, 1856; Fallot, 1931, 1945; Martín & Trigueros, 1955; Nicklés, 1896; Paquet, 1969, among others). The PhD thesis of Seyfried (1978), who carried out a detailed study of the Subbetic Jurassic of the Region of Murcia with special emphasis on the Sierra de Ricote, which was also the subject of his Bachelor's Thesis, deserves to be mentioned. Sandoval (1976), in his Bachelor's Thesis, also carried out a geological study of the Sierra de Ricote, focussing on the Jurassic and Cretaceous biostratigraphy.

Linares and Sandoval (1979) published the first taxonomic work about Bajocian (Mid Jurassic) ammonites from the Betic Cordillera. This paper was based upon the analysis of the ammonite assemblages collected in three stratigraphic sections, comprising the Lower Bajocian/Upper Bajocian transition (Humphriesianum and Niortense = Subfurcatum zones), located in the Sierra de Ricote, Murcia Region. One of these three sections, Casa de Chimeneas (JRi3 in that paper) is the most representative section for the biostratigraphic and chronostratigraphic analysis of the Lower Bajocian/Upper Bajocian transition in the Betic Cordillera and perhaps in the entire Mediterranean Province. More recently, the JRi3 section has been analysed from different stratigraphic, biostratigraphic, paleontological and carbon-isotope perspectives (Sandoval, 1983, 1990; Nieto, 1996; Sandoval et al., 2002; O'Dogherty et al., 2001, 2006).

Since the taxonomic work of Sandoval (1983), new detailed paleontological sampling has been carried out, mainly in the beds comprising the Lower Bajocian/Upper Bajocian transition, in which the ammonites, although not very abundant, have allowed to improve the biostratigraphy and chronostratigraphy of this time interval. The data provided with these new samples will allow us to increase the knowledge about the Lower Bajocian/Upper Bajocian transition.

2 Geographical and geological setting

The JRi3 section, 200 m north from Casa Chimeneas, is located along a local road that starts in the km 17 of RM-532 highway and, after passing by the Fuente Cubierta, it turns south and then east, through the Sierra de Ricote (Fig. 1a, b), 19 km north (by road) from Mula municipality, Region of Murcia (UTM geographic locations XH315202, Sheet 912, Mula). According to the paleogeographic framework, the area where the JRi3 section is located was part of the southern paleomargin of the Iberian Plate that during the Bajocian (Middle Jurassic), was located near the eastern end of the Hispanic Corridor (Fig. 1d). It was a relatively narrow sea channel that during certain time intervals (i.e. Early Bajocian–earliest Late Bajocian and Late Bathonian–Early Callovian) connected the Western Tethys with the Eastern Pacific (Aguado et al., 2017 and references therein, Sandoval, 2022). By the Early Bajocian (~ 170 Ma), the JRi3

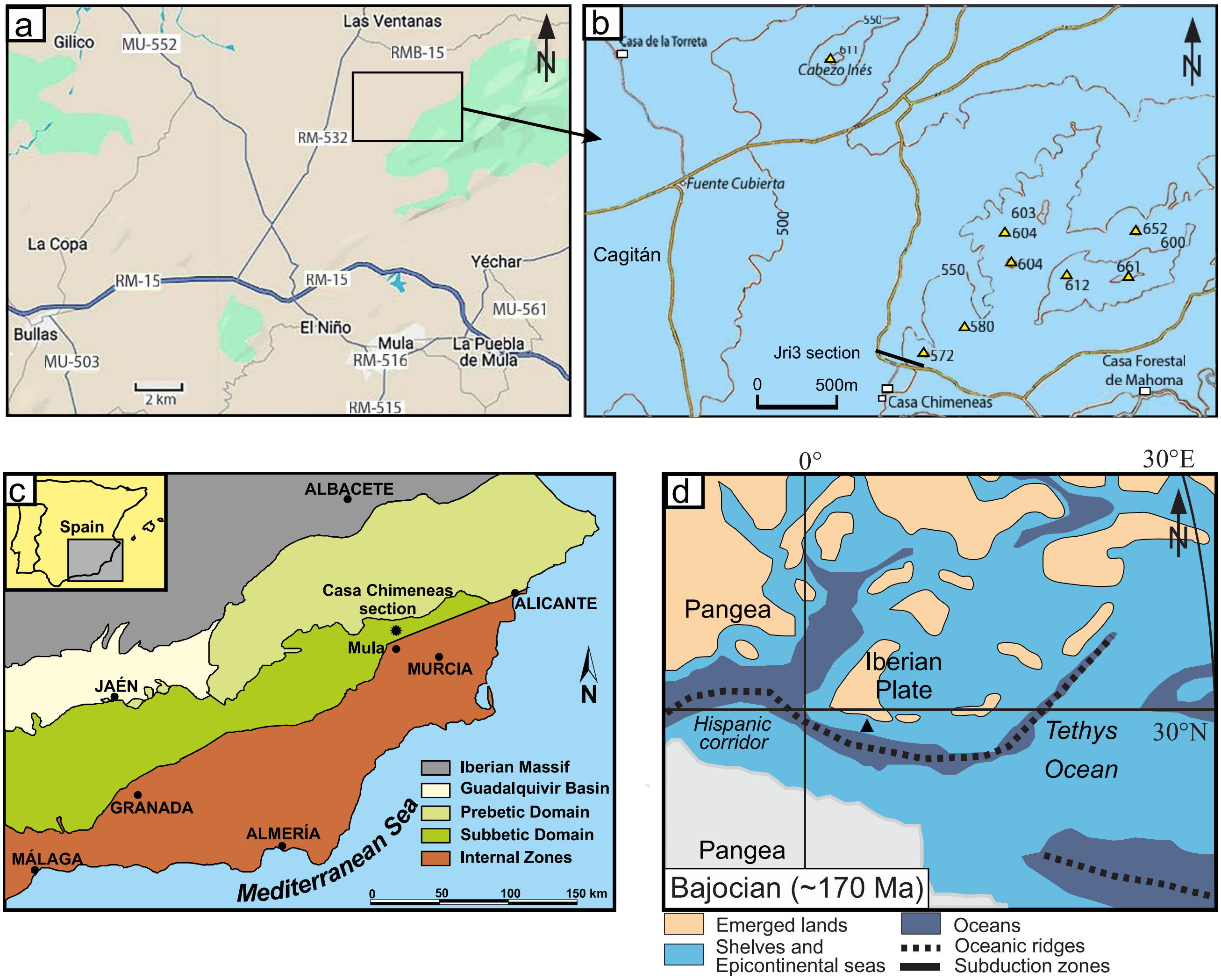

Fig. 1 **a–b**. Geographic location of the Casa Chimeneas section in the Region of Murcia; **c**, Simplified geological map of the Betic Cordillera showing the geological domain (asterisk) where the Casa Chimeneas section is located; **d**, Detailed scheme of the Western Tethys-Central Atlantic showing the approximate paleogeographic location (*black triangle*) of the Casa Chimeneas section with respect to trans-Pangaean seaway

section was located at a palaeolatitude of about 26º North (Fig. 1d) within the southern Iberian continental margin. This site is currently located in southern Spain, being part of the External Zones of the Betic Cordillera, specifically in the eastern sector of the Median Subbetic domain (Fig. 1c).

3 Material and methods

This study is mainly based on the biostratigraphic and chronostratigraphic analysis of the ammonite assemblages recorded in the Lower Bajocian/Upper Bajocian transition of the JRi3 section. Analyses of the calcareous nannofossil assemblages and their stratigraphic distributions (data from Aguado in Sandoval et al., 2002) and the carbon-isotope δ^{13}C changes (O'Dogherty et al., 2006) in this stratigraphic section are also taken into account.

The section was numbered, measured, and sampled in detail. The stratigraphic section was abbreviated to a letter-number code (JRi3 in this case) following the customary rules used in the Department of Stratigraphy and Palaeontology (University of Granada, Spain). A total of 270 specimens of ammonites were collected in detailed samplings, bed by bed, throughout the section that includes 61 successive stratigraphic levels, although some of them were barren in ammonites (see Fig. 2). After being prepared and cleaned in the laboratory, the ammonites were whitened with a coating of magnesium oxide before being photographed. Fourteen samples were collected from marly levels for analysis of calcareous nannofossils. The abundance, composition

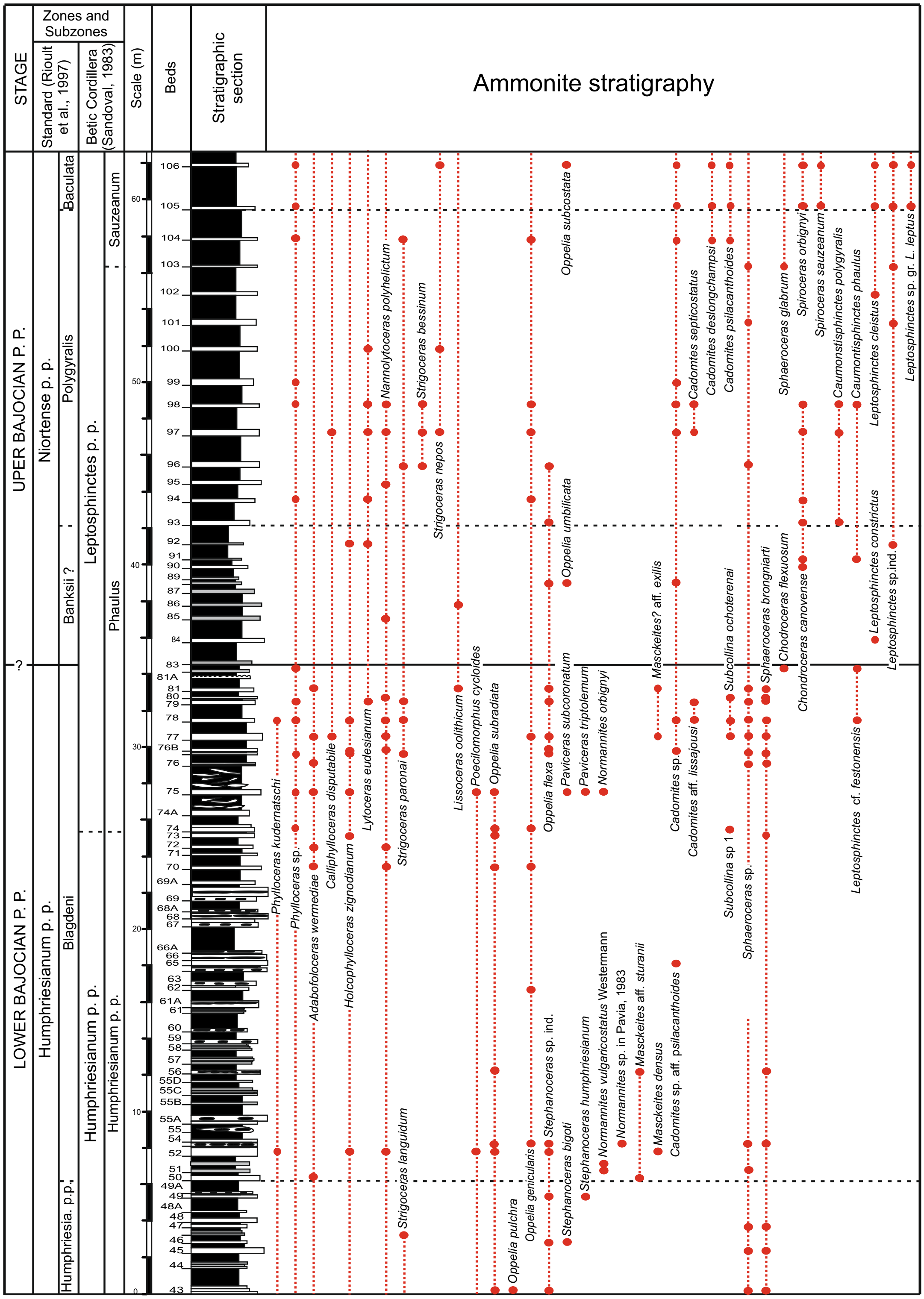

Fig. 2 Lithology of the studied section and stratigraphic range of the ammonite taxa in the Lower Bajocian/Upper Bajocian transition in the Casa Chimeneas section (JRi.3), Sierra Ricote, Mula, Murcia Region. Note (left side of the figure) the differences between the zonation proposed by Sandoval (1983, 1990) and that proposed in this work after including data from new samplings and the general taxonomic review of the complete ammonite collection from the JRi3 section

and stratigraphic range of all calcareous nannofossil taxa from the Humphriesianum (p.p.) and Niortense (p.p.) zones (Figs. 3, 4, 5) were previously studied by Aguado in Sandoval et al. (2002). In most of the studied samples, nannofossils were common to abundant, although in some of them were rare. Furthermore, the sample collected from the stratigraphic level 97 was barren of nannofossils, probably due to diagenetic processes.

In the Sect. 6 systematic palaeontology of ammonites, the following abbreviations are used: D, diameter of the shell (mm); U, umbilical diameter of the shell (mm); H, whorl-section height of the shell (mm); W, whorl-section width of the shell (mm, h = H/D; u = U/D; w = W/D. Some of these parameters are approximate, because most of the specimens were laterally flattened due to compression during diagenetic processes. Only the most significant specimens were measured. Besides, the following abbreviations are used: R refers to number of primary ribs in the last whorl, PH to phragmocone, BC to body chamber, E to external lobe, L to lateral lobe, U_2-U_5 to umbilical lobes, HT to holotype, LT to lectotype, OD to original designation, [M] to macroconch and [m] to microconch.

The present work follows the standard ammonite zonation for the Mediterranean Province (Rioult et al., 1997).

4 Results

4.1 Stratigraphy

The analysed interval is approximately 60 m thick (beds 43 to 106 of Linares & Sandoval, 1979, Fig. 2; Sandoval, 1983, Fig. 67), and includes the Lower Bajocian (Humphriesianum Zone, Humphriesianum Subzone, p. p.)-Upper Bajocian (Niortense Zone, Baculata Subzone, p. p.) interval (Figs. 2, 3). The lower part of this interval (Humphriesianum Zone) is made up of whitish-grey marls, marly limestones, and limestones (mudstones and wackestones of thin-shelled bivalves and radiolarians). Bed thickness of marly limestones varies between 10 and 60 cm, and terrigenous intercalations reach 150 cm thickness. The overlying calcareous beds (Humphriesianum Subzone and lower part of the Blagdeni Subzone) are thicker and chert nodules are relatively common. Within the upper part of the Humphriesianum Zone (Blagdeni Subzone) chert nodules disappear and bioturbations, especially *Zoophycos*, are very common. The pelagic finely shelled bivalve *Bositra* is abundant throughout the studied section.

In the upper part of the section (Niortense Zone), lithologies and microfacies are quite similar to those of the underlying Humphriesianum Zone, although chert nodules are absent and marly intercalations clearly dominate over calcareous sediments; limestone or marly limestone beds vary from 5 to 30 cm in thickness, whereas marly intercalations are frequently thicker than 100 cm. Thin-shelled bivalves (*Bositra*) are very abundant and well preserved here.

4.2 Ammonite assemblages

The new samplings of the JRi3 section carried out since 1990 (mainly by Roque Aguado, Luis O'Dogherty and José Sandoval) has increased the collection of ammonoids, improving the previous biostratigraphic data published by Linares and Sandoval (1979) and by Sandoval (1979, 1983, 1990). Throughout the stratigraphic interval herein analysed, the ammonites are preserved as internal moulds, lying sub-horizontal, frequently quite flattened by lateral symmetrical compression, but with relatively well-preserved taxonomic characters. For those taxa in which dimorphism is apparent, macroconchs and microconchs, both juveniles and adults, appear almost equivalently and without demonstrable evidence of taphonomic reworking or post-mortem transport. This is indicative of taphonic populations type 1 (Fernández-López, 1997). The ammonites, generally common or abundant, are much diversified; abundance and diversity vary throughout the analysed interval (Fig. 2), but the oppeliid *Oppelia* [M] & [m] dominates in the Lower Bajocian/Upper Bajocian transition.

4.2.1 Ammonite assemblages of the uppermost Lower Bajocian (Humphriesianum Zone)

The oppeliins (the dimorphous partners *Oppelia* [M] & [m]) dominate the ammonite assemblages in the Humphriesianum Zone in JRi3 section, but haploceratids (*Poecilomorphus cycloides* (d'Orbigny) [M] & [m]), stephanoceratins (*Stephanoceras* [M] & [m], *Masckeites* [M] & [m], sphaeroceratids (*Sphaeroceras* [M] & [m] and *Chondroceras* [M] & [m]), which are good biochronologic markers, are also common. Strigoceratids and phylloceratids dominate in some beds, and lytoceratids occur throughout the studied time interval. Cadomitins (*Cadomites* [M] & [m]), freboldítins (*Subcollina* [M] & [m]) and leptosphinctins (*Leptosphinctes* [M] & [m]) are restricted to the upper part of the zone.

4.2.2 Ammonite assemblages of the lowermost Upper Bajocian (Niortense Zone)

In the lower part of the Upper Bajocian (Niortense Zone), the ammonite assemblages show characteristic taxa with prevailing oppeliins, sphaeroceratids, and phylloceratids in the lower part of this zone (Banksii and

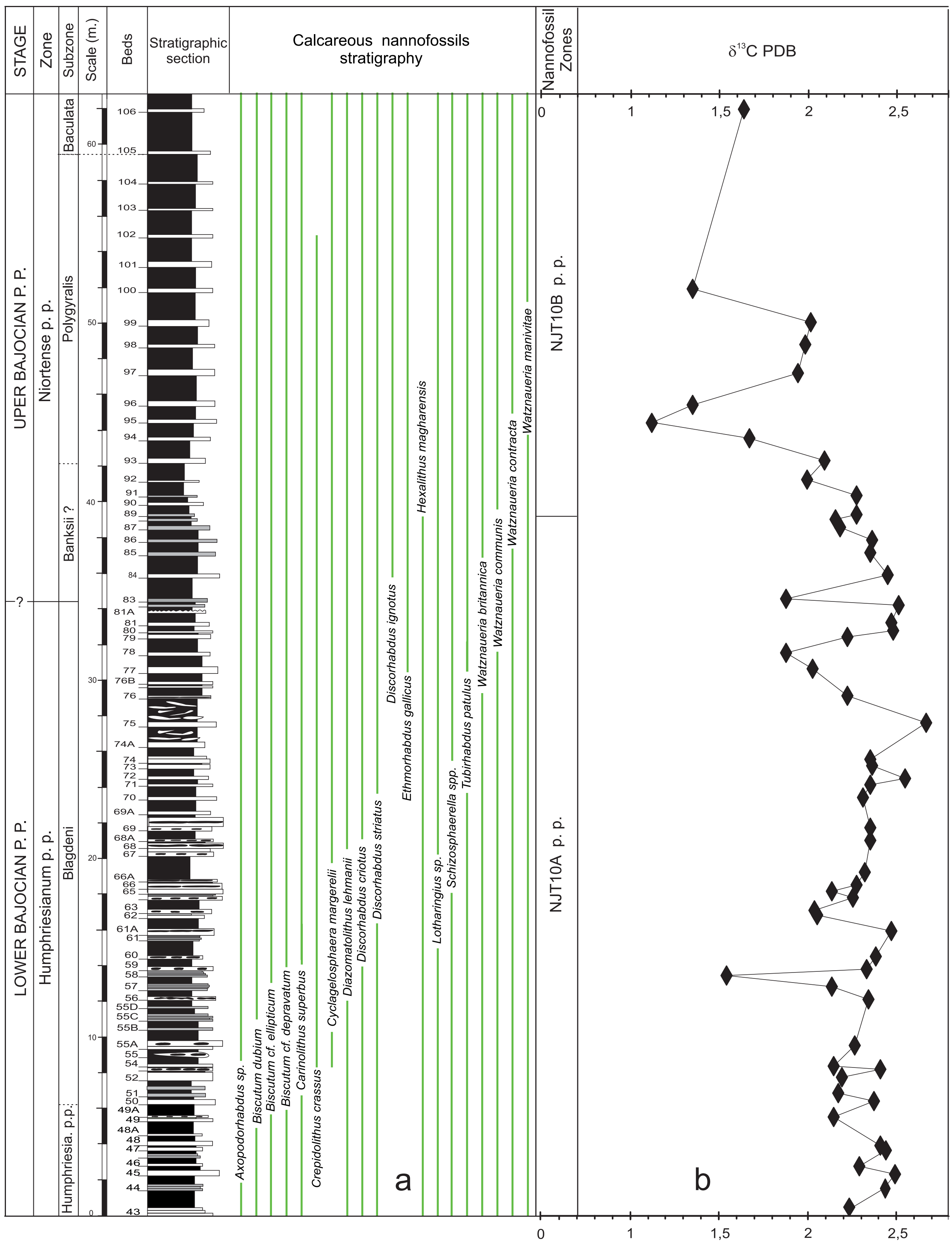

Fig. 3 **a,** Stratigraphic range of the calcareous nannofossil species identified in the Lower Bajocian/Upper Bajocian transition of the Casa Chimeneas section (JRi3), Sierra Ricote, Mula, Murcia Region. **b**, Carbon isotope curve, modified from O'Dogherty et al., (2006, Fig. 2C)

Sample	Abundance	Preservation	*Axopodorhabdus* sp.	*Biscutum dubium*	*Biscutum* sp. cf. *B. ellipticum*	*Biscutum* sp. cf. *B. depravatus*	*Carinolithus superbus*	*Crepidolithus crassus*	*Cyclagelosphaera margerelii*	*Diazomatolithus lehmanii*	*Discorhabdus criotus*	*Discorhabdus striatus*	*Discorhabdus ignotus*	*Ethmorhabdus gallicus*	*Hexalithus magharensis*	*Lotharingius* sp.	*Schizosphaerella* spp.	*Tubirhabdus patulus*	*Watznaueria britannica*	*Watznaueria communis*	*Watznaueria contracta*	*Watznaueria fossacincta*	*Watznaueria manivitae* < 9um	*Watznaueria manivitae* = 9um	*Watznaueria manivitae* > 9um	Total
115	1,73	M	3	7	4	14		1	4	1	56	65	12	8		3	20	6	264		20	3	12	11	6	520
113	2,71	M	2	11	2	4		3			60	190	6	2			40	6	430	2	12	2	9	24	8	813
101	0,75	P	1	6			2	1			4	88					17		96		3		1	5		224
97	0,00	VP												BARREN												0
94	0,23	VP	1	6	1	1	2				3	14				2	4	1	20		2		2	10	1	70
92	2,36	MP	3	15	2	2	60	1			7	232				1	8	5	280		11		6	72	2	707
88	1,26	PM	1	16			2	2		1	15	190	1		1	3	10	3	100	2	9		8	9	6	379
84	1,46	M	3	10		4	14	2	2	1	26	168	1		3	4	12	4	148	2	6		7	16	6	439
80	0,50	VP		3		1	6				1	48			5	1	6		64		2		1	12		150
77	1,01	P		6	1	3	5				6	88		1			5	1	168	1	3		3	9	2	302
76	1,52	P	3	9	1	2	10	2			5	170				5	8	4	200	1	4		20	13		457
74a	2,13	P	1	12	3	5	70	2			50	80			7	2	48	8	240	2	44		60	5		639
72	0,03	VP										2							5					1		8
69	0,76	VP		4			5				1	90					3	1	115		1		5	4		229
57	0,59	VP		2			6					32					1		132		1		1	2		177
54	1,19	P	3	11		2	6	1	1	1	6	52			3	1	32	2	164		4		52	13	2	356
46	1,39	VP		3	1		56				1	60					32	1	172		4		56	32		418
41a	0,00	VP												BARREN												0
37b	0,99	VP		8			1				3	13			4		15	3	160	9	1		17	64		298
35	1,45	VP	1	10	1	3	40			1	8	40			5	7			280	4	8		14	12		434
33a	1,22	P		14	1	4	14				4	29			5		3		224		6		32	24	5	365
32	0,68	VP	2	9	1	4	14				4	16			6		5	2	125		3		8	6		205

Fig. 4 Samples in which calcareous nannofossils were analysed. Abundance indicates specimens/field at 1250x (for each sample, 300 fields of view were investigated). Preservation: VP· = very poor, P· = poor, PM· = poor to moderate, MP· = moderate to poor, M· = moderate

Polygyralis subzones), being also common cadomitins (*Cadomites* [M] & [m]), strigoceratids, parkinsoniids (*Caumontisphinctes*[M] & [m]), leptosphinctins and lytoceratids. The leptosphinctins (mainly *Leptosphinctes* [M] & [m]) and the heteromorphous genus *Spiroceras* are very abundant characterizing the upper part of the zone, but the strigoceratids (*Strigoceras* [M] & [m]), oppeliins (*Oppelia* [M] & [m]), cadomitins (*Cadomites* [M] & [m]) and phylloceratids are also common. However, the Garantianinae *Strenoceras* and *Garantiana* that are abundant in other Mediterranean, Submediterranean or Subboreal localities (Fernández-López, 1985; Pavia, 1973; Pavia & Zunino, 2012; and references therein) are very scarce in the studied section.

4.3 Nannofossil assemblages

As aforementioned, calcareous nannofossil assemblages from the JRi3 section were investigated by Aguado in Sandoval et al. (2002). Figure 3 shows the stratigraphic range of all calcareous nannofossil species occurring during this time interval. Figure 4 shows the abundance, composition, and preservation degree of all calcareous nannofossil taxa recorded within the Humphriesianum (p.p.) and Niortense (p.p.) zones. In most of the studied samples, nannofossils are common to abundant, but scarce or absent in some cases, probably due to diagenetic processes.

The assemblages are mainly dominated by Tethyan taxa, with *Watznaueria* and *Discorhabdus* as more representative genera. The rest of the specimens, having in their majority Tethyan affinities, are assigned to the genera *Axopodorhabdus*, *Biscutum, Carinolithus, Crepidolithus, Cyclagelosphaera, Diazomatolithus, Ethmorhabdus, Hexalithus, Lotharingius, Schizosphaerella* and *Tubirhabdus*. At the species level (Check Appendix A for further information), the most abundant is *Watznaueria britannica*, whose FO, or any of the morphotypes or subspecies described by different authors, is commonly used to characterize the Aalenian/Bajocian boundary (Aguado et al., 2008; Bown et al., 1996; Cobianchi et al., 1992; De Kaenel et al., 1996; Erba, 1990; Ferreira et al., 2019; Mattioli & Erba, 1999; Molina et al., 2018; Reale et al., 1992; Suchéras-Marx et al., 2015; Visentin et al., 2023; among others). Other common to abundant species are *Discorhabdus striatus, Discorhabdus criotus* and *Carinolithus superbus*. Within *Watznaueria manivitae,* we differentiate three morphologies: smaller than 9 µm, about 9 µm and larger than 9 µm. In addition, we note a progressive increase in size within the *W. manivitae* group from

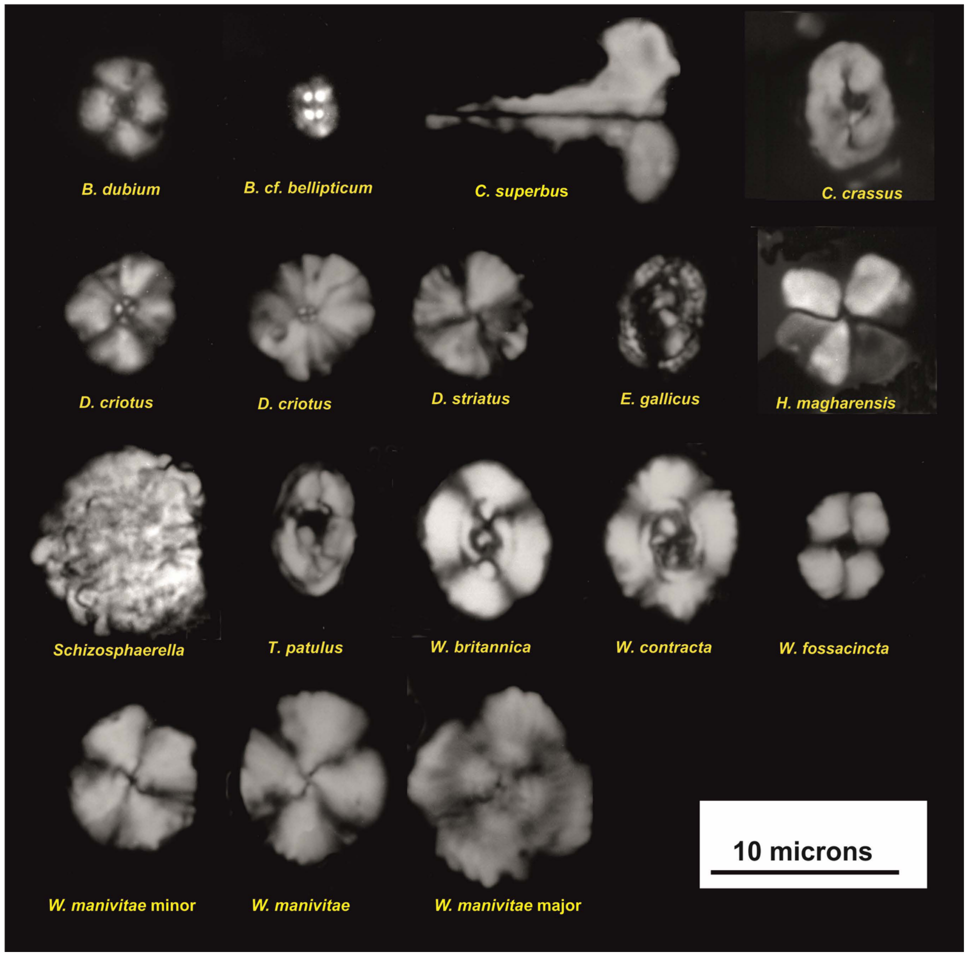

Fig. 5 Micrographs of the most abundant and biostratigraphically significant calcareous nannofossils from the Casa Chimeneas section (JRi3)

the bottom to the top of the studied section. This increase in size of *W. manivitae* throughout the Bajocian was previously stated by Erba (1990), Mattioli and Erba (1999) and Baldanza et al. (2022), among others.

The most abundant and significant species are shown in Fig. 5. The two more significant nannofossil bioevents recorded within the interval studied are the LOs of *Hexalithus magharensis* and *Carinolithus superbus.* Both LOs occur within the Niortense Zone, in the early Late Bajocian. In the JRi3 section, the LO of *H. magharensis* slightly precedes the LO of *C. superbus* (Fig. 3). These data could be of special interest, considering that the literature (e.g. Bown et al., 1996; Cobianchi et al., 1992; De Kaenel et al., 1996; Erba, 1990; López-Otálvaro & Henriques, 2018; Mattioli & Erba, 1999; Reale et al., 1992; Tiraboschi & Erba, 2010) is inconsistent with respect to the age and position of the LOs of both species. On the other hand, it is noteworthy that in the JRi3 section, the first specimens, but not first occurrences, which would be recorded below the oldest studied sample, of *Crepidolithus crassus* and *Cyclagelosphaera margerelii* are observed coinciding with the base of the Blagdeni Subzone and those of *Discorhabdus ignotus* and *Ethmorhabdus gallicus* within the upper part of the same subzone. This notable increase in diversity of the calcareous nannofossil assemblages is concomitant with the major renovation of the ammonites that took place during the Lower Bajocian/Upper Bajocian transition.

4.4 Carbon isotope stratigraphy

In JRi3 section, in the Lower Bajocian/Upper Bajocian transition (upper part of the Humphriesianum Zone and the Niortense Zone) fluctuations can be observed in the $\delta^{13}C$ curve. A moderate positive excursion in the $\delta^{13}C$ curve occurs at the Humphriesianum Zone. The $\delta^{13}C$ values of carbonates (Fig. 3b) show maximum values (2.5–2.7‰) up to the base of the Niortense Zone (Banksii Subzone) and then decrease ($\Delta = 1$‰) to lower values (1.5– 1.8‰) in the

Polygyralis Subzone. The intervals with decreasing values of the $\delta^{13}C$ curve generally coincide with high environmental stress periods (Guex, 2001; O´Dogherty et al., 2006). In turn, they can be responsible of the significant turnovers of ammonites and the increase in diversity of calcareous nannofossils assemblages such as those occurred in the Lower Bajocian/Upper Bajocian transition.

5 Discussion: biostratigraphy

5.1 Problems arising from studies on the Lower Bajocian/Upper Bajocian transition in the Subbetic Basin

As aforementioned, the most representative stratigraphic sections to analyse the Lower Bajocian/Upper Bajocian transition in the entire Subbetic Basin are located in the Sierra de Ricote (Sandoval, 1983, 1990). Even in these sections, although ammonites are abundant and diversified, the beds marking the lower boundary of the Upper Bajocian (Niortense Zone) cannot be clearly identified. It occurs in the Sierra de Ricote and also in other Subbetic localities in which the Lower Bajocian/Upper Bajocian boundary is represented. This problem could be related with: 1, the stephanoceratin species that characterize this interval, such as *Teloceras blagdeni* (Sowerby) or *T. banksii* (Sowerby), are virtually absent; 2, the forms of the dimorphous genus *Caumontisphinctes* [M] & [m] are very scarce; 3, *Leptosphinctes*, whose FO was chosen as a reference for the base of the Upper Bajocian by Sandoval (1983, 1990) also occurs in the uppermost Lower Bajocian in other basins of the western Tethys (Fernández-López, 1985; Gauthier et al., 1996; Pavia, 1983; Pavia & Zunino, 2012, and references therein); 4, although other ammonite taxa with biostratigraphic significance (Strigoceratidae, Oppeliinae, Haploceratinae and Sphaeroceratinae) present turnovers at a specific level near this boundary, these were never used as markers.

These difficulties led to the definition (Sandoval, 1983) of a new biostratigraphic unit representative for the lower part of the Upper Bajocian in the Subbetic Basin, the *Leptosphinctes* assemblage zone Sandoval, 1983. This assemblage zone was originally defined by the total range of the dimorphic pair *Leptosphinctes* [M] & [m], which usually occur together with abundant *Spiroceras, Cadomites* [M] & [m], *Oppelia* [M] & [m], *Strigoceras* [M] & [m], Phylloceratoidea and Lytoceratoidea. This assemblage zone was divided into two subzones; a lower one, Phaulus Subzone, and an upper one, Sauzeanum Subzone. In the Phaulus Subzone, characterized by the presence of *Caumontisphinctes,* the genus *Leptosphinctes* is scarce and *Spiroceras* is still not present. This subzone is quite different from the upper one, Sauzeanum Subzone, in which *Spiroceras* and *Leptosphinctes* are clearly the dominant taxa. The difficulty of accurately correlate Subbetic materials with standard ammonite zones was also highlighted by Sandoval (1990).

In previous studies of the JRi3 section (Linares & Sandoval, 1979; O'Dogherty et al., 2006; Sandoval, 1983, 1990), the Lower Bajocian/Upper Bajocian boundary was placed at the base of the stratigraphic level 174. According to the data available at that time, the assemblage in this bed records the replacement of the last Stephanoceratinae (*Stephanoceras* [M] & [m]) by the first Leptosphinctinae (*Leptosphinctes,* [M] & [m]), Cadomitinae (*Cadomites* [M] & [m]) and Parkinsoniidae (*Caumontisphinctes* [M] & [m]). However, the data from new samplings and the review of all the available material leads to new interpretations. So, some specimens coming from beds 74 to 79 that were originally classified as *Infraparkinsonia* actually belong to *Subcollina* (*S. ochoterenai* Pavia [m], or *S.* sp.1 [m]), species that in lateral view are practically indistinguishable from the primitive *Caumontisphinctes* [m], and that could appear associated with macroconchs of the first species (Fig. 2).

In the aforementioned papers, where the entire JRi3 section was studied, the Humphriesianum Zone (Romani, Humphriesianum and Blagdeni subzones) and Niortense Zone (Banksii, Polygyralis and Baculata subzones) were identified, but herein only the intervals including the Humphriesianum/Niortense transition; the Humphriesianum (p. p.) and Blagdeni subzones of the Humphriesianum Zone and the Banksii and Polygyralis subzones of the Niortense Zone will be analysed.

5.2 Lower Bajocian, humphriesianum Zone (Oppel, 1856)

5.2.1 Humphriesianum subzone (Oppel, 1856)

The presence of the macroconchs *Stephanoceras humphriesianum* (Sowerby) [M], *H. bigoti* (Munier-Chalmas) [M] and the microconchs *S. flexus* (Westermann) [m], characterize this subzone, but also *Phaulostephanus paululus* Buckman [m], *Chondroceras* [M] & [m], *Sphaeroceras* [M] & [m], *Strigoceras* [M] & [m], *Oppelia* [M] & [m], *Phylloceras kudernatschi* (Hauer), *Adaboloceras wermediae* (Kakhadzé) and *Nannolytoceras polyhelictum* (Boeckh) occur in this subzone.

5.2.2 Blagdeni subzone Spath, 1936

In the JRi3 section, the Humphriesianum/Blagdeni subzones transition coincides with beds of limestones containing frequent chert nodules in which ammonites are scarce. This, and the absence of the typical *Teloceras* makes difficult to establish the lower boundary of the Blagdeni Subzone in Sierra de Ricote. The presence of *Masckeites* cf. *sturanii* (Pavia) and the successive FOs of *M. densus* Buckman, *Normannites vulgaricostatus* Westermann sensu Pavia, *Normannites* sp. in Pavia (1983, p. 146, pl. 28, figs. 1, 5), *Paviceras subcoronatum* (Oppel), *Paviceras triptolemus* (Buckman), *Cadomites* aff. *lissajousi* Roché, *Leptosphinctes* sp., and the last record of the dimorphic couple *Stephanoceras* [M] & [m] characterize this subzone. It is interesting to highlight the presence of several specimens (from beds 77 to 79) of *Subcollina ochoterenai* Pavia, a species that occurs in the upper part of the Coronatun horizon from Ravin du Feston and Les Dourbes, in the Digne area, SE France (Pavia & Zunino, 2012). With respect to calcareous nannofossils, the first specimens, but not the first occurrences, which are located below the oldest studied sample, of the nannofossils *Cyclagelosphaera margerelii* and *Crepidolithus crassus* were identified in the base of the subzone, whilst those of *Discorhabdus ignotus* and *Ethmorhabdus gallicus* were observed near the upper boundary of the subzone, increasing the diversity of calcareous nannofossils assemblages.

In the Digne area, SE France, the distribution of the macroconch genus *Teloceras* and its dimorphic counterpart *Normannites* characterize the subzone (Pavia, 1983; Pavia & Zunino, 2012). The basal boundary of the subzone is based upon the FO of *T.* (*Teloceras*) *acuticostatum* Weisert [M] that ranges through the subzone side by side to the congeneric subgenus *Paviceras* (Gauthier et al., 1996) and by the last records of the dimorphous pair *Stephanoceras* [M] and *Itinsaites* [m]. Regarding the Iberian Range (see Fernández-López, 1985, p. 733), the lower boundary of the Blagdeni Subzone coincides with the FO of *Oppelia subcostata* (J. Buckman), *Oecotraustes westermanni* Stephanov, *Teloceras*, *Normannites*, *Paviceras hoffmanni* (Schmidtill & Kumbeck), *P. triptolemus* (Buckman), *Cadomites*, *Sphaeroceras* and *Trimarginia,* and by the last record of the genus *Skirroceras*.

5.3 Upper Bajocian, Niortense Zone (Buckman, 1893) Arkell, 1933

5.3.1 Banksii Subzone (Buckman, 1919)

The base of the Banksii Subzone has been traditionally considered to be the lower boundary of the Upper Bajocian. In the JRi3 section, as in other Subbetic areas, *Teloceras banksii* (Sowerby) is virtually absent, therefore other ammonites are necessary to recognize and characterize this subzone. *Leptosphinctes* aff. *constrictus* (Besnosov in Besnosov & Mitta, 1993), which occurs in beds 82 and 84 could be a good candidate to indicate the lower boundary of this subzone. This event is slightly above the last records of *Subcollina ochoterenai* (bed 81) and slightly below the FO of genus *Caumonstisphinctes* (bed 90). According to Pavia (1983), in the Digne area (Ravin du Feston, Les Dourbes and Ravin de la Coueste sections), southeast France, the lower boundary of the Upper Bajocian (Niortense Zone, Banksii Subzone) is marked by the FOs of the dimorphous pair *Caumontisphinctes* [M], *Infraparkinsonia*) [m]. However, later Pavia and Zunino (2012) indicated that this boundary is marked by the FO of *Caumontisphinctes diniensis* Pavia, *Leptosphinctes constrictus* (Besnosov) and *Teloceras* cf. *banksii* (Sowerby) and by LOs of most of the *Teloceras* and *Paviceras* species. C. *garnieri* (Pavia), an atypical *Caumontisphinctes,* with constrictions typical of Leptosphinctinae, occurs in the Blagdeni Subzone.

In the Iberian Range, according to Fernández-López (1985, p. 733), the lower boundary of the Upper Bajocian is marked by the FOs of the dimorphous pair *Caumontisphinctes* [M]- *Infraparkinsonia* [m], *Orthogarantiana* and T*eloceras multinodum* (Quenstedt, 1886 in 1882–1888), which coincides with the last records of the genera *Poecilomorphus*, *Stephanoceras* and *Stemmatoceras.*

5.3.2 Polygyralis subzone (Pavia, 1973; Pavia & Sturani, 1968)

The FO of *Caumontisphinctes polygyralis* Buckman in the bed 93 marks the base of this subzone in the JRi3 section. This matches the original proposal of Pavia (1973) and later confirmed by Rioult et al. (1997) and Pavia and Zunino (2012) in the Digne area. In addition to the nominative species, *Caumontisphinctes phaulus* Buckman, *Cadomites septicostatus* Buckman [M] & [m] and *Chondroceras canovense* (de Gregorio) show their FOs near the base of this subzone. This matches the data from the Iberian Range, where the FOs of C. *polygyralis* Buckman, *C. bifurcus* Buckman*, C. rota* (Bentz)*, Infraparkinsonia inferior* (Bentz)*, C. phaulus* Buckman, *Orthogarantiana? fredericiromani* (Roché) and *O. haugi* Pavia mark the base of the Polygyralis Subzone (Fernández-Lopez, 1985).

5.3.3 Baculata subzone (Kumm, 1952)

In JRi3 section, the base of the Baculata Subzone coincides with the FOs of the genus *Spiroceras* and of the species *Garantiana baculata* (Quenstedt)*,* although this latter is very scarce. Ammonites, mainly *Spiroceras*, *Leptosphinctes* [M] & [m] *Cadomites* [M] & [m], *Sphaeroceras* [M] & [m], *Oppelia* [M] & [m] and *Strigoceras* [M] & [m] are very abundant. The Sauzeanum Subzone of Sandoval (1983, 1990) is more or less coinciding with the standard Baculata Subzone.

6 Systematic palaeontology: taxonomic notes about ammonite

For developing this paper, all the ammonites collected in the JRi3 section were analysed, including those that were previously studied and/or figured (Linares & Sandoval, 1979; Sandoval, 1983, 1985, 1986, 1990). However, only those taxa that were not included in the previously published papers and that have a significant biostratigraphic value around the Lower Bajocian/Upper Bajocian transition, will be herein described and figured here.

Except for the Subfamily Frebolditinae Fernández-López & Pavia, 2015, the taxonomy of the new version of the Treatise (Énay & Howarth, 2019; Howarth, 2017) will be used, unless indicated in the text.

Suborder AMMONITINA Hyatt, 1889

Superfamily STEPHANOCERATOIDEA Neumayr, 1875

Family STEPHANOCERATIDAE Neumayr, 1875

Subfamily STEPHANOCERATINAE Neumayr, 1875

6.1 Genus PAVICERAS Gauthier, Rioult & Trévisan, 1996

Type species: *Stemmatoceras hoffmanni* Schmidtill & Krumbeck, 1938, p. 348, pl. 13, Fig. 6; OD. LT designed by Pavia, 1983, p. 115.

Description: Evolute, planulate to subcadiconic shells, depressed and elliptical whorl-section wider than tall and with a rounded venter; tubular peristome without a collar and pre-opening constrictions; strong radiate or concave primary ribs ending into prominent lateral tubercles; the secondary ribs straight, subradial or slightly proverse cross the venter. The dimorphic microconch of *Paviceras* would be represented by some forms of *Normannites,* strongly ornamented and peristome with long lateral lappets, which occur associated at the same stratigraphic levels (see Pavia, 1983; Pavia & Zunino, 2012).

Remarks: *Paviceras* was nominated, as subgenus of *Teloceras*, by Gauthier et al., (1996, p. 35), but without any description or diagnosis. Later, *Paviceras* (together with *Gibbistephanus* Buckman, 1928) was considered synonymous of *Stephanoceras* (*Stemmatoceras)* Mascke, 1907 by Howarth (2017, p. 6). However, according to Pavia and Fernández-López (2016) "the transition from *Stephanoceras* to *Teloceras* is represented by subcadiconic to planorbiconic forms, historically referred to a branch of the genus *Stemmatoceras* Mascke, 1907, that more recently has been assembled by Gauthier et al. (1996) into the subgenus *Teloceras* (*Paviceras*)". This branch is restricted to the upper part of the Humphriesianum Zone (Blagdeni Subzone) and to the lower part of the Niortense Zone. This phyletic branch is independent of another, which has an older phyletic origin (Early Bajocian, Laeviuscula Zone) to the which the subcadiconic to planorbiconic genera *Kumatostephanus* Buckman, 1922, *Stemmatoceras* Mascke, 1907 and *Pseudoteloceras* Pavia & Fernández-López, 2016 belong.

6.1.1 *Paviceras subcoronatum* (Oppel, 1856) [M]

Figure 6a

1849	*Ammonites coronatus oolithicus* Quenstedt, 1845-1849, p. 176, pl. 14. fig. 4 (primary homonym of *A. oolithicus* d'Orbigny, 1848).
?1928	*Gibbistephanus gibbosus*, nov. Buckman, 1909-1930, pl. 780, figs. a-b (HT).
1983	*Teloceras* (subgen?) *subcoronatum* (Oppel, 1856). - Pavia, p. 116, pl. 21, figs. 3, 5 (cum synonymy).
1983	*Teloceras* (subgen?) *dubium* (Schmidtill & Krumbeck, 1938). - Pavia, p. 114, pl. 19, fig. 4; pl. 20, fig. 1 (cum synonymy).
1983	*Teloceras* (subgen?) *hoffmanni* (Schmidtill & Krumbeck, 1938). - Pavia, p. 115, pl. 21, figs. 1, 2, 4 (cum synonymy).
1983	*Teloceras* (subgen?) *subcoronatum* (Oppel, 1856). - Pavia, p. 116, pl. 21, figs. 3, 5 (cum synonymy).
1983	*Teloceras* (subgen?) *triptolemus* (Buckman, 1912, Bean m.s.). - Pavia, p. 118, pl. 19, figs. 2, 3, 5, pl. 20, fig. 2 (HT) (cum synonymy?).
1985	*Stemmatoceras hoffmanni* Schmidtill & Krumbeck. - Fernández-López, p. 289, pl. 29, fig. 2
1985	*Stemmatoceras triptolemum* (Buckman). - Fernández-López, p. 288, pl. 30, fig. 1.
1996	*Teloceras* (*Paviceras*) *hoffmanni* (Schmidtill & Krumbeck). - Gauthier et al., p. 35.
1996	*Teloceras* (*Paviceras* Subgen. nov)) *blagdeniforme* (Roché). - Gauthier et al., p. 35, pl. 3, fig. 5, pl. 4, fig. 1.
2015	*Stephanoceras rectecostatum* Weisert. - Dietze et al., pl. 10, figs. 1, 2, pl. 11, figs. 7, 10)
?2017	*Gibbistephanus gibbosus* Buckman. - Chandler et al. p. 655, fig. 15 a1-2, b1-2 (HT refigured).
2017	*Ammonites triptolemus* Bean in Morris & Lycett, 1851 [M]. - Chandler et al., p. 656, figs. 17, a1-2, b1-2 (HT refigured), c1-2.
2023	*Stemmatoceras hoffmanni* Schmidtill & Krumbeck, 1938. - Sadki & Weis, p. 53, fig. 8B
2023	*Stemmatoceras triptolemum* (Buckman, 1911). - Sadki & Weis, p. 54, fig. 9A.
2023	*Stemmatoceras dubium* Schmidtill & Krumbeck, 1938. - Sadki & Weis, p. 54, fig. 7B.

Material: JRi3.75.1, JRi3.75.2 and JRi3.75.3

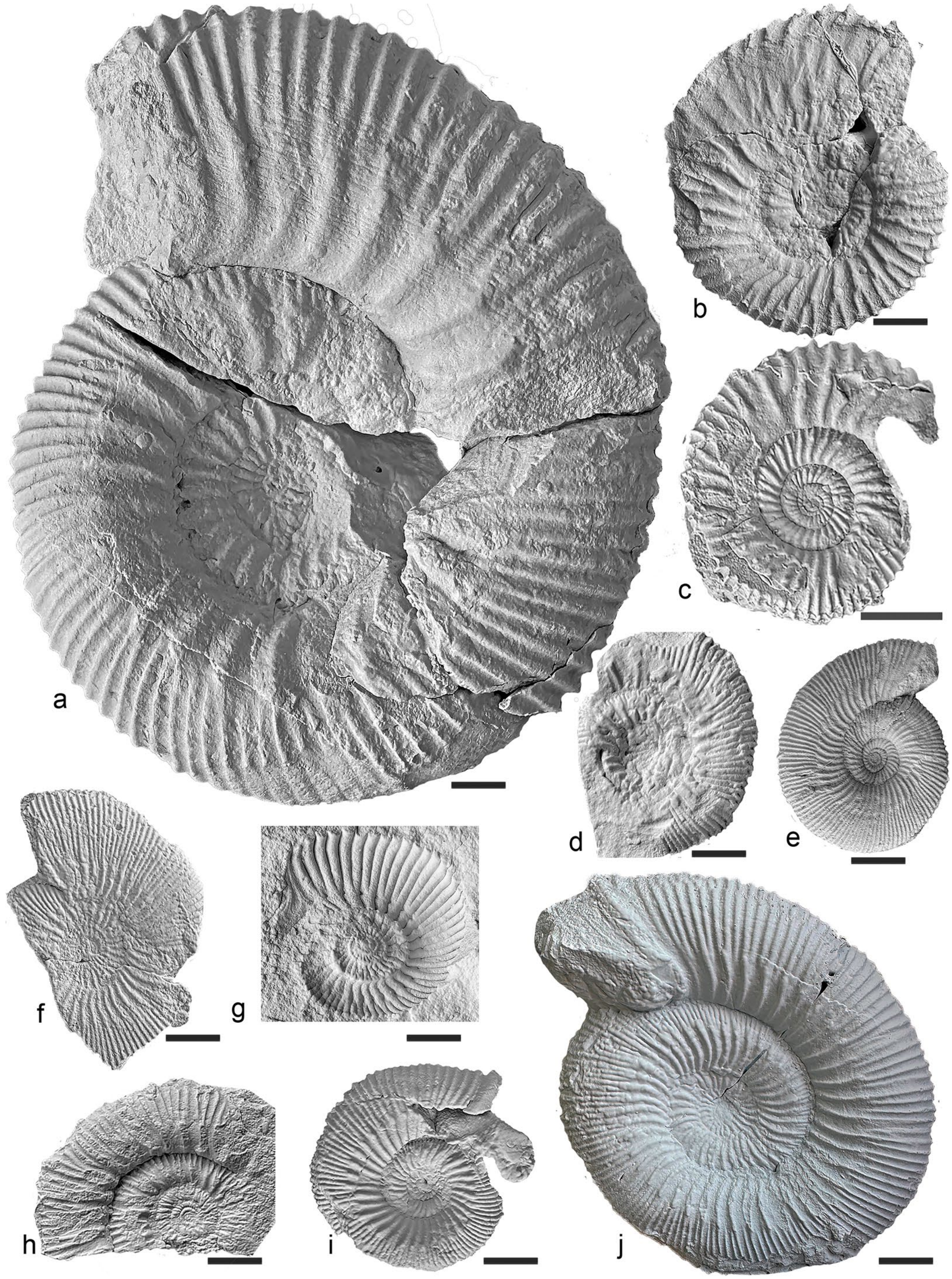

Fig. 6 **a,** *Paviceras subcoronatum* (Oppel, 1856) [M], JRi3.75.1, Lower Bajocian, Humphriesianum Zone, Blagdeni Subzone, bed, 75. **b, c,** *Normannites vulgaricostatus* Westermann, 1954 [m], JRi3.53.4, JRi3.53.3, Lower Bajocian, Humphriesianum Zone, Blagdeni Subzone, bed, 53. **d**, *Masckeites densus* Buckman, 1920 [m], JRi3.52.14, Lower Bajocian, Humphriesianum Zone, Blagdeni Subzone, bed, 52. **e, f,** *Masckeites* sp. aff. *M. sturanii* (Pavia, 1983) [M] & [m?]; **e**, JRi3.50.2, [m?], Lower Bajocian, Humphriesianum Zone, Blagdeni Subzone, bed 50; **f,** JRi3.56.1, [M], Lower Bajocian, Humphriesianum Zone, Blagdeni Subzone, bed, 56. **g, h,** *Masckeites?* aff. *exilis* (Galácz, 2012), [M] & [m]; **g,** JRi3.81.1, [m], external mould, Lower Bajocian, Humphriesianum Zone, Blagdeni Subzone, bed, 81; **h,** Ri3.77.2 [M], Lower Bajocian, Humphriesianum Zone, Blagdeni Subzone, bed, 77. **i, j,** *Cadomites* aff. *lissajousi* Roché, 1939 [M] & [m]; **i,** JRi3.79.2, [m], Lower Bajocian, Humphriesianum Zone, Blagdeni Subzone, bed 79; **j**, JRi3.78.7 [M], Lower Bajocian, Humphriesianum Zone, Blagdeni Subzone, bed 78. *Scale bars* 1 cm.

Measurements (approximate due to crushing deformation):

Specimen	D	U	u	H	h	W	w	R	Remarks	Biostratigraphy
JRi3.75.1	140.0	59.0	0.42	42.0	0.30	46.0	0.33	28	[M], adult	Humphriesianum Zone, Blagdeni Subzone
	108.0	39.0	0.36	37.0	0.34	41.0	0.38			
JRi3.75.2	197.0	93.0	0.47	61.0	0.31	72.0	0.37		[M], adult. Complete?	
	157.0	71.0	0.45	49.0	0.31	58.0	0.37			

Description: Evolute, with subcadiconic shell; funnel-shaped umbilicus with almost regular involution; spiral suture superimposed on the lateral tubercles, except in the last third of the last whorl where there is a small retraction of the whorl-section; subtrapezoidal, wider than height, to oval section with half internal slightly arched and rounded depressed ventral area; marked lateral convexity, accentuated by the spiral crown of tubercles. Concave ornamentation consisting of strong retroverse primary ribs on the umbilical wall that subsequently subradial up to half of the whorl-height where ribs widen into well-marked tubercles. Proverse strong secondary ribs, which are especially prominent on the venter; bundles of two or, more frequently, three secondary ribs are joined and free intercalated ribs also occur.

Remarks: *Paviceras subcoronatum* (Oppel, 1856), LT in Quenstedt (1848, p. 176, pl. 14, Fig. 4), *P. triptolemus* (Buckman, 1912); HT refigured in Pavia (1983, pl. 20, Fig. 2 and by Chandler et al., 2017, figs. 17b1, 17b2), *P. hoffmanni* (Schmidtill & Krumbeck, 1938, p. 348, pl. 13, Fig. 6; LT refigured in Pavia, 1983, pl. 21, Fig. 1) and *P. dubium* (Schmidtill & Krumbeck, 1938, p. 349, pl. 13, Fig. 1, LT) could represent different morphotypes of a single biospecies. The types of these four "species" are very similar and, as shown in Pavia and Zunino (2012, text-Fig. 4; see also Pavia & Fernández-López, 2016, pp. 4, 5), occur at the same biostratigraphic levels. In that case, the valid species name would be *P. subcoronatum*. Likewise *Stephanoceras rectecostatum* Weisert in Dietze et al., (2015, pl. 10, figs. 1, 2; pl. 11, figs. 7, 10) could represent the intraspecific variability of this species. The specimen JRI3.75.2, although poorly preserved, corresponds quite well to the HT of *Paviceras triptolemus.*

According to Chandler et al., (2017, p. 655), the specimens described and figured by Pavia (1983) as *Teloceras* (s. s.) *acuticostatum* Weisert, *T.* (subgen?) *dubium* (Schmidtill and Krumbeck) and *T.* (subgen?) *subcoronatum* (Oppel) could be conspecific with *Gibbistephanus gibbosus* Buckman. In our opinion, these specimens figured by Pavia (1983) are more similar to the types of the aforementioned species than to *G. gibbosus,* which occurs stratigraphically below (in the Humphriesianum Subzone).

According to Pavia (1983, p. 143), *Normannites orbignyi* Buckman constitutes the equivalent dimorphic pair of *Paviceras triptolemus*. If, as aforementioned, *P. triptolemus* is synonymous with *P. subcoronatum*, *N. orbignyi* would be the microconch dimorphic partner of *P. subcoronatum*. Likewise, Pavia (1983, p. 149) indicated that the open umbilicus, and especially the distribution throughout the Blagdeni Subzone, suggests a dimorphic pairing of *N. immutans* Pavia with *Teloceras* (s. s.) *acuticostatum.*

Normannites orbignyi Buckman*, N. quenstedti* Roché, *N. rhomboidalis* (Westermann), *N. prorectus* (Westermann), *N. fortis* Pavia and, even, *N. immutans,* which are morphologically very similar to each other and, besides, have an almost equivalent stratigraphic range (see Pavia,1983, tables II, IIIC; Pavia & Zunino, 2012, text-Fig. 4) and could represent different morphotypes of a single biospecies. In the stratigraphic level 75 of the JRi3 section, some fragmentary specimens that can be classified as *N. orbignyi* Buckman have been collected.

6.2 Genus NORMANNITES Munier-Chalmas, 1892

Type species: *N. orbignyi* Buckman, 1908, p. 146 [SD, ICZN Opinion 309, 1954d, p. 347].

6.2.1 *Normannites vulgaricostatus* Westermann, 1954 [m]

Figure 6b, c

1983 *Normannites* (s.s.) *vulgaricostatus* Westermann, 1954. - Pavia, 1983, p. 145, pl. 29, figs. 1, 3 (cum synonymy)

1983 *Normannites* sp. Pavia, p. 146, pl. 28, figs. 1, 5 (cum synonymy)

Material: JRi3.53.3 and JRi3.53.4

Measurements (approximate due to crushing deformation):

Specimen	D	U	u	H	h	W	w	R	Remarks	Biostratigraphy
JRi3.53.3	37.0	16.0	0.43	11.0	0.30			27	[m], adult?	Blagdeni Subzone
	32.0	13.0	0.41	10.0	0.31					

Description: Small microconchs, evolute**,** both specimens are laterally flattened, but whorl-section appears to be ovate compressed; strong and spaced ribs, primaries slightly proverse, and radial or slightly rursiradiate secondaries; on inner whorls primaries end in fine, elongated nodes, which progressively transforms into a faint elongated relief. Two secondary ribs generally arise from each primary, but simple ones appear sporadically. Aperture with small lateral lappets.

Remarks: These specimens are very similar to *Normannites vulgaricostatus* Westermann sensu Pavia (1983, p.145, pl. 29, figs. 1, 3), which seems to have a higher spiral expansion rate and some trifurcated ribs. In the Chaudon section (southeast France), the specimens described and figured as *Normannites* sp. by Pavia (1983) appear associated with *Normannites vulgaricostatus* at the base of the Blagdeni Subzone. The same ammonite assemblage is recorded in the JRi3 section, which together with the FO of *Masckeites* aff. *sturanii* are here considered as indicators of the base of the Blagdeni Subzone.

6.3 Genus MASCKEITES Buckman, 1920, pl. 152

Type species: *Masckeites densus* Buckman, 1920, pl. 152; OD.

6.3.1 *Masckeites densus* Buckman, 1920 [m]

Figure 6d

1920	*Masckeites densus* nov. nov. Buckman, T A-3, pl. 152 (HT).
1954	*Masckeites densus* Buckman, 1920. - Westermann, p. 332, pl. 32, fig. 1a-c (HT refigured)
1995	*Masckeites densus* Buckman, 1920. - Fernández-López, p. 316, pl. 34, figs. 2,3 (cum synonymy).
1996	*Masckeites densus* (S. Buckman). - Gauthier et al., p. 35, pl. 3, figs. 3a, b.

Material: JRi3.52.14.

Description: Incomplete specimen, evolute shell with not very marked eccentric coiling, flattened so the whorl-section cannot be well observed; thin sharp primary ribs, slightly proverse and curved forward, which at half height of the flank end in thickenings or small tubercles that are less marked in the body-chamber. From each primary arise two or more frequently three, thin but well-marked secondaries, radial or only slightly proverse that cross radially the venter.

Remarks: The poorly preserved specimen from JRi3 matches the previously figured forms of this species quite well. It occurs associated with ammonites typical of the lower part of the Blagdeni Subzone.

6.3.2 ***Masckeites*** **sp. aff.** ***M. sturanii*** **(Pavia, 1983) [M] & [m]**

Figure 6e, f

aff.	1983	*Stephanoceras* (*Stephanoceras*) *sturanii* n. sp. - Pavia, p. 94, pl. 13, figs. 4, 6 (HT).
aff.	1991	*Stephanoceras* (*Stephanoceras*) *sturanii* Pavia - Galácz, p. 878, pl. 1, fig. 5.
aff.	1994	*Lokuticeras sturanii* (Pavia, 1983) - Galácz, p. 166, pl. 3, Fig. 3.

Material: JRi3.50.2 and JRi3.56.1 (from JRi3) and JAC20.10.52 (from Camino Casa Blanca in the central Median Subbetic).

Measurements (approximate due to crushing deformation):

Specimen	D	U	u	H	h	W	w	R	Remarks	Biostratigraphy
JRi3.50.2	38.0 29.0	14.0 8.9	0.37 0.33	12.0 11.5	0.32 0.40			20	[m], adult?	Blagdeni Subzone ?
JRi3.56.1	50.0 38.0	16.0 11.0	0.32 0.29	20.0 14.5	0.40 0.38			24	[M], juv	Blagdeni Subzone
JAC20.10.52	95.0 78.0	51.0 39.0	0.54 0.50	25.0 22.5	0.26 0.29	27.0 25.0	0.28 0.32	28	[M], adult	Blagdeni Subzone

Description: Relatively involute to evolute with eccentric coiling, laterally flattened specimens, but whorl-section appears to be ovate-compressed; very thin (sharp) and dense primary ribs, concave forward; on inner whorls primaries end in a fine tubercle, which progressively transforms in a faint elongated relief. From each primary arise two to four, frequently three, very thin and sharp secondary ribs, radial or slightly proverse that cross radially the venter. The specimen JRi3.56.1 is a juvenile macroconch, whilst JRi3.50.2 is a microconch with the base of the aperture, but the lappets are missing.

Remarks: The specimens from JRi3 are quite similar to the HTof *Masckeites sturanii* (Pavia), but are more involute, and have slightly denser ribbing, greater number of trifurcations, divisions of the ribs are lower, slightly developed tubercles. Although, the smaller size and the deformation due to lateral crushing, which does not allow the type of whorl-section to be observed, they have been included with certain doubts in this species. The adult specimen not flattened, from Camino Casa Blanca section (Sandoval, 1983) is very similar to the specimens figured by Pavia (1983). The microconch form, *Masckeites densus* Buckman, has similar coiling and whorl-section, but the ribs are much thicker, the primaries are shorter and the tubercles seem to be a little better marked. The HT of *Cadomites psilacanthoides* [m], Sandoval, from Sierra de Ricote, that has been included in *Masckeites* by Galácz (1994, 2012, 2017), is stratigraphically higher, and occurs in the same beds that *Cadomites* [M], representing a microconch of this genus.

The HT of *Masckeites sturanii* (Pavia) is from the mid part of the Blagdeni Subzone of Chaudon section, Digne, southeast of France (Pavia, 1983); this species also occurs in the Lower/Upper Bajocian transition in Lókút, Hungary (Galácz, 1991, 1994). The absence of *Teloceras blagdeni* or other species that characterize the boundary between the Humphriesianum and Blagdeni subzones leads to use *M. sturanii* as an element to mark the base of this subzone at JRi3 section. The specimen JRi3.50.2 occurs associated with some forms that are common in the Humphriesianum Subzone while JRi3.56.1 occurs with ammonite that characterize the Blagdeni Subzone.

6.3.3 *Masckeites? aff. exilis* (Galácz, 2012) [M] & [m]

Figure 6g, h

aff. 1983 *Phaulostephanus diniensis* nov. sp. - Pavia, p. 122, pl. 22, Fig. 6 (only).

aff. 2012 *Phaulostephanus exilis* nov. sp. - Galácz, p. 286, Fig. 3.

Material: JRi3.77.2, JRi3.77.3, JRi3.77.4, JRi3.81.1.

Measurements (approximate due to crushing deformation):

Specimen	D	U	u	H	h	W	w	R	Remarks	Biostratigraphy
JRi3.77.2	44.0	20.1	0.46	15	0.34				[M]?	Humphriesianum Zone, Blagdeni Subzone
JRi3.77.3	30.0 24.0	13.0 9.0	0.43 0.34	10.0 8.0	0.33 0.33				[m], adult. Complete?	
JRi3.81.1	33.0 30.0	12.5 11.0	0.41 0.37	12.0 10.8	0.36 0.36				[m], adult. Complete	

Description: Small shells, evolute with moderate whorl-spiral expansion. The available specimens are laterally flattened, but the whorl-section is apparently ovate, slightly compressed. The primary ribs blunt, radial or slightly concave forward, bifurcate or trifurcate below half-flank from weak tubercles; intercostal spaces wider than the ribs, especially in adult stages. Secondary ribs, thin, but well-marked, radial or slightly rursiradiate, cross the venter without weakening; inconspicuous constrictions occur on the inner and middle whorls. A specimen (JRi3.77.2), with approximately 52 mm in diameter and incomplete, seems to represent a macroconch, the other two are microconchs, one of which (JRi3.81.1, an external mould) has expand lateral lappets.

aff. 1973 *Cadomites lissajousi lissajousi* Roché.- Pavia, p. 100, pl. 17, figs. 4, 6.

aff. 1973 *Polyplectytes* sp. ind..- Pavia, p. 100, pl. 15, Fig. 3.

pars 1983 *Cadomites* (*Cadomites*) *lissajousi* Roché. - Sandoval, p. 273, only pl. 18, Fig. 4.

1983 *Cadomites* (*Cadomites*) aff. *lissajousi* Roché. - Pavia, p. 153, pl. 22, figs. 8, 9.

Material: JRi3.78.7, JRi3. 79.2.

Measurements (approximate due to crushing deformation):

Specimen	D	U	u	H	H	W	w	N	Remarks	Biostratigraphy
JRi3.78.7	81.0	34.5	0.43	25.0	0.31			45	[M], adult	Humphriesianum
	70.0	25.4	0.36	23.0	0.33			43	Complete	Zone,
JRi3.79.2	37.0	13.5	0.36	13.5	0.36				[m], adult. Complete	Blagdeni Subzone
	31.0	10.0	0.32	12.0	0.39					

Remarks: The morphology of these specimens shows intermediate character between *Phaulostephanus* and *Masckeites*, but according to Pavia and Fernández-López (2016, p. 197; see also Galácz, 1994, p. 162, and Pavia & Zunino, 2012, p. 211), the dimorphic couple *Masckeites* Buckman [m] and *Lokuticeras* Galácz [M] are Stephanoceratinae that may be regarded as the ancestor of Cadomitinae in the uppermost Humphriesianum Zone, whereas *Phaulostephanus* represents the last link of the subfamily Mollistephaninae Pavia & Zunino, 2012. Also, Fernández-López and Pavia (2015, p. 715) suggested that the Galácz species is not attributable to a *Phaulostephanus*, but rather to the base a new lineage derived from *Phaulostephanus*. In the type locality, *M. exilis* occurs in the Blagdeni Subzone and basal Niortense Zone (Galácz, 2012, p. 287, Fig. 2); the specimens of the JRi3 section are from the upper part of the Blagdeni Subzone.

Subfamily CADOMITINAE Westermann, 1956

6.4 Genus CADOMITES Munier-Chalmas, 1892

Type species: *Ammonites deslongchampsi* d'Orbigny, 1846 in 1842–1851, p. 405; OD, ICZN Opinion 324, 1955a, p. 230, 236).

6.4.1 *Cadomites* aff. *lissajousi* Roché, 1939 [M] & [m]

Figure 6i, j

Description: Evolute, eccentric coiling, ovate whorl-section, thin ribs, primaries slightly proverse and concave forward; small tubercles at the division point of the ribs; secondaries, two or three for primary, very thin, cross radially the venter without weakening. Peristome preceded by a small constriction followed by an elevated flared smooth lip in macroconchs. In microconchs the aperture is preceded by a small constriction followed by an elevated flared lip and two long lateral lappets.

Remarks: The macroconch is very similar to the forms classified as *Cadomites lissajousi lissajousi* Roché (from Niortense Zone, Banksii Subzone) in Pavia (1973, p. 100, pl. 17, figs. 4, 6) and to *C.* aff. *lissajousi* (from Humphriesianum Zone, Blagdeni Subzone) in Pavia (1983, p. 153, pl. 22, figs. 8, 9), although these specimens have longer and somewhat more widely spaced primaries. The LT of *C. lissajousi* Roché (1939, p. 197, pl. 2, figs. 2a, 2b) has slightly more involute coiling and primary ribs longer, thicker and more spaced. It is also quite similar to the LT of *Cadomites frederici-romani* (Roché, 1939, p. 215, pl. 5, figs. 3a-c), which has the division points of the ribs somewhat higher. This species, depending on different authors, has been included in *Cadomites* [M] (Besnosov & Mitta, 1993; Pavia, 1983; Roché, 1939), *Orthogarantiana* [M] (Gauthier et al., 1996, 2002) or *Masckeites* [M] (Galácz, 2012). The microconchs are similar to the H of *Cadomites psilacanthoides* Sandoval [m], 1983 (pl. 21, Fig. 5) from the Niortense Zone of Sierra de Ricote. The specimens from JRi3 clearly constitute a dimorphous pair because they show similar morphology on inner and middle whorls and because both occur in the same level.

6.4.2 *Cadomites septicostatus* Buckman, 1923 [M] & [m]

Figure 7a, b

1923	*Cadomites septicostatus* nov. Buckman T.A. IV, 432a-b.
1983	*Cadomites* (*Cadomites*) *septicostatus* S. Buckman, 1923. - Sandoval, p. 277, pl. 22, fig. 3 (cum synonymy).
1983	*Cadomites* (*Cadomites*) sp. 1 cf. *C.* (*C.*) *septicostatus* S. Buckman, 1923. - Sandoval, p. 278, text-figs. 101f, g, 102c, pl. 20, fig. 3, pl. 21 fig. 2.
1985	*Cadomites septicostatus* S. Buckman, 1919. - Fernández-López (1985), p. 228, text-fig. 37B.
1994	*Masckeites psilacanthoides* (Sandoval, 1983). - Galácz, p. 168, pl. 3, fig. 2.

Material: JRi3.97.9 [M], JRi3.97.10 [M], JRi3.98.6 to JRi3.98.9 [m].

Measurements (approximate due to crushing deformation):

Specimen	D	U	u	H	h	W	w	R	Remarks	Biostratigraphy
JRi3.97.9	80.0	34.1	0.43	24.5	0.31			70	[M], adult	Niortense Zone,
	64.0	23.5	0.37	22.5	0.36				Complete	Polygyralis
JRi3.98.6	34.0		15.0	0.44	11.0	0.32		51	[m], adult	Subzone
	27.5		10.5	0.38	10.0	0.36			Complete	

Description: Evolute, eccentric coiling; ovate whorl-section, although the deformation does not allow us to observe its exact shape; very thin and dense ribs, primaries slightly proverse and concave forward; secondaries, two or three for each primary, very thin, cross radially the venter; very small elongate tubercles. The macroconchs have peristome preceded by a small constriction followed by an elevated flared smooth lip. In the microconch, the aperture is preceded by small constriction followed by an elevated flared lip and two lateral lappets.

Remarks: As Figs. 7a and 7b show, macroconchs and microconchs are very similar, differing only in size and apertural modifications. The macroconchs from JRi3 are very similar to the HT of *C. septicostatus*, but they have slightly denser ribs and more trifurcations; divisions of the ribs are lower, and their tubercles are slightly more developed. The microconch form (figured herein for first time) shows similarities with *Cadomites psilacanthoides* [m] Sandoval, 1983, which has more spaced ribbing and slightly less marked tubercles. The HT of *C. septicostatus* is from the Inferior Oolite of Clatcombe, Dorset, England, Niortense Zone. The specimens from JRi3 section are of the Polygyralis Subzone.

Subfamily FREBOLDITINAE Fernández-López & Pavia, 2015

Remarks: The Subfamily Frebolditinae was erected by Fernández-López and Pavia (2015, p. 715) including the genera *Bajocia* Brasil, 1895, *Subcollina* Spath, 1925, *Parabigotites* Imlay, 1961, *Parastrenoceras* Ochoterena, 1963, *Patrulia* Sturani, 1971 and *Freboldites* Taylor, 1988. The new version of the Treatise (Énay & Howarth, 2019; Howarth, 2017), perhaps without disregarding the Fernández-López & Pavia paper, includes five of these genera into three different subfamilies: Stephanoceratinae (*Freboldites*, *Parabigotites*), Garantianinae (*Subcollina, Parastrenoceras*) and Leptosphinctinae (*Patrulia*). The genus *Bajocia* does not appear registered in the new version of the Treatise.

6.5 Genus SUBCOLLINA Spath, 1925

Type species: *Subcollina yeovilensis* Spath, 1925; OD, for *Aegoceras densinodum* Wright, 1880–1882, p. 350, pl. 38, figs. 5–6.

Description: Emended after Fernández-López and Pavia (2015, p. 720) and Howarth (2017, in Treatise online, p. 22). Evolute serpenticones with generally wide and shallow umbilicus; subquadrate whorl section, slightly depressed on inner whorls, becomes somewhat compressed on the body-chamber, with flat or slightly convex flanks and slightly concave to little convex venter. The strong, straight primary ribs end in ventrolateral nodes or tubercles, from which two or three vestigial secondary ribs pass onto the venter and are usually interrupted by a narrow mid-ventral smooth band; the ventrolateral nodes alternate on each side of the venter and secondary ribs alternate or zigzag between them; innermost whorls have relatively spaced ribs only thickened

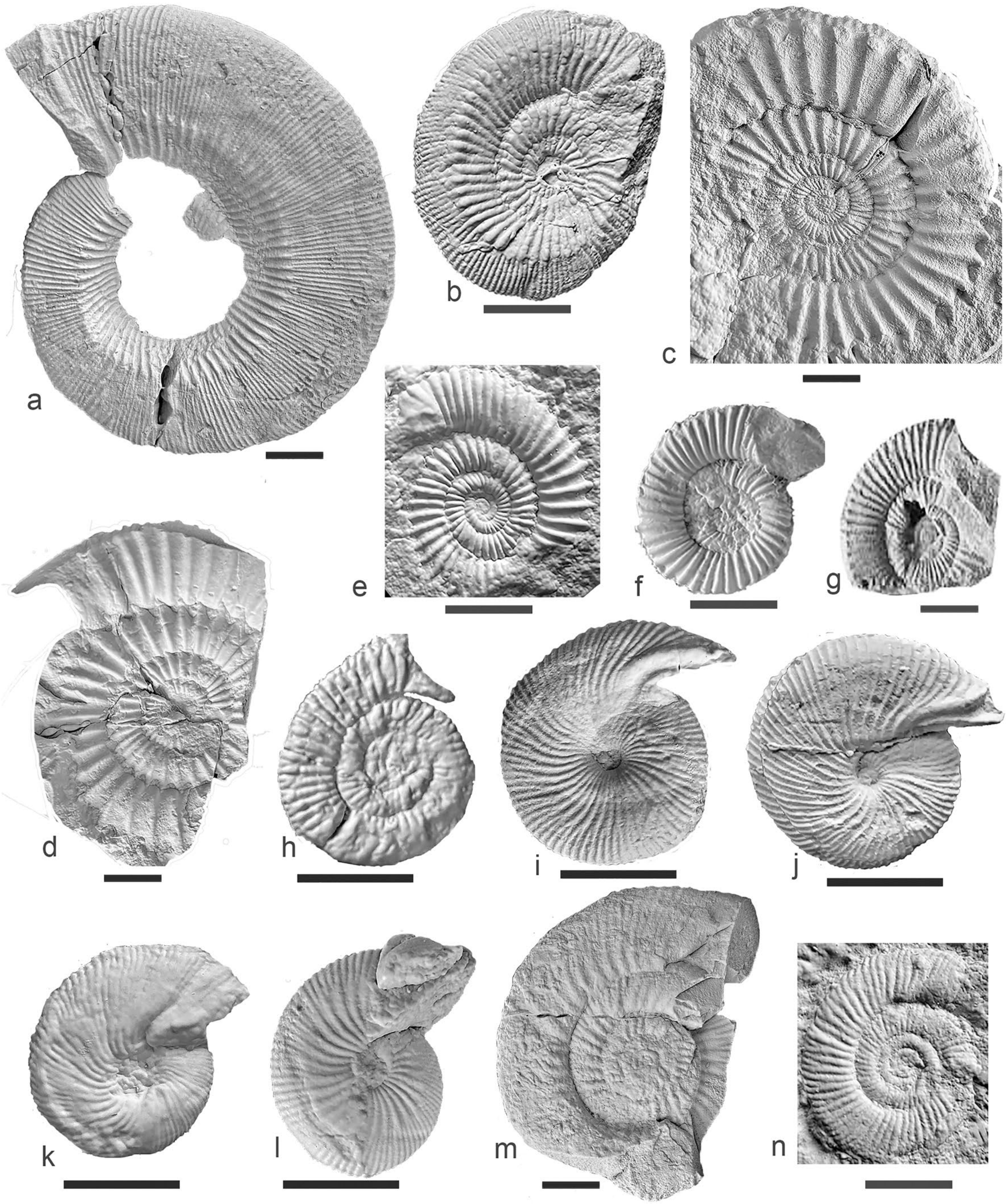

Fig. 7 **a, b,** *Cadomites septicostatus* Buckman, 1923 [M] & [m]; **a,** JRi3.97.9, [M], Upper Bajocian, Niortense Zone, Polygyralis Subzone, bed 97; **b**, JRi3.98.6 [m], Upper Bajocian, Niortense Zone, Polygyralis Subzone, bed 98. **c-f**, *Subcollina ochoterenai* Pavia, 2000 [M] & [m]; **c**, JRi3.77.1, [M], Lower Bajocian, Humphriesianum Zone, Blagdeni Subzone, bed 77; **d**, JRi3.78.1, [M], Lower Bajocian, Humphriesianum Zone, Blagdeni Subzone, bed 78; **e**, JRi3.78.6, [m], Lower Bajocian, Humphriesianum Zone, Blagdeni Subzone, bed 78; **f**, JRi3.78.5, [m], Lower Bajocian, Humphriesianum Zone, Blagdeni Subzone, bed 78. **g-h**, *Subcollina* sp.1, [m], JRi3.74.1 (specimen figured as *Caumonstisphinctes* (*Infraparkinsonia*) aff. *debilis* by Linares & Sandoval, pl.1, Fig. 13), JRi3.74.7, Lower Bajocian, Humphriesianum Zone, Blagdeni Subzone, bed 74. ***i-k,*** *Chondroceras canovense* (de Gregorio, 1886) [M] & [m]; **i,** JRi3.94.9, [M], Upper Bajocian, Niortense Zone, Polygyralis Subzone, bed 94; **j,** JRi3.93.1, Upper Bajocian, Niortense Zone, Polygyralis Subzone, bed 93; **k**, JRi3.98.14, [m], Upper Bajocian, Niortense Zone, Polygyralis Subzone, bed, 98. **l**, *Sphaeroceras brongniarti* (Sowerby, 1818) [M] ?, JRi3.76A.11, Lower Bajocian, Humphriesianum Zone, Blagdeni Subzone, bed, 76A. **m,** *Leptosphinctes* aff. *festonensis* Pavia [M]?, JRi3.78.11, Lower Bajocian, Humphriesianum Zone, Blagdeni Subzone, bed 78. **n,** *Caumontisphinctes polygyralis* Buckman, 1920 [M]?, JRi3.98.17, Upper Bajocian, Niortense Zone, Polygyralis Subzone, bed, 98. *Scale bars* 1 cm

near the ventrolateral nodes, later ribs become very dense, in intermediate whorls are more spaced and finally become denser, mainly in microconchs, in the body-chamber end. Dimorphic macroconchs (approximately 60 to 140 mm in diameter) with adult mouth border expanded laterally and projected on venter; microconchs (adult at 20–50 mm in diameter) with an elevated and expanded mouth border and small lateral lappets. Septal suture is complex in the adult stage of macroconchs, but relatively simple in microconchs and pre-adult stages with poorly incised accessory lobes, E almost as deep as L, which is trifid and almost symmetrical: the saddle L/U_2 is high, wide and asymmetrically divided by a well-marked accessory lobe; suspensive lobe U_3 is retracted.

Remarks: Fernández-López and Pavia (2015, p. 715) defined the new subfamily Frebolditinae, which was included, with certain doubt, into the family Stephanoceratidae. They included the genus *Subcollina* within Frebolditinae. Later Howarth (2017, p. 22) included *Subcollina* in Garantianinae, also into the Stephanoceratidae. According to Fernández-López and Pavia (2015, p. 720), (Niortense Zone, Banksii Subzone) of Europe (England, Germany, France, Italy and Spain) and Mexico,

6.5.1 ***Subcollina ochoterenai*** Pavia, 2000 [M] & [m]

Figure 7c–f

1928 *Strenoceras?* (n. subg.) *lucretius* d'Orbigny. - Bentz, p. 172, pl. 15, fig. 2.
1963 *Parastrenoceras lucretius* (d'Orbigny). - Ochoterena, p. 24, pl. 5, fig. 3.
2000 *Subcollina ochoterenai* n. sp. Pavia, p. 401, figs. 4.1-2
2013 *Subcollina ochoterenai* Pavia. - Pavia *et al.*, p. 144, figs. 5a-b.
2015 *Subcollina ochoterenai* Pavia. - Fernández-López & Pavia, p. 720, figs. 11a-h.

Material: 12 specimens of which 5 (JRi3.77.1, JRi3.78.1 to JRi3.87.4) are [M] and 7 (JRi3.87.5, JRi3.87.6, JRi3.87.8- JRi3.87.10 and JRi3.79.1) are[m].

Measurements (approximate due to crushing deformation):

Specimen	D	U	u	H	h	W	w	R	Remarks	Biostratigraphy
JRi3.78.1	60.0 46.0	31.5 24.0	0.52 0.52	14.2 12.0	0.23 0.26	9.00	0,15	34	[M], adult-Complete	Humphriesianum Zone, Blagdeni Subzone
JRi3.77.1	60.0 48.0	31.8 25.5	0.53 0.53	16.5 13.0	0.275 0.27			40	[M], adult. Complete?	
JGa1.R.13	74.0 54.0	43.0 31,0	0.58 0.57	17.5 14.0	0.24 0.26	15? 13?	0.20? 0.24	40	[M], adult. Complete?	
JRi3.78.5	22.0 17.0	11.0 8.5	0.50 0.50	6.0 5.0	0.27 0.29	4.00	0.18	40 34	[m], adult. Complete	
JRi3.78.6	26.5 19.0	13.5 9.50	0.51 0.50	7.0 5.5	0.26 0.30			42 34	[m], adult. Complete ?	
JRi3.79.1	39.0 30.0	20.0 15.0	0.51 0.50	10.0 8.0	0.26 0.27			48 38	[m], adult. Complete	

Subcollina includes four species: S. *lucretia* (d'Orbigny, 1850), *S. yeovilensis* Spath, 1925, *S. sandovali* Pavia, 2000 and *S. ochoterenai* Pavia, 2000. Nevertheless, Fernández-López and Pavia (2015, p. 721) described *S. lucretia* as a *nomem nudum*, because the LT (missing) was never figured and a neotype has not been designated. Its dimorphic status was described by Sandoval and Westermann (1986, p. 1259), Pavia (2000, p. 399) and Fernández-López and Pavia (2015, p. 720). *Subcollina* is known from uppermost Lower Bajocian (Humphriesianum Zone, uppermost part of the Blagdeni Subzone) to lowermost upper Bajocian

Description: The Subbetic macroconchs (60 to 74 mm in diameter) are evolute serpenticones (O/D varies from 0.53 to 0.58) with wide and shallow umbilicus. The whorl-section, not observable on inner whorl, is subquadrate to subrectangular slightly compressed with slightly gently convex flanks on the mid- and outer whorls and with flat or very slightly convex ventral area; adult mouth border is expanded laterally and projected on the venter. Ribs are strong, straight primary ribs end in ventrolateral tubercles, from which two or more frequently three vestigial secondary ribs pass onto the flat venter and are usually interrupted by a narrow mid-ventral smooth band; the ventrolateral nodes alternate on each side of the venter and secondary ribs alternate in zigzag between them. Innermost whorls have relatively spaced primary ribs thickened near the ventrolateral nodes; later (for 1 to 2 whorls) ribs become very dense; on intermediate and outer whorls ribs are more spaced again. The microconchs (22–39 mm in diameter in complete adult specimens), follow the same ornamental pattern as macroconchs, but ribs become denser in the body-chamber and present an aperture with elevated and expanded mouth border and small lateral lappets. Septal sutures are not well preserved in the specimens from JRi3 section.

Remarks: The HT of *Subcollina ochoterenai* Pavia, 2000 is the fragmentary composite mould, from Les Dourbes section, SE France (H*umphriesianum* Zone, Blagdeni Subzone), illustrated in Pavia (2000, Fig. 4.1). The specimens from the "Oolite ferrugineuse de Bayeux", figured by Pavia et al., (2013, Fig. 5a) and by Fernández-Lopez and Pavia (2015, Fig. 11-h), which include almost complete, although without aperture, macro- and microconchs, are much more representative for this species. The three well-known species of *Subcollina* (*S. yeovilensis, S. sandovali* and *S. ochoterenai*) are quite similar. Pavia (2000, p. 403) specified to that the number of secondaries and the weak ventral furrow make *S. ochoterenai* similar to *S. yeovilensis* Spath, 1925, but differs because the HT of the latter species has higher whorl section and denser primary ribbing, which results in reduced spines-nodes. However, occurrence of new material (see Pavia et al., 2013; Fernández-Lopez & Pavia, 2015) shows that there is a morphological diversity in Pavia's species. The only known specimen of *S. yeovilensis* is the HT, which is larger than any of the specimens of *S. ochoterenai* so far known. Although the two "species" are very similar and could be synonymous, *S. ochoterenai* is accepted here considering that the morphology, especially ribs and tubercles, of the forms from JRi3 section fits better with this species than with the HT of *S. yeovilensis* and because of its stratigraphic position in the stratotype (upper part of the Blagdeni Subzone) that is perfectly established. In fact, in JRi3 section this species is used for recognition of the upper part of Blagdeni Subzone.

6.5.2 *Subcollina* sp.1 [m]

Figure 7g, h

1979	*Caumonstisphinctes* (*Infraparkinsonia*) aff. *debilis* (Wetzel). - Linares & Sandoval, p. 296, pl.1, fig. 13.

Material: JRi3.74.1, JRi3.74.7.

Measurements (approximate due to crushing deformation):

Specimen	D	U	u	H	h	W	w	R	Remarks	Biostratigraphy
JRi3.74.7	18.0	9.5	0.53	4.5	0.25			47	[m], adult. Complete	Blagdeni Subzone
	14.0	7.0	0.50	4.0	0.29					
JRi3.74.1	33.0	16.0	0.49	9.0	0.27	6.0	0.18	50	[m], adult	

Description: Small, very evolute shell, subrectangular compressed whorl-section with flat or slightly convex flanks; ribs dense, fine, irregular on inner and middle whorls, radial or slightly proverse on inner whorls and radial on outer ones, bifurcate from small nodes on the ventrolateral shoulder and some simple; secondaries weaken in the central venter, leaving a slight depression in the middle; aperture with elevated expanded mouth border and big, though short lateral lappets. Septal suture is not preserved.

Remarks: One of these specimens (JRi3.74.1) was described and figured as *Caumonstisphinctes* (*Infraparkinsonia*) aff. *debilis* (Wetzel) by Linares and Sandoval (1979, p. 296, pl. 1, Fig. 13), because of the great morphological similarity of *Subcollina* [m] with some *Caumonstisphinctes* [m]. The microconchs of *S. ochoterenai* Pavia are quite similar, but have thicker ribbing with marked changes in the density of the ribs throughout ontogeny. *Subcollina sandovali* Pavia (HT in Sandoval & Westermann, 1986, figs. 32.1–2), presumably a microconch, has similar coiling, ribbing and tubercles, but is much larger in size and has a quadratic or rectangular, slightly depressed whorl-section.

Family Sphaeroceratidae Buckman, 1920.

6.6 Genus CHONDROCERAS Mascke, 1907

Type species: *Ammonites gervillii* J. Sowerby, 1818, p. 189; OD.

6.6.1 *Chondroceras canovense* (de Gregorio, 1886) [M] & [m]

Figure 7i,k

1886 *Stephanoceras* (*Sphaeroceras*) *brongniarti* Sow. mut. *canovensis* - de Gregorio, p. 11,pl. 1, only figs. 3c-e.

1971 *Sphaeroceras* (*Chondroceras*) *canovense* (de Gregorio) - Sturani, p. 146, text-figs. 42/3, 42/6, 44, 45, pl. 10, figs 14-16, 18, pl. 11, fig. 10.

1979 *Sphaeroceras* (*Chondroceras*) *canovense* (de Gregorio) - Linares & Sandoval, p. 294, pl. 2, fig. 12 (cum synonymy).

1980 *Chondroceras (Chondroceras) canovense* (de Gregorio) - Parsons, p .43, pl. 3, figs. 10-17.

Material: JRi3.91.1,JRi3.93.1, JRi3.94.4, JRi3.94.9, JRi3.97.11, J JRi3.97.12, JRi3.97.15, JRi3.97.26, Ri3.98.11, JRi3.98.14.

Description: Small shell (17 to 24 mm) in complete specimens from JRi3. Eccentric coiling, but less marked than in typical *Sphaeroceras*, and weak egression of the whorl into the body-chamber. The ribbing is moderately strong and dense (there are 26 to 32 primaries on the last whorl), mainly bifurcate but a few additional free secondaries also occur. The terminal constriction of the microconchs is very strong, without any flared collar or raised ridge behind it, and the peristome has short lateral lappet-like projections and a blunt ventral rostrum. In macroconchs, slightly larger than microconchs, the small lateral lappets and the hood are missing.

Remarks*:Chondroceras canovense* is close to *S. brongniarti* (Sowerby, 1818), but differs in the size and especially in possessing a much wider, open umbilicus. According to Sturani (1971, p. 149) the generic position of *S. canovense* is not very clear. He placed it in the subgenus *Chondroceras* taking into account that the more involute morphotypes are still more evolute than all known *Sphaeroceras,* but narrower than any known *Chondroceras*. Parsons (1980, p. 43) and Howarth (2017, in Treatise online, p. 24) maintained the same opinion. However, its general morphology, mainly the coiling, and its stratigraphic range can bring this taxon closer to *Sphaeroceras* than to *Chondroceras*. The type horizon of *C. canovense* is Niortense Zone, either Banksii or Polygyralis Subzone (Sturani, 1971, p. 146). The English material described and figured by Parsons (1980) comes from Niortense Zone (Polygyralis Subzone) to Garantiana Zone (Acris Subzone). All specimens from JRi3 section are Niortense Zone (Polygyralis Subzone) and constitute a characteristic element in this stratigraphic unit.

6.7 Genus SPHAEROCERAS Bayle, 1878

Type species: *Ammonites brongniarti* J. Sowerby, 1818, p. 190; SD H. Douvillé, 1879, p. 91.

6.7.1 *Sphaeroceras brongniarti* (Sowerby, 1818) [M] & [m]

Figure 7l

1818 *Ammonites Brongniarti* J. Sowerby, p. 190, pl. A (184), fig. 2i, HL).

1979 *Sphaeroceras* (*Sphaeroceras*) *brongniarti* (J. Sowerby, 1818). - Linares & Sandoval, p. 293, pl. 2, fig. 11.

1980 *Sphaeroceras* (*Sphaeroceras*) *brongniarti* (J. Sowerby). - Parsons, p .13, pl. 1, figs. 1-6, 8.

1985 *Sphaeroceras brongniarti* (J. Sowerby). - Fernández-López, p. 391, pl. 42, fig. 3. (cum synonymy).

1994 *Sphaeroceras brongniarti* (J. Sowerby1818). - Gautier & Rioult in Fischer et al., p. 130, pl. 46, figs. 3a-c.

1998 *Sphaeroceras brongniarti* (J. Sowerby1818). - Besnosov & Mitta, p. 25, pl. 11 figs. 4-7.

2015 *Sphaeroceras brongniarti* (J. Sowerby). - Dietze et al., p. 36, pl. 11, figs. 8-9.

2017 *Sphaeroceras brongniarti* (J. Sowerby). - Howarth, p. 45, fig. 33, 2a-b (HT), c-f.

Material: JRi3.45.1, JRi3.45.2, JRi3.45.3, JRi3.47.1, JRi3.53.5, JRi3.56.4, JRi3.(73–76). 1, JRi3.76A.11, Ri3.77.7, JRi3.78.12 to JRi3.78.15, JRi3.79.3, JRi3.79.4, JRi3.81.2.

Diagnosis: Shells are very small, globular, with a broad and regularly rounded venter; umbilicus are extremely small, nearly occluded and comma shaped. Last half of the body chamber can be more or less contracted. The aperture presents a raised ridge or a flared collar behind the terminal constriction. Primary ribs curved, prorsiradiate, thin, sharp, and dense, bifurcate or rarely trifurcate in the upper part of the flanks. The fine secondaries, thinner and dense, curve gently forward over the venter.

Remarks: Differences between the various species of the genus *Sphaeroceras* are minimal, which, together with their small size, makes their separation difficult. Besides the material from JRi3 is greatly deformed due to crushing, which prevents reliable measurements and makes classification difficult. *G. brongniarti* has generally been reported in the Humphriesianum Zone and at the base of the Niortense Zone (Dietze et al., 2015; Parsons, 1980; Pavia, 1983; Sturani, 1971; Westermann, 1956), but in some localities its range extends to the Garantiana Zone (Fernández-López, 1985, p. 392). The available specimens from JRi3 are Humphriesianum Zone (Humphriesianum and Blagdeni subzones).

Superfamily PERISPHINCTOIDEA Steinmann, 1890 in Steinmann & Döderlein, 1890

Family PERISPHINCTIDAE Steinmann, 1890 in Steinmann & Döderlein, 1890

Subfamily LEPTOSPHINCTINAE Arkell, 1950

Remarks: The Leptosphinctinae are abundant and well-preserved in the upper part of the JRi3 section (Linares & Sandoval, 1979; Sandoval, 1983). The genus *Leptosphinctes* was used, mainly based about material from Sierra de Ricote, to characterize the lower part of the Upper Bajocian in the Betic Cordillera (Sandoval, 1983, 1990). However, although in JRi3 section the genus *Leptosphinctes* occurs from the bed 78 onwards, specimens sampled from beds 78 to 102 (Blagdeni, Banksii and Polygyralis subzones) are scarce, quite corroded on the side that is well exposed, in addition to being crushed laterally, which makes their classification difficult. Some of these specimens can be assigned to *Leptosphinctes* cf. *festonensis* Pavia.

6.8 Genus LEPTOSPHINCTES Buckman, 1920

Type species: *Leptosphinctes leptus* Buckman, 1920, pl. 160; OD.

6.8.1 *Leptosphinctes* cf. *festonensis* Pavia [M]?

Figure 7m

Material: JRi3.78.11, JRi3.82.1, JRi3.82.2 and JRi3.82.3.

Measurements (approximate due to crushing deformation):

Specimen	D	U	u	H	h	W	w	R	Remarks	Biostratigraphy
JRi3.78.11	54.0	26.0	0.48	14.6	0.27					Blagdeni Subzone
	46.0	21.5	0.47	13	0.28					
JRi3.82.2	67.0	33.5	0.50	18.0	0.27				[M]?	
	50.0	24.5	0.49	16.0	0.32					

Diagnosis: Platycone, very evolute shells with ovate compressed to subcircular whorl-section, primaries radial or slightly proverse bifurcate (some simple) between at half and the upper third of the flank occasionally intercalated by single ribs. Secondaries slightly more proverse than primaries cross the venter; one or two well-marked constrictions by whorl. Aperture not preserved.

Remarks: The specimens from JRi3 are quite similar to the HT and paratypes figured by Pavia (1973) and by Pavia and Zunino (2012) and mainly to the specimens of Fernández-López (1985, p. 467, pl. 48, figs. 4, 6), but the deformation by crushing does not allow an accurate comparison of the parameters. *L. festonensis* marks a characteristic biohorizon in the upper part of the Blagdeni Subzone in the south-east of France (Pavia, 1983; Pavia & Zunino, 2012). Most records of *L. festonensis, (*Pavia, 1973, 1983; Fernández-López, 1985, p. 465; Galácz, 2012; Pavia & Zunino, 2012) are from the Humphriesianum Zone, Blagdeni Subzone. The specimen JRi3.78.11 is clearly from the Blagdeni Subzone, *Festonensis* biohorizon, whereas those from beds JRi3.82 and JRi3.84 could be from the Banksii Subzone.

Subfamily PARKINSONIINAE Buckman, 1920.

6.9 Genus CAUMONTISPHINCTES Buckman, 1920

Type species: *Caumontisphinctes polygyralis* Buckman, 1920, pl. 163; OD.

Remarks: Fernández-López and Pavia (2015, p. 723) indicated that probably *Caumontisphinctes* marks the beginning of a new lineage and the base of the family Parkinsoniidae Buckman, which is in connection with *Phaulostephanus* at the Lower–Upper Bajocian transition (see also Pavia, 2000; Pavia & Zunino, 2012). However, Énay and Howarth (2019,), perhaps without knowing the paper by Fernández-López & Pavia, included to the genus *Caumontisphinctes* into Leptosphinctinae, and indicated that probably it is a short-ranging offshoot from *Leptosphinctes* and a probable ancestor of the Parkinsoniinae.

On the other hand, if *Caumontisphinctes* [M] & [m] and *Subcollina* [M] & [m] are compared, both genera have many common characters. The coiling, whorl-section, ribbing and septal suture are quite similar in both genera; even the ventral areas, which occasionally have a feeble median furrow or flattening of secondary ribs at mid-venter can be similar. If one takes also into account that both genera appeared successively, one after the other, then phylogenetic relationships between them becomes possible. In this case, *Subcollina,* a descendant of *Phaulostephanus,* would be ancestral to *Caumontisphinctes* and this in turn the ancestor of the other Parkinsoniidae.

6.9.1 *Caumontisphinctes polygyralis* Buckman, 1920 [M]?

Figure 7n

1920 *Caumontisphinctes polygyralis* nov. Buckman, T A-3, pl. 163 (HT).

1985 *Caumontisphinctes* (*C.*) *polygyralis* Buckman. - Fernández-López, p. 399, pl. 42, fig. 1 (cum synonymy).

1996 *Caumontisphinctes polygyralis* Buckman. - Gauthier et al., pl. 6, fig. 1a, b.

2019 *Caumontisphinctes polygyralis* Buckman. - Énay & Howarth (in Treatise online), p. 6, fig. 4.1a (HT refigured).

Material: JRi3.93.2, JRi3.93.3, JRi3.97.24, JRi3.97.25 and JRi3.98.17.

Measurements (approximate due to crushing deformation):

Specimen	D	U	u	H	h	W	w	R	Remarks	Biostratigraphy
JRi3.93.2	31.0	14.0	0.45	8.5	0.27			55	[M], adult. complete	Niortense Zone, Polygyralis Subzone
	26.0	11.0	0.42	7.5	0.29					
JRi3.98.17	25.0	11.5	0.46	6.1	0.24			50	[M], adult. Complete?	
	18.0	8.0	0.44	6.0	0.33					

Diagnosis: Small, evolute, platyconic shells with almost regular involution; spiral suture coinciding with the divisions of the ribs except in the last fifth of the last whorl; the specimens are laterally flattened, but the whorl-section appears to be subrectangular compressed; the venter, observable in only one specimen, presents a small mid-ventral smooth band or groove. Ribs very dense, fine and sharp, slightly proverse or concave forward, are bifurcate at the upper of the flank or simple; inconspicuous constrictions. Aperture is not well preserved in the available specimens, but they seem to be macroconchs.

Remarks: Although *C. polygyralis* is a frequently cited species, and was chosen as a subzonal index, it is not abundant or common, and apart from its HT few specimens have been figured (Dietl, 1980; Fernández- López, 1985; Pavia, 1973; Roché, 1943; Sturani, 1971) and consequently its variability is little known. The specimens from JRi3 are smaller than the previously figured forms. The species is restricted to the Polygyralis Subzone of England, France, Germany, Italy and Spain.

7 Conclusions

1. A general analysis of the various Middle Jurassic outcrops of the Subbetic Basin shows that the JRi3 section can be considered as a reference for the study of the Lower Bajocian/Upper Bajocian boundary of the Betic Cordillera.
2. The analyses of the ammonite assemblages show that for the taxa with marked dimorphism, macroconchs and microconchs, both juveniles and adults, appear almost equivalently and without demonstrable evidence of taphonomic reworking or post-mortem transport.
3. The ammonites are diversified, but abundance is very variable, in some beds they are absent or very scarce whereas they are very frequent in others. Their study has allowed to carry out a detailed biostratigraphy of the Lower Bajocian/Upper Bajocian transition. However, the absence of *Teloceras banksii* and the scarcity of *Caumontisphinctes* make it difficult to mark the exact bed where the boundary should be located.
4. The LOs of the *Subcollina ochoterenai* and the genus *Stephanoceras* plus the FO of *Caumontisphinctes polygyralis* are the more representative taxa indicating the Lower Bajocian/Upper Bajocian boundary.
5. In terms of calcareous nannofossils, two significant bioevents were recorded in the time interval studied: the LOs of *Hexalithus magharensis* and *Carinolithus superbus*, both located within the Niortense Zone in the lowermost Upper Bajocian. In the JRi3 section, the LO of *H. magharensis* slightly precedes the LO of *C. superbus* (Fig. 3), and approximates the boundary between the NJT10a and NJT10b Calcareous nannofossil subzone boundary.
6. During the Early/Late Bajocian transition, some interesting environmental and palaeobiological events took place, such as the turnover of the ammonite assemblaage, the increase in diversity of nannofossils assemblages, the progressive increase of thin-shelled bivalves, a short $\delta^{13}C$ excursion toward light isotopic values, which are detectable in the JRi3 section. These events can be considered to be a proxy for high environmental stress.
7. In the JRi3 section several species of ammonites of great biostratigraphic value for the analysis of the Lower Bajocian/Upper Bajocian transition occur, many of which (*Subcollina ochoterenai, Normannites vulgaricostatus, Paviceras subcoronatum*, *Masckeites densus*. *M*. aff. *sturanii*, *M*. aff. *exilis*, *Sphaeroceras brongniarti* and *Caumontisphinctes polygyralis*) are described and figured herein for the first time from the Betic Cordillera
8. The dimorphic microconch pairs of *Cadomites* aff. *lissajousi* and *C. septicostatus* are indicated, described and figured for first time.

Appendix A

Alphabetical list of calcareous nannofossil species cited within the text:

Carinolithus superbus (Deflandre *in* Deflandre & Fert, 1954) Prins *in* Grün et al., 1974

Crepidolithus crassus (Deflandre *in* Deflandre & Fert, 1954) Noël, 1965

Cyclagelosphaera margerelii Noël, 1965

Discorhabdus criotus Bown, 1987

Discorhabdus ignotus (Górka, 1957) Perch-Nielsen, 1968
Discorhabdus striatus Moshkovitz & Ehrlich, 1976
Ethmorhabdus gallicus Noël, 1965
Hexalithus magharensis Moshkovitz & Ehrlich, 1976
Watznaueria britannica (Stradner, 1963) Reinhardt, 1964
Watznaueria manivitiae Bukry 1973

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