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Upper Barremian–lower Aptian charophyte biostratigraphy from Arrifes section (Algarve Basin, Southern Portugal): correlation with dinoflagellate cyst biostratigraphy

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ABSTRACT

The Arrifes section (Algarve Basin, Southern Portugal) has been studied from the viewpoint of charophyte biostratigraphy. The previous sedimentological studies in this section showed that it is built of the interbedding of continental and marine facies that contain both marine and continental palynomorphs (pollen, spores, and dinoflagellates), providing an excellent sedimentary context to perform direct correlations between marine and continental domains. In the present work, the identified charophyte biozones have been correlated with dinoflagellate biozones previously recognized in the Arrifes section, being the first time that these two biochronologies can be directly correlated. From the charophyte biostratigraphy viewpoint, two assemblages are distinguished. The older one is found between 65 and 135 m of the stratigraphic section, and it is composed of the species *Echinochara lazarii*, *Atopochara trivolvis* var. *triquetra*, *A. trivolvis* var. *trivolvis*, *Clavator grovesii* var. *jiuquanensis*, *Clavator harrisii* var. *harrisii*, *C. harrisii* var. *reyi*, and *C. harrisii* var. *zavialensis*. This assemblage belongs to the upper Barremian –lower Aptian *Clavator grovesii* var. *jiuquanensis* Eurasian biozone and also to the *Ascidiella cruciata-Pseudoglobator paucibracteatus* European biozone and it is described in beds with the dinoflagellate cyst *Subtilisphaera scabrata* (lower to lowermost upper Barremian) and *Odontochitina operculata* (from upper Barremian upwards). The younger charophyte assemblage is found between 135 and 155 m of the stratigraphic section, and it is composed of the species *A. trivolvis* var. *trivolvis*, *Clavator grovesii* var. *corrugatus*, *Clavator harrisii* var. *harrisii*, *C. harrisii* var. *reyi*, and *C. harrisii* var. *zavialensis*. This assemblage belongs to *Clavator grovesii* var. *corrugatus* biozone, previously assigned to upper Aptian (*Clavator grovesii* var. *lusitanicus* biozone). However, in the Arrifes section, this assemblage is found in beds assigned to the dinoflagellate cyst *Odontochitina operculata* (from upper Barremian–lower Aptian). The direct correlation of the base of the *C. grovesii* var. *corrugatus* biozone with the dinoflagellate cyst *O. operculata*, indicates that the base of the *Clavator grovesii* var. *corrugatus* biozone is in the upper lower Aptian, which is slightly older than was previously suggested, and it is extended until the middle Albian.

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1. Introduction

Charophyte fructifications (utricles) of the Clavatoraceae family are one of the main fossil groups used for the biostratigraphic characterization of Lower Cretaceous continental record (e.g., Grambast, 1974; Rey and Ramalho, 1974; Martín-Closas, 1989; Musacchio, 1989, 2000; Schudack, 1993; Trabelsi et al., 2016; Sanjuan et al., 2021). In the last decades, detailed biozonations have been proposed, especially in European and Chinese basins (e.g., Wang and Lu, 1982; Riveline et al., 1996; Mojon, 1996, 2002; Martín-Closas et al., 2009; Pérez-Cano et al., 2022a). However, few data can allow a precise correlation of the charophyte biozonations with the coeval standard marine biozonations, as only in some cases both domains are correlated. Continental-marine correlations can be performed in three different manners. 1) Direct correlations are established when continental and marine fossils are found interbedded or together in the same stratigraphic section or the same bed. 2) Indirect correlations are made after performing a lithostratigraphic equivalence between/among different sections, describing charophytes and marine organisms, respectively. 3) The compilation correlation is the most common type of marine-continental correlation, and it is carried out on a regional scale, using regional geological data, such as sequence stratigraphy or the age of the marine units that overlay and underlay the non-marine ones. The correlation between charophyte biozones with their coeval standard marine biozones for the Lower Cretaceous Series was first summarized by Riveline et al. (1996). In recent years, the correlation has been improved for the Barremian–lower Aptian timespan by establishing direct correlations (e.g., Martín-Closas et al., 2009) or using chemostratigraphic methods, such as Sr-isotope stratigraphy (Pérez-Cano et al., 2022a).

The present work is focused on the upper Barremian–Aptian charophyte biostratigraphy. According to the extant charophyte biozonation, three biozones are described for this stratigraphic interval. The *Ascidiella cruciata-Pseudoglobator paucibracteatus* European biozone and the *Clavator grovesii* var. *jiuquanensis* Eurasian biozone are almost equivalent and their ages are upper lower Barremian–lower Aptian and upper Barremian–lower Aptian, respectively (Pérez-Cano et al., 2022a). The *Clavator grovesii* var. *corrugatus* biozone overlies the previous biozones, and its age is considered as late Aptian – middle Albian (Riveline et al., 1996; Pérez-Cano et al., 2022a). However, the boundary between both biozones is usually difficult to describe and correlate with the marine domain due to the recorded marine transgression between the late Barremian–lower Aptian in the Tethyan Realm. This transgression reached its peak point in the early Aptian (e.g., Hardenbol et al., 1998; Wissler et al., 2003; Pictet et al., 2015; Bover-Arnal et al., 2016), restricting the deposition of continental facies to few basins, where both biozones can be found without sedimentary discontinuities (e.g., Trabelsi et al., 2016). The main goal of this work is to improve the correlation and the equivalence between integrated continental and marine biozonations in the upper Barremian–Aptian time interval. The charophyte assemblages from the Arrifes section (Algarve, Southern Portugal) have been studied to achieve this objective. This section is composed of the interbedding of shallow marine to transitional continental marls, limestones, and minor sandstones and conglomerates, which yield a significant diversity of terrestrial and marine palynomorphs, including spores, pollen grains, and dinoflagellate cysts, the latter already used as biostratigraphic markers (Mendes et al., 2023) providing a unique context to establish direct correlations between terrestrial and marine domains. The present work proposes a direct correlation between the charophyte biozones described in the study of charophyte assemblages with the dinoflagellate biozones previously identified by Mendes et al. (2023). This correlation improves the application, accuracy, and utility of extant upper Barremian–Aptian charophyte biozones.

2. Geological setting

The Algarve Basin is located in southernmost Portugal (Fig. 1A), and its sedimentary infilling is composed of rocks that range from the Upper Triassic to the recent (Manuppella et al., 1988; Fernandes et al., 2013; Terrinha et al., 2013). The first sedimentary cycle is of the Late Triassic–earliest Jurassic age corresponding to the initial continental rifting phase of Pangaea breakup in the Iberian range and formation of the Central Atlantic. The latter comprises a succession of continental red beds, followed by evaporites, and is capped by volcano-sedimentary deposits related to the Central Atlantic Magmatic Province (Verati et al., 2007; Vilas-Boas et al., 2022). The following sedimentary cycle consists of Sinemurian to Tithonian shelf carbonates deposited during the passive margin phase (Rocha, 1976; Manuppella et al., 1987; Marques and Rocha, 1988a, 1988b; Azerêdo et al., 2003; Dommergues et al., 2011; Borges et al., 2011, 2012). Changes in the thickness and facies of the carbonate sequences, together with regional unconformities and hiatuses, are attributed either to carbonate allocyclic processes, global sea level variations or regional tectonic events (Manuppella, 1988; Terrinha et al., 2013; Ramos et al., 2016).

The Lower Cretaceous sedimentary interval (Berriasian to Cenomanian) is also included in the passive margin succession. However, it differs from the Jurassic sequences due to its mixed carbonate and siliciclastic composition (Rey, 2006, 2009). Berriasian marls and dolomites are found at the base of the Lower Cretaceous sedimentary interval, and it is upwards followed by Valanginian to Barremian marls, dolomites, sandstones, and mudstones deposited in nearshore and continental settings. The Aptian to lower Albian sedimentary sequences comprise, at the base, variegated mudstones and carbonates of nearshore to lagoonal settings, followed by transgressive marl and limestone cycles. Upper Albian to Cenomanian strata are only known in the eastern Algarve Basin, where they are represented by shallow water carbonate platform limestones interbedded with marls and dolomites. The age determinations of the Lower Cretaceous strata were mostly based on foraminifera biostratigraphy (Rey and Ramalho, 1974; Ramalho and Rey, 1981; Rey, 1983, 1986, 2006; Correia, 1989, 2009) and palynology (Berthou, 1983; Berthou and Leerevel, 1990; Hochuli et al., 2006; Heimhofer, 2007; Mendes et al., 2023).

In the region of Albufeira (Fig. 1B), the Lower Cretaceous carbonates that comprise the Arrifes section can be observed on the subvertical and vertical strata outcropping on the coastal cliffs (Fig. 1C). These strata were deformed due to the tectonic inversion of the Algarve Basin, which caused the compression and the uplift of the nearby Albufeira diapir (Terrinha, 1998; Terrinha et al., 2013; Ramos et al., 2016). The present work follows the most recent sedimentological and age determination, based on dinoflagellates, of the Arrifes section carried out by Mendes et al. (2023). The section probably correlates with the Salema, Barrancão and Burgau Formations (Fig. 1E). However, there is a lateral change between the western part of the Algarve Basin and the Central part, challenging a clear attribution of the succession in the Arrifes section to particular lithostratigraphic units.

3. Materials and methods

The Arrifes section is located on the coastal cliffs at the western part of Albufeira; base: 37°04′43.12″ N, 8°16′11.10 W; top: 37°04′35.33″ N, 8°16′35.54″ W (Fig. 1B-C). The section is 194 m-thick, and it is mainly composed of marls, limestones, and marly limestones. Sandstones and conglomerates are locally found (Figs. 1C, D and 2). For the present work, between 1 and 3 kg of

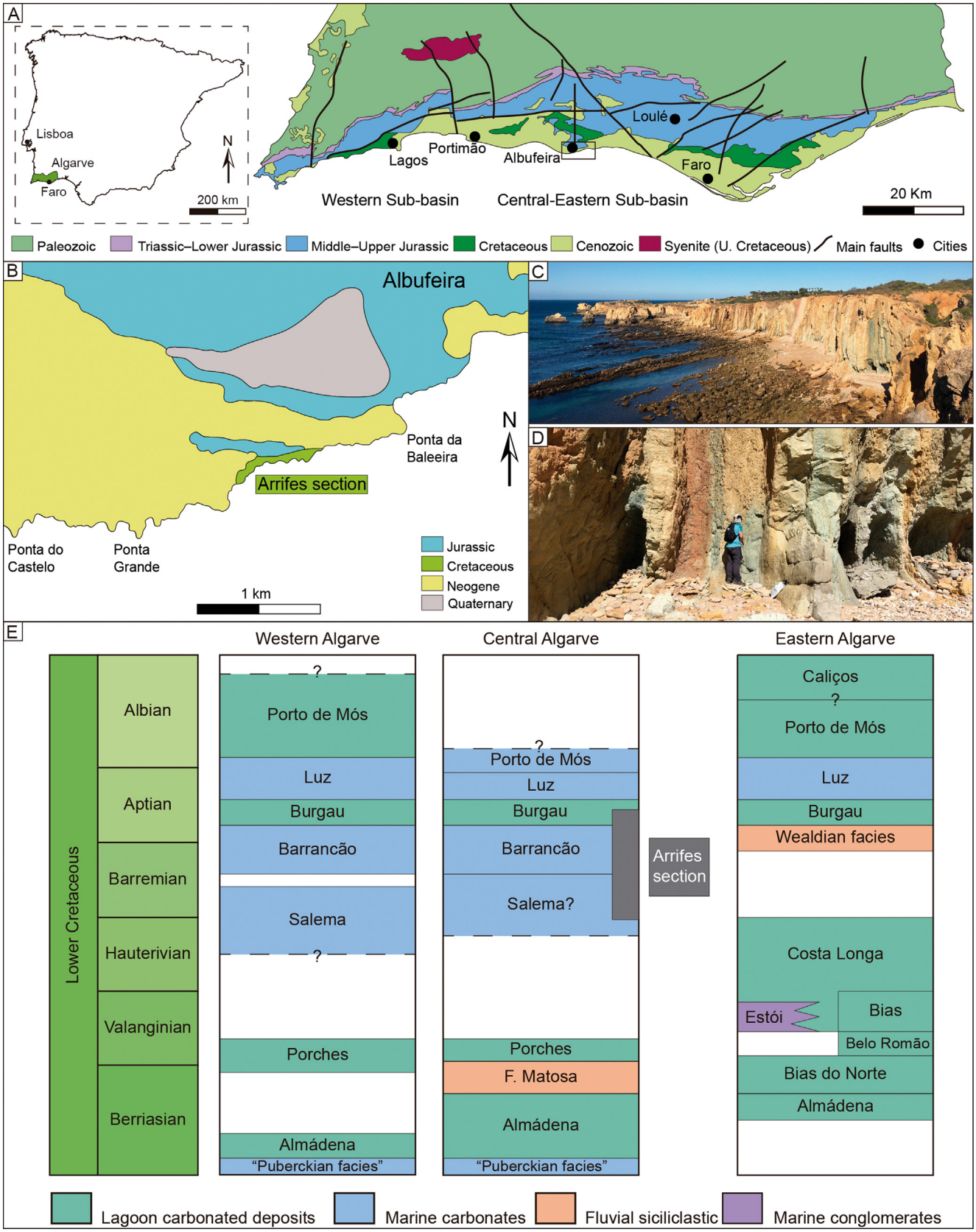

Fig. 1. A) Location and geologic map of the Algarve Basin (modified from Oliveira et al., 1992; Manuppella, 1992; Ramos et al., 2016). The squared area corresponds to the zone represented in Fig. 1C. B) Simplified map of the Albufeira region, showing the location of the Arrifes section (modified from Rocha et al., 1989). C) Outcrop of the Arrifes section. D) Detail of the Arrifes section. E) Lithostratigraphy of the Algarve Basin (adapted from Rey, 2006, Terrinha et al., 2013; Mendes et al., 2023) and the stratigraphic interval assigned to the Arrifes section in this study. The assignment of the lithostratigraphic units from the Arrifes section is tentative.

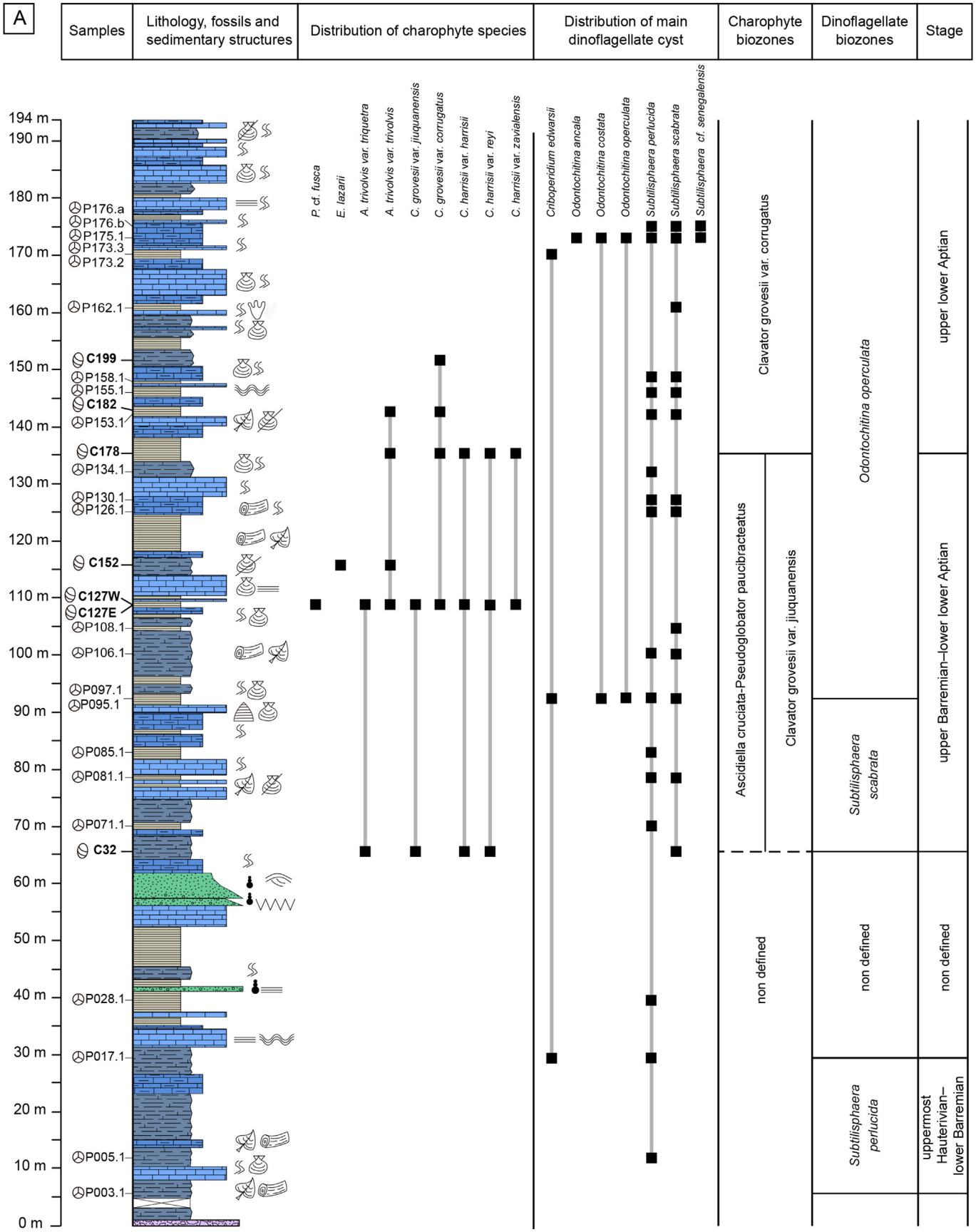

Fig. 2. A) Stratigraphic log of Arrifes section with the stratigraphic position of the studied samples, and the charophyte and dinoflagellate cysts biostratigraphy (modified from Mendes et al., 2023). The palynological sample's position and results were provided by Mendes et al. (2023). B) Key to Figure A.

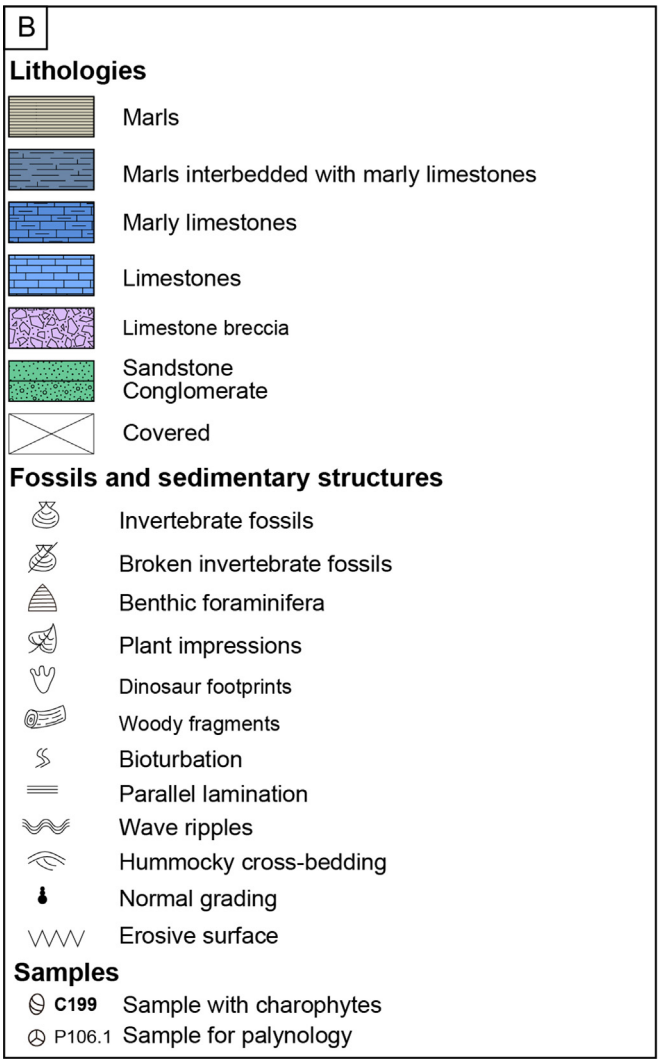

Fig. 2. (*continued*).

marls were collected from 20 marl beds along the entire section. Samples were prepared in the Palaeontological Laboratory of the Departament de Dinàmica de la Terra i de l'Oceà, Universitat de Barcelona. Each sample was put in a solution of water, oxygen peroxide (H_2O_2; eliminates the organic matter), and sodium carbonate (Na_2CO_3; deflocculates the clays). After a few days, the samples were sieved using three meshes of 1000, 500, and 200 μm. Once the samples were dried, the microfossils (including charophytes fructifications and thalli, ostracods, vertebrate remains, and other associated microfossils) were hand-picked using small brushes under a binocular microscope AmScope SE305R-PZ-LED under the magnifications of ×10, ×20, ×30, and ×60. The picked up charophytes and other fossils are temporarily stored at Institut Català de Paleontologia Miquel Crusafont and will be housed in the Geological Museum of Portugal (Lisbon) once their study is concluded. Figured specimens have provisional references (Arr-Ch-1 to Arr-Ch-37) that will have their equivalence once they are definitively housed. Appendix 1 shows the equivalence of figured specimens with this provisional reference.

4. Systematic charophyte palaeobotany

The taxonomy and systematic discussion of charophytes are not the focus of this study. This topic has been extensively discussed over the last decades (e.g., Feist and Wang, 1995; reply by Martín-Closas and Schudack, 1997), resulting in the establishment of two different visions, i.e., the phenetic and the cladistic vision. The present study follows the phylogenetic approach developed by Martín-Closas (1989, 1996) and Schudack (1993).

Rey and Ramalho (1974) first described Lower Cretaceous charophytes in the Algarve Basin, particularly in the Barremian–Aptian deposits of the western part of the basin (Burgau and Luz sections). Later, Grambast-Fessard (1980a, 1980b, 1986) described Aptian (and Albian?) charophyte flora also in the western part of the basin (Luz and Zavial sections). These studies enabled the description of *Ascidiella reticulata* var. *irregularis* (Grambast-Fessard, 1986) Martín-Closas 1996, which is, until now, only found in the Algarve.

Charophyte remains in the Arrifes section were found in seven samples, that were gathered in the middle to upper part of the stratigraphic section (Fig. 2). The charophyte assemblage is composed of 11 taxa, including charophyte fructifications and thalli (Figs. 3 and 4; Appendix 2). Most of the recovered charophyte fructifications show superficial erosion and are sometimes broken suggesting lateral transport. Charophyte thalli are very rare and when occur they are very small portions. These taphonomical features of the fructifications and thalli indicate some degree of biostratinomic selection before deposition (see e.g., Vicente et al., 2016; Pérez-Cano et al., 2022b); for that reason, the studied assemblages are usually considered parautochthonous (locally allochthonous), suggesting a short-term transport towards de inner carbonate platform. The abundance of charophyte fructifications in each sample is found in Appendix 2.

4.1. Charophyte fructifications

Division Charophyta Migula, 1897
Class Charophyceae Smith, 1938
Order Charales Lindley, 1836
Family "Porocharaceae" (Grambast, 1962) emend. Schudack, 1993

Genus *Porochara* (Mädler, 1955) emend. Schudack, 1986
Morphogroup *Porochara fusca* sensu Martín-Closas (1989, 2000) and Schudack (1993)

Porochara cf. ***fusca***
Fig. 3A–B

1952 *Aclistochara fusca* nov. sp. – Mädler p. 19–20, Pl. A, figs. 22–25.
1955 *Porochara fusca* (Mädler 1952) nov. comb. – Mädler, p 271.

Description. Five porocharacean gyrogonites have been found in sample C127W (Appendix 2). They are small (<500 μm height and wide), and ellipsoidal. The base is rounded, and the apex has an apical pore (Fig. 3B). The number of convolutions varies between 8 and 10. The inner part is recrystallized, impeding the observation of the basal plate, and consequently, these gyrogonites could be also attributed to the genus *Feistiella* Schudack, 1986. Nevertheless, they have been assigned to the genus *Porochara* as no *Feistiella* species are described in the Barremian nor the Aptian and there are no *Festiella* species with a width or length <500 μm. The species assignation remains as 'coffer to', as the number of gyrogonites is very low to make a clear morphometric analysis and identification.

Chronostratigraphic distribution. The oldest occurrence of this species is in the Bajocian, Middle Jurassic (Tiss et al., 2019) and it is extended until the and Berriasian (Martín-Closas, 2000). Its association with *Clavator grovesii* var. *jiuquanensis* (Fig. 2; Appendix 2) may indicate that this species has a very long timespan.

Family Clavatoraceae Pia, 1927
Subfamily Atopocharoidae (Grambast, 1968) emend. Martín-Closas ex Schudack, 1993

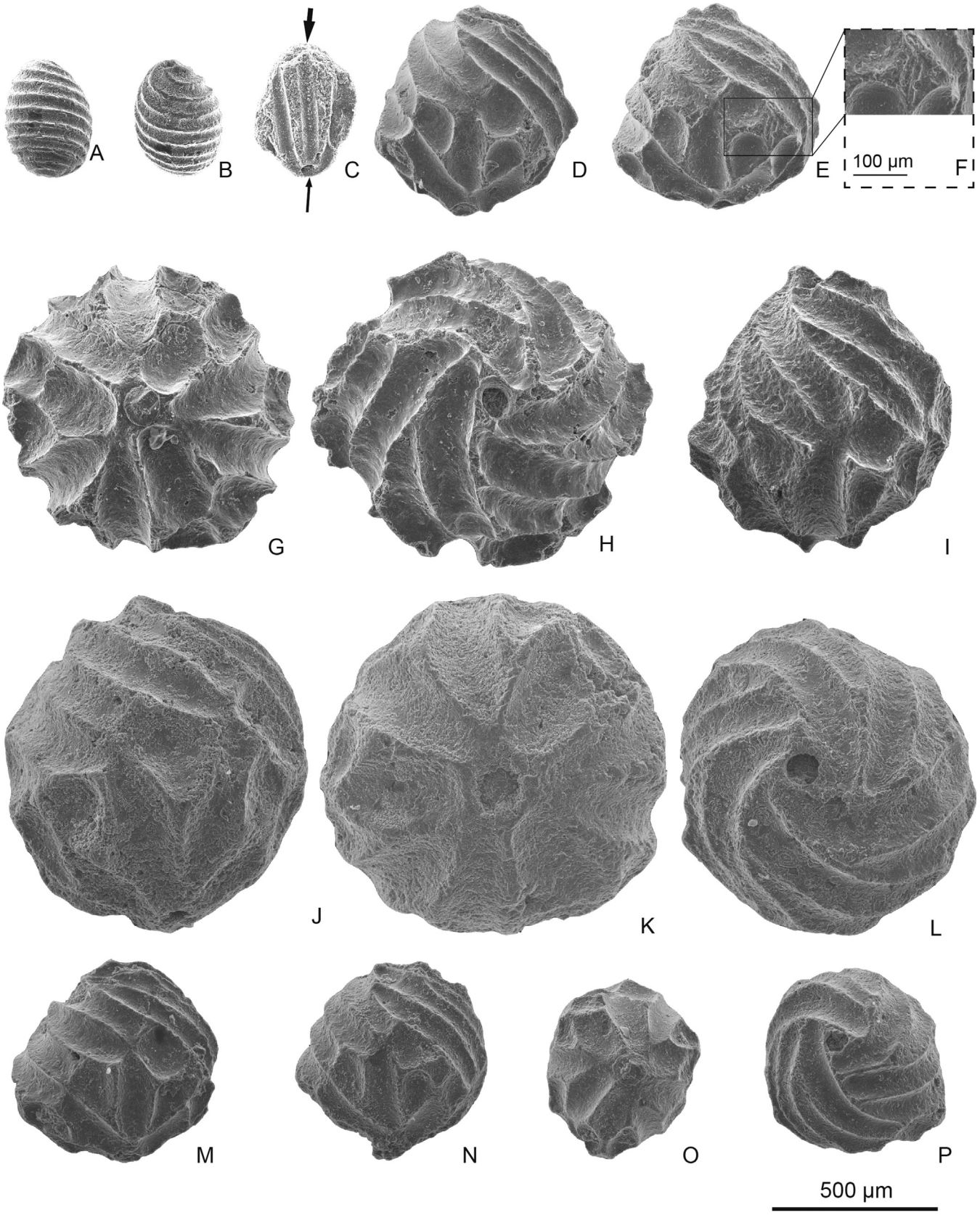

Fig. 3. SEM pictures of charophytes from the Arrifes section: *Porochara*, *Echinochara*, and *Atopochara*. A–B) *Porochara* cf. *fusca* (sample C127W; specimen Arr-Ch-1). A) Lateral view. B) Oblique-apical view, showing the apical pore. C) *Echinochara lazarii* (sample C152; specimen Arr-Ch-2). Wide arrow marks the apical neck of the gyrogonite. Thin arrow marks the basal rounded cell of the trifurcation. D–H) *Atopochara trivolvis* var. *triquetra* (sample C127W). D–E) Lateral view (specimens Arr-Ch-3 and Arr-Ch-4); F) Antheridium shield; G) Basal view (specimen Arr-Ch-5); H) Apical view (specimen Arr-Ch-6). I–P) *Atopochara trivolvis* var. *trivolvis*. I) Lateral view (sample C127W; specimen Arr-Ch-7). J–P) *Atopochara trivolvis* var. *trivolvis* (sample C178). J–L) Bigger specimens. J) Lateral view (specimen Arr-Ch-8); K) Basal view (specimen Arr-Ch-9); L) Apical view (specimen Arr-Ch-10). M–P) Smaller specimens. M–N) Lateral view (specimens Arr-Ch-11 and Arr-Ch-12); O) Basal view (specimen Arr-Ch-13); P) Apical view (specimen Arr-Ch-14).

Genus *Echinochara* (Peck, 1957) emend. Pérez-Cano, Bover-Arnal et Martín-Closas, 2020

Echinochara lazarii (Martín-Closas, 2000) Mojon ex Pérez-Cano, Bover-Arnal et Martín-Closas, 2020
Fig. 3C

2000 *Echinochara peckii* var. *lazarii* nov. var. – Martín-Closas, p. 70, Pl. 6: figs. 1–8, Pl. 7: figs. 1–6.
2020 *Echinochara lazarii* (Martín-Closas, 2000) comb. nov. Mojon ex Pérez-Cano, Bover-Arnal et Martín-Closas – Pérez-Cano et al. p. 6–8, figs. 6–9.

Description. A few utricles of this species are only found in sample C152 (Appendix 2). This utricle is composed of two superimposed series of bract-cells that cover the gyrogonite in its abaxial part (see Pérez-Cano et al., 2020). However, all the specimens of this taxon found in the Arrifes section only preserve the inner series of the utricle, which is composed of the characteristic fork-like unit formed of three long cells basally attached to a small and rounded cell. Sometimes the cast of the non-calcified gyrogonite is found attached. This species is widely distributed in the Western Tethyan basins (Pérez-Cano et al., 2020 and references therein), but this is the first time that it is described in Portugal.

Chronostratigraphic distribution. This species is described between the lower Barremian and lower Aptian (Martín-Closas, 2009; Pérez-Cano et al., 2022a).

Genus *Atopochara* (Peck, 1938)

Atopochara trivolvis (Peck, 1938) emend. Martín-Closas, 1996
Atopochara trivolvis var. ***triquetra*** (Grambast, 1968) Martín-Closas, 1996
Fig. 3D–H

1968 *Atopochara trivolvis* subsp. *triquetra* subsp. nov. – Grambast, p. 9, Pl. 3, figs. 14A–C.
1996 *Atopochara trivolvis* var. *triquetra* (Grambast, 1968) Martín-Closas nov. comb. – Martín-Closas, p. 272, Firsg. 8.

Description. Few utricles of this variety only appear in samples C32, C127E, and C127W (Appendix 2). In samples C127W and C127E, this variety is associated with *Atopochara trivolvis* var. *trivolvis*, being the latter dominant in the *Atopochara trivolvis* population (Appendix 2). Studied specimens correspond to the advanced morphotype defined by Martín-Closas and Grambast-Fessard (1986) and are distinguished by the observation of a very small antheridium shield imprint (Fig. 3F).

Chronostratigraphic distribution. This species firstly appears in the Hauterivian, where it is found associated with *Atopochara trivolvis* var. *ancora* (Grambast, 1967) Martín-Cloas, 1996 (e.g., Martín-Closas and Salas, 1994). Homogeneous populations are firstly found at the base of the Barremian (Martín-Closas and Salas, 1994; Pérez-Cano et al., 2022a). In the upper Barremian–lower Aptian it is found associated with *Atopochara trivolvis* var. *trivolvis* Peck, 1938 (see Pérez-Cano et al., 2020, 2022a).

Atopochara trivolvis var. ***trivolvis*** Peck, 1938
Fig. 4I–P

1938 *Atopochara trivolvis* n. sp. – Peck, p. 173–176, Fig. 1; Pl. 28, figs. 5–12.
1996 *Atopochara trivolvis* var. *trivolvis* – Martín-Closas, p. 113–116, Pl. 9, figs. 9–10.

Description. These utricles are especially abundant in sample C178, where it forms homogeneous assemblages with bimodal distribution (Fig. 3J–L and M–P, respectively), but it is also dominant in samples C127E and C127W associated with *A. trivolvis* var. *triquetra* (Appendix 2). This variety is distinguished from the previous one by having a more packed structure, more spiralized long cells, and very small to absence of the imprint of the antheridium shields.

Chronostratigraphic distribution. The older occurrence of this variety is in the upper Barremian, where few utricles of this species are found in a population dominated by *Atopochara trivolvis* var. *triquetra* (Pérez-Cano et al., 2020, 2022a). Homogeneous populations of this variety are found between the lower Aptian and the middle Albian (e.g., Martín-Closas, 2000; Álvarez-Parra et al., 2021).

Subfamily Clavatoroidae (Grambast, 1969) emend. Martín-Closas ex Schudack, 1993

Genus *Clavator* (Reid and Groves, 1916) emend. Martín-Closas ex Schudack, 1993

Clavator grovesii Harris, 1939
Clavator grovesii var. ***jiuquanensis*** (Wang, 1965) Grambast, 1970 emend. Martín-Closas, 1996
Fig. 4A–F

1965 *Perimneste jiuquanensis* sp. nov. – S.Wang, p. 467, Pl. 1.
1970 *Clypeator jiuquanensis* (S. Wang 1965) nov. comb. – Grambast, p.1965, Fig. D; Pl. 3, figs. 1–5.
1973 *Clypeator europaeus* n. sp. – Mädler in Neagu and Georgescu-Donos, p. 178, Pl. I, fig. 7–8; Pl. II, figs. 1–9.
1980a *Clypeator europaeus* Mädler – Grambast-Fessard, p. 37–38, Fig. 1–2; Pl. 1, figs. 1–9; Pl. 3, fig. 2.
1996 *Clavator grovesii* var. *jiuquanensis* (Wang, 1965) Grambast, 1970 emend. – Martín-Closas, p. 278, Firsg. 12.

Description. This species is common in the lower part of the stratigraphic section, being very abundant in samples C127E and C127W (Appendix 2). It is characterized by having a bilateral symmetry with two lateral and prominent cells-shields in which the 12 cells have the same length. Some specimens can have slightly twisted cells in the lateral shields with 13 cells (Fig. 4B–D). They are considered as intermediated morphologies between *C. grovesii* var. *jiuquanensis* and the *C. grovesii* var. *corrugatus*, i.e., *C. grovesii* var. *jiuquanensis* advanced or *C. grovesii* var. *corrugatus* primitive.

Chronostratigraphic distribution. This variety appears in the lower upper Barremian (Pérez-Cano et al., 2022a) and it is found in the upper Barremian and Aptian in the whole Eurasia (e.g., Martín-Closas, 2015; Li et al., 2020).

Clavator grovesii var. **corrugatus** (Peck, 1941) Martín-Closas, 1996
Fig. 4G–L

1941 *Perimneste corrugata* n. sp. – Peck, p. 295–297, Pl. 42, figs 15–24.
1962 *Clypeator corrugatus* (Peck, 1941) nov. comb. – Grambast, p. 295.
1980a *Clypeator lusitanicus* n. sp. – Grambast-Fessard, p. 39–41, Fig. 3; Pl. 1, fig. 10–12; Pl. 2, figs. 1–5; Pl. 3, fig 3–5.
1996 *Clavator grovesii* var. *lusitanicus* (Grambast-Fessard, 1980a) comb. nov. – Martín-Closas, p. 278, fig. 11.
1996 *Clavator grovesii* var. *corrugatus* (Peck, 1941) nov. comb. – Martín-Closas, p. 278, fig. 11.
2000 *Clavator grovesii* var. *corrugatus* (Peck, 1941) Martín-Closas, 1996 – p. 142–145, Pl. 14, figs. 10–12.

Description. The utricle of this species shows the characteristic bilateral symmetry, with two lateral bract-cell shields that are characterized by having 14 twisted cells. It first appears in samples C127E and C127W, where it represents <10% of the total population which is dominated by *Clavator grovesii* var. *jiuquanensis* (Appendix 2). *C. grovesii* var. *corrugatus* forms homogeneous populations in sample C178 upwards.

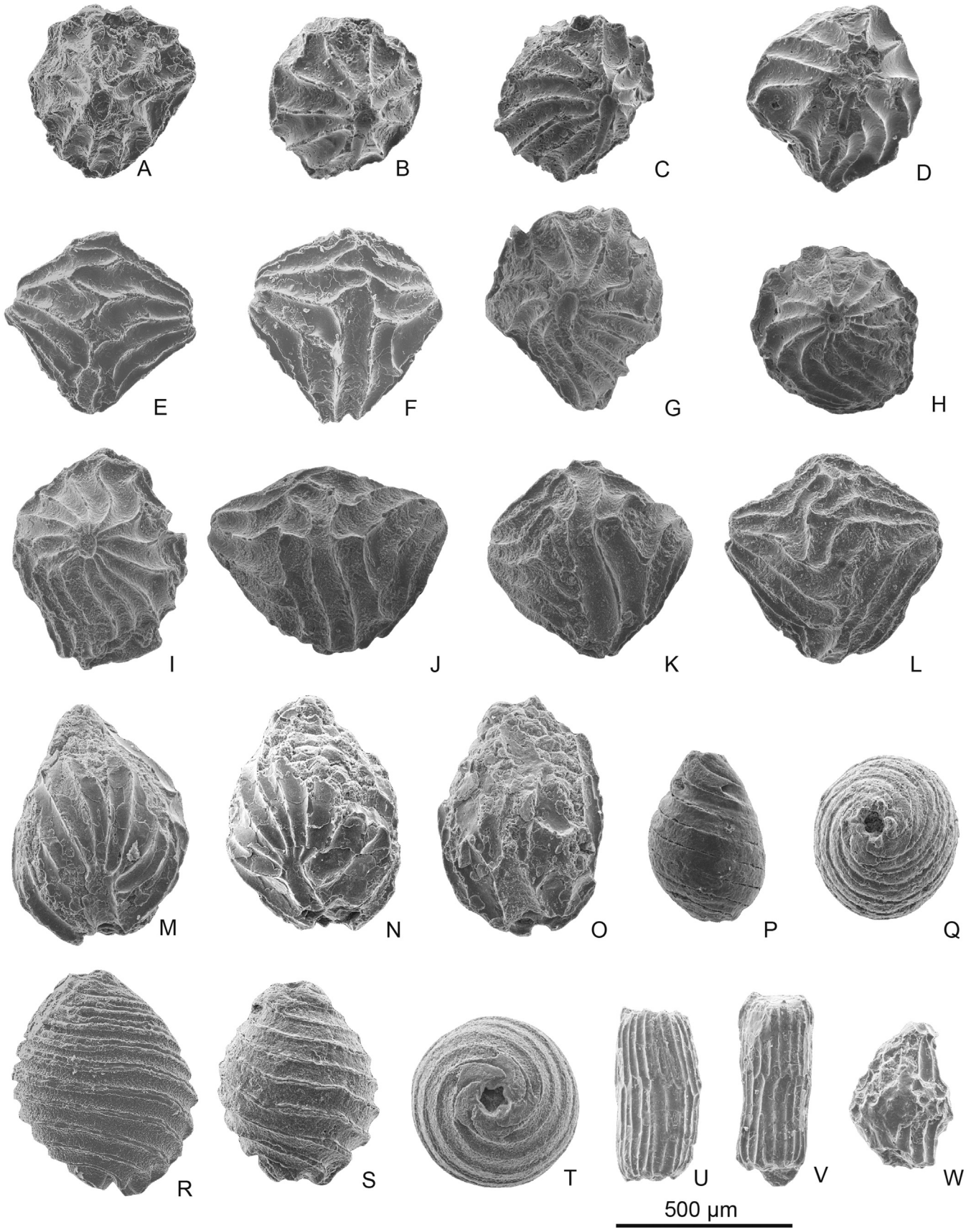

Fig. 4. SEM pictures of charophytes from the Arrifes section: utricles of genus *Clavator* and thalli portions. A–F) *Clavator grovesii* var. *jiuquanensis*. I) Lateral view of the typical morphotype (sample C127W; specimen Arr-Ch-15). B–D) Lateral views of the intermediate morphotype between *C. grovesii* var. *jiuquanensis* and *C. grovesii* var. *corrugatus*,

In the Algarve Basin, this species was described as *Clypeator lusitanicus* by Grambast-Fessard (1980a). Later, Soulié-Märsche (1994) compared the type population of *Clypeator corrugatus* with *Clypeator lusitanicus*, and observed that the morphology between both taxa was very similar. Following the strong similarities between both taxa, they were synonymized by Martín-Closas (2000).

Chronostratigraphic distribution. This taxon is found between the Aptian and lower-middle Albian in Europe of Western Europe and United States (Martín-Closas, 2000, 2015 and references therein).

Clavator harrisii (Peck, 1941) emend. Martín-Closas, 1996
Clavator harrisii var. ***harrisii*** Peck, 1941
Fig. 4M–O

1941 *Clavator harrisii* nov. sp. – Peck, p. 292–294, Pl. 42, figs. 25–37.
1996 *Clavator harrisii* var. *harrisii* Peck – Martín-Closas, p.278–279.

Description. Small populations of this species are found in samples C32, C127W, C127E, and C178. The utricles show the characteristic bilateral symmetry with two fans of cells in a lateral position. The posterior part shows strong similarities with the Barremian specimens described in Pérez-Cano (2021). It is always associated with *C. harrisii* var. *reyi* and *C. harrisii* var. *zavialensis*, being the latter taxa the dominant variety of the *C. harrisii* populations (Appendix 2).

Chronostratigraphic distribution. The chronostratigraphic distribution of this taxon is lower Valanginian–middle Albian. In the lower Valanginian, it appears associated with the older variety, *Clavator harrisii* var. *dongjingensis* (Hu and Zeng, 1981) Martín-Closas, 2000. *Clavator harrisii* var. *harrisii* usually forms homogeneous assemblages in the lower Barremian (Martín-Closas, 2000; Pérez-Cano et al., 2020, 2022a) but sometimes also in the Aptian (De Sosa Tomás et al., 2017) and in the lower-middle Albian (Álvarez-Parra et al., 2021). However, in the upper Barremian–lower Aptian it is frequently found associated with *Clavator harrisii* var. *reyi* (e.g., Martín-Closas, 2000; Pérez-Cano et al., 2020, 2022a), while in the upper Aptian to lower-middle Albian it is usually found forming mixed populations with *Clavator harrisii* var. *zavialensis* (e.g., Martín-Closas, 2000; Tibert et al., 2013; De Sosa Tomás et al., 2017).

Clavator harrisii var. ***reyi*** (Grambast-Fessard, 1980a) Martín-Closas, 1996
Fig. 4P–R

1980a *Stellatochara reyi* n. sp. – Grambast-Fessard, p. 42–44, Pl. 3, figs. 6–9.
1996 *Clavator harrisii* var. *reyi* (Grambast-Fessard, 1980a) nov. comb. – Martín-Closas p. 279.
2005 *Luzochara reyi* (Grambast-Fessard 1980a) nov. comb. – Pereira and Cabral, p. 173–178, Pl. 1, figs. 1–6.

Description. This species is found in samples C32, C127E, C127W, and C178. The specimens are characterized by only the gyrogonite with the convex cells separated by slightly undulated structures. In samples C127W and C178, there are observed gyrogonites whose cells show different degrees of calcification, showing convex and concave cells in the same gyrogonite (see Fig. 4R). These gyrogonites are considered as intermediate morphotypes between *C. harrisii* var. *reyi* and *C. harrisii* var. *zavialensis* and they are referred them as *Clavator harrisii* var. *reyi* advanced or *Clavator harrisii* var. *zavialensis* primitive.

Chronostratigraphic distribution. The first occurrences of this taxon are in the lower Barremian, where it rarely appears associated to *C. harrisii* var. *harrisii*, which is the dominant variety (Pérez-Cano et al., 2020, 2022a). *Clavator harrisii* var. *reyi* is especially abundant and dominates the *Clavator harrisii* populations in the upper Barremian–lower Aptian where it forms homogeneous populations (e.g., Martín-Closas, 2000; Pereira and Cabral, 2005; Vicente and Martín-Closas, 2013) or can be associated to *C. harrisii* var. *harrisii*, being *C. harrisii* var. *reyi* dominant upon *C. harrisii* var. *harrisii* (Pérez-Cano et al., 2020, 2022a).

Clavator harrisii var. ***zavialensis*** (Grambast-Fessard, 1980a) Martín-Closas, 1996
Fig. 4S–T

1980 *Stenochara zavialensis* n. sp. –Grambast-Fessard, p. 44, Pl. 3, figs. 10–13.
1996 *Clavator harrisii* var. *zavialensis* (Grambast Fessard, 1980a) nov. comb. – Martín-Closas, p. 279.

Description. *Clavator harrisii* var. *zavialensis* represents the last variety of the evolutionary lineage of *Clavator harrisii* (see Martín-Closas, 1996) and it is characterized by preserving only the gyrogonite that has slightly concave spiralled units separated by a double ridge. The Ringstruktur-calcification pattern, described by Schudack (1993) for clavatoroid gyrogonites is often visible at the apical tips of the spiral cells. In the Arrifes section, this taxon always appears associated to *C. harrisii* var. *reyi* and *C. harrisii* var. *harrisii*.

Chronostratigraphic distribution. This variety of *Clavator harrisii* is found in the upper Aptian–lower Albian, when it usually forms homogeneous assemblages (see e.g., Martín-Closas, 2000; Trabelsi et al., 2016).

4.2. Charophyte thalli

Genus *Munieria* (Deecke, 1883) emend. Granier in Granier et al., 2015

Munieria grambastii Bystrický, 1976
Fig. 4U

1976 *Munieria grambastii* n. sp. – Bystrický, p. 48–54, Pl. I, figs. 1–14; Pl. II, figs. 1–16; Pl. IV, fig. 2.
2020 *Munieria grambastii* Bystrický 1976 – Pérez-Cano et al. p. 21–22, Firgghgs. 16A–G, Fihug. 17A–K

Description. A few small portions of this thallus (isolated internodes) are found in samples C127E and C127W, C178, and C182. The biological affinity of *Munieria* has been extensively discussed, as it has been attributed to charophytes (e.g., Martín-Closas, 2000; Pérez-Cano et al., 2020) or dasylacladeans (Feist et al., 2003). The interdigitation of the cortical cells in the middle part of the internode and the inner growth of the internode (Martín-Closas, 2000; Pérez-Cano et al., 2020; respectively), demonstrated its pertaining

(*C. grovesii* var. *jiuquanensis* advanced or *C. grovesii* var. *corrugatus* primitive). B–C) (sample C127E; specimens Arr-Ch-16 and Arr-Ch-17); D) sample C127W; specimen Arr-Ch-18) E) Abaxial view (sample C127W; specimen Arr-Ch-19); F) Adaxial view (sample C127W; specimen Arr-Ch-20). G–L) *Clavator grovesii* var. *corrugatus* (sample C178). G–I) Lateral view, showing different morphologies of the shield (specimens Arr-Ch-21, Arr-Ch-22, and Arr-Ch-23). J–K) Adaxial view (specimens Arr-Ch-24 and Arr-Ch-25). L) Abaxial view (specimen Arr-Ch-26). M–O) *Clavator harrisii* var. *harrisii* (sample C127W). M–N) Lateral view. Each specimen shows different morphologies of the lateral fan (specimens Arr-Ch-27 and Arr-Ch-28). P) Adaxial view, showing the phylloid imprint and different cells at the top that completely cover the gyrogonite in the adaxial part (specimen Arr-Ch-29). P–Q) *Clavator harrisii* var. *reyi*. P) Lateral view (sample C32; specimen Arr-Ch-30); Q) Apical view (sample C178; specimen Arr-Ch-31). R) Lateral view of the morphotype between *C. harrisii* var. *reyi* and *C. harrisii* var. *zavialensis* (*C. harrisii* var. *reyi* advanced or *C. harrisii* var. *zavialensis* primitive), (sample C127W; specimen Arr-Ch-32). S–T) *Clavator harrisii* var. *zavialensis*. S) Lateral view (sample C178; specimen Arr-Ch-33). T) Apical view (sample C127W; specimen Arr-Ch-34). U–W) Charophyte thalli. U–V) *Munieria grambastii* (sample C127W, specimens Arr-Ch-35 and Arr-Ch-36, respectively). W) *Clavatoraxis* sp. (sample C127W, specimen Arr-Ch-37).

to the Clavatoraceae family. This thallus morphology is associated with some species of the genus *Clavator* except *Clavator harrisii*.

Genus *Clavatoraxis* Martín-Closas et Diéguez, 1998

Clavatoraxis sp.
Fig. 4V

Description. This thallus morphology has been found in samples C127W, and C178. It consists of a corticated thallus with the characteristic hemispherical spine-cell rosettes upon the cortical cells. The portions are very short, impeding their identification at the specific level. This thallus morphology has been associated to the species *Atopochara trivolvis* (e.g., Martín-Closas, 2000) and *Clavator harrisii*, the latter due to the anatomical connection between both organs (e.g., De Sosa Tomás et al., 2017; Pérez-Cano, 2021).

5. Charophyte biostratigraphy and correlation with marine domain

The present work follows the charophyte biozonation proposed by Riveline et al. (1996) and later modified by Martín-Closas et al. (2009) and Pérez-Cano et al. (2022a). These biozones are partial range biozones, i.e., defined by the FAD of index species (or at the first homogeneous population in the case of the anagenetic lineages), but with the inclusion of several other species that enabled to identify of the biozone in the case that the index species is not observed. By the way, these biozones can be considered equivalent to assemblage biozones or Oppelzones. Two clavatoracean assemblages with biostratigraphic interest are distinguished in the middle to upper part of the studied Arrifes section and are correlated with the dinoflagellate cyst biozones previously described in the section (Fig. 2).

5.1. Upper Barremian–lower Aptian

The lower assemblage is described between 65 m and 135 m of the stratigraphic section (Fig. 2), and it is characterized by the association of *Echinochara lazarii*, mixed populations of *Atopochara trivolvis* var. *triquetra* and *Atopochara trivolvis* var. *trivolvis*, mixed populations of *Clavator grovesii* var. *jiuquanensis* and *Clavator grovesii* var. *corrugatus* (rare) and intermediate morphotypes between both taxa, and mixed populations of *Clavator harrisii* var. *harrisii*, *Clavator harrisii* var. *reyi*, and *Clavator harrisii* var. *zavialensis*, and intermediate morphotypes between *C. harrisii* var. *reyi* and *C. harrisii* var. *zavialensis*. Based on the occurrence of *Clavator grovesii* var. *jiuquanensis*, this charophyte association has been ascribed to the upper Barremian–lower Aptian *Clavator grovesii* var. *jiuquanensis* Eurasian biozone (Pérez-Cano et al., 2022a). This charophyte assemblage partially corresponds to the upper lower Barremian–lower Aptian *Ascidiella cruciata-Pseudoglobator paucibracteatus* European biozone (see, Pérez-Cano et al., 2022a).

The lowermost part of the upper Barremian–lower Aptian *Clavator grovesii* var. *jiuquanensis* biozone could be correlated with the occurrence of *Subtilisphaera scabrata* dinoflagellate cyst biozone (Fig. 2; Mendes et al., 2023). This key dinoflagellate cyst ranges from the FO of the aforementioned species to the FO of *Odontochitina operculata* (Leereveld, 1995, 1997), being assigned to the lower Barremian–lowermost upper Barremian. The upper part of the *Clavator grovesii* var. *jiuquanensis* biozone is correlated with the *Odontochitina operculata* dinoflagellate cyst biozone (Fig. 2). The *Clavator grovesii* var. *jiuquanensis* biozone was tentatively correlated with the key marine dinoflagellate cyst identified by Mendes et al. (2023) for the Arrifes section.

The correlation between the *Clavator grovesii* var. *jiuquanensis* biozone with the dinoflagellate biozones is in agreement with the previous correlation of both biozones with the ammonite biozonation. Thus, the base of *C. grovesii* var. *jiuquanensis* biozone was correlated with the *Toxancyloceras vandenheckii* ammonite biozone, based on a direct correlation between both biozones (Martín-Closas et al., 2009) and Sr-isotope stratigraphy (Pérez-Cano et al., 2022a). The upper part of the *Subtilisphaera scabrata* biozone was also correlated with the *T. vandenheckii* ammonite biozone (Leereveld, 1995, 1997). Moreover, charophyte assemblages that belong to the European *Ascidiella cruciata-Pseudoglobator paucibracteatus* charophyte biozone and the Eurasian *Clavator grovesii* var. *jiuquanensis* charophyte biozone were correlated against the lower Aptian *Deshayesites weisii* ammonite biozone (*Deshayesites forbesi* ammonite biozone according to Reboulet et al., 2011) in the Subalpine Chains and Jura Mountains (Martín-Closas et al., 2009; Fig. 5). Furthermore, *Clavator grovesii* var. *jiuquanensis* is also described in lower Aptian strata that were chemostratigraphically correlated with the marine domain in the Chinese basins (Li et al., 2020). *Odontochitina operculata* biozone is also correlated with the lower Aptian ammonite biozones (Leereveld, 1995, 1997).

5.2. Lower Aptian

The second assemblage is described from the 135 m until the top of the section (Fig. 2) and is characterized by the co-occurrence of homogeneous populations of *Atopochara trivolvis* var. *trivolvis*, homogeneous populations of *Clavator grovesii* var. *corrugatus*, *Clavator harrisii* var. *harrisii*, *Clavator harrisii* var. *reyi*, and *Clavator harrisii* var. *zavialensis*. This assemblage corresponds to the typical assemblage of the *Clavator grovesii* var. *lusitanicus* biozone of Riveline et al. (1996), which was described on the basis of the Tincup Creek biozone of Grambast (1974). The First Occurrence (FO) of *C. grovesii* var. *corrugatus* in the Arrifes section is in a sample in which it is associated with *C. grovesii* var. *jiuquanensis* (C127W; Fig. 2). However, in the case of anagenetic lineages the occurrence of mixed populations with two varieties that also contain specimens that are intermediate morphotypes between two varieties is very common (e.g., Martín-Closas, 1989; Martín-Closas and Salas, 1994; Pérez-Cano et al., 2020, 2022a). For this reason, in the present work, the base of the biozone is pointed at the first homogeneous population of *C. grovesii* var. *corrugatus* (Fig. 2), at sample C178, following the criterion established in Pérez-Cano et al. (2022a) for biozones based on anagenetic varieties.

Clavator grovesii var. *lusitanicus* was synonymized to *Clavator grovesii* var. *corrugatus* by Martín-Closas (2000). Following this synonymy, the charophyte biozone *Clavator grovesii* var. *lusitanicus* of Riveline et al. (1996) is here redefined as follows:

Name: *Clavator grovesii* var. *corrugatus.*

Definition: Partial range biozone defined between the FAD of homogeneous populations of *Clavator grovesii* var. *corrugatus* and homogeneous populations of *Atopochara trivolvis* var. *restricta* (Grambast-Fessard 1980b) Martín-Closas 1996.

Correlations: In the Arrifes section, the base of *Clavator grovesii* var. corrugatus biozone is placed in a marly layer inside an interval that contains the dinoflagellate key taxa *Odontochitina operculata* and attributed to the homonymous biozone (Fig. 2; Mendes et al., 2023). This interval is defined by the occurrence of this taxon, and ranges from the FO of *Odontochitina operculata* to the FO of *Cribroperidinium tenuiceras*, indicating an age no older than the late Barremian (Costa and Davey, 1992; Leereveld, 1995, 1997). The base and the top of this dinoflagellate biozone are also well-correlated with the standard ammonite biozonations. Thus, the FO of *O. operculata* is correlated with the *Toxancyloceras vandenheckii*

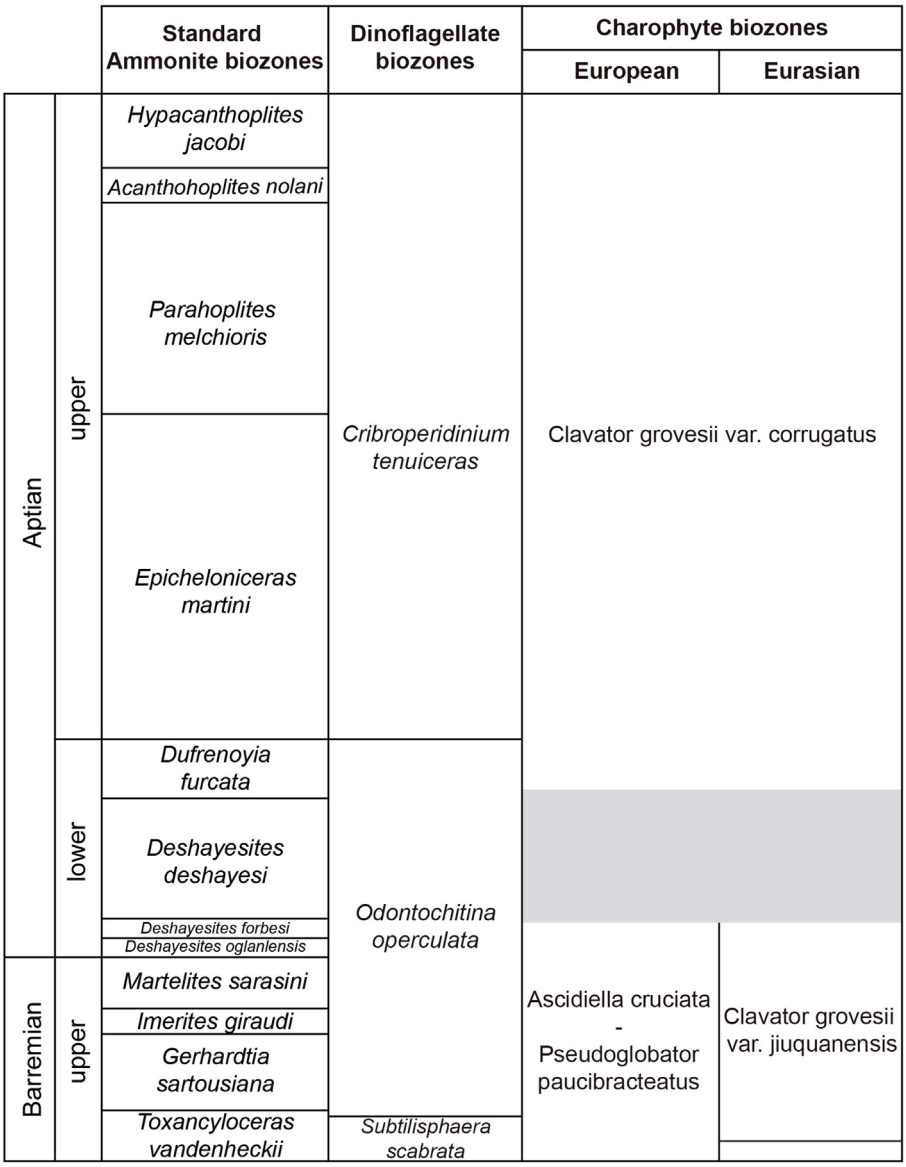

Fig. 5. Correlation of the upper Barremian–lower Aptian charophyte biozones with the dinoflagellates biozones and the standard ammonite biostratigraphy. Ammonite biozonation after the latest proposal of Reboulet et al. (2018). Dinoflagellate biozonation after Leereveld (1995, 1997) and Moullade et al. (1998). Dinoflagellate biozonation includes those biozones identified in the studied section, i.e., *Subtilisphaera scabrata* and *Odontochitina operculata* (see Mendes et al., 2023), and follows the biozonation schemes proposed by Leereveld (1995, 1997). Charophyte biozonation partially modifies the proposal of Pérez-Cano et al. (2022a). Greyish Area corresponds to the range in which the base of *C. grovesii* var. corrugatus biozone must be placed (see explanation in text). The comparison with other charophyte biozonations can be seen in Appendix 3.

ammonite biozone (Leereveld, 1995, 1997), while the FO of *Cribroperidinium teuniceras* correlates with the *Dufrenoyia furcata* ammonite biozone (Moullade et al., 1998) close to the lower–upper Aptian boundary (Masure et al., 1998). The FO of *C. teuniceras* was used as a tentative marker for the lower–upper Aptian boundary in the Luz section, in the western part of the Algarve Basin (Heimhofer et al., 2007). However, this key taxon was not recorded in the Arrifes section (Mendes et al., 2023).

The base of the *Clavator grovesii* var. *lusitanicus* biozone of Riveline et al. (1996) was placed in the lower–upper Aptian boundary. However, only the upper part of this biozone (lower Albian) was previously correlated with the coeval marine biostratigraphy (Riveline et al., 1996 and references therein). The direct correlation between the FAD of the first homogeneous population of *C. grovesii* var. *corrugatus*, considered the base of the *Clavator grovesii* var. *corrugatus* biozone, and the *O. operculata* dinoflagellate biozone indicates that the base of the *Clavator grovesii* var. *corrugatus* biozone must be lower Aptian, below the lower–upper Aptian boundary.

Following previous correlations of the *Clavator grovesii* var. jiuquanensis biozone against the standard ammonite biostratigraphy (see chapter 5.1), and the direct correlation of the base *Clavator grovesii* var. corrugatus biozone with the *Odoncthinia operculata* dinoflagellate biozone described in this work, the base of the *Clavator grovesii* var. *corrugatus* biozone must be upper lower Aptian, between the top of the *Deshayesites forbesi* and the *Dufrenoyia furcata* ammonite biozones (Fig. 5). The top of this charophyte biozone is in the middle Albian, as charophyte assemblages of this biozone are correlated against middle Albian ammonite biozones (see Riveline et al., 1996 and references therein).

Horizon: upper lower Aptian–middle Albian.

6. Conclusions

The present study shows a marine-continental correlation between the charophyte biozones and the dinoflagellate key taxa previously described in the Arrifes section (Algarve Basin, Portugal) in the upper Barremian–Aptian record. This is the first time that these two biochronologies can be directly correlated and it has allowed the improvement of the charophyte biochronology and biostratigraphy of the Aptian record.

The *Clavator grovesii* var. *jiuquanensis* biozone is identified by the occurrence of the index species, *Clavator grovesii* var. *jiuquanensis*, and the clavatoracean species associated, including *Echinochara lazarii*, *Atopochara trivolvis* var. *triquetra* and *A. trivolvis* var. *trivolvis*, *Clavator harrisii* var. *harrisii*, *Clavator harrisii* var. *reyi*, and *C. harrisii* var. *zavialensis*. The base of this biozone at the Arrifes section is directly correlated with the occurrence of the dinoflagellate cyst *Subtilisphaera scabrata*. This correlation agrees with previous correlations with the *Toxanclyoceras vandenheckii* ammonite biozone made for each biozone and reinforces the previous timespan suggested for this biozone.

The *C. grovesii* var. *corrugatus* biozone is described after the occurrence of the index species, *C. grovesii* var. *corrugatus*, that is associated with *A. trivolvis* var. *trivolvis*, *Clavator harrisii* var. *harrisii*, *Clavator harrisii* var. *reyi*, and *Clavator harrisii* var. *zavialensis*. The base of this biozone is correlated with the occurrence of the dinoflagellate cyst *Odontochitina operculata*, as well as, with the standard ammonite biozonation. This enables to redefine of the lower boundary of the *C. grovesii* var. *corrugatus* biozone to the upper lower Aptian, between the *Deshayesites forbesi* and the *Dufrenoyia furcata* ammonite biozones. Consequently, the total timespan of *C. grovesii* var. corrugatus biozone is upper lower Aptian–middle Albian. The use of chemostratigraphic methods should help to pinpoint with more precision the base of the *C. grovesii* var. corrugatus biozone in the upper lower Aptian, inside the interval defined by the previously mentioned ammonite biozones.

These two charophyte biozones (i.e., *Clavator grovesii* var. *jiuquanensis* and *Clavator grovesii* var. *corrugatus*) are described in the Arrifes section. These charophyte biozone contains intermediate morphotypes between *Clavator grovesii* var. *jiuquanensis* and C. grovesii var. *corrugatus* and intermediate morphotypes between *Clavator harrisii* var. *reyi* and. *C. harrisii* var. *zavialensis*, indicating sedimentary continuity along the upper part of the section. These features highpoint the unique palaeobotanical and biostratigraphical context of the Algarve Basin, featuring the importance of the Arrifes section as an excellent candidate to become the type section for the Aptian charophyte biostratigraphy.

Data availability

Data will be made available on request.

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Appendix 1. Specimens and provisional reference of each figured specimen.

Figure	Taxon	Sample	Ref. prov.	Ref. Museum
Fig. 3				
A and B	*Porochara* cf. *fusca*	C127W	Arr-Ch-1	
C	*Echinochara lazarii*	C152	Arr-Ch-2	
D	*Atopochara trivolvis* var. *triquetra*	C127W	Arr-Ch-3	
E and F	*Atopochara trivolvis* var. *triquetra*	C127W	Arr-Ch-4	
G	*Atopochara trivolvis* var. *triquetra*	C127W	Arr-Ch-5	
H	*Atopochara trivolvis* var. *triquetra*	C127W	Arr-Ch-6	
I	*Atopochara trivolvis* var. *trivolvis*	C127W	Arr-Ch-7	
J	*Atopochara trivolvis* var. *trivolvis*	C178	Arr-Ch-8	
K	*Atopochara trivolvis* var. *trivolvis*	C178	Arr-Ch-9	
L	*Atopochara trivolvis* var. *trivolvis*	C178	Arr-Ch-10	
M	*Atopochara trivolvis* var. *trivolvis*	C178	Arr-Ch-11	
N	*Atopochara trivolvis* var. *trivolvis*	C178	Arr-Ch-12	
O	*Atopochara trivolvis* var. *trivolvis*	C178	Arr-Ch-13	
P	*Atopochara trivolvis* var. *trivolvis*	C178	Arr-Ch-14	
Fig. 4				
A	*Clavator grovesii* var. *jiuquanensis*	C127W	Arr-Ch-15	
B	*Clavator grovesii* var. *jiuquanensis* adv.	C127E	Arr-Ch-16	
C	*Clavator grovesii* var. *jiuquanensis* adv.	C127E	Arr-Ch-17	
D	*Clavator grovesii* var. *jiuquanensis* adv.	C127W	Arr-Ch-18	
E	*Clavator grovesii* var. *jiuquanensis*	C127W	Arr-Ch-19	
F	*Clavator grovesii* var. *jiuquanensis*	C127W	Arr-Ch-20	
G	*Clavator grovesii* var. *corrugatus*	C178	Arr-Ch-21	
H	*Clavator grovesii* var. *corrugatus*	C178	Arr-Ch-22	
I	*Clavator grovesii* var. *corrugatus*	C178	Arr-Ch-23	
J	*Clavator grovesii* var. *corrugatus*	C178	Arr-Ch-24	
K	*Clavator grovesii* var. *corrugatus*	C178	Arr-Ch-25	
L	*Clavator grovesii* var. *corrugatus*	C178	Arr-Ch-26	
M	*Clavator harrisii* var. *harrisii*	C127	Arr-Ch-27	
N	*Clavator harrisii* var. *harrisii*	C127	Arr-Ch-28	
O	*Clavator harrisii* var. *harrisii*	C127	Arr-Ch-29	
P	*Clavator harrisii* var. *reyi*	C32	Arr-Ch-30	
Q	*Clavator harrisii* var. *reyi*	C178	Arr-Ch-31	
R	*Clavator harrisii* var. *zavialensis* primitive	C178	Arr-Ch-32	
S	*Clavator harrisii* var. *zavialensis*	C178	Arr-Ch-33	
T	*Clavator harrisii* var. *zavialensis*	C178	Arr-Ch-34	
U	*Munieria grambastii*	C127W	Arr-Ch-35	
V	*Munieria grambastii*	C127W	Arr-Ch-36	
W	*Clavatoraxis* sp.	C127W	Arr-Ch-37	

Appendix 2. Distribution of the charophyte taxa in the studied samples.

Supplementary material 1
The number of charophyte fructifications found in each sample of the Arrifes section.

	Samples						
	C32	C127W	C127E	C152	C178	C182	C199
Porocharaceae							
Porochara cf. *fusca.*		5					
Clavatoraceae							
Atopocharoidae							
Echinochara lazarii				15			
Atopochara trivolvis var. *triquetra*	2	15	3	1			
Atopochara trivolvis var. *trivolvis*		60			231	9	
Clavatoroidae							
Clavator grovesii var. *jiuquanensis*	10	27	76				
Clavator grovesii var. *corrugatus*		2	9		327	18	4
Clavator harrisii var. *harrisii*	1	24	5		3		
Clavator harrisii var. *reyi*	5	20	48		53	1	
Clavator harrisii var. *zavialensis*		124	64		220	7	

Appendix 3. Comparison of the described herein upper Barremian–Lower Aptian biostratigraphy with Riveline et al. (1996), and Pérez-Cano et al. (2022a).