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J. A. Moreno-Bedmar
Universitat de Barcelona

M. Company
Universidad de Granada

T. Bover-Arnal
Universitat Bayreuth

R. Salas
Universitat de Barcelona

G. Delanoy
Universite de Nice - Sophia Antipolis

See next page for additional authors

Authors
J. A. Moreno-Bedmar, M. Company, T. Bover-Arnal, R. Salas, G. Delanoy, Florentin J. Maurrasse, A. Grauges, and R. Martinez

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J.A. MORENO-BEDMAR [1] M. COMPANY [2] T. BOVER-ARNAL [3] R. SALAS [1] G. DELANOY [4] F.J.-M.R. MAURRASSE [5]
A. GRAUGES [6] R. MARTÍNEZ [6]

[1] **Departament de Geoquímica, Petrologia i Prospecció Geològica, Universitat de Barcelona**
Martí i Franquès s/n, 08028 Barcelona, Spain. Moreno-Bedmar E-mail: j.a.moreno@ub.edu Salas E-mail: ramonsalas@ub.edu

[2] **Departamento de Estratigrafía y Paleontología, Facultad de Ciencias, Universidad de Granada**
Avenida Fuentenueva s/n, 18002 Granada, Spain. E-mail: mcompany@ugr.es

[3] **Abteilung Geologie, Fakultät für Biologie, Chemie und Geowissenschaften, Universität Bayreuth, Universitätsstr**
30, D-95440, Bayreuth, Germany. E-mail: Telm.Bover@uni-bayreuth.de

[4] **Département des Sciences de la Terre, Université de Nice-Sophia Antipolis**
28 Avenue Valrose F-06100 Nice, France. E-mail: gerard.delanoy06@orange.fr

[5] **Department of Earth Sciences, Florida International University**
11200 S.W. 8th street, Miami, FL 33199, United States. E-mail: maurrass@fiu.edu

[6] **Departament de Geologia (Paleontologia). Universitat Autònoma de Barcelona**
Edifici C. 08193-Bellaterra, Spain. Grauges E-mail: antonigrauges@hotmail.com Martínez E-mail: Ricard.Martinez@uab.cat

ABSTRACT

The present paper analyses the stratigraphic distribution of ammonites collected in the Lower Aptian sediments of the Maestrat Basin (E Spain). The faunal successions obtained from the systematic sampling of ten selected sections located in several sub-basins led us to identify four biostratigraphic units (from base to top: *Deshayesites oglanlensis*, *Deshayesites forbesi*, *Deshayesites deshayesi* and *Dufrenoyia furcata* Zones) that are directly correlatable with the current Mediterranean standard zonation.

This study further provides essential biochronologic information to accurately date the different lithostratigraphic units included in the interval studied. Thus, the upper part of the Xert Formation can be tentatively attributed to the lowermost Aptian (*D. oglanlensis* Zone). The Forcall Formation, which has yielded most of the ammonites, practically extends within most of the Lower Aptian. Its lower and middle parts (Cap de Vinyet and Barra de Morella Members) correspond to the upper part of the *D. oglanlensis* Zone and the lower part of the *D. forbesi* Zone, respectively. The base of the Morella la Vella Member (upper part of the Forcall Formation) includes the local record of Oceanic Anoxic Event 1a (OAE 1a) and correlates with the *Roloboceras hambrovi* horizon (middle/upper part of the *D. forbesi* Zone). The boundary between the Forcall Formation and the Villarroya de los Pinares Formation is diachronous and varies depending on the sub-basins. The base of the Villarroya de los Pinares Formation can be dated as the middle-upper part of the *D. furcata* Zone in the Galve, Perelló and Salzedella sub-basins.

KEYWORDS | Ammonoids. Lower Aptian. Biostratigraphy. Maestrat Basin. E Spain.

INTRODUCTION

Our knowledge of the Lower Aptian ammonoids in the Mediterranean Tethys has improved considerably during the last two decades. Most recent published papers concerning aspects of ammonite biostratigraphy and taxonomy from this stratigraphic interval include the Trans-Caspian area (Bogdanova and Tovbina, 1994; Bogdanova and Prozorovsky, 1999; Cecca et al., 1999a); Roumania (Avram, 1995, 1999; Avram and Melinte, 1998), Bulgaria (Ivanov and Stoykova, 1998); Czech and Slovac Republics (Vašíček, 1995, 2008; Vašíček et al., 2004); Austria (Vašíček and Summesberger, 2004); northern Italy (Cecca and Landra, 1994); southeastern France (Delanoy, 1995, 1997; Cecca et al., 1999b, 2000; Dauphin, 2002; Ropolo et al., 1999, 2000a, 2000b, 2000c, 2006, 2008a, 2008b; Dutour, 2005); and southeastern Spain (Aguado et al., 1997). These works have contributed, to a greater or lesser extent, to the elaboration of the successive versions of the standard Mediterranean zonations (see Reboulet and Klein et al., 2009).

The occurrence of Lower Aptian ammonoids in the Iberian Chain (Eastern Spain) has been known since the middle 19th century (Vilanova, 1859; 1863, and Coquand, 1865). Most recently, several preliminary short papers have been published on the area (Moreno, 2007; Moreno et al., 2007; Moreno-Bedmar et al., 2008, 2009), however a comprehensive work on the ammonite successions of this age is still lacking. In this work, we analyze the Lower Aptian mediterranean ammonoid record of the Maestrat Basin (Eastern Spain) and provide the results of an extensive and detailed biostratigraphic study based on the analysis of ammonite distribution in ten selected sections located throughout the Maestrat Basin (Fig. 1B-C). We were able to identify all the biostratigraphic units usually recognized as being associated with the Early Aptian ammonite zonation. As discussed in the text below, some taxonomic discrepancies led us to further reconsider some definition and correlation problems not fully resolved in the current standard zonation. Also, this study enabled us to accurately date and correlate the lithostratigraphic units and their lateral equivalents that yielded the ammonite fauna in the studied area.

GEOLOGICAL SETTING

The study area is located in the Maestrat Basin. This basin was a significant embayment opened to the Tethyan Alpine area, which was invaded by an epeiric sea during the Late Jurassic-Early Cretaceous time span. From the faunistic point of view, this basin was located in the eastern part of the Boreal region (Anglo-Paris Basin, Lower Saxony Basin and the Polish Basin) and the southern part of other Mediterranean basins such as the Vocontian Basin (Fig. 1A).

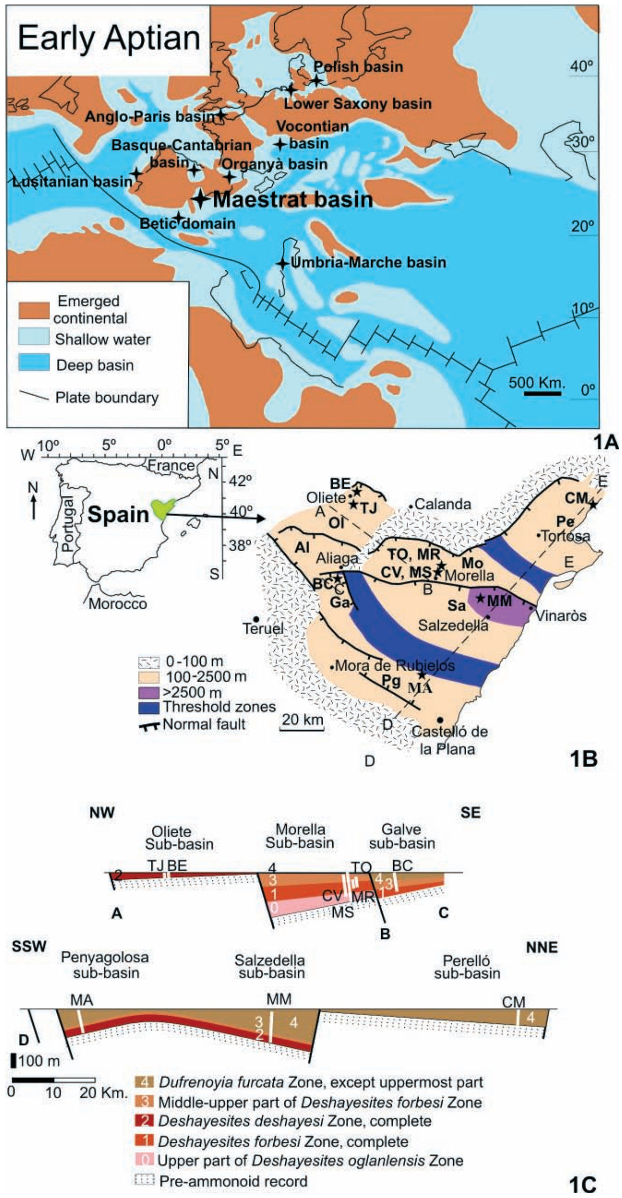

FIGURE 1 | **A) Palaeogeographic reconstruction of the Proto North Atlantic and Tethyan realm during the Early Aptian, with the most important basins (modified after Masse et al., 2000). B) Simplified paleogeographic map of the Maestrat Basin during the Early Cretaceous (modified after Salas et al., 2001), and location of the ten sections studied. MA: Mas Agustina section; MM: Mola Murada section; BC: Barranco de las Calzadas section; CV: Cap de Vinyet section; TO: Todolella section; MR: Mas del Roc section; MS: Mas Segura section; CM: Cala dels Moros section; TJ: Tejería de Josa section, and BE: Barranco Emilia section; Ol: Oliete sub-basin; Al: Aliaga sub-basin; Mo: Morella sub-basin; Pe: Perelló sub-basin; Ga: Galve sub-basin; Sa: Salzedella sub-basin; Pg: Penyagolosa sub-basin (modified after Salas et al., 2001). C) Geological cross-sections, A-C and D-E, showing the ammonoid biozones in the ten sections studied of the Forcall Formation. Datum at the Lower-Middle Aptian boundary. For more details about ranges of ammonoids of these sections, see fig. 2.**

The Maestrat Basin is located in the eastern part of the Iberian Chain (Eastern Spain, Fig. 1B). The Iberian Chain developed by inversion of Mesozoic rifts during the Palaeogene. The Maestrat Basin was one of these rifts, which developed during the Late Jurassic-Early Cretaceous rifting phase related to the opening of the Central Atlantic and North Atlantic domains (Salas and Casas, 1993; Salas et al., 2001). This rifting stage controlled the evolution of the Maestrat Basin, and structured the basin into four main fault zones and a number of sub-basins (Fig. 1B, Salas and Guimerà, 1996). In this paper we study ten sections within six sub-basins (Fig. 1B-C and Fig 2). The climax of rifting during the Lower Aptian coincides with deposition of the Xert and Forcall Formations (Figs. 2 and 3). Thus, during this time interval, the fault-controlled rapid syn-rift subsidence was the most important factor in producing accommodation (see also Bover-Arnal et al., 2010). This interval of rapid subsidence also coincided with the broad Tethyan transgression well-documented in the Early Aptian (see references in Bover-Arnal et al., 2010), especially in the Forcall Fm. In fact, this formation represents the most transgressive deposits composed of relatively deep water hemipelagic sediments, as suggested by the fossil assemblage within a marly succession, embedded between platform carbonates (Xert and Villarroya de los Pinares formations, respectively; Fig. 2). In addition, the onset of Oceanic Anoxic Event 1a is situated close to the maximum flooding interval of the widespread Tethyan transgression. Later, during uppermost Lower and Middle Aptian, a slow subsidence interval (Fig. 3) corresponds with an important marine regression. Hence, the available accommodation was drastically reduced, favouring the development of shallow-water carbonate platforms with typical Urgonian biotic associations, characterized by rudist bivalves, orbitolinids and corals, belonging to the upper part of the Villarroya de los Pinares and Benassal formations (Bover-Arnal et al., 2010).

LOWER APTIAN STRATIGRAPHY

The Lower Aptian stratigraphic framework in the Maestrat Basin (Fig. 2) is composed of seven lithostratigraphic units with the rank of formations: i) Arcillas de Morella, ii) Margas de Cervera del Maestre, iii) Calizas y margas de Xert, iv) Calizas de Alacón, v) Margas del Forcall, vi) Cali-

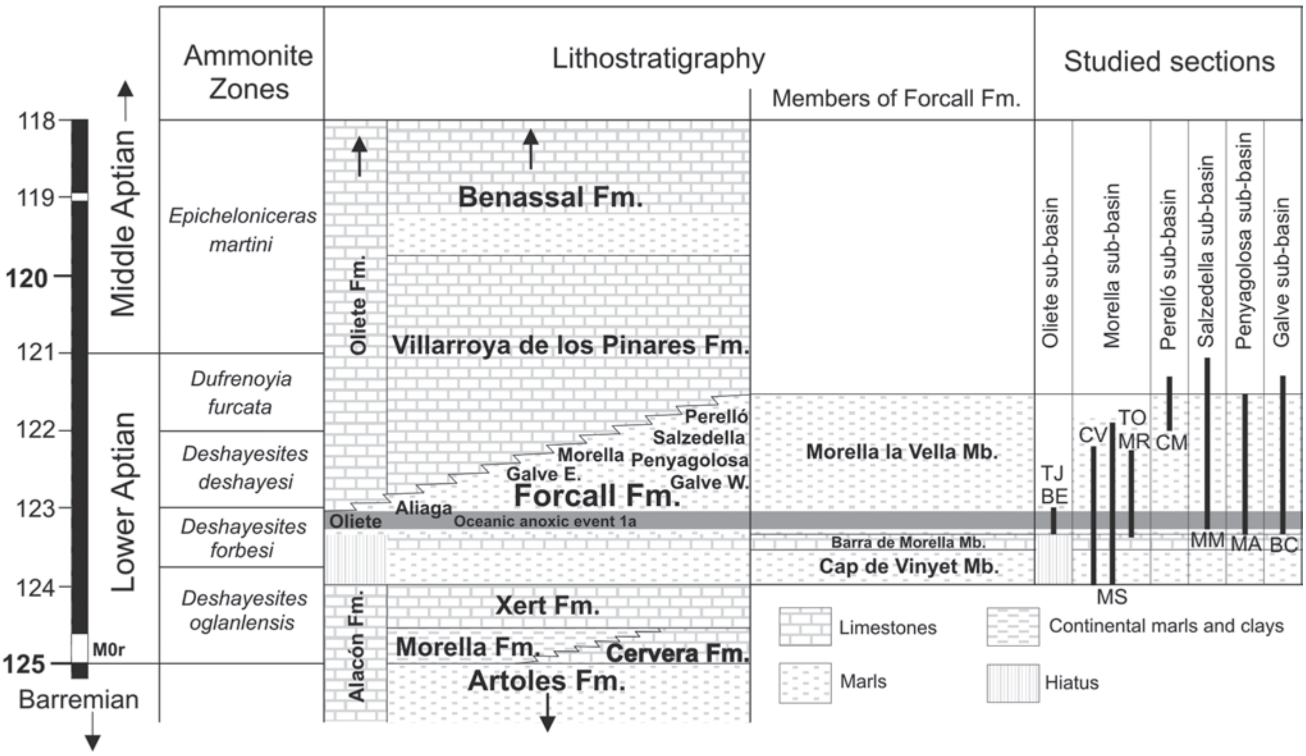

FIGURE 2 | **Stratigraphic framework and age relationships of the Aptian deposits in the Maestrat Basin. Position of OAE1a is indicated by shaded level (after Moreno-Bedmar et al., 2008, 2009). Ol: Oliete sub-basin; Al: Aliaga sub-basin; Ga: Galve sub-basin; E: East; W: West; Mo: Morella sub-basin; Pe: Perelló sub-basin; Sa: Salzedella sub-basin, and Pg: Penyagolosa sub-basin. Stratigraphic positions of the ten sections studied of the Forcall Formation relative to ammonoid biozones. MA: Mas Agustina section; MM: Mola Murada section; BC: Barranco de las Calzadas section; CV: Cap de Vinyet section; TO: Todolella section; MR: Mas del Roc section; MS: Mas Segura section; CM: Cala dels Moros section; TJ: Tejería de Josa section and BE: Barranco Emilia section. Absolute ages after Gradstein et al. (2004).**

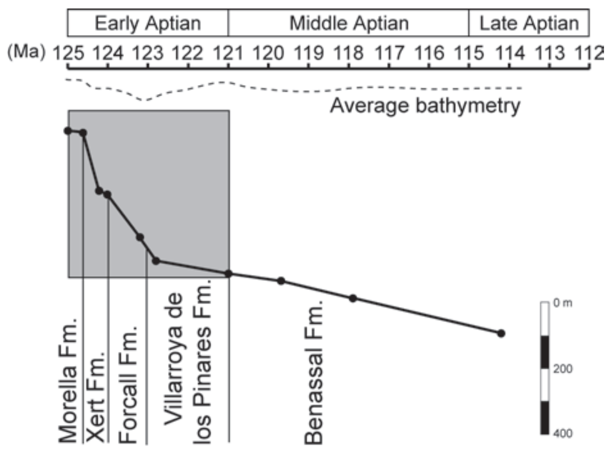

FIGURE 3 | **Backstripped total subsidence (decompacted) for the Aptian of the Villarroya de los Pinares section (Galve sub-basin) corrected with bathymetries (modified from Bover-Arnal et al., 2010). Dashed line shows the average bathymetric curve. The solid curve shows the accommodation variation of the Lower Aptian for each lithostratigraphic unit.**

zas de Villarroya de los Pinares, and vii) Calizas de Oliete (Canérot et al., 1982; Salas, 1987; Salas et al., 2001).

The Arcillas de Morella Formation (Canérot et al., 1982) overlies the shallow-water carbonate and siliciclastic deposits of the Calizas y margas de les Artoles Formation (Salas, 1987) of Barremian age (Canudo et al., 1996). This unit is up to 200 m thick and consists of red clays and continental sandstones with some marine intercalations, particularly in its higher part, deposited in an estuarine-delta complex. In the eastern part of the basin (Salzedella sub-basin), the continental sediments of the Morella Formation change to marine marls of the margas de Cervera del Maestre Formation (Canérot et al., 1982). The geomagnetic polarity interval M0r has been identified within these marls, dating the earliest Aptian (Salas et al., 2005).

Both Morella and Cervera del Maestre Formations gradually change upwards to the Calizas y margas de Xert Formation (originally misspelled by Canérot et al., 1982, as Chert Formation). This is up to 250 m thick and composed of sandstones, sandy limestones with rudists and corals, and orbitolinid marls deposited in an infralitoral environment. Ammonoids are very scarce in this formation, and only one specimen indicating a lowermost Aptian age has been found (see below). In the western, outermost part of the Basin (Oliete sub-basin), this stratigraphic interval is represented by a shallower-water carbonate deposit called Calizas de Alacón Formation (Canérot et al., 1982).

The Margas del Forcall Formation (Canérot et al., 1982) consists of alternating marls, marly limestones, limestones and silty/sandy limestones with abundant orbitolines and ammonoids. This unit corresponds to a deeper and more open marine environment. Many authors have referred to this formation as "Margas con Plicatulas", due to the fact that the bivalve *Plicatula placunea* Lamarck is abundant in, and seems restricted to, these marls. The Forcall Formation is Lower Aptian in age. This unit is separated from the underlying Xert Formation by a hardground, surface of discontinuity related to a general rapid sea level rise associated with regional drowning. This marly unit has been divided into three members (Canérot et al., 1982) as shown in fig. 2. The lower one, or Margas de Cap de Vinyet (originally misspelled as "Cap de Biñet" by Canérot et al., 1982) is made up of yellowish marls and marly limestones, which have provided some rare ammonoids. The middle member, Barra de Morella, is a set of thick bioclastic limestone beds devoid of ammonoids. The upper member, or Margas de Morella la Vella, is mainly constituted of dark, clayey marls with some sparse limestone beds, and a good ammonite record of the middle part of the Lower Aptian.

The Margas del Forcall Formation shows its best and more complete outcrops, and maximum thickness in the Morella and Galve sub-basins (200 and 180 metres, respectively). The lowermost part of the Morella la Vella Member in the Morella sub-basin contains a remarkable feature that consists of a distinct beige-colored indurated bed, up to 2 meters thick, that has provided a rich ammonite association characterized by the presence of roloboceratids (Fig. 4). This bed also marks the base of the stratigraphic interval corresponding to the local record of OAE 1a (Moreno-Bedmar et al., 2008, 2009). The lateral equivalent of this bed in the Galve sub-basin is a coral rubble bank, up to 5 meters thick, incrusted with *Lithocodium* and *Bacinella* (Fig. 5).

The three members of the Margas del Forcall Formation have also been recognized in the Penyagolosa and Salzedella sub-basins, but only the upper one shows good outcrops. In the Penyagolosa sub-basin, this marly upper member includes, in its lower part, a distinct bar, up to 10 metres thick, of dolomitized limestone beds with ammonite fauna indicating the *Deshayesites deshayesi* Zone (Fig. 6).

In the Aliaga and Oliete sub-basins, which underwent a reduced accommodation, the lower and middle members of the Forcall Formation are lacking and only an equivalent deposit of the Morella la Vella Member is present, reaching a thickness of nearly 40 metres. A well-developed hardground separating the base of this member from the underlying Alacón Formation can be seen in several sections of the Oliete sub-basin. Just above the hard-ground, or somewhat higher, a characteristic reddish nodular limestone, less than 40 cm thick, has provided abundant, incipi-

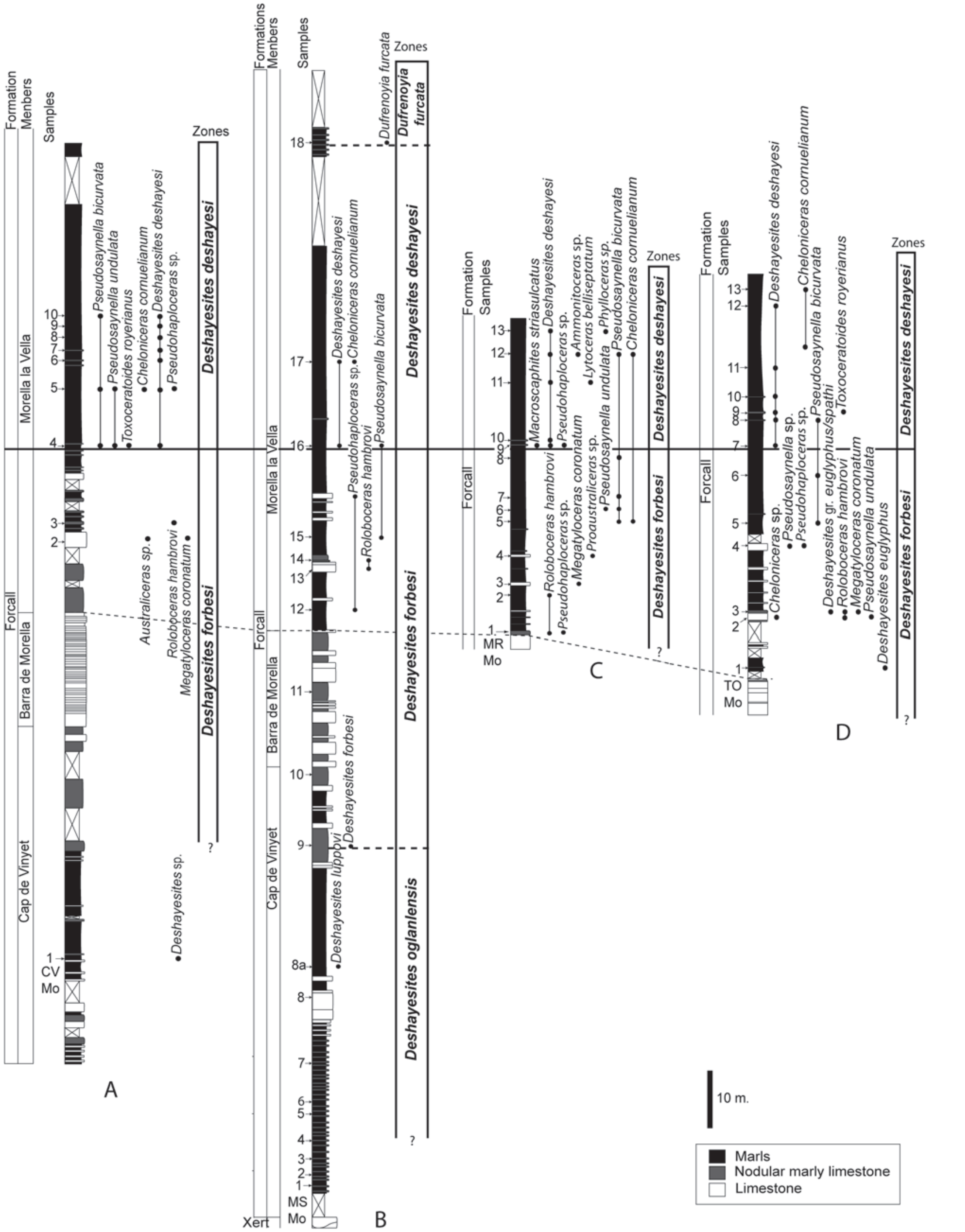

FIGURE 4 | **Correlation across four stratigraphic sections studied in the Morella sub-basin, A) Cap de Vinyet; B) Mas Segura; C) Mas del Roc and D) Todolella sections. Datum at the boundary of *Deshayesites forbesi* / *Deshayesites deshayesi* biozones. The correlation between the Barra de Morella and Morella la Vella Members boundary is also indicated.**

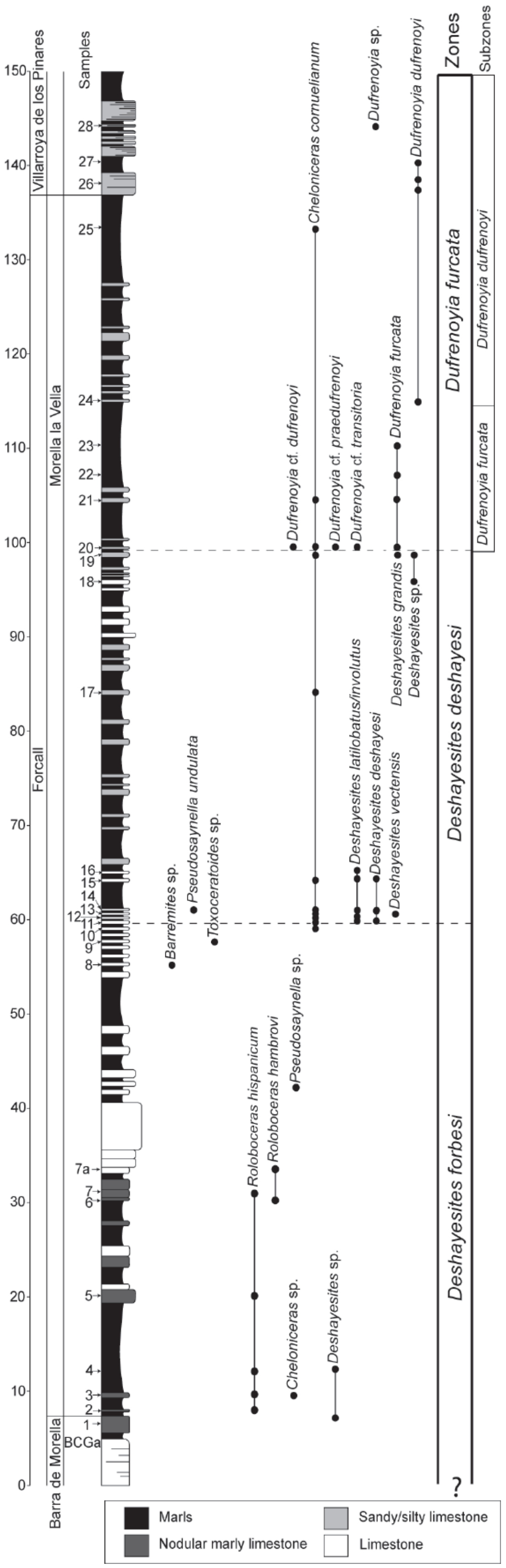

FIGURE 5 | **Galve sub-basin, Barranco de las Calzadas section.**

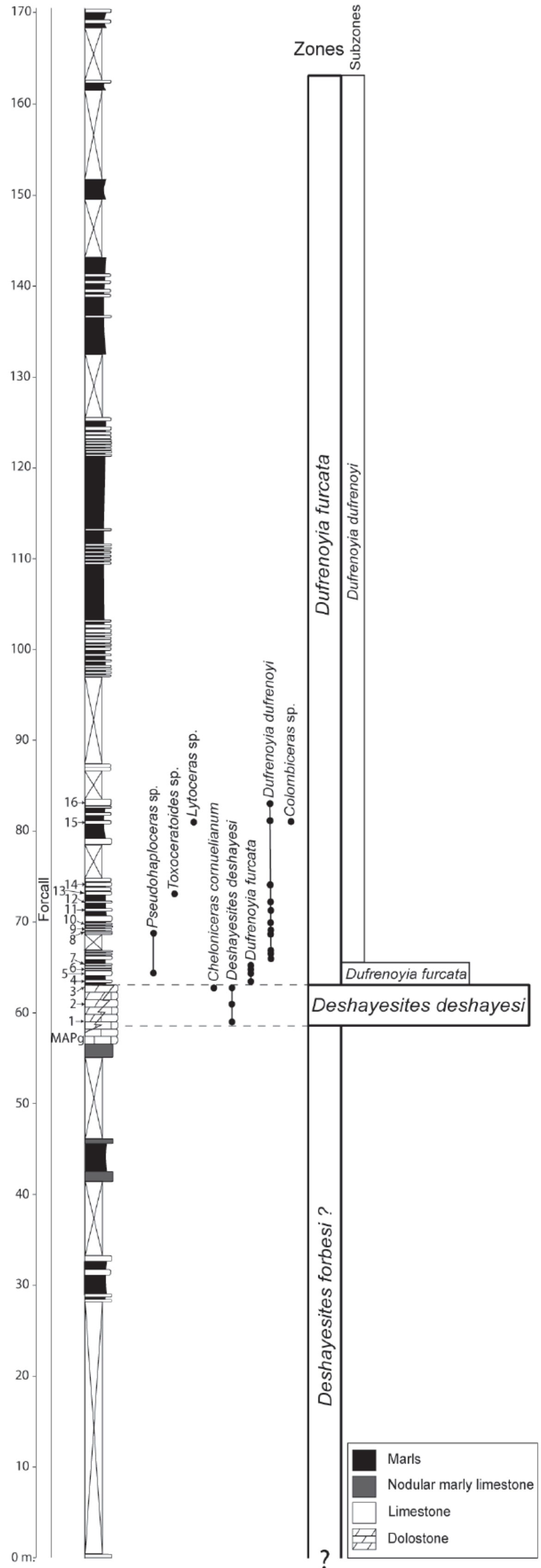

FIGURE 6 | **Penyagolosa sub-basin, Mas Agustina section.**

ently reworked nautiloids and ammonoids (Moreno et al., 2007).

The upper limit of the Margas del Forcall Formation intergrades with the Calizas de Villarroya de los Pinares Formation (Canérot et al., 1982), which reaches a maximum thickness of 300 meters and consists essentially of varying beds of limestones with rudists and corals, oolites and bioclasts, and orbitolinid marls. The ammonite faunas associated with the Villarroya de los Pinares Formation indicate that the deposit is distinctly diachronous (Fig. 2) from west to east. Its oldest occurrence in the western part of the Maestrat basin (Oliete sub-basin) starts around the boundary between the *Deshayesites forbesi* and *Deshayesites deshayesi* Zones, and is represented by the lateral equivalent Calizas de Oliete Formation (Canérot et al., 1982). The youngest record of the base of the Villarroya de los Pinares Formation occurs in the eastern and deeper part of the basin where it correlates with the upper half of the *Dufrenoyia furcata* Zone. Only rare ammonoids from the uppermost Lower Aptian, upper part of *Dufrenoyia furcata* Zone, have been found in the Galve, Salzedella and Perelló Sub-basins (Figs. 5, 7-8). The youngest levels of the Villarroya de los Pinares Formation reach the lower part of the Middle Aptian in some parts of the Basin. This age assignment is based on the record of the caprinid rudist extinction event that characterizes the boundary between the Early and Middle Aptian (Skelton, 2003).

PREVIOUS WORKS

The first reports of Lower Aptian cephalopods in the Maestrat Basin are from the publications of Vilanova (1859, 1863) and Coquand (1865). These authors described and figured a number of species of ammonoids and nautiloids, including some new forms coming from several localities of the Teruel and Castellón provinces.

Weisser (1959) studied some sections of the Galve sub-basin, which yielded a few ammonoids, and was the first to present a rudimentary biostratigraphic scheme of the Aptian stage of the Iberian range. He recognized a lower Bedoulian with *D. weissi*, and an upper Bedoulian with *D. deshayesi.*

Wiedmann (1965) presented an essay of correlation for the entire Lower Cretaceous of the Iberian Peninsula. He subdivided the Lower Aptian of the Maestrat Basin into two units. The lower unit (designated as 'Deshayesitien') would be characterized by the presence of *D. weissi* and *D. consobrinus*. In the upper unit (designated as 'Roloboceratien') he mentioned, among others, several species of *Roloboceras*, *Cheloniceras*, *Deshayesites* and *Dufrenoyia*.

Marin and Sornay (1971), in a synthetic short note on the Aptian stratigraphy of the Maestrazgo Basin, rejected the proposal discussed by Wiedmann (1965), and attributed the "marnes à Plicatules" (equivalent to the Margas del Forcall Formation) to the entire Bedoulian and locally to the base of the Gargasian. Shortly thereafter, these authors (Sornay and Marin, 1972) published a detailed study of the Tejería de Josa section (Oliete Sub-Basin), where they described and illustrated an interesting fauna of roloboceratids from the base of the local equivalent of the "marnes à Plicatules".

Canérot (1974) listed some ammonoids from the same formation that he ascribed to middle-upper Bedoulian. Murat (1983), in a study of the Oliete Sub-basin, correlated the whole Forcall Formation with the *Deshayesites forbesi* Zone of Casey (1961), on the basis of the occurrence of the genus *Roloboceras* throughout the formation in this area. Also, in the framework of regional geologic surveys, Neumann (1987) attributed the Forcall Formation to the *Deshayesites forbesi* and *Deshayesites deshayesi* Zones, whereas Salas (1987) assigned the formation to the *Deshayesites deshayesi* and *Tropaeum bowerbanki* Zones of the boreal zonation proposed by Casey (1961).

Martínez et al., (1994), undertook further sampling in the Maestrat Basin and the Catalan Coastal Range in order to complement existing materials available from previous collections for a detailed analysis of the Lower Cretaceous ammonite succession in these areas. In the Lower Aptian, Forcall Formation, they recognized the *Deshayesites forbesi*, *Deshayesites deshayesi* and *Tropaeum bowerbanki* Zones of the zonal scheme proposed by Casey (1961).

Moreno (2007) reviewed the taxonomy of some deshayesitids from the *Deshayesites deshayesi* Zone of the Morella sub-basin, and Moreno et al., (2007) provided further precision concerning the age of the Margas del Forcall Formation in the Oliete sub-basin. In the latest work, Moreno-Bedmar et al., (2009) recognized the Oceanic Anoxic Event 1a (OAE 1a) in the Oliete, Galve and Morella sub-basins, where it is correlated with the upper part of the *Deshayesites weissi* Zone.

MATERIAL AND METHODS

The study includes about 2000 specimens of ammonoids collected essentially by the first author during the years 2006-2009 from numerous Lower Aptian outcrops in the Maestrat Basin. Ammonoids are generally rare and sparsely distributed throughout the interval studied, especially in its lower part. Only a few individual beds yielded abundant material. The ten most suitable sections that showed best exposure and stratigraphic record were select-

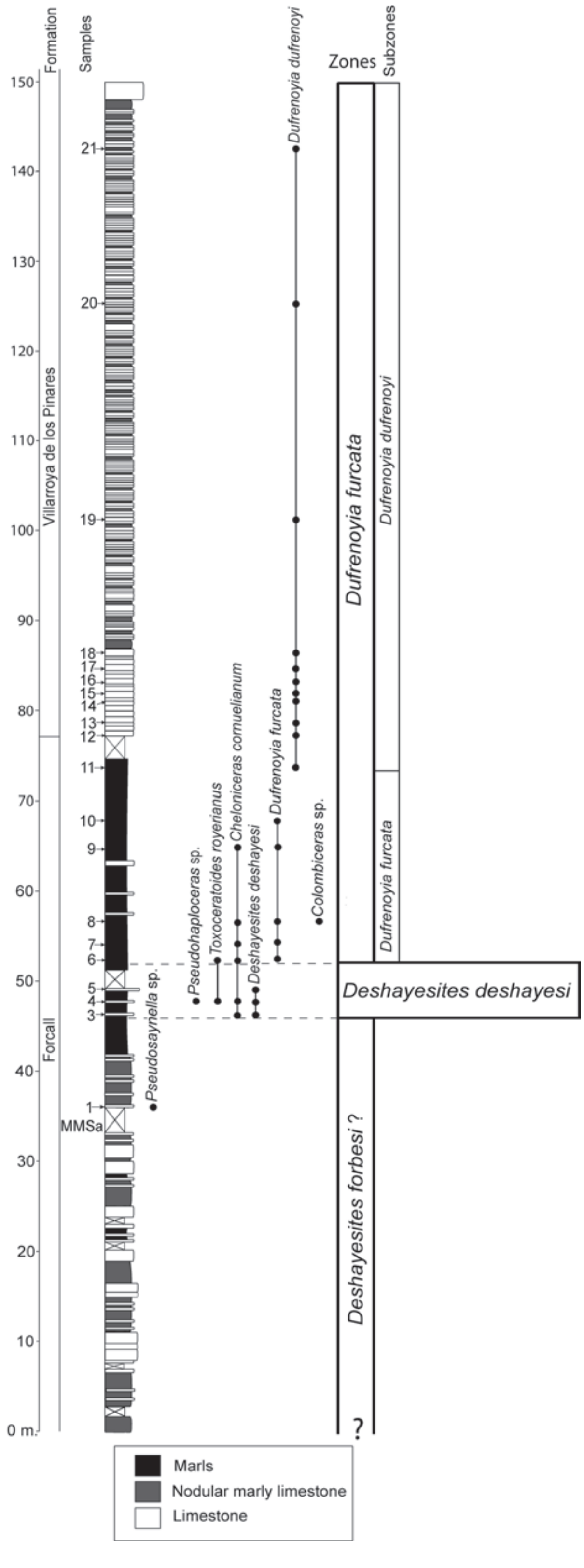

FIGURE 7 | **Salzedella sub-basin, Mola Murada section.**

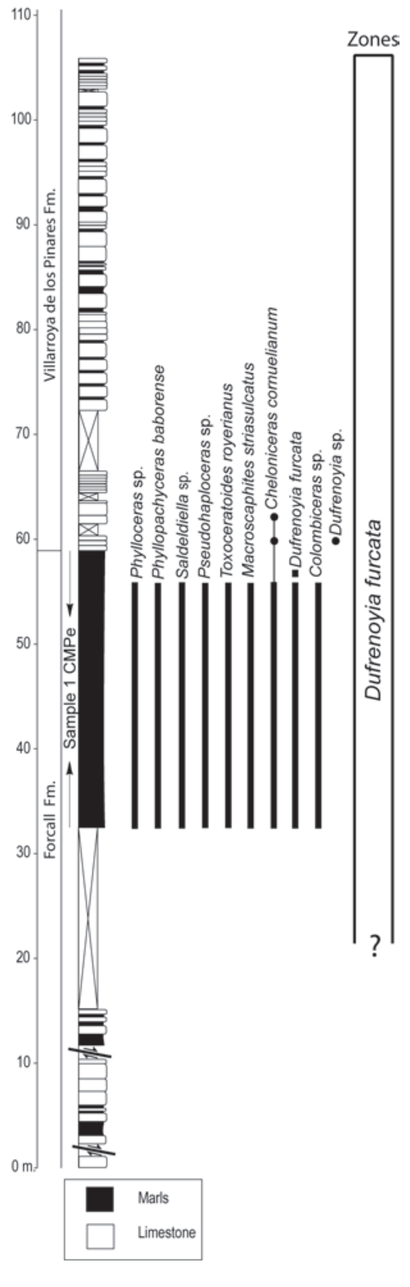

FIGURE 8 | **Perelló sub-basin, Cala dels Moros section.**

ed for detailed study of ammonite temporal succession and their systematics on a bed-by-bed sampling program.

The location of these sections is shown in Figure 1, and includes the following: Cap de Vinyet, Mas Segura, Todolella and Mas del Roc in the Morella Sub-basin (Fig. 4); Barranco de las Calzadas in the Galve Sub-basin (Fig. 5); Mas Agustina in the Penyagolosa Sub-basin (Fig. 6); Mola Murada in the Salzedella Sub-basin (Fig. 7); Cala dels Moros in the Perelló Sub-basin (Fig. 8) and Tejería de Josa and Barranco Emilia in the Oliete Sub-basin (Fig. 9).

Materials collected from these sections were supplemented with specimens deposited in the collections of the Museu Geològic del Seminari de Barcelona (MGSB), the Universitat Autònoma de Barcelona (PUAB), and Museu Paleontològic Juan Cano Forner in Sant Mateu (Valencia region), as well as various specimens from several private collections.

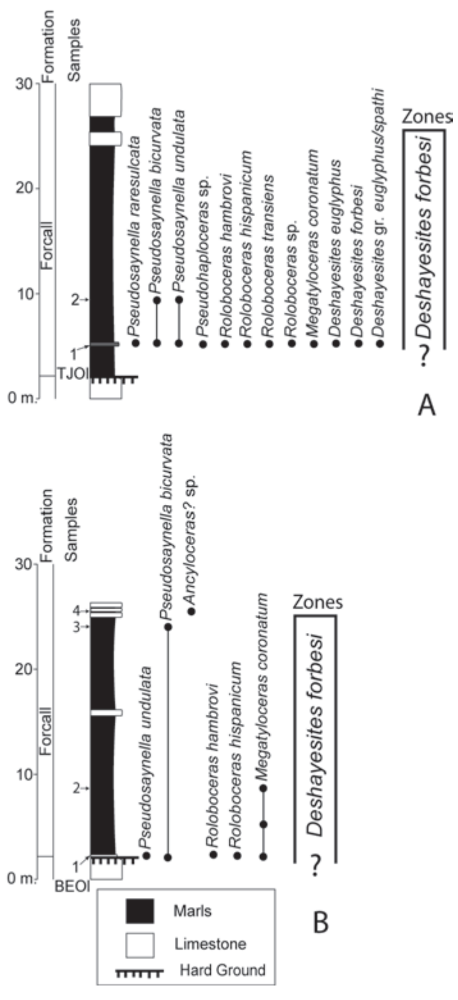

FIGURE 9 | **Oliete sub-basin, A) Tejería de Josa sections and B) Barranco Emilia.**

All ammonite specimens collected during the present study have been deposited in the permanent collections of either the Museu de Valltorta (MV), Region of Valencia, or the Conjunto Paleontológico de Teruel (CPT), Aragón, in fulfillment of the clauses specified in the permissions obtained for collecting paleontological material in the study areas.

TAPHONOMIC ASPECTS

The ammonoids are preserved as internal calcareous or pyritized molds, which are abundant only in some beds. In the Maestrat Basin, the ammonoids are not reworked except in one bed of the Oliete sub-basin (samples BEOl-1 and TJOl-1, correspond to the same bed in the different sections, see fig. 9). The limestone bed (samples BEOl-1 and TJOl-1) from the basal part of the Margas de Forcall Formation in the Oliete sub-basin is distinctive by the abundance of ammonite species and reworked specimens in both sections (Moreno et al., 2007). Most ammonoid and nautiloid specimens collected at that level have been determined to be reworked because they are partially worn out, and small oysters and serpulids are encrusting the internal molds of the cephalopods. Since these assemblages are condensed and partially accumulated as a lag deposit, there may be mixing of taxa, therefore caution is advised in the interpretation of the biozones. However, in the Barranco Emilia section, *Megatyloceras coronatum* (Rouchadzé) is found in the bed with reworked specimens, but also occurs as non-reworked specimens at younger levels in beds BEO1-2 and 3 (Fig. 9B). Since *M. coronatum* ranges in an interval below the first appearance of *Deshayesites deshayesi*, these specimens thus corroborate the stratigraphic position of the limestone bed as well as BEO1-2 and 3 below that zone, and within the infrajacent *Roloboceras hambrovi* subzone. It is conceivable that the deposits in the lower part of *Roloboceras hambrovi* subzone are reduced, as shown by the condensed bed, but the presence of the zone is confirmed by *M. coronatum* in normal stratigraphic succession. Furthermore, the δ13 C positive excursion correlative with the onset of OAE1a occurs within the level with *Megatyloceras coronatum*, thus substantiating the stratigraphic position of this event within the *Roloboceras hambrovi* zone (Moullade et al., 2000; Renard et al., 2005; Moreno-Bedmar et al., 2008, 2009; and others).

AMMONITE BIOSTRATIGRAPHY

Our analysis of the stratigraphic distribution of the ammonite species identified in the Lower Aptian of the Maestrat Basin allowed us to establish a detailed faunal succession that can be easily correlated with the current standard

Mediterranean Zonation, (Reboulet and Klein et al., 2009) see fig. 10. We have differentiated four zones, all of which can be considered as interval zones whose lower boundary is defined by the first occurrence of the index species, and their upper boundary coincides with the base of the superjacent zone. Each zone is also characterized by a diagnostic ammonite assemblage, which permits identification even in absence of the index species.

Deshayesites oglanlensis Zone

Definition and characterization: The lower boundary of this zone is defined by the first appearance of *Deshayesites oglanlensis* Bogdanova. This zone was proposed by Raissossadat (2002) and adopted in the subsequent versions of the standard zonation (Hoedemaeker and Reboulet et al., 2003; Reboulet and Hoedemaker et al., 2006; Reboulet and Klein et al., 2009). It was introduced to replace the former *Deshayesites tuarkyricus* Zone, because of the restricted geographic distribution of this latter index species.

Discussion: The *Deshayesites oglanlensis* Zone has hardly been identified in the studied sections. Ammonite specimens attributable to this interval are very scarce (Fig. 11). Only three specimens were available for diagnosis, one from the Salzedella Sub-basin and two from the Morella Sub-basin. The specimen from the Salzedella Sub-basin belongs to the private collection of Francisco Roig (Benassal, Region of Valencia). It is poorly preserved, but can be determined with little doubt as *Procheloniceras* sp. The stratigraphic range of taxa of the genus *Procheloniceras* extends from the uppermost Barremian (*Martelites sarasini* Subzone) up to the lowermost part of the *Deshayesites weissi* Zone (Delanoy, 1995, 1997; Ropolo et al., 2008b), which is biostratigraphically coeval with the *Deshayesites forbesi* Zone. The specimen in our study comes from the Xert Formation, which overlies the Cervera del Maestre Formation containing the geomagnetic polarity interval M0r (Fig. 1). Since this geomagnetic polarity interval marks the base of the Aptian (Erba, 1996), an uppermost Barremian age can be ruled out for this specimen.

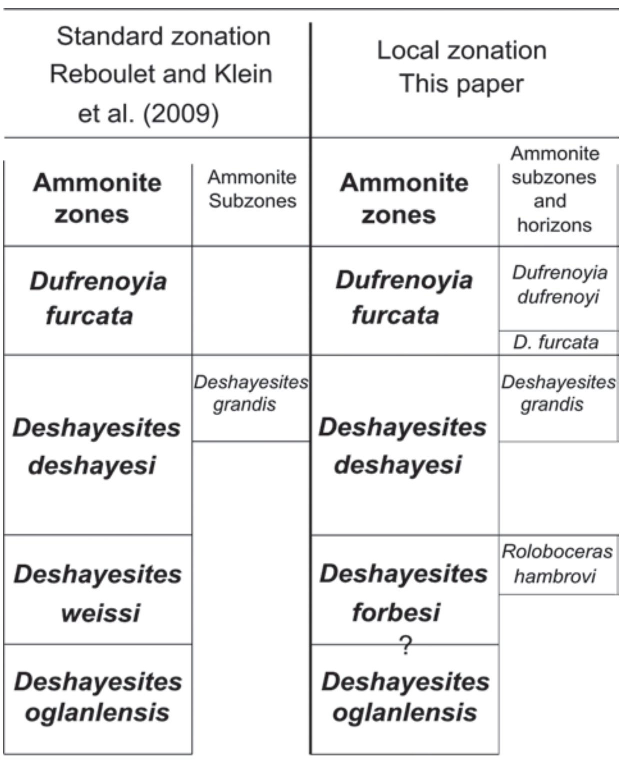

FIGURE 10 | **Lower Aptian standard ammonite zonation of the Mediterranean Region of Reboulet and Klein et al. (2009), and Lower Aptian local zonation proposed in this study for the Maestrat Basin.**

One of the specimens from the Cap de Vinyet Member, has been determined as *Deshayesites antiquus* Bogdanova (Fig. 12A) is a characteristic form of this Zone. The other specimen from the Morella Sub-basin is attributed to *Deshayesites luppovi* Bogdanova (Fig. 12B). It was found in the middle part of the Cap de Vinyet Member in the Mas de Segura section (Fig. 4B), about 20 meters below the first appearance of the species *Deshayesites forbesi* Casey, which characterizes the next zone. The species *D. luppovi* was originally reported (Bogdanova, 1979, 1983) from the *Deshayesites tuarkyricus* Zone (=*Deshayesites oglanlensis* Zone) and the lower part of the *Deshayesites weissi* Zone in Turkmenistan. This stratigraphic distribution has been subsequently corroborated by Bogdanova and Prozorovsky (1999), Bogdanova and Mikhailova (2004) and García-Mondéjar et al., (2009). However, Avram (1999) and Cecca et al., (1999a) found this species only in the *Deshayesites weissi* Zone, whereas Ropolo et al., (1999, 2000 a-c, 2006) recorded it exclusively in the *Deshayesites oglanlensis* Zone.

Delanoy (1995, 1997) and Aguado et al., (1997) reported the occurrence of a bed containing abundant specimens and fragments of a form that seems very close to *D. luppovi* from several sections in SE France and SE Spain. Delanoy (1995, 1997) assigned these specimens to *Deshayesites* sp., whereas Aguado et al., (1997) identified them as *D.* cf. *luppovi*. This form occurred between the assemblage constituted by specimens of *Kutatissites* and *Procheloniceras* with deshayesitids characteristic of the *Deshayesites oglanlensis* Zone, and the fauna that clearly belongs to the *Deshayesites weissi* Zone. These authors placed this form in the upper part of the *Deshayesites oglanlensis* Zone, and we tentatively attribute a similar stratigraphic position to our specimens from the Maestrat Basin.

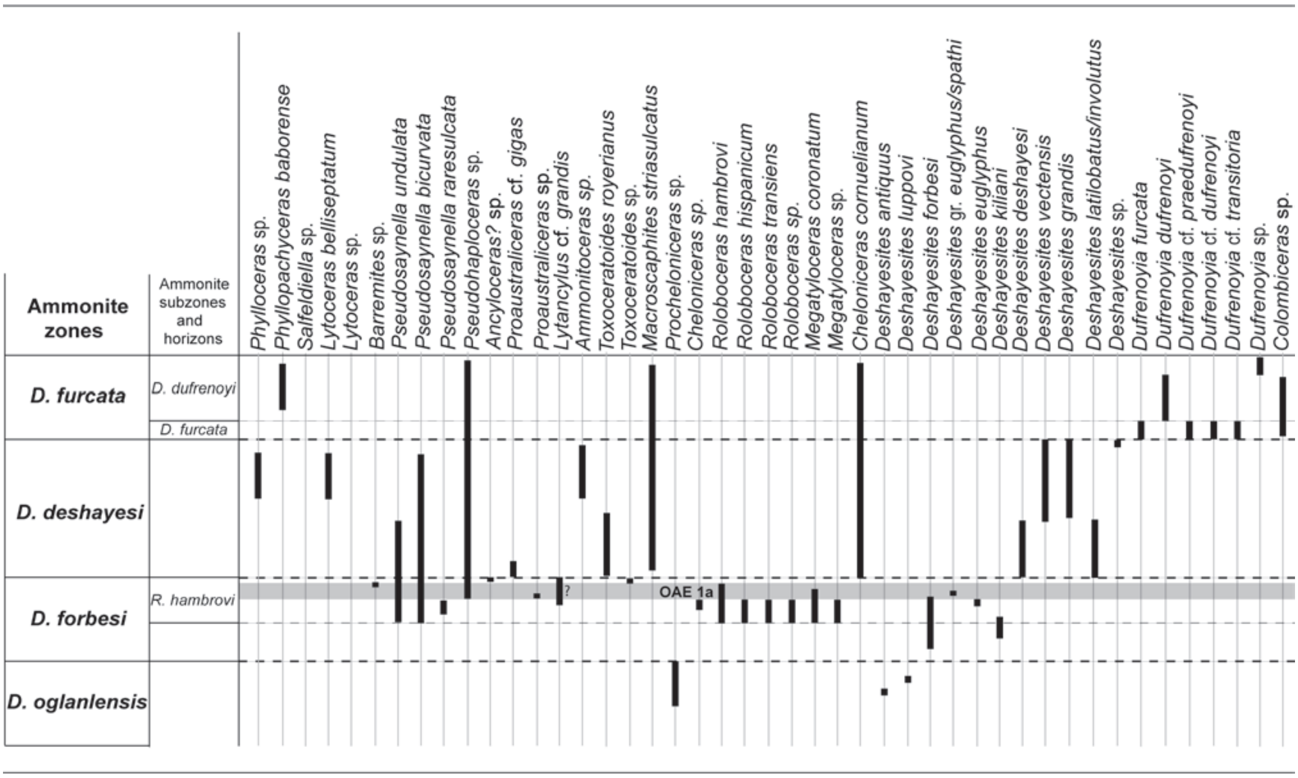

FIGURE 11 | **Range of the forty-five species recognized in the Maestrat Basin. OAE 1a after Moreno-Bedmar et al. (2008, 2009).**

Deshayesites forbesi Zone

Definition and characterization: In this paper we use the base of this zone to coincide with the first local occurrence of the index species. This biostratigraphic unit was used for the first time by Casey (1961) who listed several species of *Deshayesites*, *Roloboceras* and *Megatyloceras* as its main faunal characteristic. The succession of the *Deshayesites* species allowed Casey (1961) and Casey et al., (1998) to further subdivide the zone into four subzones, from oldest to youngest: *Deshayesites fittoni*, *Deshayesites kiliani*, *Deshayesites callidiscus*, and *Deshayesites annelidus* Subzones.

The *Deshayesites forbesi* Zone was recognized in most of the sections studied in the Maestrat Basin, (Figs. 4-5, 9), although complete exposures are rare and only visible in some sections of the Morella and Galve Sub-basins. In these areas, the *Deshayesites forbesi* Zone comprises the upper part of the Cap de Vinyet Member, the Barra de Morella Member and the basal part of the Morella la Vella Member of the Margas del Forcall Formation. Ammonoids are scarce in the upper part of the Cap de Vinyet Member, where only some specimens of *Deshayesites* cf. *forbesi* Casey, *Deshayesites* cf. *kiliani* Spath, and *Deshayesites* sp. have been found, and completely absent in the Barra de Morella Member. However, in the Morella, Galve and Oliete Sub-basins, the lower part of the superjacent Morella la Vella Member yielded a rich and well diversified ammonite assemblage comprising the following taxa: *Deshayesites euglyphus* Casey, *D.* gr. *euglyphus/spathi* Casey (Fig. 12D, Electronic annex (E.a.), I A), *D. forbesi* Casey (Fig. 12C), *Deshayesites* sp., *Cheloniceras* sp., *Roloboceras hambrovi* (Forbes) (Electronic annex (E.a.), I B-D, E.a., II A), *R. hispanicum* Sornay and Marin (E.a., I E, E.a., III A-D), *R. transiens* Casey, *Roloboceras* sp. (E.a., IV A), *Megatyloceras coronatum* (Rouchadzé) (E.a., IV B-D,), *Pseudosaynella raresulcata* (d'Orbigny), *P. undulata* (Sarasin) (E.a., IV F), *P. bicurvata* (Michelin) (E.a., IV E), *Pseudosaynella* sp., *Barremites* sp. (E.a., IV G), *Pseudohaploceras* sp., *Toxoceratoides royerianus* (d'Orbigny), *Ancyloceras*? sp., *Proaustraliceras* sp. and *Lithancylus* cf. *grandis* (Sowerby) (E.a., IV H). This assemblage, particularly the deshayesitid and roloboceratid species, is diagnostic of the middle/upper part of the *Deshayesites forbesi* Zone (Casey, 1961; Casey et al., 1998).

Roloboceratids (mainly represented by adult and subadult) constitute the main component of the assemblage, whereas deshayesitids are much less common. These *Roloboceras* beds define a very characteristic horizon (*R. hambrovi* horizon in Fig. 11) within the lower part of the Morella la Vella Member, and include the local record of Oceanic Anoxic Event 1a (Moreno-Bedmar et al., 2008,

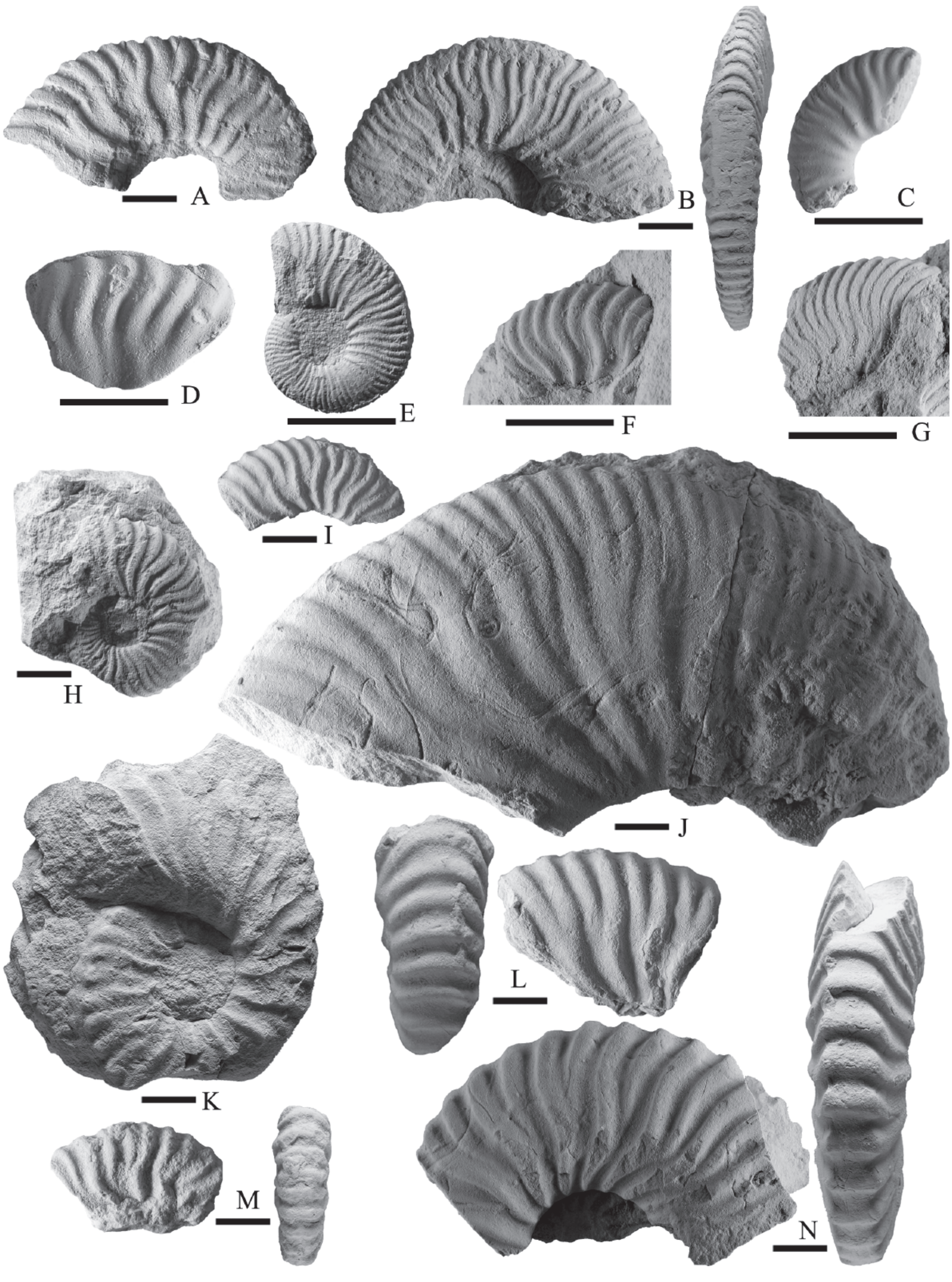

FIGURE 11 | **A)** ***Deshayesites antiquus*****, specimen PUAB-12535, Cap de Vinyet Member of Cap de Vinyet area. B)** ***Deshayesites luppovi,*** **specimen MV 900.1, Mas Segura section, sample MSMo-8a. C)** ***Deshayesites forbesi*****, specimen PUAB 48071, Tejería de Josa section, sample TJOl-1. D)** ***Deshayesites*** **gr.** ***euglyphus*****, specimen PUAB-48072, Tejería de Josa, sample TJOl-1. E)** ***Deshayesites deshayesi*****, specimen MV 425.1, Mola Murada section, sample MMSa-3. F)** ***Deshayesites deshayesi*****, specimen MV 425.2, Mola Murada section, sample MMSa-3. G)** ***Deshayesites deshayesi*****, specimen MV 471.2, Todolella section, sample TOMo-9. H)** ***Deshayesites vectensis*****, specimen CPT-3599, Barranco de las Calzadas section, sample BCGa-13. I)** ***Deshayesites deshayesi*****, specimen MV 471.1, Todolella section, sample TOMo-9. J)** ***Deshayesites grandis*****, specimen CPT-3618, Barranco de las Calzadas section, sample BCGa-19. K)** ***Dufrenoyia furcata*****, specimen MV 481.2, Mas Agustina section, sample MAPe-5. L)** ***Dufrenoyia furcata*****, specimen MV Se18.1, Mas Segura section, sample MSMo-18. M)** ***Dufrenoyia furcata*****, specimen CPT-3649, Barranco de las Calzadas section, sample BCGa-20. N)** ***Dufrenoyia*** **sp., specimen CPT-3728, Barranco de las Calzadas section, sample BCGa-28. Scale bar, 1cm.**

2009). This horizon has also been recognized in the Cassis-La Bédoule area (Provençal Platform, SE France) where Busnardo (1984) introduced a *R. hambrovi* Zone at the base of the upper Bedoulian in his zonal scheme for SE France (see also Ropolo et al., 2006, 2008a, 2008b).

Discussion: The successive versions of the standard Mediterranean ammonite zonation (Hoedemaeker and Bulot et al., 1990; Hoedemaeker and Company et al.,1993; Hoedemaeker and Cecca et al., 1995; Rawson and Hoedemaeker et al., 1999; Hoedemaeker and Rawson, 2000; Hoedemaeker and Reboulet et al., 2003; Reboulet and Hoedemaeker et al., 2006; Reboulet and Klein et al., 2009) have routinely used the species *Deshayesites weissi* (Neumayr and Uhlig) as index of the second zone of the Aptian stage. Although originally described in northern Germany, this species has often been reported in the Mediterranean region. Nevertheless, *Deshayesites weissi* has never been the object of a systematic revision and its status remains unclear, because the original figures are difficult to interpret, the types are lost and their stratigraphic position is not known. It is for this reason that several authors (Bogdanova and Mikhailova, 2004; Ropolo et al., 2006; Reboulet and Hoedemaeker et al., 2006; Reboulet and Klein et al., 2009; García-Mondéjar et al., 2009) stressed the inadequacy of this taxon as zonal index. We did not find any true *D. weissi* in our study, and previous records of this species from the Maestrat Basin (Weisser, 1959; Martínez et al., 1994) are considered here to be misidentifications.

Due to the absence of *D. weissi* in the materials studied, and the problems associated with its identification, we prefer to use *D. forbesi* as zonal index for this stratigraphic interval. In fact, many of the species listed above in the Maestrat Basin are also present in the *Deshayesites forbesi* Zone of southern England (Casey, 1961). It is important to emphasize, however, that there are some difficulties in recognizing the lower boundary of the *Deshayesites forbesi* Zone in our sections. The fauna from the lower part of the interval attributed to this zone in the Maestrat Basin is scarce and poorly preserved, lacking diagnostic species of the *Deshayesites fittoni* Subzone. Therefore, we cannot rule out that the upper part of the underlying *Deshayesites oglanlensis* Zone (namely the beds with *D. luppovi*, see above) could actually correlate with the base of the *Deshayesites forbesi* Zone sensu Casey (1961). A similar problem arises in the exact correlation of the *Deshayesites weissi* Zone and the *Deshayesites forbesi* Zone. Although it is commonly accepted that the two units are time equivalent (Erba, 1996, fig. 3; Bogdanova and Tovbina, 1994, table I; Bogdanova and Mikhailova, 2004, table I; Gradstrein et al., 2004; Moreno et al., 2007; Ropolo et al., 2008a; García-Mondéjar et al., 2009, among others), there is no corroborative evidence to show that the lower boundaries of the two units are strictly isochronous.

Martínez et al., (1994) placed the rich ammonite assemblage composed of several species of *Pseudosaynella*, *Roloboceras* and *Megatyloceras*, collected from the base of the Tejería de Josa section (Oliete Sub-basin; see Fig. 9A), in the *Deshayesites deshayesi* Zone. This age assignment was based on the presence of a single deshayesitid specimen that they identified as *D. deshayesi*. We reviewed this specimen (Fig. 12D) and concluded that it was misidentified. It is a juvenile fragment consisting of just 1/5 of whorl, with strong blunt ribs typical of the inner whorls of morphotypes belonging to the *D. euglyphus* species group, which is characteristic of the *Deshayesites forbesi* Zone. Similar divergences in the interpretation of deshayesitid species could also explain the inclusion by Ropolo et al. (2006) of the *Roloboceras* beds of the Cassis-La Bédoule area in the *Deshayesites deshayesi* Zone (see Moreno-Bedmar et al., 2009).

Deshayesites deshayesi Zone

Definition and characterization: This zone corresponds to the stratigraphic interval between the successive first appearance datum of *Deshayesites deshayesi* (d'Orbigny) and *Dufrenoyia furcata* (Sowerby), respectively. A "Zone à *Hoplites Deshayesi* (= *Deshayesites deshayesi*) et *Ancyloceras Matheroni*" was used for the first time by Jacob (1907) to refer to the entire Bedoulian.

We recognized this ammonite zone in most of the sections studied in detail (Figs. 4-7). It was not identified in the Oliete Sub-basin sections (Fig. 9), where the shallow-water facies of the Alacón Formation directly overly beds with fauna of the upper *Deshayesites forbesi* Zone. In the other sub-basins, the *Deshayesites deshayesi* Zone occurs within the middle/upper part of the Morella la Vella Member of the Margas del Forcall Formation. The following taxa were found associated with this zone: *Deshayesites deshayesi* (d'Orbigny) (Fig. 12E-G, I, E.a., IV I-L), *Deshayesites vectensis* (Spath) (Fig. 12H, E.a.,V A), *Deshayesites* sp. (E.a.,V C), *Deshayesites latilobatus/involutus* group (E.a.,VI A), *Deshayesites grandis* (Spath) (Fig. 12J, E.a.,V B), *Cheloniceras cornuelianum* (d'Orbigny) (E.a.,VI B), *Pseudosaynella bicurvata* (Michelin), *Pseudosaynella undulata* (Sarasin), *Pseudohaploceras* sp., *Lytoceras belliseptatum* Anthula (E.a.,VIII A), *Phylloceras* sp., *Ammonitoceras* (*Epancyloceras*) sp., *Proaustraliceras* cf. *gigas* (Sowerby) (E.a.,VII A), and *Toxoceratoides royerianus* (d'Orbigny).

Discussion: The species *D. deshayesi* has been differently interpreted in the literature (see Casey, 1964). The differences are due in some extent to the fact that the original figures of d'Orbigny (1841) and Leymerie (1842) correspond to small pyritized phragmocones which are difficult to compare with adult or subadult specimens.

This imprecision in the identification of the species led to a widespread confusion concerning its actual stratigraphic range, thus, for decades, *D. deshayesi* was thought to be present throughout the Lower Aptian. In fact, the participants at the “Colloque sur le Crétacé inférieur” in Lyon (1963) recognized the *Deshayesites deshayesi* Zone for the entire Bedoulian (Flandrin, 1965). Paradoxically, Kilian (1910-1913) had long before stated that typical forms of this species were restricted to the upper part of the Lower Aptian, which he divided into a lower “Zone des *Parahoplites Weissi* und *Douvilleiceras Albrechti-Austriae*” and an upper “Zone des *Parahoplites Deshayesi*”.

Casey (1961, 1964) provided final clarification on the stratigraphic position of *D. deshayesi* and restricted the concept of the *Deshayesites deshayesi* Zone which he further divided into two subzones: the oldest being the *Cheloniceras parinodum* Subzone and the youngest being the *Deshayesites grandis* Subzone. According to Casey (1964, 1980), *D. deshayesi*, together with *D. multicostatus* Swinnerton, *D. consobrinoides* (Sinzow) and *D. latilobatus* (Sinzow) would be confined to the lower subzone, whereas *D. grandis* Spath, *D. geniculatus* Casey, *D. vectensis* Spath and *D. wiltshirei* Casey would characterize the upper one. However, *D. involutus* Spath could be present in the two subzones. Nevertheless, the taxonomic adequacy and relationships of all these nominal species deserve to be studied in more detail in order to assess their validity. In fact, the specimens attributed to *D. involutus*, *D. latilobatus* and *D. grandis* are generally large-sized forms that presumably correspond to adult or subadult specimens. In contrast, the types and most of the specimens assigned to *D. deshayesi* are juvenile phragmocones that show striking similarities with the inner whorls of the aforementioned species.

Dufrenoyia furcata Zone

Definition and characterization: The base of this zone is marked by the first appearance of *Dufrenoyia furcata* (Sowerby). This biostratigraphic unit was used for the first time by Jacob (1907), who placed it at the base of the Gargasian.

The *Dufrenoyia furcata* Zone was identified in the uppermost part of the Morella la Vella Member in the Morella, Galve, Penyagolosa, Perelló and Salzedella Sub-basins (Figs. 4-8) and also at the onset of the Villarroya de los Pinares Formation in the Galve, Salzedella and Perellò Sub-basins. The exact position of its upper boundary could not be determined because ammonoids become completely absent in higher levels of the Villarroya de los Pinares Formation. This zone is characterized by the presence of the following taxa: *Dufrenoyia furcata* (Sowerby) (Fig. 12K-M, E.a.,VI D-E, VIII D-E, IX A), *D. dufrenoyi* (d’Orbigny), *D.* cf. *dufrenoyi* (d’Orbigny) (E.a.,VI C), *Dufrenoyia* cf. *praedufrenoyi* (d’Orbigny) (E.a.,VIII B), *Dufrenoyia* cf. *transitoria* Casey (E.a.,VIII F), *Dufrenoyia* sp. (Fig. 12N), *Cheloniceras cornuelianum* (d’Orbigny) (E.a.,VIII C), *Colombiceras* sp., *Pseudohaploceras* sp., *Macroscaphites striasulcatus* (d’Orbigny), *Phyllopachyceras baborense* (Coquand) and *Salfeldiella* sp.

Discussion: In the Gargas region (SE France), Dutour (2005) subdivided the *Dufrenoyia furcata* Zone into two subzones, characterized by *D. furcata* and *D. dufrenoyi*, respectively. We also recognized these two subzones in some of the sections studied in the Galve, Salzedella and Penyagolosa Sub-basins (Figs. 5-7), where *D. dufrenoyi* clearly replaces *D. furcata* in the upper part of the zone. Nonetheless, we could not separate the two successive horizons (*D. praedufrenoyi* and *D. dufrenoyi*) identified by Dutour (2005) within the *Dufrenoyia dufrenoyi* Subzone. It is worth noting that in the upper part of the *Dufrenoyia dufrenoyi* Subzone we collected some rare specimens with ribs that show pattern similar to that of *D. dufrenoyi*, but that cross the ventral region.

García-Mondéjar et al., (2009) recently reported the synchronous occurrence of the genera *Deshayesites* and *Dufrenoyia* throughout a thick, about 220 metres, stratigraphic interval in the Aralar region of the Basque-Cantabrian Basin (N Spain). Such association has never been found elsewhere, because the record has so far shown that *Dufrenoyia* replaces *Deshayesites* without any overlap at the base of the *Dufrenoyia furcata* Zone. These authors argued that the overly expanded sections of the Aralar region, reflecting a high sedimentation rate, could have preserved the transition interval between the zones. Our data, however, do not corroborate this assertion. Our study of well-expanded sections that comprise the boundary between the *Deshayestites deshayesi* and *Dufrenoyia furcata* zones, as at Barranco de las Calzadas (Fig. 5), showed that the faunal change is rather abrupt. Specimens of *Dufrenoyia* recorded in the first bed (BCGa-20) of the *Dufrenoyia furcata* Zone still show very primitive characters (the ribs cross the ventral region, which is still slightly convex) and closely resemble the last *Deshayesites*, but the range of the two genera did not overlap.

ACCOMMODATION AND BIOZONES DISTRIBUTION

During the Lower Aptian, the fault-controlled rapid syn-rift subsidence was the most important factor in producing accommodation (Fig. 3). The Lower Aptian rapid interval of syn-rift subsidence was recorded throughout the Maestrat Basin, but showing differential subsidence patterns between the different sub-basins as shown in figure 13. For instance, in the Morella sub-basin, the thickness of the *Dufrenoyia furcata* biozone is around 10 meters (Fig. 4B), whereas this sedimentary record thickens up to 100 meters in the southern Salzedella and Penyagolosa sub-basins. In this regard, the available accommodation space within each sub-basin also played a key role in the facies and biozones distribution.

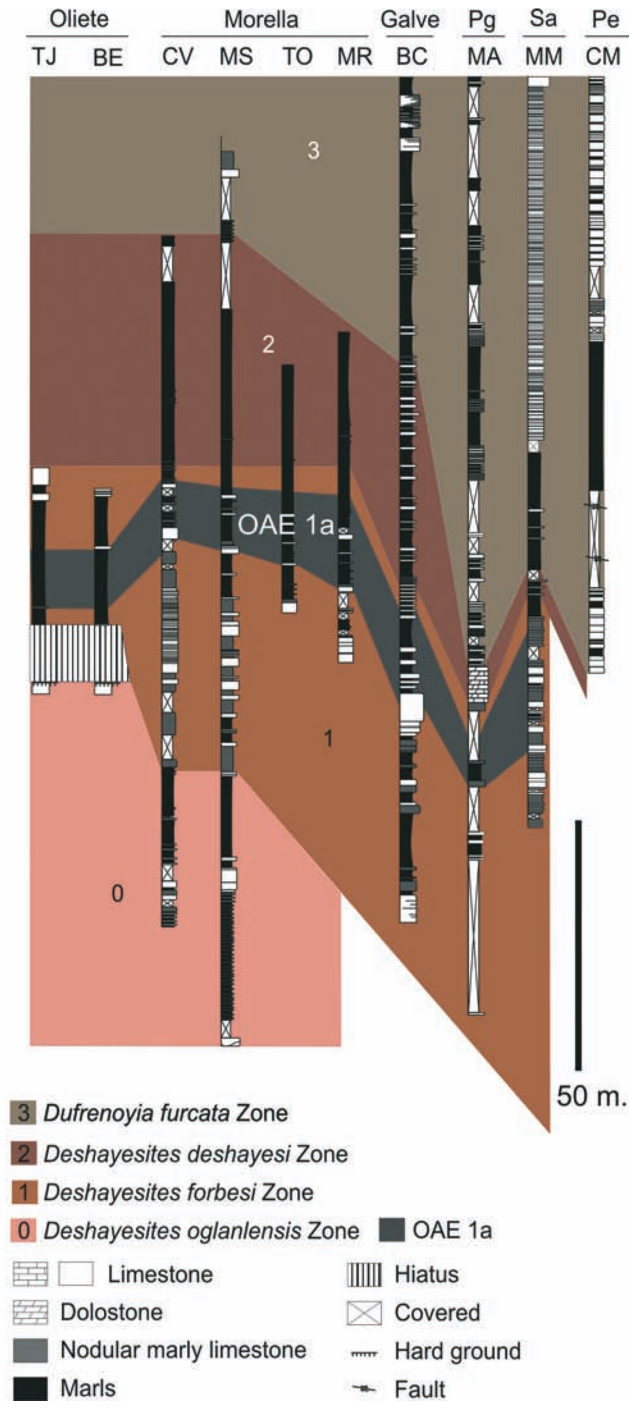

FIGURE 13 | **Correlation of the ten sections studied by means ammonoid biozones. The extensional Lower Aptian structure is not indicated.**

In the case of the Oliete sub-basin, the gain in accommodation space mainly developed during the middle and upper part of the *Deshayesi forbesi* Zone, declining substantially later. As a consequence, the timing of the Forcall Formation, formed by basinal deeper water marly sediments, is much reduced in relation to the marine shallow water carbonate sediments of the Oliete Formation (Fig. 2).

Salzedella and Penyagolosa sub-basins display a similar pattern of accommodation space during the Lower Aptian time span (Figs. 1C and 13). In these sub-basins, the *Deshayesites deshayesi* Zone exhibits a thickness extremely reduced, about 10 meters. Later, the next biozone of *Dufrenoyia furcata* experienced a significant gain in accommodation space with more than 100 m of thickness.

CONCLUSIONS

The analysis of the ammonite stratigraphic distribution in ten selected sections in the Maestrat Basin (E Spain) allowed us to establish the faunal succession for the Lower Aptian in the region. We recognized, from oldest to youngest the following Zones: *Deshayesites oglanlensis*, *Deshayesites forbesi*, *Deshayesites deshayesi*, and *Dufrenoyia furcata*. We also identified a *Roloboceras hambrovi* horizon in the middle/upper part of the *Deshayesites forbesi* Zone, and the twofold subdivision proposed by Dutour (2005) for the *Dufrenoyia furcata* Zone, *Dufrenoyia furcata* and *Dufrenoyia dufrenoyi* subzones. Our results improve the resolution of the current Mediterranean zonation and test the correlation potential of the biostratigraphic events that define and characterize its different units. Moreover, the introduction of the *Deshayesites forbesi*, instead of *Deshayesites weissi*, as index of the second zone of the Aptian, and the identification of the *Roloboceras hambrovi* horizon allow a more direct correlation with the Boreal zonation.

This study further enabled us to more accurately determine the age of the lithostratigraphic units defined in the region. Thus, the upper part of the Xert Formation and the lowermost part of the Cap de Vinyet Member (base of the Forcall Formation) are correlative with the *Deshayesites oglanlensis* Zone. The upper part of the Cap de Vinyet and the Barra de Morella Members of the Forcall Formation correspond to the lower part of the *Deshayesites forbesi* Zone. The lower part of the Morella la Vella Member (upper Forcall Formation), which includes the local record of OAE 1a, clearly correlates with the *R. hambrovi* horizon (middle/upper part of the *Deshayesites forbesi* Zone). The boundary between the Forcall Formation and the Villarroya de los Pinares Formation is diachronous and varies, depending on the sub-basins, between the uppermost part of the *Deshayesites forbesi* Zone and the middle/upper part of the *Dufrenoyia furcata* Zone. The base of the Villarroya de los Pinares Formation can be dated as middle-upper part of the *Dufrenoyia furcata* Zone in the Galve, Perelló and Salzedella Sub-basins. The transition between the Forcall Fm. and Villarroya Fm. is a diachronous limit, which varies depending on the control by syn-rift tilted blocks in different parts of the Basin.

During the Lower Aptian, the fault-controlled rapid syn-rift subsidence was the most important factor in producing accommodation space. At the same time, this interval of rapid subsidence coincided with the broad, well-documented Early Aptian Tethyan transgression, especially in Forcall Fm, which contains the *Deshayesites oglanlensis*, *Deshayesites forbesi*, *Deshayesites deshayesi* and *Dufrenoyia furcata* Zones.

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ELECTRONIC APPENDIX

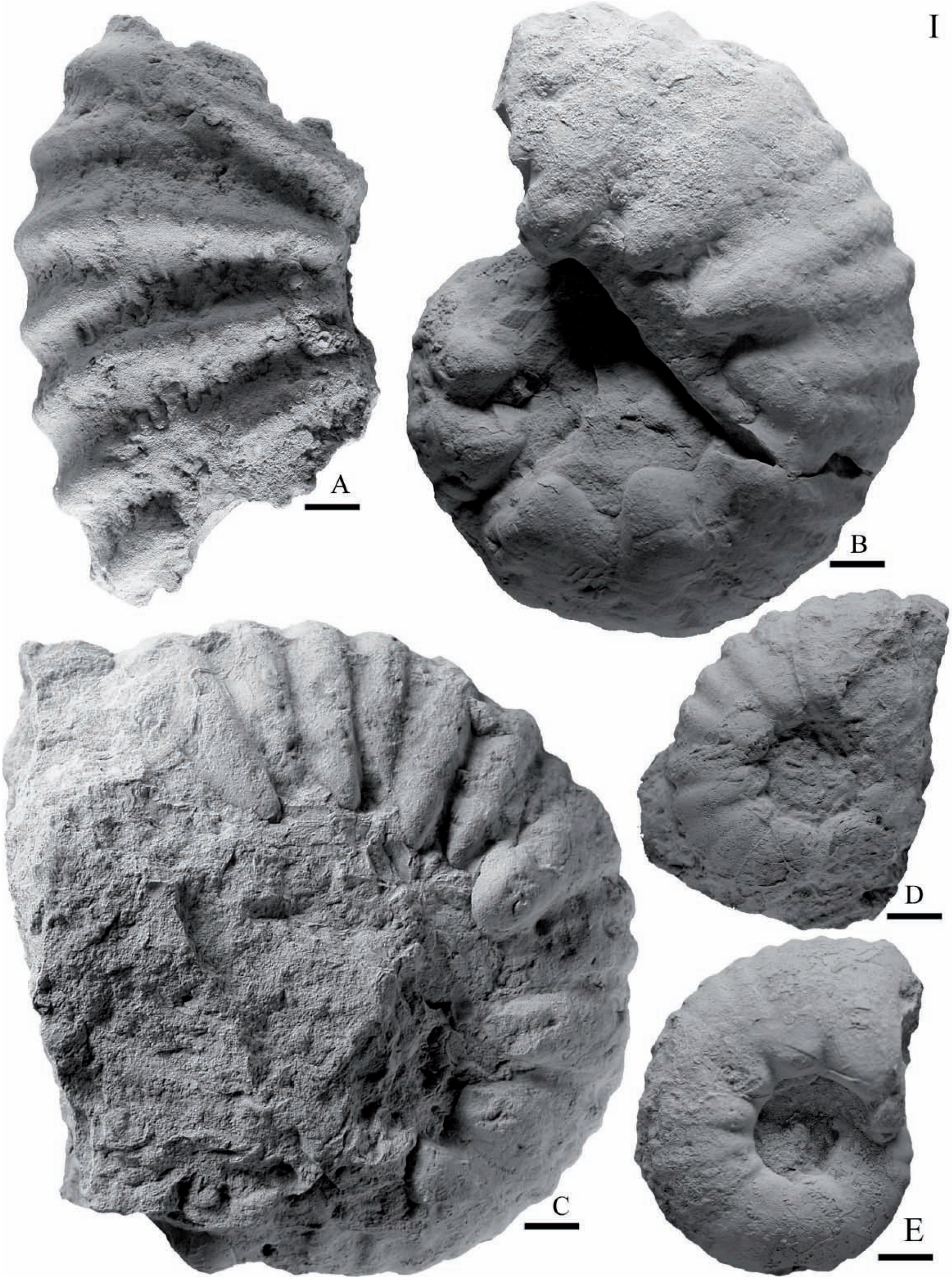

FIGURE I | **A) *Deshayesites* gr. *euglyphus/spathi*, specimen PUAB 68517, Todolella section, sample TOMo-3. B) *Roloboceras hambrovi* (Forbes), specimen MV 673.1, Mas del Roc section, sample MRMo-2. C) *Roloboceras hambrovi*, specimen MV 644.1, Cap de Vinyet section, sample CVMo-3. D) *Roloboceras hambrovi*, specimen PUAB 48049, Tejería de Josa section, equivalent to sample TJOI-1. E) *Roloboceras hispanicum*, specimen PUAB 48102, Tejería de Josa section, equivalent to sample TJOI-1. Scale bar, 1cm.**

II

FIGURE II | **A) *Roloboceras hambrovi*, specimen CPT-3790, Barranco de las Calzadas section, sample BCGa-6. Scale bar, 1cm.**

FIGURE III | **A) *Roloboceras hispanicum*, specimen CPT-3234, Barranco de las Calzadas section, sample BCGa-3. B) *Roloboceras hispanicum*, specimen RA-1 (Ramiro Álvarez. Barcelona, Particular collection), Tejería de Josa section, equivalent to sample TJOI-1. C) *Roloboceras hispanicum*, specimen CPT-3788, Tejería de Josa section, sample TJOI-1. D: *Roloboceras hispanicum*, specimen RM-2 (Ramon Margalef, Barcelona particular collection), Tejería de Josa section, equivalent to sample TJOI-1. Scale bar, 1cm.**

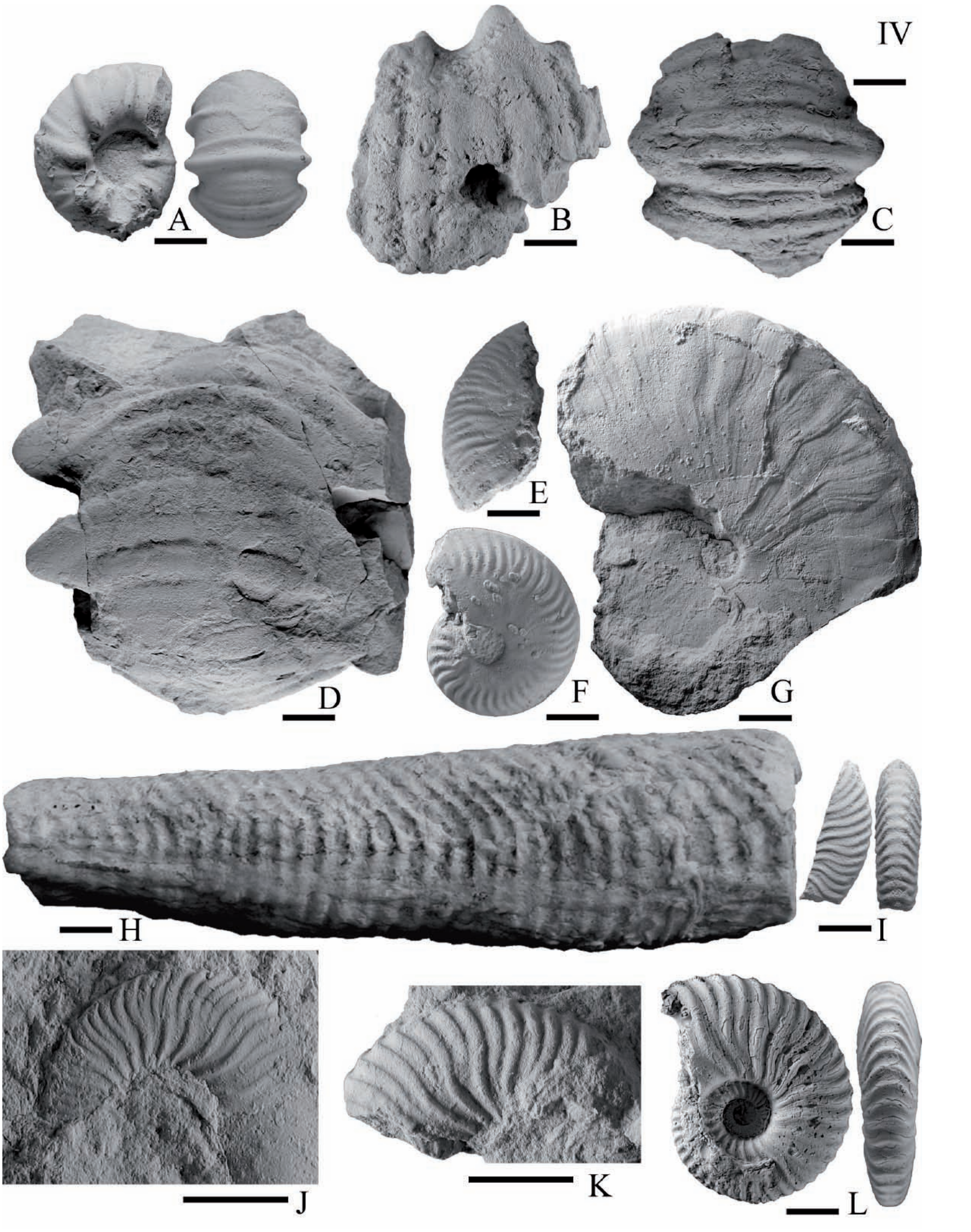

FIGURE IV | **A)** ***Rolobocera*****s sp., specimen PUAB 48136, Tejería de Josa section, equivalent to sample TJOI-1. B)** ***Megatyloceras coronatum*****, specimen MV 645.3, Cap de Vinyet section, sample CVMo-2. C)** ***Megatyloceras coronatum*****, specimen PUAB 48008, Tejería de Josa section, equivalent to sample TJOI-1. D)** ***Megatyloceras coronatum*** **specimen MV 674.1, Mas del Roc section, sample MRMo-3. E)** ***Pseudosaynella bicurvata*****, specimen PUAB 5911 Tejería de Josa section, equivalent to sample TJOI-1. F)** ***Pseudosaynella undulata*****, specimen PUAB 48385, Tejería de Josa, equivalent to sample TJOI-1. G)** ***Barremites*** **sp. specimen CPT-3729, Barranco de las Calzadas section, sample BCGa-8. H)** ***Lithancylus*** **cf.** ***grandis*****, specimen MSM 46-A-120, Xert (Castelló). I)** ***Deshayesites deshayesi*****, juvenile specimen CPT-3612, Barranco de las Calzadas section, sample BCGa-14. J)** ***Deshayesites deshayesi*****, specimen MV 650.1, Cap de Vinyet section, sample CVMo-6. K)** ***Deshayesites deshayesi*****, specimen MV 471.7, Todolella section, sample TOMo-9. L)** ***Deshayesites deshayesi*****, specimen MGSB 73018, Morella area. Scale bar, 1cm.**

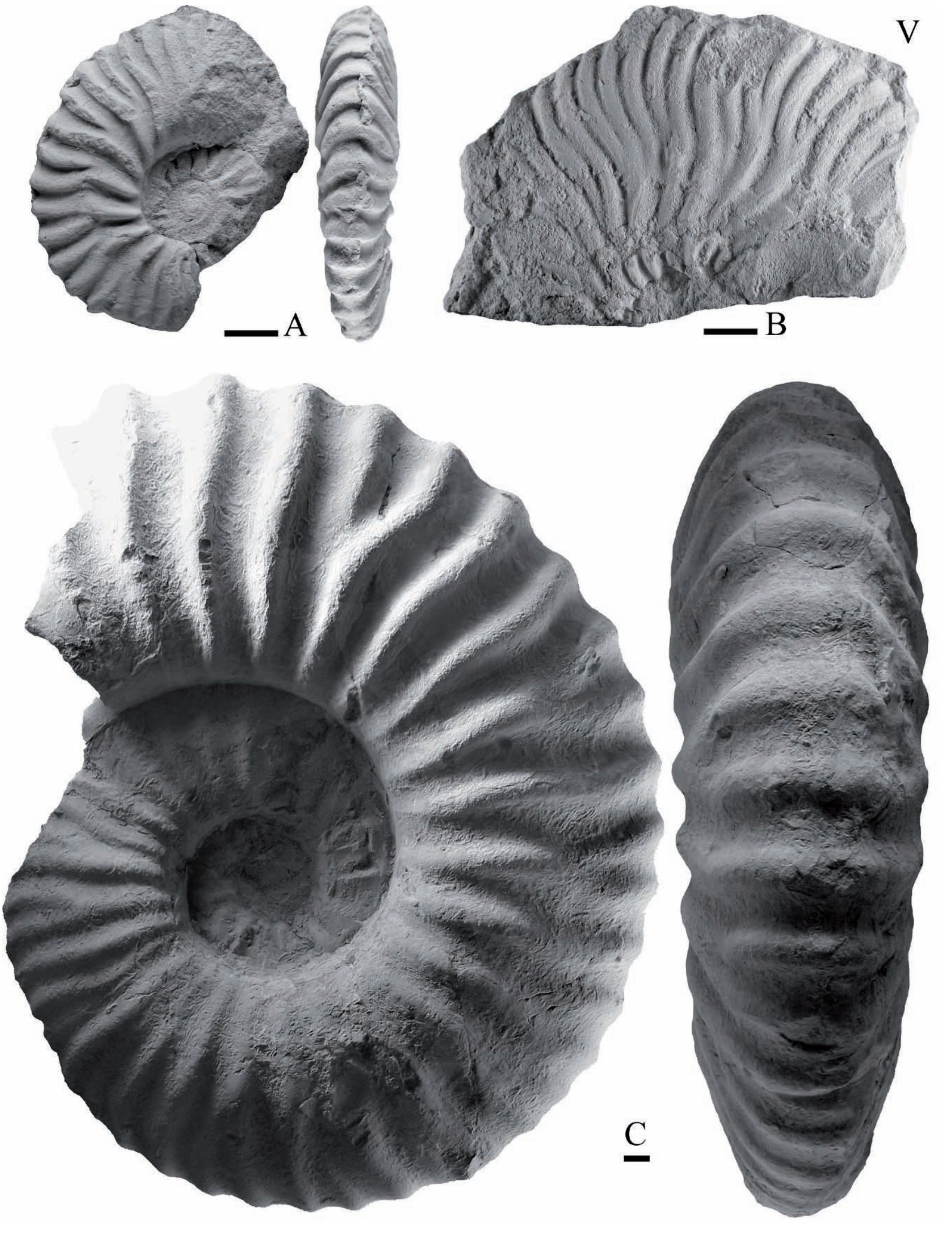

FIGURE V | **A)** ***Deshayesites vectensis*****, specimen CPT-3237, El Portulés, La Solana section, sample SOGa-1. B)** ***Deshayesites grandis*****, specimen CPT-3236 from Villarroya de los Pinares area. C)** ***Deshayesites*** **sp., specimen CPT-3624, Barranco de las Calzadas section, sample BCGa-19. Scale bar, 1cm.**

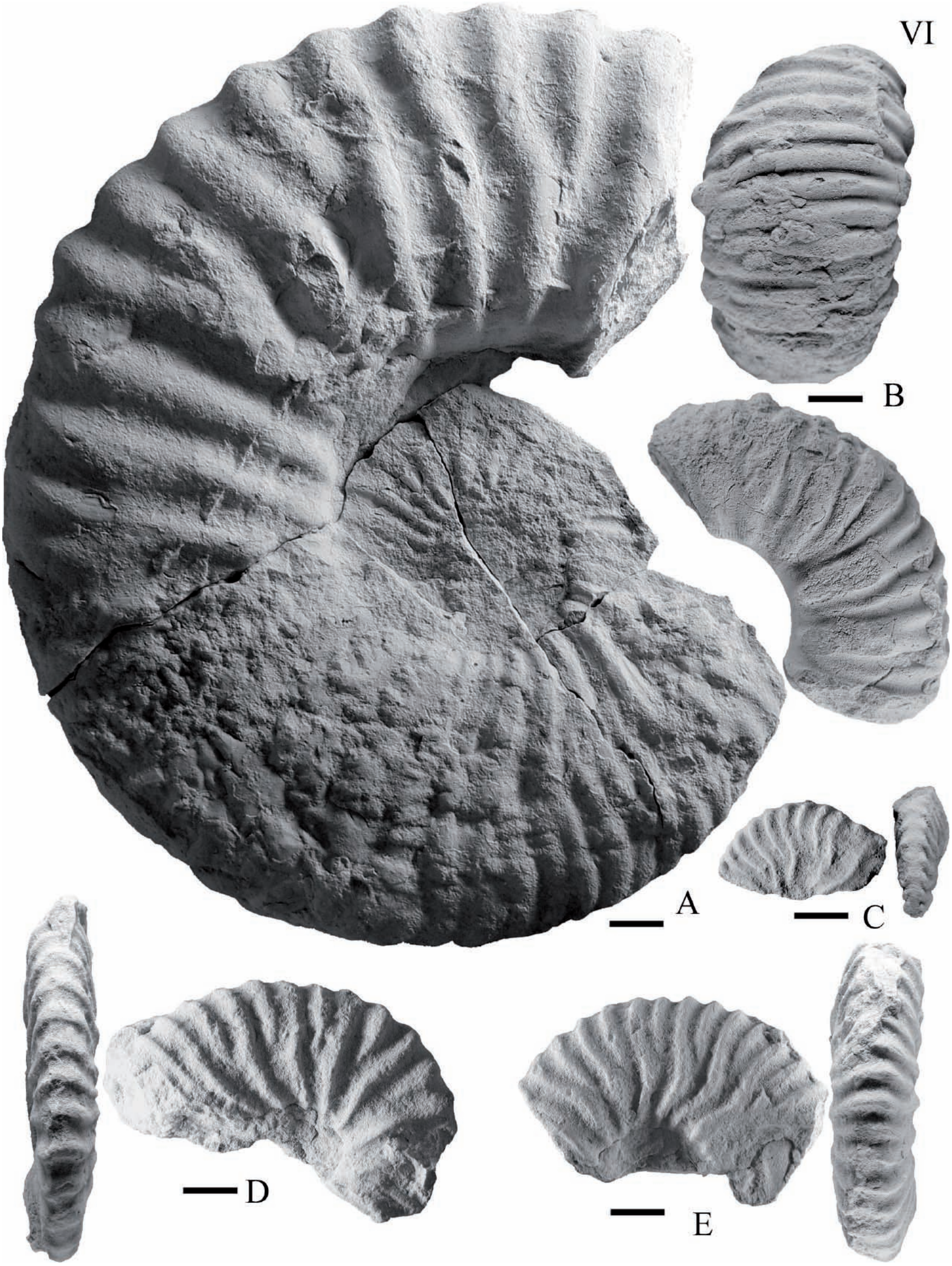

FIGURE VI | **A)** ***Deshayesites latilobatus/involutus*****, sub-adult specimen CPT-3567, El Portules, Villarroya de los Pinares area. B)** ***Cheloniceras cornuelianum*** **(d'Orbigny), specimen CPT-3235 from Villarroya de los Pinares area. C)** ***Dufrenoyia*** **cf.** ***dufrenoyi*****, specimen CPT-3697, Barranco de las Calzadas section, sample BCGa-20. D)** ***Dufrenoyia furcata*****, specimen CPT-3637, Barranco de las Calzadas section, sample BCGa-20. E)** ***Dufrenoyia furcata*****, specimen CPT-3656, Barranco de las Calzadas section, sample BCGa-20. Scale bar, 1cm.**

FIGURE VII | **A) *Proaustraliceras* cf. *gigas*, specimen PUAB 48642, Villarroya de los Pinares area, lower part of *Deshayesites deshayesi* zone. Scale bar, 1cm.**

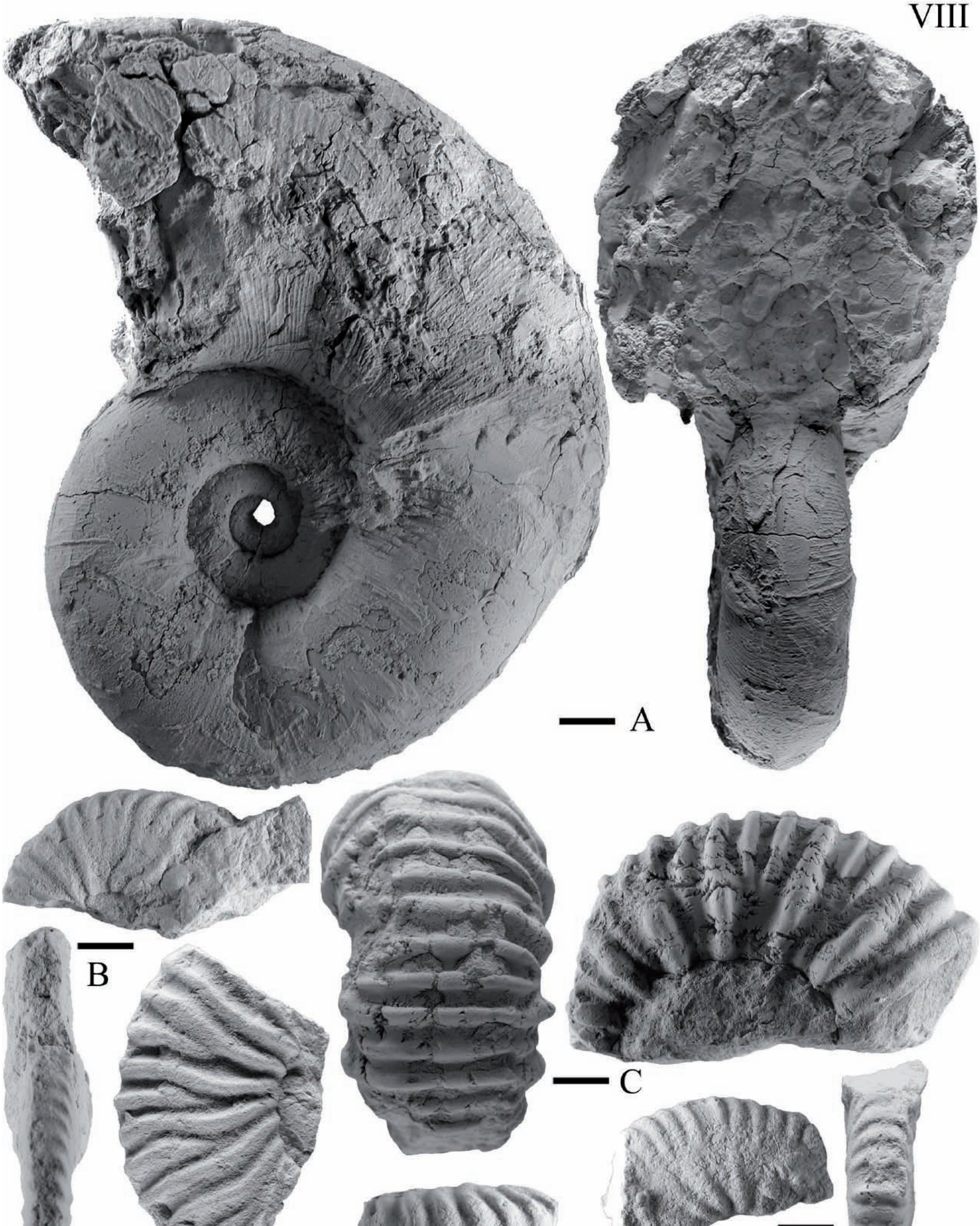

FIGURE VIII | **A)** ***Lytoceras belliseptatum*** **specimen DT-2 (Domingo Tolos collection, La Jana, Castelló), Mas del Roc section, (equivalent to samples MRMo-11-13). B)** ***Dufrenoyia*** **cf.** ***praedufrenoyi*****, specimen CPT-3660, Barranco de las Calzadas section, sample BCGa-20. C)** ***Cheloniceras cornuelianum*****, specimen CPT-3726, Barranco de las Calzadas section, sample BCGa-21. D)** ***Dufrenoyia furcata*****, specimen CPT-3690, Barranco de las Calzadas section, sample BCGa-20. E)** ***Dufrenoyia furcata*****, specimen CPT-3686, Barranco de las Calzadas section, sample BCGa-20. F)** ***Dufrenoyia*** **cf.** ***transitoria*****, specimen CPT-3679, Barranco de las Calzadas section, sample BCGa-20. Scale bar, 1cm.**

FIGURE IX | **A)** ***Dufrenoyia furcata*** **specimen DT-1, Nogueruelas. Scale bar, 1cm.**