
Multicostate zeillerids (Brachiopoda, Terebratulida) from the Lower Jurassic of the Eastern Subbetic (SE Spain) and their use in correlation and paleobiogeography

J.F. BAEZA-CARRATALÁ ^{|1|} and F. GARCÍA JORAL ^{|2|}

^{|1|} Departamento de Ciencias de la Tierra y del Medio Ambiente, Universidad de Alicante
Campus San Vicente del Raspeig s/n, 03690, Alicante, Spain. E-mail: jf.baeza@ua.es

^{|2|} Departamento & U.E.I. de Paleontología, Facultad de Ciencias Geológicas, Universidad Complutense-C.S.I.C.
C/ José Antonio Novais, 2, 28040, Madrid, Spain. E-mail: fgjoral@geo.ucm.es

| A B S T R A C T |

The Lower Jurassic multicostate zeillerids of the Subbetic Domain are described here for the first time. A new species (*Fimbriothyris? dubari*) is erected, and the affinities of the remaining three species are discussed. These taxa appear as part of an assemblage that includes several other brachiopods belonging to the Terebratulida, Rhynchonellida and Spiriferinida orders, which are specified. The correlation of this assemblage with others from neighbouring basins is attempted, with the aim to precise its chronostratigraphical position. A Sinemurian-Pliensbachian transition age is proposed. The spatial distribution of the Lower Jurassic multicostate zeillerids is analysed, revealing its strictly Mediterranean character, limited to some South-western Tethys areas. This allows discarding the supposed subboreal (northwest European) influences in the Subbetic faunas proposed by several authors. The relationship of this group of brachiopods with the initial stages of break-up and subsequent drowning of the Lower Jurassic carbonate platforms is also confirmed.

KEYWORDS | Brachiopods. Sinemurian. Pliensbachian. Systematics. Paleobiogeography. Western Tethys.

INTRODUCTION

The multicostate zeillerids are a rare group of brachiopods with a rather restricted distribution within the Mediterranean area of Western Tethys during the Lower Jurassic. The spatial and temporal limitations shown by this group, together with the fact that they are easily distinguished from other contemporary brachiopods, make them a very useful group in paleobiogeographic studies and in the establishment of biostratigraphic correlations.

Until the revision of the brachiopods housed in the Jiménez de Cisneros collections (Baeza-Carratalá, 2008), no multicostate zeillerids had been reported in the Lower Jurassic of the East Subbetic basin (Alicante and Murcia Provinces). This collection is one of the most important concerning Mediterranean Jurassic brachiopods in the world, resulting from many years of field and laboratory work carried out between 1903 and 1936, kept by the Jiménez de Cisneros family. This collection includes several specimens from the Rabillo de Quibas locality (Fig. 1),

which were originally assigned by Jiménez de Cisneros (1920) to *Rhynchonella lubrica*, and later to *Terebratulapacheia* (Jiménez de Cisneros, 1923c). After the previously mentioned revision, these specimens have been assigned to the genera *Tauromenia* and *Fimbriothyris*. This new classification led to a detailed analysis of this group of fossils and new sampling at several localities of the Lower Jurassic of the Eastern Subbetic, resulting in the finding of two further species of the genus *Tauromenia* (*T. polymorpha* and *T. aff. brevicostata*).

This paper describes the multicostate zeillerids from the Eastern Subbetic, studying both the specimens from the Jiménez de Cisneros collection and those resulting from the new sampling carried out for this study; for this reason, some species from the historical collection that were not found in the recent prospecting campaigns have also been included

GEOLOGICAL SETTING

The localities where the studied brachiopod have been recorded (Fig. 1) belong to the mainly calcareous Jurassic outcrops located in the southern area of the province of Alicante and the northern zone of the province of Murcia (SE Spain). They belong to the easternmost area of the External Zone of the Betic Cordillera, within the Subbetic

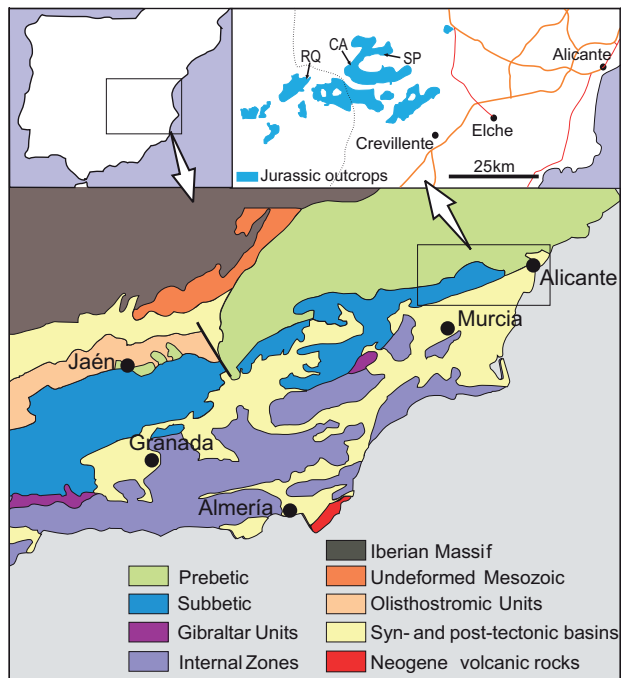


FIGURE 1 | Location map showing the studied localities within the geological context of the Betic Cordillera. RQ: Raballo de Quibas Section; SP: Sierra Pelada Section; CA: Cerro de la Cruz de La Algueña (historical locality cited by Jiménez de Cisneros). Geologic map modified after Vera (2004).

domain. This region is characterized by the predominance of typical pelagic seamount sedimentation during most of the Jurassic and Early Cretaceous (Azéma *et al.*, 1979).

The rocks where these brachiopods were collected are mainly massive white shallow platform wackestones that show a lateral and upward change of facies to oolitic and oncolitic grainstones, also massive and whitish. They belong to the lower part of the intermediate member of the Gavilán Formation that Van Veen (1969) defined at the type-locality as “Pseudo-oolitic Limestones Member”. These lithostratigraphical units have been extensively used and described in wide areas of the Betic Cordillera (*e.g.*: García-Hernández *et al.*, 1979; Ruiz-Ortiz, 1980; Molina-Cámara, 1987; Andreo *et al.* 1991; Rey, 1993; Nieto 1997; Tent-Manclús, 2003; Ruiz-Ortiz *et al.*, 2004, among others). There is a discontinuity at the top of this pseudo-oolitic unit, above which different rocks appear, however heterogeneously around the basin. These rocks correspond to either thin layers of dark limestones with chert nodules (Tent-Manclús, 2003), or red crinoidal limestones broadly considered as the upper member of the Gavilán Formation in the Subbetic domain (Van Veen, 1969; Molina-Cámara, 1987; Nieto, 1997; Ruiz-Ortiz *et al.*, 2004), otherwise individualised by Tent-Manclús (2003) as the “Crevillente Glauconitic Limestone Formation”. At their base, the red crinoidal limestones are frequently observed infilling fractures in the underlying white limestone sequence. Overlying the Gavilán Formation, the hemipelagic-pelagic conditions become widespread in the Subbetic basin (Fig. 2) leading to the deposition of marls and marly limestones corresponding to the Zegrí Formation.

STUDIED MATERIAL

The brachiopod fauna from numerous localities of the Subbetic Lower Jurassic has been studied and published in a number of papers (*cf.* Jiménez de Cisneros, 1920, 1923a,b,c, 1935; Iñesta, 1988, 1993; Baeza-Carratalá, 2004, 2008; among others). However, according to recent research only two of these localities have yielded multicostate zeillerids: Raballo de Quibas and Sierra Pelada (Fig. 1) where *Tauromenia polymorpha* and *T. aff. brevicostata* have been found. Other localities where Jiménez de Cisneros collected specimens belonging to this group of zeillerids, either do not exist anymore (*e.g.* Cerro de la Cruz de La Algueña in Figure 1), or have yielded no specimens from the group during the recent sampling work.

Sierra Pelada Section

This locality is situated in the neighbourhood of the village of La Romana, along the CV-840 road to the village of La Algueña. The white wackestones of this locality present large-scale cross-bedding, with levels containing a high concentration of brachiopods (Fig. 3), dominated by

Calcirhynchia plicatissima and “*Zeilleria mariae sensu Jiménez de Cisneros*”. These two species constitute more than 90% of the collected specimens. The morphological studies carried out in the latter locality did not display zeillerid structures, pointing out the need for a different systematic attribution that will be pursued in a forthcoming paper. It is noteworthy that in this species there is neither a dorsal median septum nor dental plates and it has a “short-looped” brachidium, without descending and ascending branches.

Towards the top of the section, pocket-like accumulations of brachiopods are frequent in levels with abundant bivalves, mainly pectinids. The multicostate zeillerids appear in these pocket-like accumulations, together with large numbers of individuals belonging to different species of *Securina* (this marks the maximum abundance event of the genus *Securina* in the basin). Other species represented in these accumulations are *C. plicatissima*, *Gibbirhynchia curviceps*, *Lobothyris andleri* as well as some endemic new taxa belonging to the genus *Lychnothyris* among others (cf. Baeza-Carratalá, 2008).

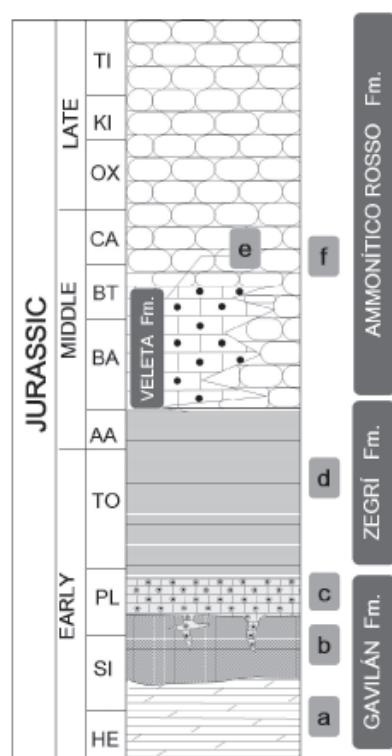


FIGURE 2 | Simplified diagram of the lithostratigraphical framework of the Jurassic in the studied area. Abbreviations: a) dolostones; b) white shallow water platform limestones; c) crinoidal red limestones; d) pelagic marls and marly limestones; e) silty limestones; f) nodulose red limestones/marly limestones (*ammonitico rosso*); HE: Hettangian; SI: Sinemurian; PL: Pliensbachian; TO: Toarcian; AA: Aalenian; BA: Bajocian; BT: Bathonian; CA: Callovian; OX: Oxfordian; KI: Kimmeridgian; TI: Tithonian.

Rabillo de Quibas Section

This section is located along the road C-3223 between Pinoso and Abanilla. The massive white limestones of the intermediate member of the Gavilán Formation present, at the lower part of the section, high oolite content, often displaying levels that resemble true oolitic limestones. These are intercalated with other levels without visible oolitic content. Above them, pink limestones with frequent fragments of corals, algae and most of all, big bivalves, develop.

It is in the pink tract where most of the identified brachiopods are located (Fig. 4), including multicostate zeillerids (*Tauromenia polymorpha* and *T. aff. brevicostata*), costate spiriferinids, *Lychnothyris* sp. nov., and other endemic new taxa of rhynchonellids and terebratulids (cf. Baeza-Carratalá, 2008).

SYSTEMATIC DESCRIPTIONS

The specimens described in this paper that come from the new field sampling are stored in the Department of Earth and Environmental Sciences of the University of Alicante; the remaining belongs to the Jiménez de Cisneros Collection.

Order: Terebratulida WAAGEN, 1883

Suborder: Terebratelloidea MUIR-WOOD, 1955

Superfamily: Zeillerioidea ALLAN, 1940

Family: Zeilleriidae ALLAN, 1940

Subfamily: Zeilleriinae ALLAN, 1940

GENUS *Fimbriothyris* DESLONGCHAMPS, 1884

Fimbriothyris? dubari sp. nov.

(Fig. 5, 1a-c)

1942 *Zeilleria* sp. nov.?, Dubar, Pl. II, fig. 17.

Material. Two fragmented specimens from the Jiménez de Cisneros Collection labelled: I-II-19-T38-1 and I-II-19-T38-2, coming from the historical locality of Cerro de la Cruz de La Algueña (Fig. 1). The dimensions of the best preserved individual are: 15.0mm length; 13.4mm width and 9.3mm thick. This species was not found in the recent samplings.

Diagnosis. Medium-sized shell, equi-biconvex, piriform to sub-pentagonal in outline, longer than wider, with sub-erect beak and wide and shallow planareas. Lateral commissure close to the beak ridge of the brachial valve, anterior commissure rectimarginate. Costulation composed by numerous and dense ribs developed only in

the anterior third of the shell, without bifurcation; long posterior smooth stage. Internal structures unknown.

Description.

External characters: Medium-sized zeillerids with equibiconvex shells, piriform to sub-pentagonal in outline. Shell length greater than width. The maximum thickness is held in the posterior third of the shell and the maximum width in the central area. The beak is sub-erect with a small foramen. Both valves show strongly sharp beak ridges on both flanks of the shell. These are very long, even reaching the mid-length of the shell in the dorsal valve. These beak ridges delimit wide and moderately depressed planareas in the middle of which the straight lateral commissure runs close to the beak ridge of the brachial valve. The anterior commissure is rectimarginate. Costation composed by numerous and dense ribs (20-21) developed only in the anterior third of the shell, without bifurcation; long posterior smooth stage.

Internal characters: Internal structures unknown because there is no appropriate material for making serial

sections. The studied specimens show two long dental plates and a short dorsal median septum.

Remarks. The studied specimens closely resemble those figured and described by Dubar (1942), who recognised them as a separate species, but without giving them a new name. Though the internal structure remains unknown, we have included the new species in the genus *Fimbriothyris* considering the likeness of the external features, mainly the pattern of ribbing, with those of the type species of the genus (*Fimbriothyris delancei* Manceñido, 1978 *Terebratula guerangeri* Deslongchamps, 1856). The dense and marginal ribbing (20 ribs, in our case), without bifurcation, the flat wide smooth initial stage, together with the subpentagonal outline and a flatter lateral profile, allows to differentiate it from other taxa with similar morphologies, such as *Tauromenia polymorpha*. Also characteristic of this species are the long and sharp beak ridges of both valves. These extend in the ventral valve up to almost mid-length, but are shorter in the brachial valve. Consequently, wide and shallow planareas are

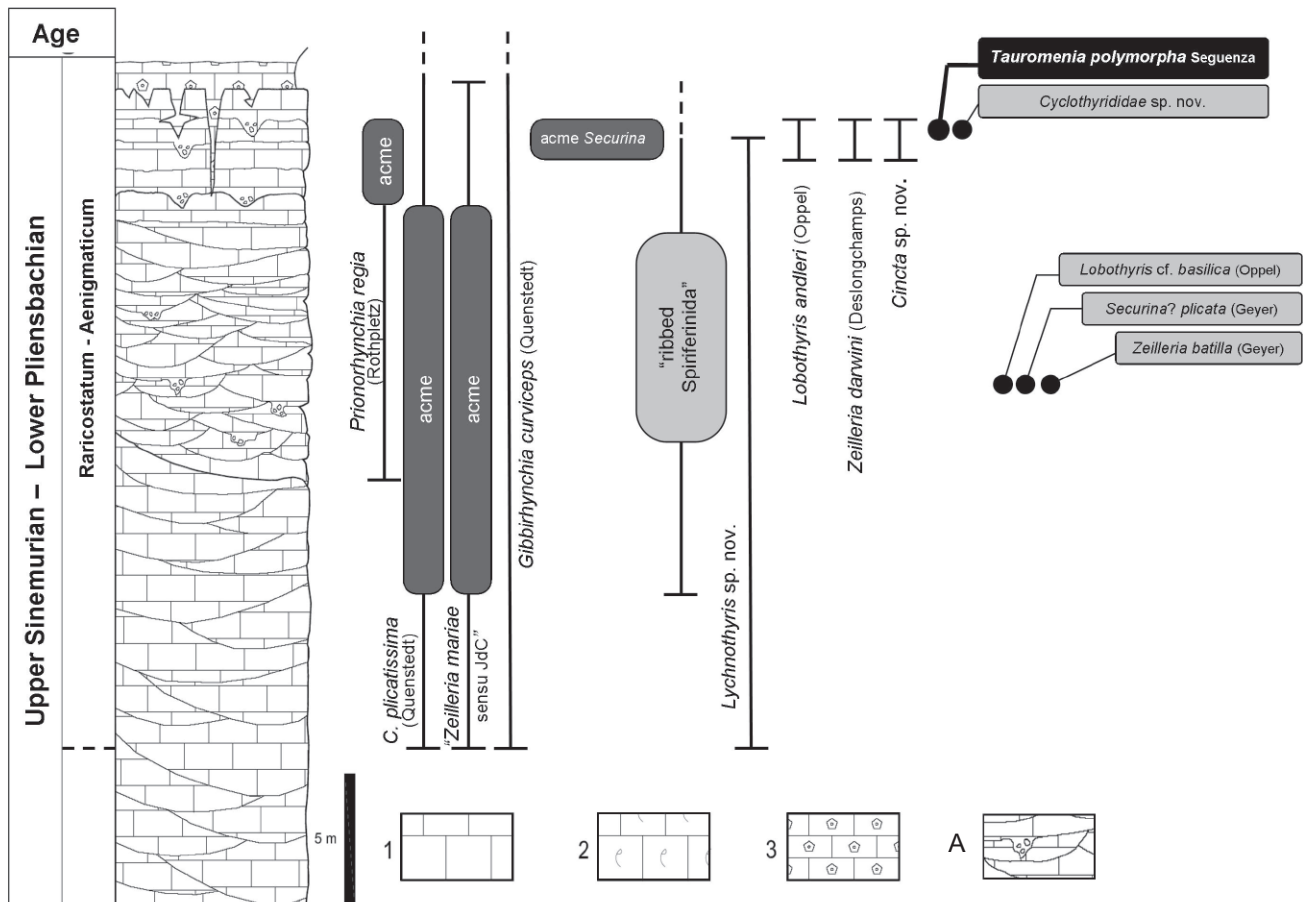


FIGURE 3 | Stratigraphic sketch of the Sierra Pelada Section, showing the record of brachiopods. 1, 2) micritic limestones: with oolites 1), and with corals and pectinids 2). 3) crinoidal red limestones. A) cross-bedding levels with highly localized “pocket-like” brachiopod accumulations.

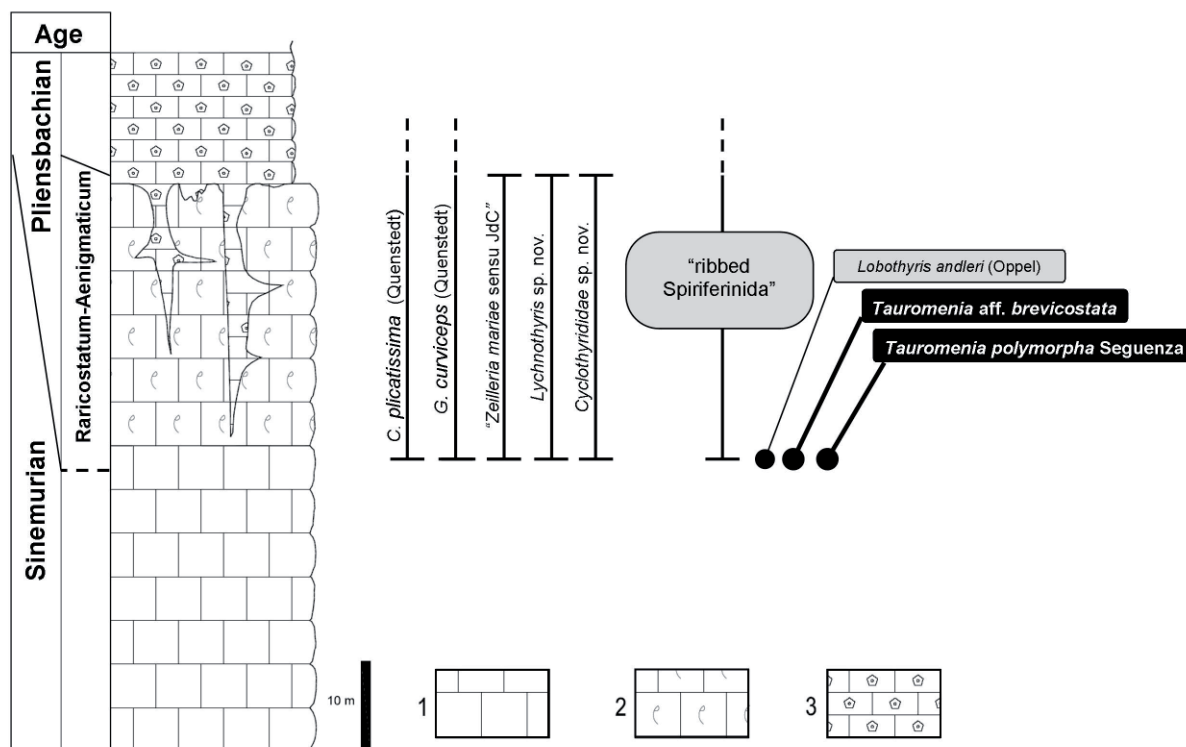


FIGURE 4 | Stratigraphic sketch of the Rabillo de Quibas Section, showing the record of brachiopods. Legend as in Figure 3.

observed, that are more developed in the pedicle valve since the lateral commissure comes closer to the brachial beak ridge. A slight difference in our material with the specimen figured by Dubar resides in the relatively stronger costation of the Spanish material.

Stratigraphic Distribution. Dubar (1942) proposes a Lotharingian (Late Sinemurian) age for this species in Morocco. It has not been possible to assert this age in the Subbetic, since it was not found in the studied sections.

Fimbriothyris? sp.

(Fig. 5, 7)

1942 *Zeilleria* sp. (aff. *tenuiplicata* n. sp.?), Dubar, Pl. I, fig. 22.

Material. Two fragmented specimens from the Jiménez de Cisneros Collection labelled: I-II-2-1 (dimensions: 19.9mm length, 16.7mm width) and I-II-25-4 (17.9mm length, 13.6mm width). The former comes from the Cerro de la Cruz de la Algueña (Fig. 1), a historical locality missing nowadays, and the latter is of unknown origin. This species has not been found in the new samplings at the studied sections.

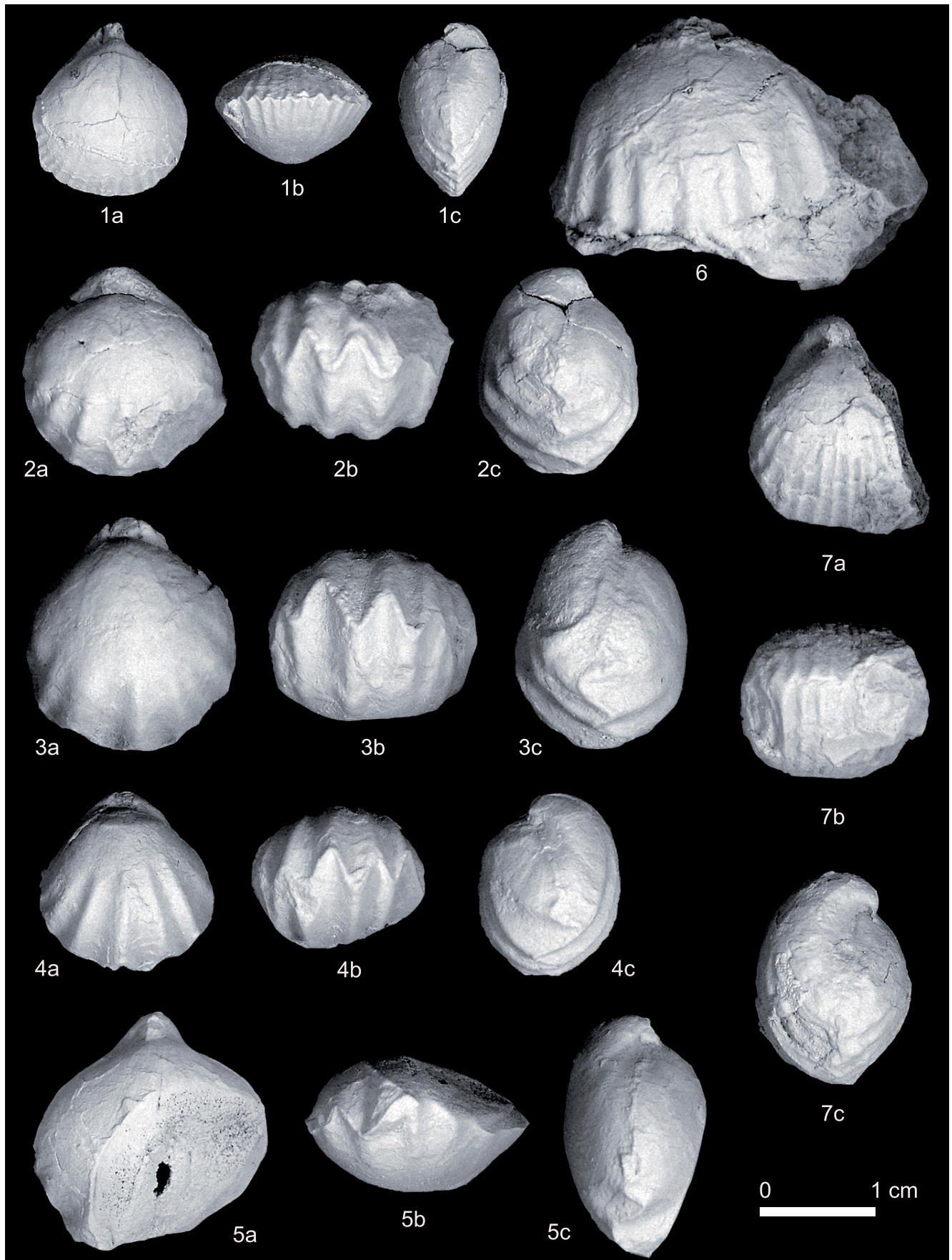
Description.

External characters: Medium-sized shells, equibiconvex, with an ovoid fusiform dorsal outline, and the

anterior border truncated that confers it a sub-rectangular to elliptic frontal profile. Shell length greater than width. The maximum width and thickness are located in the mid-length. The beak is very robust and incurved with a medium-sized foramen, sub-circular in cross-section. The sharp beak ridges of both valves extend to almost the mid-length of the shell, defining wide and depressed planareas. The lateral commissure is straight and the anterior one is rectimarginate. The shell presents 23 to 25 ribs, densely packed, frequently bifurcate and covering most of the surface of the shell but for a short posterior smooth stage.

Internal characters: The specimens are not adequate to make serial sections. A short dorsal median septum is visible on the external surface of both specimens.

Remarks. Dubar (1942) described several morphologies in what can be considered the “*Zeilleria tenuiplicata* group” [*Zeilleria tenuiplicata*-Z. aff. *tenuiplicata*-Z. cf. *tenuiplicata*-Z. sp. aff. *tenuiplicata*?]. Alméras *et al.* (2007) includes most of these morphologies in the genus *Tauromenia*, except for *Zeilleria* sp. aff. *tenuiplicata* n. sp.? (Dubar, *op. cit.*, p. 45; Pl. I, fig. 22). Our material resembles the morphology of the latter taxa, and we agree with Alméras *et al.* (*op. cit.*) that it should better be placed in *Fimbriothyris*, according to the morphological external characters (ovoid fusiform and truncated outline, beak



robust, sharp and well-developed beak ridges in both valves and the ribbing pattern).

These forms can be distinguished from *Tauromenia tenuiplicata* s.s. by a more robust and incurved beak, thicker profile, a higher number of ribs and a truncated front profile. The main difference with *Fimbriothyris? dubari* lies in the thicker shells of *Fimbriothyris? dubari*, its more incurved beak and in the ribbing, which is frequently bifurcate and covers a wider extent of the shell in the latter.

Stratigraphic Distribution. Dubar (1942) locates the specimen from Morocco in the Lotharingian (Late Sinemurian), but with doubts. The specimens from the Subbetic described by Jiménez de Cisneros (1935) were referred to the “Middle Lias” of the Cerro de la Cruz de La Algueña. Nevertheless, we have not been able to confirm this provenance because the precise location was not found.

Subfamily: Vectellinae BAKER, 2006

GENUS *Tauromenia* SEGUENZA, 1885

Tauromenia polymorpha SEGUENZA, 1885

(Fig. 5, 2-4)

1885 *Tauromenia polymorpha* sp. nov., Seguenza, p. 253.

1887 *Zeilleria polymorpha* (Seguenza). Di Stefano, Tav. II, fig. 47-53, 56.

1923c *Terebratula pacheia* Uhlig. Jiménez de Cisneros, p. 2, fig 2, 2.

1942 *Zeilleria* cf. *polymorpha* (Seguenza). Dubar, Pl. II, fig. 9-10.

1942 *Zeilleria polymorpha* (Seguenza). Dubar, Pl. II, fig. 11-15; text-fig. 11-14.

1965 *Tauromenia polymorpha* Seguenza. Muir-Wood *et al.*, fig. 705: 4.

1989 *Tauromenia polymorpha* Seguenza. Pozza, Tav. 2, fig. 2.

2003 *Tauromenia polymorpha* Seguenza. Elmi *et al.*, fig. 4: 15.

2007 *Tauromenia polymorpha* Seguenza. Alméras *et al.*, Pl. 11, fig. 14.

Material. 13 specimens, 10 recently collected in the sections of Rabillo de Quibas and Sierra Pelada; the remaining are from the Jiménez de Cisneros Collection. The dimensions of the best preserved specimens are shown in Table 1.

Description.

External Characters: Medium-sized shells, equibiconvex with a flatter dorsal valve and spherical in outline. Shell length slightly greater than width. The maximum width lies near the mid-length. The beak is robust and subcrotaliform, with a medium-sized foramen. The beak ridges are rounded and long and the inter-areas are narrow. The lateral commissure is straight and slightly inclined towards the pedicle valve. The anterior commissure is weakly uniplicate, with a slight asymmetry. The costation consists of 7 to 8 robust and spaced ribs, without bifurcation, limited to the anterior part of the shell, thus showing up an extended smooth stage. This smooth area is larger in the dorsal valve.

Internal Characters: These were not studied by serial sectioning because of the presence of inappropriate infilling. A large dorsal median septum is revealed on the cast of several specimens, running near to the mid-length. The dental plates are also visible.

Remarks. The referred specimens fit with the main features described by previous authors for the species. The robust subcrotaliform beak observed in our material, the rounded beak ridges, the weakly uniplicate anterior margin and the ribbing pattern corresponds to the diagnostic features of the genus *Tauromenia* (Seguenza, 1885). Nonetheless, since *Tauromenia* was considered by Muir-Wood *et al.* (1965) as a possible synonym of *Fimbriothyris*, the species *polymorpha* has been referred to indistinctly for both genera. *Fimbriothyris* has been used by Alméras (1987) and Taddei-Ruggiero and Vörös (1987), whereas *Tauromenia* was preferred by Pozza (1989), Benhamou *et al.* (2000), Elmi *et al.* (2003) and Alméras *et al.* (2007).

Some morphology close to *Tauromenia polymorpha* can be found in the literature, such as *T. brevicostata* (Dubar, 1942; Elmi *et al.*, 2003). The main differences between both species are a bigger foramen observed in *T. brevicostata*, together with a flattened morphology and the shorter extent of the costation. Also close morphologies are observed in *Zeilleria itoensis* (= *Tauromenia itoensis* in Alméras *et al.*, 2007) described by Dubar (*op. cit.*), which however, present a lengthened pseudo-pentagonal dorsal outline. Certain similarities with the specimens here studied are also found in *Zeilleria aretusa* (Di Stefano, 1887), though this species presents a narrower and longer outline and its ribs cover the whole surface of the shell.

FIGURE 5 | Representative specimens of the described multicostate zeillerids. 1) *Fimbriothyris? dubari* sp. nov. Holotype labelled I-II-19-T38-1, from the Cerro de La Cruz de La Algueña. Jiménez de Cisneros Collection. 2) *Tauromenia polymorpha* (Seguenza). Specimen labelled I-XIII-B11-1. Unknown origin, Jiménez de Cisneros Collection. 3) *Tauromenia polymorpha* (Seguenza). Specimen labelled O-XIII-5-1. Unknown origin, Jiménez de Cisneros Collection. 4) *Tauromenia polymorpha* (Seguenza). Specimen labelled SP-D-T Pol-1, collected by the authors in the Sierra Pelada Section. 5) *Tauromenia* aff. *brevicostata* (Dubar). Specimen labelled O-XII-9-1, partially preserved, determined as *Rhynchonella lubrica* by Jiménez de Cisneros (1920), from the Rabillo de Quibas Section, Jiménez de Cisneros Collection. 6) *Tauromenia* aff. *brevicostata* (Dubar). Specimen labelled O-XII-9-2, partially preserved, determined as *Rhynchonella lubrica* by Jiménez de Cisneros (1920), from the Rabillo de Quibas Section, Jiménez de Cisneros Collection. 7) *Fimbriothyris?* sp. Specimen labelled I-II-25-4. Unknown origin, Jiménez de Cisneros Collection. In each case, a) dorsal view; b) frontal view; c) lateral view.

Other forms of “marginally multicostate zeillerids”, with the ribs restricted to the anterior third of the shell, have been figured by Dal Piaz (1907), Delance (1974), Alméras (1987) and Manceñido (1993). The last author figures specimens of *Fimbriothyris* cf. *tranzensis* that differ from the specimens here studied by having more elongate shells, with a conspicuous furrow and a sigmoid lateral commissure. Similarly sulcate specimens are figured by Delance (1974) as *Fimbriothyris guerangeri*, which also present longer than wider shells.

Jiménez de Cisneros (1923c) considered these multicostate morphologies as *Terebratula pacheia*, a species currently assigned to *Hesperothyris*, (Superfamily Lobodothyridoidea, Family Hesperithyrididae), and thus very distant from the Zeillerids, since they lack a true septum and dental plates, beside presenting a shorter brachidium. Though no serial sections could be performed on the studied material, a rather long medium dorsal septum and two dental plates in the pedicle valve have been observed in some specimens preserved as internal moulds. Alméras *et al.* (2007, fig. h.t. 27A) describe the internal structure of the genus in detail, adding the presence of a wide and shallow septalium to the relatively long septum.

Stratigraphic Distribution. Dubar (1942) recorded this species in the Lotharingian (Upper Sinemurian) of Morocco. Taddei Ruggiero and Vörös (1987) give a Sinemurian age for this species in Calabria. Pozza (1989) recorded it at Cingoli (Umbria-Marche) in the Sinemurian (Semicostatum-Obtusum Zones). Benhamou *et al.* (2000), Elmi *et al.* (2003) and Alméras *et al.* (2007), in Algeria, place the species between the Late Sinemurian (Raricostatum Zone) and Early Carixian (Lower part of the Jamesoni Zone=Aenigmaticum Zone of the Mediterranean Domain). The South-eastern Spanish specimens described by Jiménez de Cisneros (1923c) come from white waxy limestones from the “Liassic” of the Barranco de la Calera. These levels appear to be equivalent in age to the levels in which our recent samplings were done.

***Tauromenia* aff. *brevicostata* DUBAR, 1942**

(Fig. 5, 5-6)

1920 *Rhynchonella lubrica* Uhlig.-Jiménez de Cisneros, p. 9.

aff. 1942 *Zeilleria brevicostata* n. sp. Dubar, Pl. II, fig. 20-22.

aff. 2003 *Tauromenia brevicostata* Dubar.Elmi *et al.*, fig. 4: 17.

aff. 2007 *Tauromenia brevicostata* Dubar.Alméras *et al.*, Pl. 11, fig. 15.

Material. Two fragmented specimens from the Rabillo de Quibas locality.

Description.

External Characters: Medium-sized shells, equi-biconvex but with both valves showing a flat profile. Outline varies from

TABLE 1 | Main biometric parameters of *Tauromenia polymorpha* (Seguenza) specimens from this study. L: Length; W: Width; T: Thickness; Nr: rib number (dorsal valve)

Specimen	L	W	T	Nr	W/L	T/L	T/W
O-XIII-5-1	19.9	17.7	14.8	8	0.9	0.7	0.8
I-XIII-B11-1	17.8	16.6	13.7	7	0.9	0.7	0.8
I-XI-T27(27)-1	17.1	15.1	-	7	0.9	-	-
S.Pe-F.pol.1	19.3	17.8	-	7	0.9	-	-

spherical to sub-pentagonal, being almost equidimensional. The beak is curved and the foramen is small. The beak ridges are sharp and short, with shallow and subelliptical inter-areas. The lateral commissure is straight and the anterior commissure is rectimarginate. The costation consists of robust and spaced ribs (10?), without bifurcation, limited to the anterior part of the shell.

Internal Characters: These were not studied by serial sectioning because of the presence of inappropriate infilling. A medium-sized dorsal median septum and short dental plates are visible on the cast of the specimens.

Remarks. This denomination is referred to specimens with equi-biconvex, rectimarginate morphologies, their outlines varying from spherical to sub-pentagonal. These specimens resemble closely those described as *Tauromenia brevicostata* (Dubar, 1942), but differ in the more incurvated beak and the distinctly smaller foramen. Additionally, short lateral beak ridges defining shallow inter-areas of elliptic outline are observed, as well as a spaced costation. The fragmentation of the specimens does not permit to determine the exact number of ribs, probably 10, which are wide and rounded. We propose to refer this material to the species of Dubar (*op. cit.*), but not in a conclusive way, due to the few specimens and its poor state of preservation.

Stratigraphic Distribution. Dubar (1942) places this species in the Lower Lotharingian (lower part of the Upper Sinemurian) of the Atlas; Alméras *et al.* (2007) recorded it in Western Algeria in the interval Upper Sinemurian (Raricostatum Zone)-Early Carixian (Lower Jamesoni Zone=Aenigmaticum Zone of the Mediterranean Domain).

CORRELATION AND DATING

No ammonites have been recorded at the studied localities, being very scarce in the whole of the Gavilán Formation (Vera, 1998). This is also true for similar facies of this age in many other regions, to the point that Benhamou *et al.* (2000) remarked that, frequently, the only markers for these monotonous massive limestone series of the Lower Jurassic platforms are the brachiopods, in spite of their lower biostratigraphic precision compared to that of the ammonoids.

In account for this, the strongly differentiated morphology of the multicostate zeillerids, together with their restricted geographical and stratigraphic distribution, makes this group one of the best correlation elements for these units. Benhamou *et al.* (2000) point out that the occurrence of multicostate zeillerids is especially significant in the first stages of the deepening of the platform during the Early Jurassic transgression over North Africa. A similar situation might be inferred for the Subbetic basin. This occurrence could be favoured because of the increase of available space derived from this normal and listric faulting period (Tent-Manclús, 2003; among others) and the development of a hard substrate and dissected rocky surfaces which offered an increased number of niches for diversification of the epibenthonic fauna (cf. Vörös, 1993).

The record of multicostate zeillerids in the studied localities of the Subbetic basin, represented mainly by *Tauromenia* species, is associated to the acme of *Calcirhynchia plicatissima*, *Gibbirhynchia curviceps*, *Prionorhynchia regia* and “*Zeilleria mariae sensu Jiménez de Cisneros*”, and to the event of maximum diversity and abundance of *Securina* (*S. partschi*, *S. securiformis* and *S. plicata*). These records have been included by Baeza-Carratalá (2008) in his “Assemblage 1” where they appear to be associated with *Lobothyris andleri*, *L. basilica*, *Zeilleria darwini* and *Z. batilla*, as well as to some endemic new taxa of the genera *Cincta*, *Lychnothyris* and others, exclusively recorded in these levels. Additionally, other species with wider distributions in the basin appear in this assemblage (*Cisnerospira angulata*, *Liospiriferina alpina*, *Zeilleria mutabilis*, *Linguithyris aspasia*).

This assemblage shows great affinities to the “Faune 2” described by Elmi *et al.* (2003) and Alméras *et al.* (2007) in Western Algeria. The most significant taxa in this “Faune 2” are *Tauromenia polymorpha* and *T. brevicostata*, accompanied by *Zeilleria darwini*, *Z. batilla*, *Z. mutabilis*, *Gibbirhynchia curviceps*, *C. angulata*, *L. alpina* and *Lobothyris punctata*, all of them present in our area of study. Correlating with other European and African basins, these authors give a Late Sinemurian (Raricostatum Zone)–Early Carixian (Lower Jamesoni Zone=Aenigmaticum Zone of the Mediterranean Domain) age for this assemblage. This age determination is supported by the scarce ammonites found in overlying levels (*Gemmellaroceras* sp., *Metaderoceras* sp.) of the upper part of the Lower Carixian (Benhamou *et al.*, 2000, 2002).

The most remarkable difference between the Eastern Subbetic and the Algerian assemblages is the high abundance in the first of *Prionorhynchia regia*, a species that is recorded in Algeria immediately above the “Faune 2”. Other species recorded in the Subbetic basin and absent in Algeria are *Lobothyris andleri*, reported from

the Hettangian and Sinemurian of Austria and Hungary (Vörös, 1982; Siblík, 1999; Vörös *et al.*, 2003, Dulai, 2003; Vörös and Dulai, 2007) or *L. basilica* (Oppel) that has been cited in the Middle Hettangian of Western Carpathians (Tomašových, 2000).

The multicostate zeillerids are also recorded in close paleogeographic domains in the Upper Sinemurian–Lower Pliensbachian interval. Thus, Di Stefano (1887) cited *Zeilleria polymorpha* from the Lower-Middle Lias transition in Taormina (East Sicily). This species was newly recorded in the Sinemurian of the same region and of Calabria by Taddei-Rugiero and Vörös (1987). Dubar (1942) places *Z. polymorpha* within the Upper Sinemurian of Morocco, being especially abundant at the middle part of this stratigraphic interval. Pozza (1989) cited it from the Upper Sinemurian of Marche Apennines, within the Semicostatum and Oxynotum Zones interval. More recently, Owen and Rose (1997) described specimens of *Calpella aretusa* (a probable synonym of *Tauromenia polymorpha*, according to Alméras *et al.*, 2007) in the Lotharingian (Upper Sinemurian) of Gibraltar.

According to their stratigraphic regional position, the levels with multicostate zeillerids in the studied area have been considered by Tent-Manclús (2003) and Caracuel *et al.* (2004) of Sinemurian age. Contrarily, the isotopic ratios of Sr obtained in more western areas of the basin led Ruiz-Ortiz *et al.* (2004) to place the middle tract of the Gavilán Formation (which would include the levels of our study) within the Middle Carixian (Jamesoni–Ibex Zones). Considering all the correlation data previously exposed, we propose an age of Late Sinemurian (Raricostatum Zone) to Early Pliensbachian (Aenigmaticum Zone) for

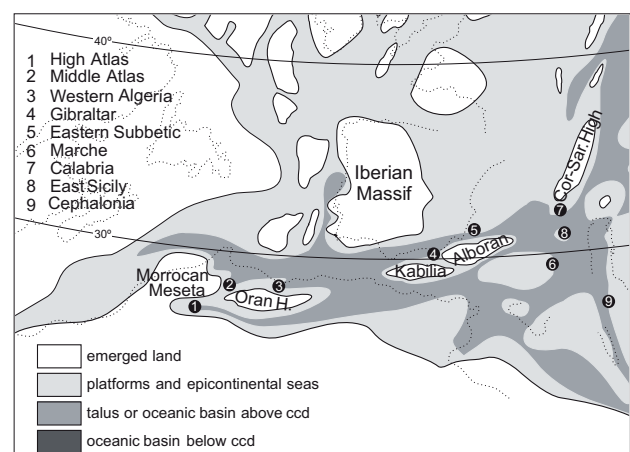


FIGURE 6 | Paleogeographical distribution of multicostate zeillerids in the westernmost Tethys during the Lower Jurassic. Numbers refer to the regions where these brachiopods have been reported. References for the localities outside the Subbetic domain are given in the text. Paleomap modified after Bassoulet *et al.* (1993).

the brachiopod assemblages that contain multicostate zeillerids in the Eastern Subbetic basin.

PALEOBIOGEOGRAPHIC IMPLICATIONS

The multicostate zeillerids show a markedly restricted geographic distribution in the Lower Jurassic, limited to certain southern areas of Western Tethys (Fig. 6). They are recorded in the High and Middle Atlas in Morocco (Dubar, 1942), Western Algeria (Benhamou *et al.*, 2000; Elmi *et al.*, 2003; Alméras *et al.*, 2007), Eastern Sicily and Calabria (Di Stefano, 1887; Taddei-Ruggiero and Vörös, 1987), Apennines (Pozza, 1989), Gibraltar (Owen and Rose, 1997) and Cephalonia in Western Greece (Manceñido, 1993).

The Mediterranean affinity of the assemblages in which they are found is characterized by the coexistence of *Tauromenia* and *Fimbriothyris* with taxa which are typical representatives of the Mediterranean Bioprovince in the sense of Ager (1967, 1971), Vörös (1977, 1984) or Manceñido (2002), such as *Securina*, *Prionorhynchia*, *Linguithyris* and others. This is also reinforced by the coexistence of *Tauromenia* with *Lychnothyris*, a terebratulid genus equally restricted to certain areas of this province (Vörös, 1983, 2009).

Nevertheless, Pérez-López *et al.* (1993) have proposed rather a sub-boreal (Northwest European) character in the Sinemurian for other south-western areas of the Betic Cordillera. This interpretation is based on the record of the genus *Calcirhynchia* (*C. calcaria*, *C. calcicosta*) in the Internal Subbetic locality of Sierra Harana, and on the absence of multicostate zeillerids and *Prionorhynchia*. They consider the latter forms as representative of the initial phases of the development of the carbonate platforms in the southern Tethys areas more westerly located (Algeria, Morocco). However, the new data presented in this paper show that these taxa (multicostate zeillerids and *Prionorhynchia*) appear together with *Calcirhynchia* and *Gibbirhynchia* in the Eastern Subbetic. In fact, these last two genera have very wide distributions. According to Savage *et al.* (2002), the former genus is distributed in several Alpine regions, and the latter is almost cosmopolite, extending from Canada to Turkey and from Greenland to Argentina. Thus, it seems more appropriate to use other taxa of more restricted distribution for the establishment of possible paleobiogeographic links.

On the other hand, Owen and Rose (1997) have described costate terebratulids (*Merophricus*) and zeillerids (*Calpella aretusa*=*Tauromenia polymorpha*) associated to *Gibbirhynchia*, *Liospiriferina* as well as a new genus *Pontaltorhynchia*, in some units from the Upper Sinemurian of Gibraltar, denominated “Tariquides” by Durand-Delga *et al.* (2007). These units are situated close to the contact

between the Internal Zones of the Betic Cordillera and the Betic-Rifean Flysch Domain. The latter authors relate the brachiopod fauna of Gibraltar to the North African Tethysic faunas, on the basis of the absence of costate terebratulids and zeillerids in the faunas close to the South Iberian margin (the Internal Subbetic-Penibetic Units). Thus, the presence of these taxa in Gibraltar as well as the likeness with the facies of the margin of the Alboran Block lead them to conclude that the “Tariquides” do not belong to the southern margin of Iberia. However, in this paper we confirm the presence of multicostate zeillerids in both margins.

Considering the absence of multicostate zeillerids and terebratulids in high latitudes, these brachiopods have been used by Ager and Walley (1977) to propose an East-West route of migration in the Western Tethys, restricted by paleoclimatic parameters in the dispersion of the faunas. The new records from the Subbetic domain fit well with this pattern, occupying an intermediate position connecting the most oriental sectors of this migration route to those located more to the southwest (Fig. 6).

CONCLUSIONS

Multicostate zeillerids have been recognized, for the first time, in the Early Jurassic of the Subbetic Basin. A systematic study of the material of this group of brachiopods represented in the basin has enabled to identify four species, one of them new (*Fimbriothyris? dubari* sp. nov.).

These brachiopods and the assemblage to which they belong, have been correlated with similar records in neighbouring basins, allowing to date the levels in which they occur as close to the Sinemurian-Pliensbachian boundary. More precisely, we propose for these a chronostratigraphic position within the Raricostatum Zone-Aenigmaticum Zone interval. With this we provide additional information to previous approaches to the dating of these levels, which were based on isotopic data and on their stratigraphic position within the regional context.

The Mediterranean paleobiogeographical character of this fauna is verified, discarding subboreal (Northwest European) influences. The multicostate zeillerids have a restricted area of distribution in the South Westernmost Tethys, within a temporal and spatial interval that can be related with the initial phases of the break-up and drowning of the Lower Jurassic carbonate platforms.

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