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Latest Pliensbachian –Early Toarcian brachiopod assemblages from the Peniche section (Portugal) and their correlation

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In the present paper we describe the distribution of brachiopods in the proposed Toarcian GSSP (Global Boundary Stratotype Section and Point) at Peniche. We differentiated four assemblages in the stratigraphic interval from the upper Emaciatum Zone of the Pliensbachian to the Levisoni Zone of the Toarcian. Assemblage 1 clearly presents Northwestern European affinities, with many species that are also present in Southern England. In the last levels of the Pliensbachian and in the Mirabile Subzone (the first level of the Toarcian), Assemblage 2 contains taxa that still present Northwestern European affinities, but with a more restricted, even endemic, distribution. The majority of the species in these levels are known from the Iberian Range in Spain and other neighboring basins. An important faunal change takes place in the Semicelatum Subzone, coinciding with the base of the Cabo Carvoeiro Formation, giving rise to Assemblage 3. In this assemblage we observed a clear decrease in the size of the specimens, coinciding with the establishment of the “Koninckella Fauna”; this fauna is found in several localities in both Northwestern European and Mediterranean areas where the paleoenvironment is relatively deep or poorly oxygenated. Brachiopods disappear in Peniche just above the Polymorphum – Levisoni zonal boundary, as has been observed in several other localities in Western Tethys. Their renewal is marked by the presence of Soaresirhychia bouchardi several meters above the extinction level, constituting Assemblage 4.

Introduction

The GSSP for the base of the Toarcian Stage has been proposed at Ponta do Trovão in the Peniche section (Lusitanian Basin, Portugal, Fig. 1) (e.g. Elmi, 2006; Rocha, 2007; Rocha et al., 2013). Stratigraphically, it comprises the upper part of the Lemedo Formation (Fm.) and the lower part of the Cabo Carvoeiro Fm., generally characterised by marl-limestone alternations, with an increase in siliciclastic sediments in the Levisoni Zone. In this sector of the Lusitanian Basin, the Pliensbachian-Toarcian boundary is recorded in the uppermost part of the Lemedo Fm., included in a continuous succession from the Sinemurian to the Aalenian (e.g. Mouterde, 1955; Duarte and Soares, 2002; Duarte, 2007; Duarte et al., 2010) (Figs. 1 and 2).

Brachiopods are frequent in the Peniche section, which has been referred to and described by several authors since the XIX century (Choffat, 1880, 1947; Alméras et al., 1988, 1995; Alméras, 1996) but never described in detail. Exhaustive sampling in the last few years has enabled identification of 25 species belonging to four orders of brachiopods in this section, ranging from the Emaciatum Zone (Elisa Subzone) of the Pliensbachian to the Levisoni Zone of the Toarcian (Fig. 2). The aim of this paper involves describing the brachiopod assemblages recorded in Peniche and discussing their paleobiogeographic affinities in order to assist in the correlation of the GSSP with other sections containing brachiopods. The detailed systematic paleontology of the brachiopods from this and other sections of the Lusitanian Basin will be treated separately in a forthcoming paper.

Brachiopod assemblages

Four brachiopod assemblages have been distinguished in the relevant interval of the Peniche section. Their stratigraphic distribution is shown in Fig. 2, and some representative specimens are illustrated in Fig. 3:

- 1 The levels with *Tauromeniceras elisa* (Fucini) contain the following species: *Liospiriferina* cf. *rostrata* (Schlotheim),

Figure 1. A. Synthetic geological map of the Lower Jurassic outcrops in the Lusitanian Basin with location of the studied section (based in Duarte et al., 2010). B. The Pliensbachian-Toarcian boundary at Ponta do Trovão, Peniche section.

Liospiriferina aff. *nicklesi* (Corroy), *Prionorhynchia serrata* (Sowerby), *Gibbirhynchia northamptonensis* (Davidson) and *Lobothyris punctata* (Sowerby). In the levels with *Emaciaticerias Canavaria-Tauromeniceras* sp. var., *L. cf. rostrata* and *L. aff. nicklesi* persist, accompanied by the appearance of *Quadratrhyrachia quadrata* Buckman, *Homoeorhynchia acuta* (Sowerby), *Lobothyris subpunctata* (Davidson) and *Zeilleria quadrifida* (Lamarck). All these taxa have been grouped in Assemblage 1.

- 2 In the levels immediately below the Pliensbachian–Toarcian boundary and within the Mirabile Subzone, several species presenting a more restricted geographic distribution appear, such as *Liospiriferina* cf. *falloti* (Corroy), *Cisnerospira* n. sp., *Gibbirhynchia* aff. *reyi* Alméras and Fauré, *Gibbirhynchia cantabrica* García Joral and Goy, *Lobothyris edwardsi* (Davidson), *Lobothyris* cf. *arcta* (Dubar) and *Zeilleria culeiformis* (Rollier). Assemblage 2 is defined by these taxa.
- 3 The most significant renewal episode takes place at the base of the Semicelatum Subzone, coinciding with the contact between the Lemede and the Cabo Carvoeiro formations (Duarte and Soares, 2002; Duarte, 2007). The response of the brachiopod fauna to this change involves a marked decrease in the size of the taxa. Spiriferinids, for example, are all minute, and it is difficult to ascertain whether they are miniaturized specimens of morphologically similar taxa known in neighboring basins, such as *Liospiriferina falloti* (Corroy), or different species altogether. Assemblage 3 comprises *Liospiriferina subquadrata* (Seguenza), *Aulacothyris* n. sp., *Cirpa fallax* (Deslongchamps), *Nannirhynchia pygmaea* (Morris), *Koninckella liasina* (Bouchard) and *Pseudokingena deslongchampsii* (Davidson), the latter three being typical components of the so-called “Couches à Leptaena” (Choffat, 1880) or “Koninckella Fauna” (Alméras et al., 1988; Alméras and Elmi, 1993; Vörös, 2002, among others). Several taxa from Assemblage 2 coexist with those of Assemblage 3, mostly in the lower part of the Semicelatum Subzone.

- 4 Diversity becomes very low at the top of the Semicelatum Subzone and the brachiopod record ceases very close to or just above the Polymorphum – Levisoni zonal boundary, as observed in other neighboring localities (García Joral et al., 2011; Comas-Rengifo et al., 2013). Their reappearance is marked by the scant record of *Soaresirhynchia bouchardi* (Davidson), several meters above the Polymorphum – Levisoni boundary, defining Assemblage 4. From these levels upwards, brachiopods remain extremely scarce until the uppermost Bifrons Zone is reached.

Paleobiogeographic affinities and correlation

The presence in other basins of the species recorded in Peniche is shown in Fig. 4. This figure omits the species classified as *affinis* or *confer* and only includes the taxa classified with certainty. This also entails a critical review of some attributions. For example, *K. liasina* has been cited in Swabia by Rau (1905), but the figured specimens (plate I, figures 26–54) have a rounded outline that is very different from the typical quadrangular one of this species. It is likely another older species. The affinities of the studied fauna have been related with the paleobiogeographic framework of the Western Tethys summarized for this time interval by Manceñido (2002).

The brachiopods of Assemblage 1 clearly present NW European affinities. All the recorded species are known in England, and many are typical of the European or North African basins outside the Alpine Belt. On the contrary, only scarce records of *L. punctata* or *Z. quadrifida* are quoted in the well-known assemblages of the Mediterranean Province from this age (cf. Manceñido, 1993; Alméras et al., 2007; Vörös, 2009; Baeza-Carratalá, 2013, among others). There is a noteworthy presence in Peniche of *P. serrata*, a species only known previously from Southern England but belonging to a typical Mediterranean genus occurring only occasionally in the NW European Province. *P. serrata* has been cited in Sicily by Di Stefano (1891), but these forms likely correspond to *Prionorhynchia quinqueplicata*

Figure 2. Stratigraphic distributions of the brachiopods recorded at Ponta do Trovão, Peniche section. Blue: Assemblage 1; red: Assemblage 2; green: Assemblage 3; orange: Assemblage 4. MI= Mirabile Subzone. Stratigraphic log adapted from Duarte (1995).

Figure 3. Photographs of some representative species of the Ponta do Trovão section. 1: *Liospiriferina* aff. *nicklesi* (Corroy); PE982.1; Emaciatum Zone, Elisa Subzone. 2: *Liospiriferina* cf. *falloti* (Corroy); P5.1; Polymorphum Zone, Semicelatum Subzone. 3: *Cisnerospira* n. sp.; PE984.1; Polymorphum Zone, Mirabile Subzone. 4: *Liospiriferina* *subquadrata* (Seguenza); P9.1; Polymorphum Zone, Semicelatum Subzone. 5: *Prionorhynchia* *serrata* (Sowerby); PE964.1. Emaciatum Zone, Elisa Subzone. 6: *Homoeorhynchia* *acuta* (Sowerby); PE982.1; Emaciatum Zone, Elisa Subzone. 7: *Cirpa* *fallax* (Deslongchamps); P4.1; Polymorphum Zone, Semicelatum Subzone. 8: *Gibbirhynchia* *northamptonensis* (Davidson); PE975.1; Emaciatum Zone, Elisa Subzone. 9: *Gibbirhynchia* aff. *reyi* Alméras and Fauré; PE984.1; Polymorphum Zone, Mirabile Subzone. 10: *Gibbirhynchia* *cantabrica* García Joral and Goy; P1.1; Polymorphum Zone, Semicelatum Subzone. 11: *Soaresirhynchia* *bouchardi* (Davidson); P61.1. Levisoni Zone. 12: *Zeilleria* *quadrifida* (Lamarck); PE979.1; Emaciatum Zone, Elisa Subzone. 13: *Zeilleria* *culeiformis* (Rollier); PE983.1; Emaciatum Zone, Elisa Subzone. 14: *Lobothyris* *subpunctata* (Davidson); PE983.2; Emaciatum Zone, Elisa Subzone. 15: *Nannirhynchia* *pygmaea* (Morris); P19.2; Polymorphum Zone, Semicelatum Subzone. 16: *Pseudokingena* *deslongchampsii* (Davidson); P13.1; Polymorphum Zone, Semicelatum Subzone. 17: *Koninckella* *liasina* (Bouchard); P19.1; Polymorphum Zone, Semicelatum Subzone. a: dorsal view; b: lateral view; c: frontal view. All photographs are in life size, except a', b' and c' (X2).

(Zieten). Assemblage 1 from Peniche is similar to the Assemblage 1 recorded in Northern and Eastern Spain by García Joral et al. (2011) and, to a lesser extent, to the F6 assemblage recorded in Algeria by Alméras et al. (2007). The main particularity of the Peniche assemblage involves the presence of *P. serrata*, *G. northamptonensis* and *H. acuta*, species unknown in the Spanish or North African record.

Assemblage 2 also shows NW-European affinities at the generic level, but with a more restricted or even endemic distribution at species level; none of the species classified with certainty been found in the African basins. This is the same as observed in Assemblage 2 of García Joral et al. (2011), which contains three species in common with Peniche (*G. cantabrica*, *L. edwardsi* and *Z. culeiformis*). Similar to the above mentioned case of *Prionorhynchia serrata*, *Cisnerospira* n. sp. exhibits the particularity of belonging to a genus known in the Pliensbachian of the Betics and other Mediterranean basins (Baeza-Carratalá, 2013), but also in the Uppermost Pliensbachian and Lowermost Toarcian of Southern England and Normandy, the original area of its type-species *Cisnerospira adscendens* (Deslongchamps).

Assemblage 3 is the only assemblage without an equivalent in the Iberian Range in Spain, despite the fact that this basin is very rich in brachiopods in this stratigraphic interval (cf. García Joral and Goy,

2000; García Joral et al., 2011). The taxa present in Peniche are widely distributed in sections of both the North-European and the Mediterranean basins where the environment appears to be characterized by low oxygen levels or sedimentation in narrow deep troughs (cf. Alméras and Elmi, 1993; Alméras et al., 1997; Pozza and Bagaglia, 2001; Vörös, 2002, 2003). Thus, the paleobiogeographic distribution of Assemblage 3 (the so-called “Koninckella Fauna”) does not follow the marked provincialism observed in the Pliensbachian, but rather is controlled by paleoenvironmental features that overstep provincial boundaries. This is well illustrated by its distribution within the Lusitanian Basin, where Assemblage 3 is associated with the more western, deeper localities (cf. Alméras et al., 1988; Alméras and Elmi, 1993).

The brachiopod record ceases in the uppermost Polymorphum Zone. The next recorded assemblage consists of a single species, *S. bouchardi*, appearing above the extinction level after a long stratigraphic interval without brachiopods. Similar monospecific assemblages of *S. bouchardi* are known in many other basins in the Western Tethys, both in Northwestern European and Mediterranean areas (see García Joral et al., 2011 and Baeza-Carratalá et al., 2011 for a review). The wide distribution and the morphological features

Assemblages	Peniche	England	North and West France	Pyrenees	SE. France	Iberian Range	Asturias	Swabia	Betics	Sicily	Central Apennines	Algerian Tell	Beni Snassen	Traras Mts.
4	<i>Soaeresirhynchia bouchardi</i> (DAVIDSON)													
3	<i>Liospiriferina subquadrata</i> (SEGUENZA)													
3	<i>Cirpa fallax</i> (DESLONGCHAMPS)													
3	<i>Nannirhynchia pygmaea</i> (MORRIS)													
3	<i>Pseudokingena deslongchampsii</i> (DAV.)													
3	<i>Koninckella liasina</i> (BOUCHARD)													
2	<i>Gibbirhynchia cantabrica</i> G ^a JORAL & GOY													
2	<i>Lobothyris edwardsi</i> (DAVIDSON)													
2	<i>Zeilleria culeiformis</i> (ROLLIER)													
1	<i>Prionorhynchia serrata</i> (SOWERBY)													
1	<i>Gibbirhynchia northamptonensis</i> (DAV.)													
1	<i>Quadratirhynchia quadrata</i> BUCKMAN													
1	<i>Homoeorhynchia acuta</i> (SOWERBY)													
1	<i>Lobothyris punctata</i> (SOWERBY)													
1	<i>Lobothyris subpunctata</i> (DAVIDSON)													
1	<i>Zeilleria quadrifida</i> (LAMARCK)													

of *S. bouchardi* (“juvenile” shape, high variability and normally dense populations) correspond to an opportunistic species that colonizes environments without brachiopods following an extinction event (García Joral and Goy, 2000; Gahr, 2005; García Joral et al., 2011). As explained for Assemblage 3, this behavior oversteps provincial boundaries, thus enabling wide correlation.

Conclusions

Brachiopods are abundant and diverse in the proposed GSSP section of Peniche. Below the Pliensbachian – Toarcian boundary the recorded taxa are very similar to the Southern England Faunas and enable correlation with the basins of Western Europe and North Africa outside the Alpine Belt. In the first level of the Toarcian (Mirabile Subzone), taxa are more restricted in their paleobiogeographic distribution, allowing correlation with several neighboring European basins. At the base of the Semicelatum Subzone, an important environmental change takes place, leading to the establishment of the so-called “Koninckella Fauna”. Correlation based on this brachiopod assemblage does not depend upon provincialism as in the previous assemblages, but rather on the presence of specific environmental conditions recognized in certain localities in the basins both of the Northwestern European and the Mediterranean Provinces. Brachiopods cease to appear close to the Polymorphum–Levisoni zonal boundary, as observed in many other Western Tethys basins. The reappearance of the group takes place well above this boundary and is marked by the presence of the widely distributed species *Soaeresirhynchia bouchardi*.

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Figure 4. Palaeogeographic distribution of the recorded assemblages. Sources: England: Davidson (1852-84); Ager (1956-67, 1990). North and West France: Deslongchamps (1859); Alméras et al. (1997, 2010). Pyrenees: Alméras and Fauré (2000). Southeast France: Alméras and Moulan (1982); Alméras and Elmi (1987); Alméras et al. (1997). Swabia: Quenstedt (1868-1871); Rau (1905). Asturias: García Joral and Goy (2009). Iberian Range: García Joral and Goy (2000); García Joral et al. (2011). Betics: Baeza-Carratalá et al. (2011); Baeza-Carratalá (2013). Central Apennines: Pozza and Bagaglia (2001); Vörös (2003); Graziano et al. (2006). Sicily: Seguenza (1885); Di Stefano (1891); Algerian Tell: Alméras et al. (2007). Beni Snassen: Alméras et al. (1988); Alméras and Elmi (1993). Traras Mountains: Alméras et al. (2007).

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