Early Jurassic (Sinemurian) gastropods from the Lusitanian Basin (west of Portugal)

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Vitón, Í., Comas-Rengifo, M.J. & Paredes, R. 2020. Early Jurassic (Sinemurian) gastropods from the Lusitanian Basin (west of Portugal). [Gasterópodos del Jurásico Inferior (Sinemuriense) de la Cuenca Lusitánica (oeste de Portugal)]. Spanish Journal of Palaeontology, 35 (2), 147-166.

ABSTRACT

The Sinemurian gastropod specimens herein studied come from two sources: from museum collections and from samplings in field. The study of the Sinemurian gastropod specimens housed in the collections of the Museu Geológico (Laboratório Nacional de Energia e Geologia), Museu Nacional de História Natural e da Ciência (University of Lisbon), Museu da Ciência (University of Coimbra) and of the Museu de História Natural e da Ciência (University of Porto), has allowed the systematic and taxonomical update of this material. These specimens come mostly from Sinemurian outcrops in S. Pedro de Moel area and Coimbra region, and were collected by Paul Choffat and collaborators in the geological field works in relation to the cartography of the Portuguese Geological Map in 1887 and 1903. The review of these collections permitted to recognise original material that was used to describe several characteristic species of the Lusitanian Basin, namely Scurriopsis (Scurriopsis) schmidti, Cryptaenia sp., Nerinella ficalhoi, and Boehmiola exilis.

The study of the specimens sampled in field has allowed confirming the origin and stratigraphic position of those specimens collected by Choffat. This sampling was carried out in materials of Coimbra and Água de Madeiros formations.
(Obtusum and Oxynotum chronozones) cropping out in S. Pedro de Moel, Praia Polvoeira, and Praia Pedra do Ouro.

A total of 386 specimens have been studied, 266 have been assigned to 14 taxa of 14 families, 13 genera and 8 species. Most of these taxa belong to the subclass Caenogastropoda (61.31% of the specimens), to the order Allogastropoda (30.66%), and the superfamilies Campaniloidea (28.83%) and Nerinoidea (20.8%). The most common species are endemic of the Lusitanian Basin, namely *Oonia casta* Böhm, 1901. Other species are known in Germany, Luxembourg and Austria basins.

**Keywords:** Systematics, S. Pedro de Moel, Coimbra, Obtusum, Oxynotum.

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1. INTRODUCTION

Portuguese Sinemurian gastropods, and Lower Jurassic ones in general, were studied mainly in the early 20th century as part of regional geological publications (Sharpe, 1850a; Choffat, 1903; Hallam, 1971) or fossil atlases (Böhm, 1901; Mouterde & Rocha, 1981). Hallam (1971, p. 255) wrote: “the few [gastropod] species that occur in Portugal are widely distributed forms that call for no special comment, but *Nerinella*”. Few recent studies of the Lusitanian Basin gastropods have been conducted, and none based upon a detailed stratigraphic analysis, although new species are described in Sharpe (1850a), Böhm (1901) and Choffat (1903), and some of them, such as *Boehmiola exilis*, have been used as guide fossils (Choffat, 1903).

In the last few years, gastropod faunas from other Lower Jurassic European basins have been published, mainly in Germany (Gründel, 2003, 2007a, 2007b, 2010; Nützel & Gründel, 2015; Schubert *et al*., 2008), Austria-Hungary (Szabó, 2008a, 2016), England (Gründel *et al*., 2011; Todd & Munt, 2010) and Italy (Conti *et al*., 2004; Fischer *et al*., 2002; Gatto & Monari, 2010; Szabo *et al*., 2019). Researches about faunas from France (Gatto *et al*., 2015), Luxembourg (Monari *et al*., 2011) and Turkey (Okan & Hosgör, 2007), and other non-European countries, such as Argentina (Damborenea & Ferrari, 2008; Ferrari, 2009, 2013, 2014; Ferrari *et al*., 2014) have also been published. This work aims to provide taxonomical update of the Sinemurian gastropods of the Lusitanian Basin.

2. GEOLOGICAL AND GEOGRAPHICAL CONTEXTS

The Sinemurian in the Lusitanian Basin (LB, W Portugal) crops out in three main geographical areas: S. Pedro de Moel, the outskirts of Coimbra and Peniche (Fig. 1). Due to anthropic changes in the landscape, the outcrops on the outskirts of Coimbra are no longer accessible as they were 100 years ago and the specimens in museum collections are therefore the most available source of palaeontological and geological information for this area.

Most of the gastropods studied were collected from the central-coastal region of the basin (Fig. 1). S. Pedro de Moel (Leiria district, Extremadura province) is the nearest reference location, in which two areas can be distinguished and summarised as North and South. The most complete and representative Sinemurian successions of the LB (Comas-Rengifo *et al*., 2013) crop out in these areas. In the North, Penedo do Cabo (SPM) section, between Praia Velha (PV) and Praia da Concha, 600 m north of Penedo da Saudade lighthouse, shows the lower part of the Coimbra Formation (Fm.), Obtusum chronozone (Fig. 2), which is represented as unit D in Azêredo *et al*., (2010; fig. 3). In the south, 3.5 km from S. Pedro de Moel, lies Praia Pedra do Ouro (OU) and Praia da Polvoeira (PO) sections; they both show the upper part of Obtusum chronozone and lower part of Oxynotum chronozone (Fig. 2).

A continuous carbonate succession crops out from PV to PO, which represents three second-order transgressive-regressive subcycles (Azêredo *et al*., 2010, 2014; Comas-Rengifo *et al*., 2013; Duarte *et al*., 2008; Paredes *et al*., 2016). The materials containing gastropods are in a transgressive subcycle with a maximum flood event in the Água de Madeiros Fm.
Azêredo et al. (2010, 2014) subdivided the Penedo do Cabo sedimentary succession into several lithological units. Five big limestone samples named SPM and PV were studied (Figs 2-3), coming from the lower part of unit D (Azêredo et al., 2010, 2014), where bivalves are rare and small, and gastropods are common. Unit D is characterised by 25 m of limestones and marl-limestones alternating in layers of variable thickness, with marl interbeds that become increasingly thicker towards the top. The materials are highly bioturbated and the most frequent macrofossils are gastropods, bivalves and echinoderms. The gastropods and bivalves do not show a prevalent orientation, nor a homogeneous distribution, and show a medium level of fragmentation, with some specimens almost complete and others very fragmented. Fossils are concentrated in the lower part of almost every layer. The material studied comes from between layers 311 and 323 of Azêredo et al. (2010, 2014), which Dommergues et al. (2010) dated as upper Sinemurian, Obtusum chronozone. Layer 322 is the richest in fossils.

Two taphofacies (sensu Fernández-López, 2000) can be described in unit D (Fig. 4). Taphofacies type 1 is characterised by mudstone with evidence of rapid burial and a high sedimentation rate, where the gastropod specimens are found partially infilled with sediment and recrystallized. Taphofacies type 2 is characterised by a wackestone-packstone, associated with slow burial and a low sedimentation rate. Gastropods are usually found as inner moulds, although complete shells are also present in some layers showing few traces of re-sedimentation, with the presence of articulated skeletons of echinoderms.

The sediments of the upper part of the Coimbra Fm. (around 25 m) and the lower part of the Água de Madeiros Fm. (Polvoeira Mb.) crop out to the south of S. Pedro de Moel, between PO and OU (Figs 1, 5). They were studied by Duarte et al. (2010), Paredes (2012), and Paredes et al. (2013, 2016) in relation to benthic associations. The gastropods studied herein were collected bed by bed. The lower part of the section is represented by limestones, sometimes bioclastic, marl-limestones and marlstones with some layers of black shales (high level of organic matter). As from the layer PO122, and all along the Água de Madeiros Fm., an increase in marl and black layers can be observed which, according to Paredes et al. (2016), coincides with the beginning of a transgressive cycle. This also coincides with an increase in the diversity of brachiopods, bivalves and gastropods (Fig. 5).

The Coimbra Fm. outcrops from the northern area of the LB, where some specimens of the Portuguese Geological Services come from, is often represented by dolomite series; thus the gastropods are badly preserved. At present, these outcrops are not always visible because covered by vegetation and new buildings.
Five museum collections were accessed for the present paper: the Museu Geológico de Portugal (SGP), the Museu Nacional de História Natural e da Ciência (MUNAC), the LNEG Archive (Alfragide), the Museu da Ciência – Universidade de Coimbra (MCUC.MIN), and the Museu de História Natural e da Ciência – Universidade do Porto (UP).
Figure 5. Stratigraphic log of the Praia Polvoeira beach (PO) and Praia Pedra do Ouro beach (OU) sections with the stratigraphic gastropod distribution. Modified from Duarte et al. (2012). Photos: R. Paredes.

MHNFCP). In addition, a detailed bed by bed sampling in S. Pedro de Moel was performed in the Penedo do Cabo outcrop (SPM and PV), at Praia Pedra do Ouro (OU) and at Praia Polvoeira (PO). The museum collection specimens come from the S. Pedro de Moel region and from the outskirts of Coimbra; furthermore, one specimen come from Peniche (Table 1; Supplementary Information).

In the SGP collection, the original catalogue numbers of the specimens have been kept. In addition, new official numbers (from SGP31700 to SGP31889) have been introduced for the other specimens collected in 19th–20th century lacking a catalogue number. At the MUHNAC, the numbers are provisional, because the specimens studied have not yet been catalogued. The alphanumeric abbreviation refers to the drawer row and the following number refers to the drawer number in the storage organization of the collection. Choffat and his collectors also collected the specimens with the acronym MCUC.MIN and UP.MHNFCP thereafter referred. That material was originally housed in the SGP collection. Afterwards, some duplicates were sent in 20th century to Lisbon, Coimbra (in 1925) and Porto Universities, for Palaeontology teaching purposes where geology and palaeontology were introduced as new disciplines.
Table 1. Relation of fossil localities and number of identified specimens in the museum collections.

| Area            | Locality                     | SGP | MCUC | UP.MHNFCP | MUHNAC |
|-----------------|------------------------------|-----|------|-----------|--------|
| S. Pedro de Moel| Polvoeira (S. Água de Madeiros) | 22  | 5    |           |        |
|                 | Ninho do Corvo (N do farol)   | 8   | 20   |           |        |
|                 | Penedo do Cabo (N Pedrianes)  | 53  | 28   |           |        |
|                 | Praia S. Pedro de Moel        | 6   |      |           |        |
| S. Pedro de Moel| Undefined                    | 2   |      |           |        |
| Coimbra         | Coimbra                      | 1   |      |           |        |
|                 | Palheira                     | 2   |      |           |        |
|                 | Monte de Vera                | 8   |      |           |        |
|                 | Volta do Monte               | 10  |      |           |        |
| Coimbra         | Alcouce                      | 1   |      |           |        |
|                 | Almaroz (Almalaguês)         | 11  |      |           |        |
|                 | Villa Secca / Almaroz        | 9   |      |           |        |
|                 | Miranda do Corvo             | 8   |      |           |        |
| Peniche         | Peniche                      | 1   |      |           |        |
| Unknown         |                              | 13  | 3    | 5         |        |
| Total           |                              | 147 | 62   | 2         | 5      |

In the present paper we employ the measurements proposed by Gatto & Monari (2010) (Fig. 6), following the terminology used by Cox (1960). The linear measurements were taken with the use of a calliper (Vogel Germany-Electronic Digital Calliper) when possible, and when not, on digital images using the software Adobe Photoshop to 0.1 mm accuracy. The angular measurements were taken with Adobe Photoshop CS6 version 13.0.1. In the Systematic chapter, all the measurements are given in millimetres. Numbers in italics mean that measurement is approximate (circa) due to fragmentation or state of preservation. The measurements of taxa are those that better represent the average of all the material studied.

The photos were taken with different cameras (Canon 7D, Nikon D60 and Olympus) and a microscope (Leica MZ16A associated with the software LAS - Leica Application Suite - v3.8). The best-preserved specimens were coated with magnesium oxide in order to enhance sculpture for photography.

The non-museum collection specimens referred hereafter are housed at the Departamento de Geodinámica, Estratigrafía y Paleontología, Facultad de Ciencias Geológicas, Universidad Complutense de Madrid. The identifying numbers make reference to the levels represent in Figure 5.

4. SYSTEMATIC PALAEONTOLOGY

The systematic is based on Bouchet et al. (2017), who modified significantly the hierarchical order made by previous authors, hence they “purposely abstained to attribute an author and date to names above superfamily”. Therefore, we will follow their criteria. For some specific issues, Gründel (2001, 2008, 2010) and Conti et al. (2004) have been taken into account.

Class GASTROPODA Cuvier, 1795
Subclass PATELLOGASTROPODA
Order PATELLIDA
Superfamily Lottioidae Gray, 1840
Family Acmaeidae Forbes, 1850
Genus Scurriopsis Gemmellaro, 1879
Subgenus Scurriopsis Gemmellaro, 1879
Scurriopsis (Scurriopsis) schmidtii (Dunker, 1844) (Fig. 7a)

1846 Patella schmidtii; Dunker, p. 187.
1855 Patella schmidtii Dunker; Terquem, p. 281, Pl. 18, figs. 4 (4, 4a, 4b).
v 1901 Patella delgadoi sp. nov.; Böhm, p. 213, Pl. 8, figs. 1-2, Text-fig. 1.
1988 Scurriopsis schmidtii; Meier & Meiers, p. 25, Pl. 2, figs. 4a-b.

This species is cited in the Hettangian of Luxembourg, France and Germany.

Subclass VEITIGASTROPODA
Order PLEUROTOMARIIDA
Superfamily Eotomarioidea Wenz, 1938
Family Gosseletinidae Wenz, 1938
Genus Cyclostomaria Szabó, 1980

Cyclostomaria aff. monarii Szabó, 2008b (Fig. 12.1)

aff. 2008b Cyclostomaria monarii sp. nov.; Szabó, p.174, figs. 4.1-4.7.

Material. 4 specimens: SGP31714, SGP31821?, OU.65, OU.68.11, upper Sinemurian, Oxynotum chronozone.

Description. All of the specimens are cross-sections of a low-spired shell. Last whorl well convex, rounded. Specimen OU68.11 preserves a fragment of shell displaying a moderately wide selenizone that runs slightly above the periphery, and shell ornamented with spiral threads and collabral riblets. The number of threads and riblets cannot be counted because there are not completed whorls. Collabral riblets, irregularly sized and distributed, dominate in the adapical area of the whorl, whereas spiral ones dominate in the abapical region.

Remarks. The morphological characters of these specimens are similar to those described by Szabó (2008b) for Cyclostomaria monarii from the Pliensbachian, Margaritatus chronozone of the Bakony Mountains (Hungary). Specimens herein described and Cyclostomaria monarii differ in the position of the selenizone, whereas in C. monarii it is in a central position, near the mid-line of the whorl surface between the periphery and the adapical suture, in the specimens herein described, the selenizone runs just above the periphery.

Superfamily Ptychomphaloidea Wenz, 1939
Family Ptychomphalidae Wenz, 1938

Remarks. Some authors, as Gründel (2001), argue that Ptychomphalidae should be in superfamily Eotomarioidea instead of Ptychomphaloidea. Bandel (2009) consider the position in superfamily Ptychomphaloidea because of temporal divergence between the type species of Eotomaria (Ordovician) and Ptychomphalus (Jurassic), although admitting close similarities between both genera. Bouchet et al. (2017) compiled Bandel’s position.

Figure 7. In the lower part of the figure are the original drawings by Böhm (1901) of Scurriopsis (Scurriopsis) schmidtii (=Patella delgadoi in Böhm, 1901) (left) and Cryptaenia sp. (right). a) Scurriopsis (Scurriopsis) schmidtii, SGP1283. b-c) Cryptaenia sp. (b) SGP1284(1); (c) SGP1284(2). Scale bars = 5 mm. Photos: R. Paredes.

2010 Scurriopsis (Scurriopsis) schmidtii (Dunker); Gründel, p. 4, Pl. 1, figs. 1-2.
2011 Scurriopsis (Scurriopsis) schmidtii; Monari et al., p. 352, Fig. 5A–C.
Genus Cryptaenia Deslongchamps, 1864

_Cryptaenia_ sp.  
(Figs 7b-7c)

v. 1901 _Cryptaenia_ sp.; Böhm, p. 213, Text-figs. 2-3.

**Material.** 1 specimen: SGP1284, Sinemurian.

**Description.** Shell cyrtoconoidal and sublenticular with low spire. Four whorls flat with flush sutures. The last whorls are not complete and the aperture is missing. Ornamentation is not preserved or is lacking. The presence of the selenizone cannot be assessed.

**Remarks.** According to Böhm (1901) these two specimens could represent two different species. Ferrari (2014) pointed out that _Cryptaenia_ is very similar to _Ptychomphalus_. Many species traditionally assigned to the former are currently included in the latter. The specimen described and figured by Böhm (1901), here re-illustrated (Figs 10a-10b), has not been reviewed in any recent publication; thus, further material is required in order to perform an in-depth analysis and to clarify its specific taxonomic position.

The genus _Cryptaenia_ has also been cited in the Lower Jurassic (Hettangian-Pliensbachian) of Europe and South America (Ferrari, 2014).

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Order SEGUENZIIDA

Superfamily _Seguenzioidea_ Verrill, 1884

Family _Eucyclidae_ Koken, 1896

**Remarks.** The systematics of the family _Eucyclidae_ is controversial. Some authors, such as Okan & Hosgör (2007), Szabó (2008a), Monari _et al_. (2011), and Szabó _et al_. (2019) include it in the superfamily _Eucycloidea_. Others, such as Gründel (2007a), consider that it belongs to the superfamily _Trochoidea_. Todd & Munt (2010), Ferrari _et al_. (2014), and Ferrari & Kaim (2019) place it in the superfamily _Seguenzioidae_.

Following Bouchet & Rocroi (2005) and Bouchet _et al_. (2017), the _Eucyclidae_ family is included in the superfamily _Seguenzioidae_. As Monari _et al_. (2011) and Szabó _et al_. (2019) pointed out, this classification is based upon molecular analysis (Kano, 2008), although there are substantial morphological and anatomical differences between eucyclids and seguenzioids that justify as well its assignation to superfamily _Eucycloidea_.

Subfamily _Eucycloscalinae_ Gründel, 2007a

Genus _Eucycloscala_ Cossmann, 1895

_Eucycloscala_ sp.  
(Figs 12.2-12.3)

cf. 2007a _Eucycloscala_ sp. cf. _brunhuberi_ (Schnittmann); Gründel, p. 7, pl. 2, fig. 3.

**Material.** 15 specimens: SGP (31700, 31708–31713, 31716?), Sinemurian; OU (40.7, 40.8, 40.42, 47.12, 69.2, 69.7, 69.9), upper Sinemurian, Oxynotum chronozone.

**Measurements.**

| Label    | H  | HL | HA | W  | WA |
|----------|----|----|----|----|----|
| SGP31713 | 16.5 | 11.4 | 6.3 | 13.1 | 5.5 |

**Description.** The specimens partially preserve the shell. The spire is conoidal. The state of preservation does not allow the surface or the outline of the teleoconch to be observed. The peristome is subcircular. A spiral keel, thickened by small nodules, can be observed in the lower part of each whorl at periphery. In the first whorls (the intermediate whorls are not visible in any of the specimens), spiral and collabral ribs intersect, giving to the ornament a mesh-like appearance. On the base both types of ribs are also visible, although the collabrals are thinner.

**Remarks.** Gründel (2007a) gives a description of _Eucycloscala_ cf. _brunhuberi_ based on juvenile specimens, from Sinemurian, Obtusum chronozone, of SW Germany. The specimens here described could be similar to this species, but it cannot be assured that they are the same because of the state of preservation.

The SGP specimens are labelled as coming from Polvoeira (Table 1). As Pedra do Ouro is very near, perhaps in the original labels Pedra do Ouro and Polvoeira were considered as one single location and these specimens might also come from the OU40–OU69 layers.

Order TROCHIDA

Superfamily _Trochoidea_ Rafinesque, 1815

Family _Ataphridae_ Cossmann, 1895

**Remarks.** Kaim _et al_. (2014) considered _Ataphrus_ Gabb, 1869 as _nomen dubium_, because as they pointed out, and Bouchet _et al_. (2017) compiled, the holotype of the type species _Ataphrus crassus_ Gabb, 1869 is poorly preserved and both its type locality and age are uncertain. For this reason, they substituted the family name _Ataphridae_ with _Collonidae_. However, Monari _et al_. (2018) maintained that this view is not justified. According to these authors, although the holotype is imperfectly preserved, it shows all the characters indicated in the original diagnosis and the uncertainty about its origin does
Ataphridae indet.
(Fig. 12.4)

Material. 1 specimen: OU.69.10, upper Sinemurian, Oxynotum chronozone.

Measurements.

| Label      | H  | HL | HA | W  | WA | α  | α₁ |
|------------|----|----|----|----|----|----|----|
| OU.69.10   | 5.6| 3.7| –  | 5.9| –  | –  | 55.7|

Description. Recrystallized shell. Shell turbiniform with low spire. Four well convex whorls with well impressed suture. The last whorl is not complete and the aperture is missing. Ornamentation is not preserved or is lacked.

Remarks. Due to the scarcity of the material and the poor state of preservation of OU.69.10, we cannot give a more precise taxonomical assignation.

Subclass CAENOGASTROPODA

Family Pseudomelaniidae Hoernes, 1884

Genus Pseudomelania Pictet & Campiche, 1862

Remarks. According to Kaim (2004), this genus is in doubt due to the fact that the original material of the type species, *Pseudomelania gresslyi* Pictet & Campiche, 1862, is an indeterminable inner mould. Species generally included in this genus have shells with a high, slender spire, not umbilicate, oval-shaped aperture and without ornamentation.

*Pseudomelania costae* (Sharpe, 1850a)  
(Figs 8, 12.5-12.7)

1850a *Rostellaria costae* sp. nov.; Sharpe, p. 193, Pl. 20, fig.1.

v. 1981 *Pseudomelania costae*; Mouterde & Rocha, p. 59, Pl. 2, fig. 4.

Material. 48 specimens: MCUC.MIN (2999–3001, 3032, 3033, 3035, 3066, 3067, 3078–3082), SGP (1016, 1017, 31715, 31727–31731, 31763?, 31774?, 31777, 31778?, 31779–31785, 31787, 31791, 31792, 31841, 31881, 31888), MUHNAC.G2.21.1.1, UP.MHNFCP.154782, UP.MHNFCP.154821, Sinemurian; PO (51, 54.1, 54.2), upper Sinemurian, Obtusum chronozone; OU (52.21, 62.19-5, 69.42-1, 69.56), upper Sinemurian, Oxynotum chronozone.

Superfamily Pseudozyglopleuroidea Knight, 1930

Family Zygopleuridae Wenz, 1938

Subfamily Zygopleurinae Wenz, 1938

Genus Pseudokatosira Nützel & Gründel, 2007
Pseudokatosira? aff. undulata Benz, 1832

(Fig. 12.8)

1832 Turritella undulata sp. nov. Benz in Zieten, S. 43, af: 32, fig. 2.

1861 Chemnizia undulata Benz; Stoliczka, p. 163, Pl. 1, fig. 1.

2007 Pseudokatosira undulata (Benz, 1830); Nützel & Gründel, p. 62, Pl. 1, figs. 1-6.

2008a Pseudokatosira? aff. undulata; Szabó, p. 91, figs. 84A-B, J-K.

2010 Pseudokatosira undulata (Benz); Todd & Munt, p. 162, Pl. 24, fig. 2.

2015 Pseudokatosira undulata (Benz, 1832 in Zieten); Nützel and Gründel, p. 16, Pl. 8, figs. A-E.

Material. 31 specimens: SGP (31701–31706, 31824, 31835, 31887), Sinemurian; OU (26.21, 26.40, 40.1, 40.2, 40.4, 40.10, 47.1, 47.2, 47.4, 62.1, 62.2, 62.3, 62.4, 62.5, 62.6-1, 62.6-2, 62.19-3, 69.3, 69.4, 69.35, 71), upper Sinemurian, Oxynotum chronozone.

Measurements.

| Label   | H   | HL  | HA  | W   | WA  | α    | α₁   |
|---------|-----|-----|-----|-----|-----|------|------|
| OU.40.1 | 18.5| 5.5 | 2.2 | 5.1 | –   | 30.5 | 15.6 |
| OU.62.1 | 16.4| 5.7 | 3.2 | 5.5 | –   | 40.3 | 17.6 |

Description. Some specimens preserve the shell. The protoconch is not preserved. The teleoconch has ten whorls, with slightly convex flanks and a slightly impressed suture. The base is round. The peristome is continuous and elliptical, with an angular adapical border. Collabral ornamentation is represented in every whorl by opisthocyrt continuous and closely set ribs. The number of ribs cannot be established because the specimens are embedded in the matrix. Specimens OU40.1 and OU40.10 possess up to 11 ribs, which enables an estimation of between 13 and 18 ribs per whorl.

Remarks. Hallam (1971) quoted the presence of the genus Katosira in S. Pedro de Moel, Oxynotum chronozone, although neither description nor figure is available; however, he is likely referring to this species. Szabó (2008a) cited this species in the upper Sinemurian, Oxynotum chronozone of the Austrian Alps.

The specimens SGP31701-31706 preserve the original labels, which indicate that these specimens come from Polvoeira locality. As Pedra do Ouro is very near, perhaps in the original labels Pedra do Ouro and Polvoeira were considered as one single location and the specimens SGP31701-31706 might also come from the OU26 to OU71 layers. The original location of specimen SGP31835 is Palheira, an inner outcrop nearby Coimbra.

Superfamily Campaniloidea Douvillé, 1904

Family Ampullinidae Cossmann, 1919

Genus Oonia Gemmellaro, 1878

Remarks. The genus is assigned to family Ampullinidae following Bouchet et al. (2017) and Gründel (2001), although this family is under review (Gründel & Kaim, 2006; Kaim, pers. comm. 2018).

Oonia casta Böhm, 1901

(Figs 12.9-12.12)

1901 Oonia casta sp. nov.; Böhm, p. 221, Pl. 8, figs. 7-8.

Material. 79 specimens: MCUC.MIN (3003, 3005–3010, 3012–3015, 3017, 3018, 3021–3025), SGP (31722, 31723, 31736, 31742, 31745, 31746, 31750–31753, 31757, 31760–31762, 31764, 31765, 31788–31791, 31793, 31794–31797, 31799–31803, 31825–31829, 31832, 31848–31857, 31869–31878), MUHNAC.G2.21.1.2, MUHNAC.G2.21.1.3, MUHNAC.G2.21.2, Sinemurian; OU (40.41, 68), upper Sinemurian, Oxynotum chronozone.

Measurements.

| Label   | H   | HL  | HA  | W   | WA  | α    | α₁   |
|---------|-----|-----|-----|-----|-----|------|------|
| MIN.3012| 12.5| 8.6 | 5.3 | 7.7 | 4.4 | –    | 46.5 |
| MIN.3018| 9.5 | 6.7 | 5.8 | –   | –   | 72.1 | 55.4 |

Description. The shell is preserved in some specimens. The protoconch is not preserved. The teleoconch has seven whorls with convex sides. Suture well-marked, almost straight. Base round and convex. Peristome is usually incomplete, but the aperture shape can be defined as oval. No ornamentation is observed. Prosocline growth lines.

Remarks. The morphological characters and dimensions are very similar to those described by Fischer et al. (2002) as Pseudomelania (Oonia) turgidula (Gemmellaro, 1878) from the lower Sinemurian of Monte Cucco (Italy). However, P. turgidula has much less convex whorls with less impressed suture, and the whorls, especially the last one, are higher than O. casta. Moreover, Gemmellaro (1878, p. 156) notes in the original diagnosis that the columellar lip is covered by a thin callus. This feature cannot be observed in the specimens described herein.

As both P. costae and O. casta are species with a significant number of specimens, we have considered the
elaboration of morphometric comparisons between both species. As it was expected, both species are represented as two different groups in PCA analysis (Fig. 9), mainly explained by H and HL measurements.

Order NEOGASTROPODA
Family Purpurinidae Zittel, 1895

Remarks. Gründel (2003) assigned this family to superfamily Purpurinoidea. Nevertheless, Bouchet et al. (2017) did not recognise this superfamily.

Genus Microschiza Gemmellaro, 1878

Microschiza sp. (Figs 12.13-12.14)

cf. 1855 Littorina clathrata Deshayes; Terquem, p. 250, Pl. 14, fig. 4.
cf. 1909 Litorina semiornata Münster; Brösamlen, p. 252, Pl. 19, figs. 47-48.
cf. 1988 Microschiza clathrata Deshayes; Meier & Meiers, p. 42, 47, Pl. 8, fig. 28 a-b, Text-Fig. 7.
cf. 2003 Microschiza semiornata (Münster); Gründel, p. 28, Pl. 7, figs. 2-3.

Material. 10 specimens: MCUC.MIN.3011, SGP (31719, 31734, 31737, 31820?, 31842), Sinemurian; PO (77.1, 84), upper Sinemurian, Obtusum chronozone; PO.128.12, OU.69.6, upper Sinemurian, Oxynotum chronozone.

Measurements.

| Label       | H   | HL  | HA  | W   | WA  |
|-------------|-----|-----|-----|-----|-----|
| SGP31719    | 19.9| 13.4| 7.6 | 12.7| 6.5 |

Description. Teleoconch with five whorls. Whorls with straight flanks, slightly convex adapically. A well-marked Figure 9. PCA analysis showing the morphological differentiation of the specimens, mainly explained by the H and HL measurements in the first component. Two species groups are clearly differentiated. Blue dots are the specimens assigned as Oonia casta, and red crosses are Pseudomelania costae specimens.
sutural shelf, with a 90° shoulder, gives to the shell a stair-like appearance. Aperture elliptical. The adapical margin of the whorls bears a row of tubercles. Growth lines are not preserved.

**Remarks.** According to Gründel (2003), *Microschiza semiornata* (Münster) (=*Littorina clathrata* Deshayes) has a high degree of intraspecific variability. The species is described from the upper Hettangian, Angulata chronozone, of S Germany and Luxembourg.

The specimen SGP31719 is labelled as coming from Praia da Polvoeira (Table 1). As Pedra do Ouro is very near, perhaps in the original labels Pedra do Ouro and Polvoeira were considered as one single location and SGP31719 might also come from the OU69 layer. The specimen SGP91842 is labelled as coming from Monte de Vera, an inland location at the south of Coimbra.

Subclass HETEROBANCHIA
Order ALLOGASTROPODA

**Remarks.** Bouche et al. (2017) do not recognise Allogastropoda. However, considering Gründel (2010), we keep this Order.

Superfamily Nerinoidea Zittel, 1873
Family Ceritellidae Wenz, 1938
Genus *Boehmiola* Strand, 1928

**Remarks.** Gründel et al. (2011) and Gründel & Nützel (2012) maintained that *Consobrinella* is most probably junior synonym of *Boehmiola* (=*Ephyra* Böhm 1901, non Péron & Lesueur, 1810). However, since the protoconch of *Boehmiola* is unknown, these relationships remain still uncertain.

*Boehmiola exilis* (Böhm, 1901)
(Fig. 10)

1901 *Ephyra exilis* sp. nov.; Böhm, p. 223, Pl. 8, figs. 5-6, Text-figs. 7-9.

v 1981 *Boehmiola exilis*; Mouterde & Rocha, p. 56, Pl. 1, figs. 6-7.

**Material.** 15 specimens: SGP (31808–31817, 31863?, 31878, 31886, 31889), lower Sinemurian. OU.69.47?, upper Sinemurian, Oxynotum chronozone.

**Description.** Shell turriculated. The apical part of the shell and aperture are not preserved in any of the specimens. Surface of whorls slightly convex, with a narrow and pronounced sutural ramp. Collabral ribs regularly repeating, slightly opisthoclinc, straight to slightly prosocyrt on most of the whorl surface and becoming strongly prosocyrt in the upper part of the whorl and on the sutural shelf.

Family Nerinellidae Pchelintsev, 1960
Genus *Nerinella* Sharpe, 1850b

*Nerinella ficalhoi* Choffat, 1903
(Figs 11, 12.15–12.19)

v 1903 *Nerinella ficalhoi* sp. nov.; Choffat, p. 107, figs. 12–15.

v 1981 *Nerinella ficalhoi*; Mouterde & Rocha, p. 59, Pl. 1, fig.13; Pl. 2, fig. 8.

**Material.** 42 specimens: MCUC.MIN (3002, 3036, 3037, 3039, 3040, 3050–3054, 3056–3058, 3060, 3061, 3068–3076, 3085, 3086, 3088, 3089), SGP (1153, 1154, 1156, 31732, 31738, 31744, 31768, 31769, 31771, 31773, 31776, 31824, 31861?, 31862?), Sinemurian.

**Measurements.**

| Label     | H  | HL | HA | W  | WA |
|-----------|----|----|----|----|----|
| MIN.3068  | 29.1| 6.1| 3.7| 6.3| 2.5|
| SGP1154   | 29.6| 11.4| 6.1| 6.3| 2.2|

**Description.** The protoconch and first teleoconch whors are missing in all the specimens. Shell turriculated with high spire. The most complete specimen (MCUC.MIN.3085) preserves seven whors. Side of whors straight with rounded shoulders and narrow sutural ramp. Suture slightly oblique. Aperture elliptical, becoming narrow adapically. Its height is more than half the height of the last whorl. Growth lines mostly prosocyrtic but closer to sigmoidal shape. The shell has a labial fold, visible in...
Tangarilda subturritella (d’Orbigny, 1850)  
(Figs 12.20–12.21)

1846 Melanita turritella sp. nov.; Dunker, p.169.  
1847 Melanita turritella; Dunker, p.109, Pl. 13, figs. 5–7.  
1850 Cerithium subturritella; d’Orbigny, p.255.  
1901 Promathildia turritella; Böhm, p. 216, Pl. 8, figs. 15, 17.  
1981 Promathildia (Teretrina) turritella; Mouterde & Rocha, p. 54, Pl. 1, figs. 3a-b.  
1988 Promathildia turritella; Meier & Meiers, p. 36, Pl. 9, fig. 20.  
2010 Tangarilda subturritella (d’Orbigny); Gründel, p. 10, Pl. 3, figs. 3–7; Pl. 4, fig. 1.

Material. 15 specimens: MCUC.MIN.3049, SGP (1155, 31733, 31786, 31864–31866, 31883–31885), MUHNAC.G2.21.2, MUHNAC.G2.21.3, Sinemurian; OU (69.46, 69.48, 69.50), upper Sinemurian, Oxynotum chronozone.

Measurements.  
| Label  | H  | HL | HA | W  | WA | α  | α1 |
|--------|----|----|----|----|----|----|----|
| OU.69.48 | 7.1 | 2.1 | –  | 3.3 | –  | 44.1 | 21.5 |

Description. Shell turriculated. Whorls convex with well-marked suture. In the middle part of each whorl, there are two spiral threads of the same width. The surface of the whorl between the two spiral threads is concave. A third thread weaker than the other two can be observed adapically in the last whorl of OU.69.48. Opisthocyrtic growth lines can be observed in the specimen OU.69.48. They match with the genus diagnosis by Gründel (2010), as they are asymmetrical “with the backmost point between the adapical and the middle spiral rib”.

Remarks. Gründel (2010) cited this species in lower Hettangian of Germany. Meier & Meiers (1988) describe it as an uncommon species in the Angulata chronozone, upper Hettangian of Luxembourg. Choffat (1903) and Mouterde & Rocha (1981) cite this species in upper Hettangian of Portugal, although this stratigraphic position should be revised.

Superfamily Cimoidea Warén, 1993  
Family Cimidae Warén, 1993

Remarks. Gründel & Nützel (2013) used the name Tofanellidae for this family. However, Bouchet et al. (2017) considered Tofanellidae as synonym of Cimidae.
Genus *Cristalloella* Bandel, 1995

*Cristalloella* sp. (Fig. 12.22)

**Material.** 4 specimens: MCUC.MIN.3062, SGP31772? Sinemurian; OU (52.20, 69.42-2), upper Sinemurian, Oxynotum chronozone.

**Measurements.**

| Label     | H   | HL  | HA | W  | WA | α     | α₀    |
|-----------|-----|-----|----|----|----|-------|-------|
| MIN.3062 | 9.8 | 2.2 | –  | 3.1| –  | –     | –     |
| OU.52.20 | 8.0 | 3.9 | –  | 4.3| –  | 43.2  | 25.4  |

**Description.** Shell conospiral turriculated. The protoconch is not preserved. Up to twelve whorls, convex surface well-marked suture. A strong spiral keel is visible at the middle of each whorl. Growth lines are visible.

**Remarks.** Gründel & Nützel (2013) described two subgenera, *Cristalloella* (*Cristalloella*) and *Cristalloella* (*Wonwalica*). In contrast, Kaim (2004) maintained that the *Cristalloella* species couldn’t be differentiated from the *Wonwalica* species at the genus level. Gründel & Nützel (2013) indicate that *Wonwalica* possesses fewer whors and is broader than the typical subgenus. In the material studied, OU.52.20 and OU.69.42 have fewer whors, four to six, and are broader than MIN.3062 and SGP31772. Following Gründel & Nützel (2013), OU.52.20 and OU.69.42 could belong *Cristalloella* (*Wonwalica*) sp., and MIN.3062 and SGP31772 could be *Cristalloella* (*Cristalloella*). However, due to the state of preservation and the shortage of material we cannot assure these taxonomical assignments.

Gründel & Nützel (2013) confer to the genus a stratigraphic distribution between the Upper Triassic and the Middle Jurassic (Callovian) of Germany, France, New Zealand and North Italy.

Superfamily *Acteonoidea* D’Orbigny, 1843

Family *Cylindrobullinidae* Wenz, 1938

**Remarks.** Gründel & Kaim (2006) include this family in the superfamily *Acteonelloidea*. Kaim (2004) includes the family *Cylindrobullinidae* in the superfamily *Cephalaspidea*. On the other hand, Gründel & Nützel (2012) follow the assignation to superfamily *Acteonoidea* but include this in Order *Architectibranchia*. In the present paper, we follow the classification of Bouchet & Rocroi (2005) and Bouchet et al. (2017).

Genus *Cylindrobullina* v. Ammon, 1878

Cylindrobullina sp.

**Material.** 8 specimens: SGP (31786, 31791, 31803–31806, 31844), MUHNAC.G2.21.2, Sinemurian.

**Description.** Shell conospiral shell. Low spire with three or four whors. Convex surface with overlapping suture. The first whors are very tight and the last whorl measures almost the total shell height. The aperture is long, with a rounded base that becomes narrow adapically; its height is almost equal to that of the last whorl. No ornamentation or growth lines are visible.

**Remarks.** It has been no possible to figure this species because of the preservation state and because as all the

**Figure 12.** 1) *Cyclostomaria* aff. *monarri* Oxynotum chronozone, Praia Pedra do Ouro beach, Água de Madeiros Fm. Cross section, with part of the shell preserved. OU.68.11. 2-3) *Eucycloscala* sp. Oxynotum chronozone, Praia da Pedra do Ouro beach, Água de Madeiros Fm. Apertural views showing detail of the selenizone and the spiral rib with nodules; (2) OU.47.12; (3) OU.40.7. 4) *Ataphridae* indet. Oxynotum chronozone, Praia Pedra do Ouro beach, Água de Madeiros Fm. Lateral and basal views. OU.69.10. 5-7) *Pseudomelanina costae*, (5) Oxynotum chronozone, Praia da Polvoeira, Água de Madeiros Fm.; apertural (5a) and dorsal (5b) views. PO.54.2; (6-7) Oxynotum chronozone, S. Pedro de Moel, Coimbra Fm.; (6) apertural view, MCUC.MIN.3078; (7) dorsal view, MCUC.MIN.2999. 8) *Pseudokotaispis?* aff. *undulata*, Oxynotum chronozone, Praia da Pedra do Ouro beach, Água de Madeiros Fm. Lateral view. OU.40.1. 9-12) *Oonia casta*, Oxynotum chronozone, Praia da Concha, Coimbra Fm.; (9) apertural view. MCUC.MIN.3012; (10) dorsal view showing the pattern of growth lines. MCUC.MIN.3009; (11) apertural view. MCUC.MIN.3018; apertural (12a) and dorsal (12b) views showing the pattern of growth lines. MCUC.MIN.3013. 13-14) *Microschiza* sp., Oxynotum chronozone, Praia da Polvoeira, Água de Madeiros Fm. Dorsal views showing a row of tubercles. 15-19) *Nerinella ficalhoi*, Oxynotum chronozone, Coimbra Fm.; (15, 16) Penedo da Saudade (S. Pedro de Moel). Inner moulds, lateral and apertural views; (15) MCUC.MIN.3037; (16) MCUC.MIN.3052; (17-19) Penedo do Cabo, apertural and dorsal views showing detail of the whorl surface; (17) MCUC.MIN.3085; (18) MCUC.MIN.3086; (19) MCUC.MIN.3088. 20-21) *Tangarilda subturritella*. Dorsal views; (20) Oxynotum chronozone, Penedo da Saudade (SPM), Coimbra Fm., MCUC.MIN.3049; (21) Oxynotum chronozone, Praia da Pedra do Ouro beach, Água de Madeiros Fm., OU.69.48. 22) *Cristalloella* sp., Oxynotum chronozone, Penedo da Saudade (SPM), Coimbra Fm. Dorsal views showing detail of the whorl surface. MCUC.MIN.3062. Scale bars in Figures (1-3, 5-7, 9-19) = 10 mm; Scale bars in Figures (4, 8, 20-22) = 5 mm.
specimens are embedded in rock, it was not possible to take high-quality photos. Nevertheless regarding the preserved features these specimens match with those describe and figure by Böhm (1901; p. 266, pl. 8, fig. 19), and it has been considered interesting to leave proof of the presence of this taxa.

5. DISCUSSION AND CONCLUSIONS

A total of 386 Sinemurian gastropod specimens were studied. Of these, 96 were newly collected in the S. Pedro de Moel area and 290 were from museum collections. Among the new collected material, 77 specimens came from Pedro do Ouro (OU) and 19 from Polvoeira (PO) sections. From the main museum collections (the Museu Geológico de Portugal and Museu da Ciência - University of Coimbra), 283 Sinemurian gastropods were studied: 198 from SGP and 85 from MCUC. Moreover, other 5 specimens from MUHNAC and 2 from UP.MHNFCP are catalogued as Sinemurian.

Among these 386 specimens, 266 have been taxonomically identified (Table 1; Supplementary Information); the other 120 specimens were simply recognized as Gastropoda. 147 specimens from SGP, 62 from MCUC, and all the specimens from MUHNAC and UP.MHNFCP have been identified (Table 1). Moreover, 44 from OU and 6 from PO have been determined at some taxonomical level.

Adding to these 386 specimens, 5 bed samples from SPM (Figs 2, 3a) and PV (Figs 2, 3b-3d), that include numerous gastropod specimens, were studied. These specimens were not removed from the sediment in order to study in detail the distribution of the gastropod shells and their state of preservation. All of them were regarded taphonomically as autochthonous assemblages (Fernández-López, 2000), giving valuable information about the type of preservation and palaeocommunities approaches.

The following taxa have been identified in these samples: a) SPM (Fig. 3a). This is a monospecific sample of Nerinella ficalhoi; b) PV322b_1 (Fig. 3b). 56 specimens have been counted: 50 of them represent Tangarilda subturritella, with heights between 4.7 and 12.3 mm, 2 specimens belong to Pseudomelania indet., and 2 specimens to Cylindrobullina sp; c) PV322b_2 (Fig. 3c). 17 specimens have been counted: 13 represent T. subturritella, with height between 8.1 and 10.3 mm, 3 specimens belong to Oonia casta, one is fragmented and the others show heights of 15.4 and 18.6 mm, and one specimen represents Pseudomelania costae, which has a height of 24.6 mm; d) PV322mt (Fig. 3d). From PV322 there are two sample assemblages in which P. costae and T. subturritella dominate. In the first one, 11 specimens have been counted: 7 of P. costae and 4 of T. subturritella. One specimen of P. costae preserves three whorls, with a total height of 52.1 mm, another almost complete one has a height of 42.8 mm. There are other smaller ones, and the lowest height is 17.7 mm. The T. subturritella specimens present homogeneous heights of 5.7 mm. The second sample has 18 specimens, 14 of T. subturritella, with heights between 3.3 and 8.6 mm. The other 4 specimens belong to P. costae; two are incomplete, the larger one preserves three whorls with a height of 18.6 mm, the third one is almost complete, with a height of 15.2 mm and the fourth is the smallest, with a height of 3.8 mm. Other 3 specimens can be observed in axial cross-section.

In summary, in the layer 322, the most frequent species are T. subturritella and P. costae. Moreover, O. casta and Cylindrobullina sp. can be found albeit less frequently. To date, Nerinella ficalhoi has only been found in the stratigraphically lowest level, that one cited by Choffat as bed 4 (“Cam.4”) of Penedo do Cabo. It is located most probably below the bed 315 of Azeredo et al. (2010; fig. 3) log. Future research should specify the precise position of these records. The most continuous and best-exposed upper Sinemurian p.p. outcrops are located in the vicinity of S. Pedro de Moel, including OU and PO sections, where 300 of the 386 specimens (77.72%) come from. The outcrops of Coimbra Fm. located inland are badly exposed or inaccessible, but 59 specimens (15.28%) could be studied in the SGP collection, the only one that keep gastropods from these outcrops.

The specimens of P. costae and O. casta, labelled as coming from Penedo do Cabo, Penedo da Saudade and S. Pedro de Moel, likely belong to levels close to those of the Obtusum chronozone sampled at the Praia Velha and Praia da Concha. The specimens labelled in SGP as coming from Polvoeira belong to species also identified in Praia Pedro do Ouro (OU) and Praia da Polvoeira (PO) sections, which most probably indicates that they precisely come from the same outcrops studied recently in this area. In relation with the stratigraphic distribution of the taxa studied, it is remarkable that Pseudomelania costae and Oonia casta are the most frequent and widely distributed species, being found in the Obtusum and Oxynotum chronozones.

Nerinella ficalhoi and Cylindrobullina sp. have been only found in the Obtusum chronozone. Microschiza sp., Pseudokatosira? aff. undulata, Eucycloscala sp., and Cyclostomaria aff. monarii have only been recorded in the Oxynotum chronozone.

Tangarilda subturritella, which is common in the Obtusum chronozone, has also been identified in the bed OU69 of the Oxynotum chronozone.

Cryptaenia sp., Boehmiola exilis, and Scurriopsis (Scurriopsis) schmidtii have only been identified in the SGP collection; they were labelled as coming from the Almaroz site. This is the only locality where this association has been recognised.
Microschiza sp., T. subburritella, and S. (S.) schmidtii have been cited in the upper Hettangian of Luxemburg and SW Germany. Different species of Nerinella have been identified in N Europe, in older stratigraphic levels than those of S Europe (Sharpe, 1850b). These data open up an interesting path of research into possible north-southern migration way. In agreement with this hypothesis, similar forms to ones described here as Pseudokatosira aff. undulata and Eucycloscala sp. have been found in lower Sinemurian levels of German and Austrian outcrops. In contrast, forms similar to Cyclostomaria aff. monarrii and B. exilis have been described in the Pliensbachian of the Bakony Mountains (Hungary) and of Dorset (England), respectively.

To date, N. ficalhoi has only been cited in LB; thus, it might constitute an endemic species. This could also be the case of P. costae and O. casta.

ACKNOWLEDGEMENTS

Acknowledgments are due to Dr Roberto Gatto for the detailed revision of the manuscript; to both reviewers, Dr Stefano Monari and Dr Mariel Ferrari, for providing valuable comments on the manuscript; to Dr Luís Vítor Duarte (Marine and Environment Research Centre, Faculdade de Ciências e Tecnologia, Universidade de Coimbra) for the cession of Figure 2; to Dr Miguel Ramalho and his collaborators (Museu Geológico de Portugal), João Muchagata (MHNC-UP), Susana Machado (LNEG-Alfragide), Liliana Póvoa and João Paulo Lopes (MUHNAC) for their attention in their institutions, to Museu da Ciência (University of Coimbra) management, for lending the Sinemurian gastropod collection; to Cormac De Brun for the English review of the manuscript. We emphasise with special thanks the photographic work and collaboration edition of images received from Carlos Alonso (UCM). This paper benefited from the use of the Portuguese Infrastructure of Scientific Collections (PRISC.pt). This work is a contribution to the Portuguese E-Infrastructure for Information and Research on Biodiversity (PORBIOTA) and to the project CGL2015-66604-R (MINECO, Spain) and to the UCM group 910431 “Procesos Bióticos Mesozoicos”.

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