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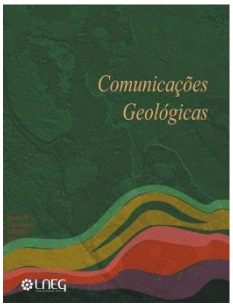
Ribeiria pholadiformis Sharpe *in* Ribeiro (Rostroconchia): history of the study, type-locality and unit, and the topotypical collection of the Geological Museum of Portugal



Ribeiria pholadiformis Sharpe *in* Ribeiro (Rostroconchia): história do estudo, localidade e unidade-tipo e a coleção topotípica inédita do Museu Geológico de Portugal

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Abstract: *Ribeiria pholadiformis* Sharpe *in* Ribeiro, the type-species of Ribeirioida (Rostroconcha), was erected almost 170 years ago, based on portuguese fossils from the Middle Ordovician of the Buçaco Syncline. In this paper, we review the history of the study of this species and clarify the type-locality and unit for this taxon: the Cácemes Group (Darriwilian) in the Palheiros stream section (Penacova). The reconstitution of Sharpe's original label led to discover that one of the paralectotypes is the external mould of the lectotype, being this specimen now divided between the Geological Survey Museum, Keyworth (the latter) and the Natural History Museum, London (the former). Furthermore, we report an unpublished collection of 25 specimens of topotypic material, gathered during the 19th century under the guidance of Nery Delgado, deposited in the Geological Museum of Portugal. Its study will allow assessing the morphological variability of the species for the first time.

Keywords: Middle Ordovician, Darriwilian, Buçaco Syncline, Brejo Fundeiro Formation, Fonte da Horta Formation.

Resumo: *Ribeiria pholadiformis* Sharpe *in* Ribeiro, a espécie-tipo de Ribeirioida (Rostroconcha), foi definida há quase 170 anos com base em fósseis portugueses do Ordovícico Médio do Sinclinal de Buçaco. Neste artigo revemos a história do estudo desta espécie e esclarecemos qual a localidade e unidade-tipo: o Grupo Cácemes (Darriwiliano) no setor da ribeira de Palheiros (Penacova). A reconstituição da etiqueta original de Sharpe permitiu descobrir que um dos paralectótipos é o molde externo do lectótipo, estando este espécime agora dividido entre duas instituições: o *Natural History Museum*, Londres (o primeiro) e o *Geological Survey Museum, Keyworth* (o segundo). Adicionalmente, damos a conhecer a constituição da coleção inédita de material topotípico de *R. pholadiformis* do Museu Geológico de Portugal, constituída por 25 exemplares recolhidos durante a segunda metade do século XIX sob a orientação de Nery Delgado. O seu estudo permitirá avaliar a variabilidade morfológica da espécie pela primeira vez.

Palavras-chave: Ordovícico Médio, Darriwiliano, Sinclinal de Buçaco, Formação Brejo Fundeiro, Formação Fonte da Horta.

1. Introduction

Some fossil groups are more attractive to palaeontologists and palaeontology enthusiasts than others, and it is difficult to explain why. Their abundance and rarity are not enough to explain the asymmetries. If it is true that rarity can increase interest, as is the case with many vertebrates, it is also true that some of the most abundant groups, such as ammonites and trilobites, continue to top the list of the most desirable. Is it then related to their strangeness or to the fact that they are already extinct and, in the latter case, how many millions of years ago they lived? Maybe it helps, but people love fossils of fish or dragonflies, even if they are phenotypically indistinct from those that swim and fly today. Moreover, if they are not extinct, will their representation in today's ecosystems have any influence? Hardly, since arthropods and molluscs, the most diverse and abundant phylum today can be loved (the former) or, apart from the ammonoids, despised (the latter). Even within the palaeontological scientific community, we cannot assume that being more useful (*e.g.* valuable for biostratigraphy or palaeogeography) makes a group more loved, because often a group will only prove useful when there are enough people studying it globally, generating and cross-checking data. Rostroconchs are an extinct class of molluscs. They are rare. They are even very ancient, appearing and becoming extinct in the Palaeozoic. In addition, they are strange. Nevertheless, they are not famous or loved... and certainly, their morphological resemblance to bivalves does not help.

In the middle of the 19th century, *Ribeiria pholadiformis* Sharpe in Ribeiro, 1853, the first known ribeirioid (Rostroconchia), was described in Portugal. Although the fossil record of Rostroconchia has been documented since the early 19th century (Martin, 1809; Sowerby, 1815), it took more than 150 years for the group to be recognised as a natural biological entity (Pojeta *et al*., 1972). Ribeirioida, one of the three orders of Rostroconchia, was originally assigned to the phylum Mollusca (Ribeiro, 1853), later positioned in Arthropoda (Salter, 1864; Etheridge, 1878; Schubert and Waagen, 1904; Kobayashi, 1933),

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and finally returned to its pioneer framework as a member of the molluscs Rostroconchia (Pojeta and Runnegar, 1976).

This paper reviews the history of the study of the type-species of Ribeirioida - *Ribeiria pholadiformis* -, clarifies the constitution of the type-material, type-locality and type-unit of this taxon and reports an unpublished collection of topotypic material from the Middle Ordovician of the Buçaco Syncline, which will allow the morphological variability of this classic species to be evaluated for the first time at the units where it was erected.

2. History of the Study

The establishment of the genus *Ribeiria* concurred with the beginning of the geological and stratigraphic studies s.s. in Portugal, in a pioneering work published in 1853 by Carlos Ribeiro, in collaboration with Daniel Sharpe, John William Salter and Thomas Ruppert Jones (Ribeiro, 1853). In charge of the geological study of the Buçaco Syncline, Ribeiro contacted Daniel Sharpe, a British merchant (later on president of the Geological Society of London) who had lived for some years in Portugal during the 1830s and had studied the geology of the surroundings of Lisbon and Oporto (Sharpe, 1834, 1841, 1849). After an exchange of correspondence (Ribeiro, 1850), Ribeiro sent to Sharpe, then living in London, a collection of ordovician and carboniferous fossils from that region which led to the mentioned publication (Ribeiro, 1853). Sharpe was in charge of the study of the molluscs, defining, among other taxa, the new genus *Ribeiria* (named after Carlos Ribeiro) and the new species *R. pholadiformis*. The material was briefly described and illustrated (Ribeiro, 1853, pl. 9, fig. 17). However, as was the custom at the time, neither holotype nor type-locality or type-unit were selected, the occurrence being only documented as either in the 'Serra de Bussaco' or in 'Mucela' (the name by which Ribeiro referred to the hill south of the Mondego River, present-day Atalhada and Bidueiro hills; see Ribeiro, 1853, fig. 1). In the following years, the species was identified in the Middle Ordovician of Spain (Verneuil and Barrande, 1855) and France (Tromelin and Lebesconte, 1876) and congeneric forms were described in central Europe.

The extensive record of *Ribeiria pholadiformis* in Portugal was revealed by Delgado (1908) who, after decades of palaeontological prospection in the Portuguese Ordovician outcrops, documented several occurrences in the Middle Ordovician of Buçaco, Góis, Mação and Valongo regions in units that currently correspond to the Brejo Fundeiro Formation (Oretanian), Monte da Sombadeira and Fonte da Horta Formation (Dobrotivian), of central Portugal, and the upper part of the Valongo Formation (Dobrotivian), of the northern region.

The study of the type-material of *R. pholadiformis* was only resumed by Pojeta and Runnegar (1976), in an important work where the proposal still accepted today for the phylogeny of rostroconchs was presented. It was in this context that they reviewed Carlos Ribeiro's collection and selected a lectotype (Pojeta and Runnegar, 1976, est. 7, fig. 3), from among the set of available syntypes (now paralectotypes) (Fig. 2). The material was finally figured in a photographic plate (Pojeta and Runnegar, 1976, est. 7, figs. 3-10), but the authors did not indicate the exact geographical provenance of the specimen selected for lectotype nor of the others, reporting them all as having the same general provenance: "Llandeilian(?) (Middle Ordovician) of Portugal."

In the 1980s, the establishment of the lithostratigraphy of the Middle/Upper Ordovician of central Portugal by Young (1985, 1988) allowed the documentation of material from the same hypothetical type-unit (Fonte da Horta Formation) and provenance (Buçaco Syncline), as well as conspecific specimens from correlated units of the Amêndoa-Carvoeiro Syncline. By the same time, several advances in the knowledge of the geographical distribution of *R. pholadiformis* were made. Gutiérrez-Marco *et al*. (1984) detailed the occurrences of rostroconchs in the Spanish Central Iberian Zone. In turn, Babin and Destombes (1990) confirmed the presence of the species in the Middle Ordovician of Morocco. Subsequently, Gutiérrez- Marco (1997) summarized the geographical and stratigraphic distribution of the genus *Ribeiria* and other ribeirioids of the high-latitude Gondwana Realm.

More recently, Sá (2005, 2008) identified the species *Ribeiria pholadiformis* in the Moncorvo Formation of the lower Oretanian (Darriwilian, Middle Ordovician) of the Moncorvo Syncline. In recent years, some new species from *Ribeiria* have been described (*e.g*. Sánchez, 2005; Polechová, 2015), but no new occurrences of *R. pholadiformis* have been added to the geographical and stratigraphic distribution as known in the 1990s. Recently, Polechová (2015) considered that the character on which the differentiation of the species *Ribeiria apusoides*, from the Middle and Upper Ordovician of the Czech Republic, from *R. pholadiformis* is based, is questionable, motivating the resumption of this issue.

3. Clarification of the *Ribeiria pholadiformis* type-material and type-locality: geographic, geological and lithostratigraphic setting

The collection of *Ribeiria pholadiformis* sent by Carlos Ribeiro to Daniel Sharpe in the 1850s would include three specimens (Fig. 2b), represented by internal moulds and the corresponding external ones, in a total of six pieces from three distinct localities of the Buçaco Syncline (Fig. 1). This Variscan structure is located on the western edge of the Portuguese Central-Iberian Zone, and is about 40 km long (maximum width of 4.5 km), between the regions of Luso (Aveiro), to the northwest, and Ponte de Sótão (Coimbra), to the southeast (Fig. 1b). Geographically, it is located in the central region of Portugal's mainland, in the alignment of the Buçaco and Atalhada mountains that extends from the District of Aveiro to that of Coimbra.

In 1911, Daniel Sharpe's entire collection of Portuguese Palaeozoic fossils was transferred to the Natural History Museum (NHM), London, with the exception of a single specimen (Ribeiro, 1853, pl. 9, figs. 7b,c). This one remained in the Geological Society Collection, now belonging to the British Geological Survey (BGS) and was later designated as the lectotype of *R. pholadiformis* by Pojeta and Runnegar (1976, p. 50, pl. 7, figs. 3-7). It is unknown why this specimen, among hundreds of fossils, was left behind. During our research, Daniel Sharpe's original label was reconstructed (Fig. 2a-b); it originally had this fossil glued to the bottom right-hand corner of the card, so it may have fallen off or been separated for display at the time of transfer.

It has been generally agreed (*e.g*. Young, 1985; Sá, 2008) that the lectotype and most (if not all) of the material collected and described by Ribeiro (1853) comes from the Fonte da Horta Formation. Although the collection sites were indicated in the original labels of Ribeiro's specimens, neither Ribeiro (1853) nor Pojeta and Runnegar (1976) included this provenance information in their works. On the other hand, Ribeiro (1853) gathered under the same designation ("Lowest Division") almost the whole Ordovician sequence and therefore did not differentiate stratigraphic units in his collections. This was, in fact, one of the reasons why Delgado (1870, p. 23, infrapaginal note 1), even though he worked closely with Carlos Ribeiro, chose to exclude the materials published in 1853 from his biostratigraphic revision of the Palaeozoic of Buçaco. Until now, it was thought that the type-material of *R. pholadiformis* included four specimens, the lectotype designated by Pojeta and Runnegar (1976), deposited at BGS, and three paralectotypes, deposited at NHM.

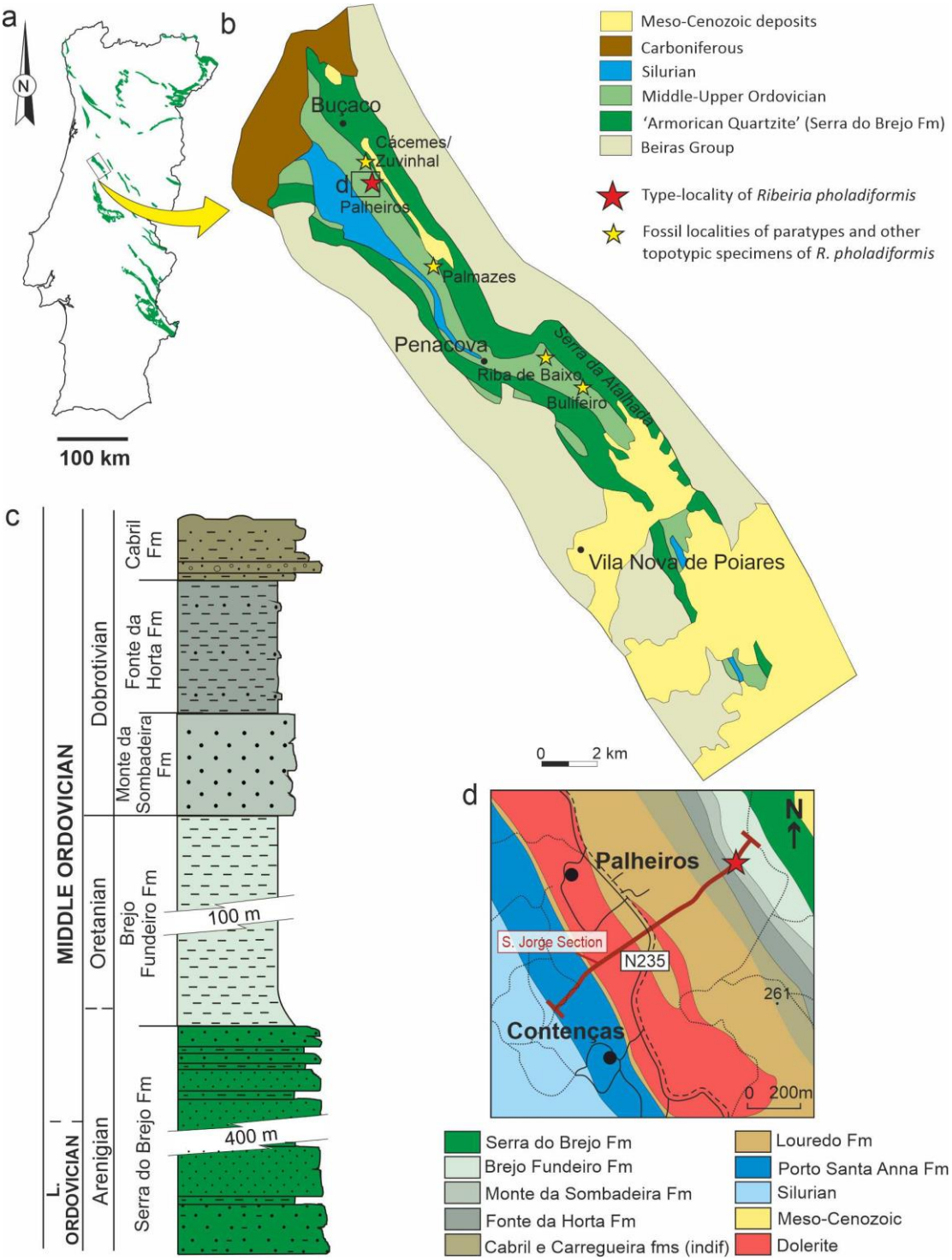

Figure 1. Geological setting of fossil sites in the Buçaco Syncline, modified from Sá *et al*. (2011) and Pereira (2017). (a) Geological sketch map showing the outcrops of Ordovician rocks in Portugal. (b) Geological sketch map of the Buçaco Syncline and *Ribeiria pholadiformis* fossil localities. (c) Stratigraphic log of the Middle Ordovician of the Buçaco Syncline. (d) Geological map of the *Ribeiria pholadiformis* type-locality.

Figura 1. Esquemas geológicos das localidades fossilíferas do Sinclinal de Buçaco, modificado de Sá *et al*. (2011) e Pereira (2017). (a) Mapa com os afloramentos ordovícicos de Portugal. (b) Mapa geológico simplificado do Sinclinal de Buçaco, com indicações das localidades fossilíferas. (c) Log estratigráfico do Ordovícico Médio do Sinclinal de Buçaco. (d) Mapa geológico da localidade-tipo de *Ribeiria pholadiformis*.

The reconstitution of the original label allowed us to conclude that there are only three specimens, represented by six samples, and that the lectotype chosen is the internal mould of one of the paralectotypes (an external mould; Fig. 2c-d). Because this correspondence has not been noticed before, internal and external moulds of the same specimen are today deposited in different institutions, with different numbers and status (one as lectotype, the other as paralectotype). In addition, for the same reason, until now it has not been possible to clarify the provenance of the lectotype, since this information was only associated with its external mould.

Figure 2. Original labels and type-material of the *Ribeiria pholadiformis* (a–f) and details of the Geological Museum of Portugal fossil collection (g–l). (a) Daniel Sharpe's original label of the *R. pholadiformis* type-material. (b) Reconstruction of the fossils' position in the original label. (c), (e) Internal mould of the lectotype of *R. pholadiformis* and its label (NHM PL. 4177, right-lateral and left-lateral views). (d), (f) External mould of the lectotype of *R. pholadiformis* and its label (BGS 7798, left valve in lateral view). (g)–(i) Original labels of *R. pholadiformis* from the Geological Museum of Portugal (GM) collection. (j)–(l) Some *R. pholadiformis* specimens of the GM collection, from the Vale de S. Jorge section (k, l) and Portela de Oliveira (j) [(internal moulds, in right-lateral view (j, l) and left-lateral view (k)]. Scale=5mm.

Figura 2. Etiquetas originais e material-tipo de *Ribeiria pholadiformis* (a–f) e detalhes da coleção do Museu Geológico de Portugal (g–l). (a) Etiqueta original de Daniel Sharpe do material-tipo de *R. pholadiformis*. (b) Reconstrução da posição dos fósseis na etiqueta original. (c), (e) Molde interno do lectótipo de *R. pholadiformis* e etiqueta atual (NHM PL. 4177, vista lateral direita e vista lateral esquerda). (d), (f) Molde externo do lectótipo de *R. pholadiformis* e etiqueta atual (BGS 7798, valva esquerda em vista lateral). (g)–(i) Etiquetas originais de *R. pholadiformis* da coleção do Museu Geológico de Portugal (MG). (j) – (l) Alguns exemplares de *R. pholadiformis* da coleção do MG, do corte do Vale de S. Jorge (k, l) e Portela de Oliveira (j) [(moldes internos, em vista lateral direita (j, l) e vista lateral esquerda (k)]. Escala=5mm.

Similar situations of museum specimens consisting of more than one component being split up for some reason have been described by Donovan and Schoor (2016).

Having clarified the problem of the three existing specimens, one (NHM PL. 4178; internal and corresponding external mould) comes from Riba de Baixo (Penacova), another (NHM PL.4176) from 'Serra de Mucela' (Vila Nova de Poiares/Arganil), and the third one (NHM PL. 4177), which we now know corresponds to the external mould of the lectotype (BGS 7798; internal mould), comes from Ribeira de Palheiros (Penacova), clarifying the type-locality of the species (Fig. 1d). If for the first two localities, from which the two paralectotypes come, we are able to determine that the material originates from the Fonte da Horta Formation (Fig. 1c), due to the existence of trilobites from the same locality in Carlos Ribeiro's collection that are restricted to this unit (Pereira, 2017), the same is unfortunately not possible for the type-locality.

The valley corresponding to the Palheiros stream coincides with the 'Vale de S. Jorge' section, published by Delgado (1908, p. 38), allowing the determination that in this sector the species occurs either in the Brejo Fundeiro Formation (Oretanian; layer 25 of Delgado, 1908, unit "schistes à Orthis ribeiroi") or in the Fonte da Horta Formation (Dobrotivian; layer 19 of Delgado, 1908, unit "schistes à Homalonotus oehlerti"). We could not find any specimen of another group from the same locality in Carlos Ribeiro's collection that would have allowed us to cross-reference biostratigraphic data.

Since it is not possible to clarify which formation the lectotype comes from, the Cácemes Group (Oretanian to Dobrotivian, Darriwilian) should be determined as the type-unit of *R. pholadiformis*, a broader lithostratigraphic unit that includes both the Brejo Fundeiro and the Fonte da Horta formations (Fig. 1c). For more information on these units, see Sá *et al*. (2011).

4. The *Ribeiria pholadiformis* topotype collection of the Geological Museum of Portugal

Excluding the small collection of the *Ribeiria pholadiformis* type-material, only Young (1985, pl. 42, figs. 1-4), in his unpublished PhD thesis, figured new material from the same region (two specimens), without adding new data to Pojeta and Runnegar's (1976) considerations. In the present work, the stratigraphic collection gathered during the second half of the 19th century under the guidance of Nery Delgado, deposited in the Geological Museum of Portugal, was reviewed. It comprises unpublished topotypical material (Cácemes Group) of *Ribeiria pholadiformis*, coming from several localities of the Buçaco Syncline (Fig. 1), including the Palheiros stream (type-locality). These specimens were not only never documented nor revised, but also never separated/grouped in the palaeontological collection (organized by taxa). So, all the abundant materials from the "Schistes à Orthis ribeiroi" and "Schistes à Homalonotus oehlerti" were reviewed, in order to detect all the specimens of *R. pholadiformis*. Based on a detailed analysis of the descriptions of the stratigraphic sections and fossil lists of the Buçaco Syncline, published by Delgado (1908), we here revised all the samples from the beds 18 to 23 of the 'Zuvinhal Section' (op. cit, pp. 33-35), beds 19 to 25 from '*Vale de S. Jorge* Section' (op. cit., pp. 41-43), as well as all materials from many other fossil localities scattered around the area of the Buçaco Syncline from the two lithobiostratigraphic units before mentioned by Delgado (1908). For future reference, it is important to note that the numbering of the beds in the geological sections published by Delgado (1908) does not always match their numbering in the collection. This may be due to final adjustments when this important study was being written. For example, the materials from bed 25 of the '*Vale de S. Jorge* Section' (Delgado, 1908, p. 43) are labelled as coming from bed 26. Similarly, the materials from bed 19 of the same section (Delgado, 1908, p. 41) are labelled as coming from bed 20. A total of 25 specimens were found from the following localities (Fig. 1b):

- *"Camada 20 do Corte do Vale de S. Jorge"* (Fig. 2i)
- *"Camada 26 do Corte do Vale de S. Jorge"* (Fig. 2k-l)
- *"650 m a N50ºE de Palheiros"*
- *"Portela de Oliveira (Palmazes)"* (Fig. 2j)
- *"200m a S40ºE do Zuvinheiro"*
- *"Cácemes"*
- *"350m a N80ºW de Riba de Baixo"*
- *"300m a E de Riba de Baixo"*
- *"400m a S70ºE de Riba de Baixo"*
- *"350m a N15ºW do Bulifeiro"*

Most of the specimens had only a small stick-on label indicating the locality of collection, without any other kind of identification. A few specimens had a label identifying *Ribeiria pholadiformis* (Fig. 2g) and a single specimen from bed 20 (bed 19 in Delgado, 1908) from the '*Vale de S. Jorge* Section' had the distinct identification "*?an diffte. de R. pholadiformis*" (Fig. 2h). This certainly corresponds to the name *Ribeiria* sp. of Delgado (1908, p. 41). Unfortunately, no specimen identified as *Ribeiria oehlerti nomen nudum*, a hypothetical new species listed by Delgado (1908) from the Fonte da Horta Formation, was located. Until future research allows us to locate this/these specimen/s, it will not be possible to verify or refute the synonymy with *R. pholadiformis*, although, considering the morphological variability observed in this collection, the opinion of Sá (2008) that it is the same species is reinforced.

This unprecedented topotypic collection, consisting of a significant number of specimens from the same stratigraphic levels in very close localities (*e.g*. Fig. 2j-l), will allow to assess for the first time the morphological variability of the species, independent of the influence of local taphonomic processes, which play a determining role in the preservation of rostroconchs (*e.g*. Amler and Rogalla, 2013). This work is currently in progress, and it is hoped that it will also clarify the relationship of *R. pholadiformis* with *R. apusoides* from the Middle and Upper Ordovician of the Czech Republic, discussed by Polechová (2015).

5. Conclusions

In this work, we revisited the history of the study of *Ribeiria pholadiformis*, the type-species of Ribeirioida (Rostroconcha), erected almost 170 years ago based on portuguese fossils from the Middle Ordovician of the Buçaco Syncline. The analysis of the type-material and the reconstruction of the original label made it possible to recognize one of the paralectotypes as the external mould of the lectotype. Through this assignment, it was possible to finally clarify the type-locality and unit of this species: the Cácemes Group (Darriwilian) in the Palheiros stream section. The lectotype, composed of two pieces (part and counterpart) is now divided between two institutions (Geological Survey Museum and the Natural History Museum) and both were informed of this correspondence to update their databases. Furthermore, we report an unpublished collection of 25 specimens of topotypic material, currently under study, gathered during the 19th century under the guidance of Nery Delgado, deposited in the Geological Museum of Portugal. This collection houses many fossils from different groups of Palaeozoic invertebrates that remain unstudied, more than a hundred years after their collection and documentation in Nery Delgado's masterful work (Delgado, 1908).

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