

NEW INSIGHTS ON THE HIRNANTIAN PALYNOSTRATIGRAPHY OF THE RIO CEIRA SECTION, BUÇACO, PORTUGAL

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INTRODUCTION

The Lower Palaeozoic successions of Portugal are well represented in the Central Iberian Zone (CIZ), one of the main tectonostratigraphic domains of the Iberian Massif.

Located in the CIZ, the Buçaco Syncline presents one of its most complete Palaeozoic sequences. With a NW-SE orientation, the Lower Palaeozoic lithostratigraphic succession, includes several Ordovician units that ranges from the Lower Ordovician (Tremadocian stage) to the Upper Ordovician (Hirnantian stage) and are unconformably overlain by the Silurian Sazes Formation, at least of Wenlock and Ludlow epochs, in the Rio Ceira Section (Fig.1).

This sequence is also well known by its rich palaeontological content in macrofauna (e.g. trilobites, bryozoans, echinoderms, ostracods, brachiopods, graptolites) and microfauna (conodonts, chitinozoans, acritarchs) (Delgado, 1908; Henry and Thadeu, 1971; Mitchell, 1974; Henry et al., 1974, 1976; Elaouad-Debbaj, 1978; Henry, 1980; Paris, 1979, 1981; Romano, 1982; Romano et al., 1986; Young, 1985, 1987, 1988, 1989).

The aim of the present work is to present the new palynostratigraphic (cryptospores, acritarchs and chitinozoans) results obtained in the Ribeira do Braçal, Ribeira Cimeira and Casal Carvalhal Formations (Young, 1985, 1988) that were collected along the Rio Ceira Section, in the Buçaco Syncline. The results obtained in the Ribeira do Braçal Formation confirms the Hirnantian age attributed to this unit, based on the macrofauna content recovered at the base of this formation (Young, 1985, 1987). For the first time, Ordovician cryptospores are described in this sequence. This study will also provide information to support the undergoing surveying mapping project undertaken by the LNEG (Portuguese Geological Survey) (Sequeira, in prep.).

Future work in the north part of the syncline, to correlate the data recently obtained with the Rio Ceira Group outcropping at the SW limb, is being planned.

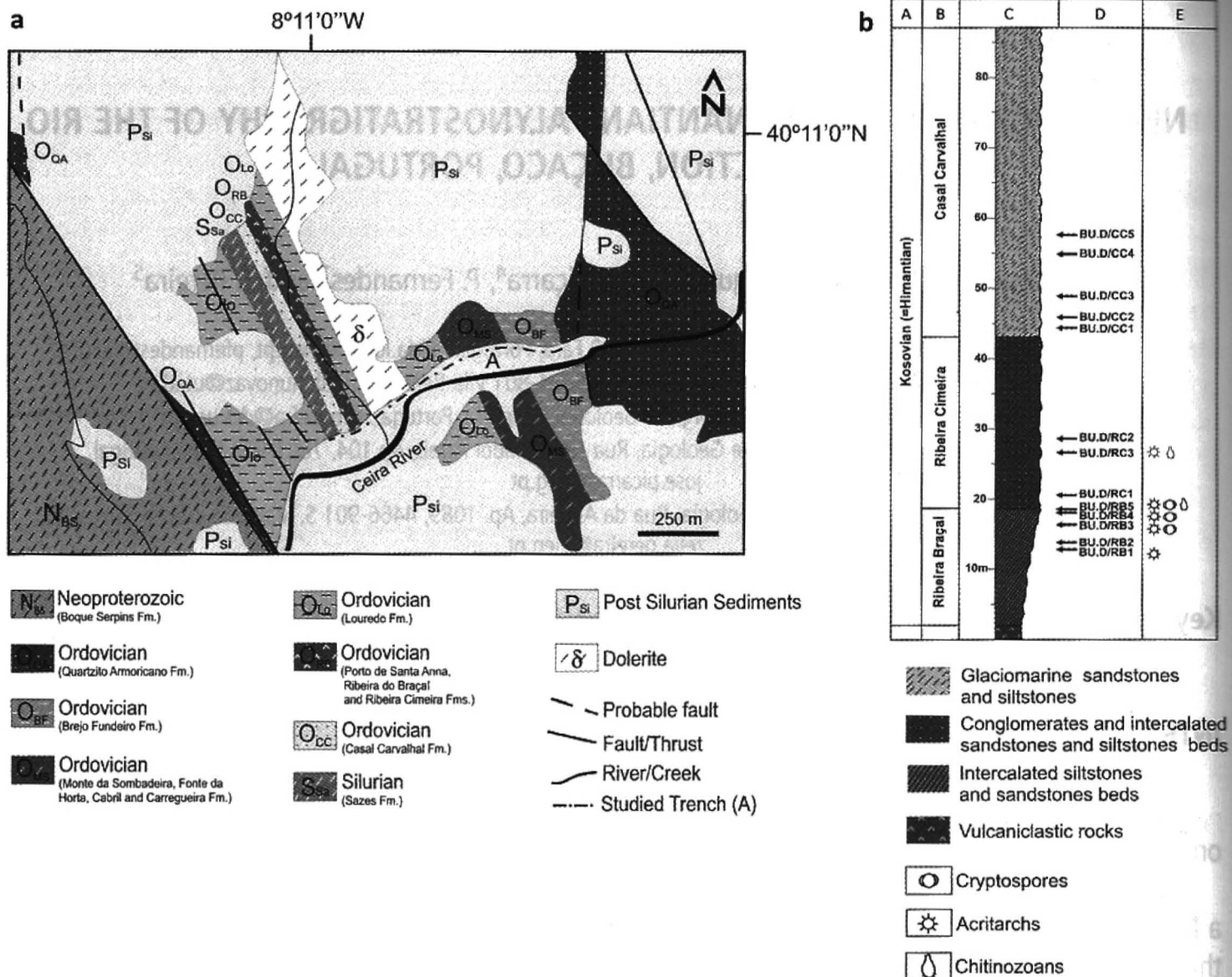


Figure 1. a, Simplified geological sketch map of the Buçaco Region, Rio Ceira Section (adapted from Soares et al., 2007), indicating the position of the studied trench (A). b, Stratigraphic log of the studied formations in the Rio Ceira Section with sample positions, modified from Young (1988) (A, Chronostratigraphy; B, Formations; C, Lithology; D, Samples; E, Fossils).

GEOLOGICAL SETTING

In the south area of the syncline, the Ordovician sedimentary sequence includes, from the base to the top (Mitchell, 1974; Young 1985, 1988; Oliveira et al., 1992; Sá, 2005):

- Armorican Quartzite Formation, with a sedimentary record that indicates a transgressive episode registered by alternations of quartzites, siltstones and pelitic beds above basal conglomerates, of Arenigian age, based in palaeontological studies (Delgado, 1908; Paris, 1981; Romano et al., 1986; Paris, 1990).
- Cécemes Group that includes the Brejo Fundeiro, Monte da Sombadeira, Fonte da Horta, Cabril and Carregueira Formations. The pelitic shales of the Brejo Fundeiro, Fonte da Horta and Carregueira Formations are intercalated with the sandstones of the Monte da Sombadeira and Cabril Formations that reflects two detrital episodes with tempestitic facies (hummocky cross-stratification) (Young, 1985, 1988; Soares et al., 2007). The age of this group ranges from the Oretanian to the early Berounian based in biostratigraphical studies (Delgado, 1908; Mitchell, 1974; Henry et al., 1976;

Paris, 1981; Young, 1985, 1988; Brenchley et al., 1986).

- Sanguinheira Group, which starts with the Louredo Formation, composed of dominant pelitic succession that alternate with sandstones, of an early to mid Berounian age, based in several fossils groups (bivalves, ostracods, brachiopods and trilobites) (Young, 1985, 1988; Soares et al., 2007). At the base of Louredo Formation, an oolitic ironstone bed occurs, the Favaçal Bed, rich in microfossils (chitinozoans) that give an early mid Berounian age (Henry and Thadeu, 1971; Henry et al., 1976; Paris, 1979, 1981).
- Venda Nova Group (Young, 1985, 1988; Soares et al., 2007) includes the volcano sedimentary unit of Porto de Santa Anna Formation with a thin bed of oolitic ironstone at the base. Biostratigraphic data present (Young, 1985, 1987) indicates late Berounian and Kralodvorian ages.
- Rio Ceira Group, that includes the Ribeira do Braçal and Ribeira Cimeira Formations (Young, 1985, 1988; Soares et al., 2007). The Ribeira do Braçal Formation shows a regressive sequence composed of alternated siltstones and sandstones and is dated as Kosovian (= Hirnantian) based in biostratigraphical content (Young, 1985, 1987). The Ribeira Cimeira Formation rests unconformably over the Ribeira Braçal Formation and consists of finning-upward sequences of conglomerates, sandstones and siltstones (Young, 1985, 1988; Soares et al., 2007).
- Casal Carvalhal Formation, characterized of sandstones and siltstones that are interpreted as glaciomarine sediments with a Kosovian (= Hirnantian) age. A Silurian age is not excluded for the top of this unit (Young, 1985, 1988; Soares et al., 2007).

PALYNOSTRATIGRAPHY

The Rio Ceira Section is located in the south area of the Buçaco Syncline, along the Ceira River. This section exposes, from northeast to southwest, a stratigraphic sequence that ranges from the Ordovician to the Silurian. The section was logged and all samples were processed for palynological studies. Standard palynological laboratory procedures using fluoridric and chloridric acids were employed in the extraction and concentration of the palynomorphs from the host sediments (Wood et al., 1996). The slides were examined with transmitted light, per BX40 Olympus microscopes equipped with a digital camera. All samples, residues, and slides are stored in the LNEG-LGM (Geological Survey of Portugal) at S. Mamede Infesta, Portugal. The acritarch biostratigraphic scheme used for the Ordovician-Silurian boundary follows Vecoli (2008). For the cryptospore biostratigraphy it is followed Burgess (1991) and Rubinstein and Vaccari (2004).

Forty two samples were collected in the Ordovician and Silurian sequence of the Rio Ceira Section and thirteen of them were collected from the Ribeira do Braçal, Ribeira Cimeira and Casal Carvalhal Formations, all of them attributed to the Hirnantian. In this section, the Ribeira do Braçal Formation contacts directly over the Porto de Santa Anna Formation and is discordant with the Ribeira Cimeira Formation at the top. The Casal Carvalhal Formation is continuous with the Ribeira Cimeira Formation and discordant with the Sazes Formation at the top.

From the five samples collected from the Ribeira do Braçal Formation, four of them were positive and yielded moderately to well preserved palynomorphs (cryptospores, acritarchs and chitinozoans) assigned to the Hirnantian age. The assemblage recovered, presents acritarchs: *Leiofusa* sp., *Leiosphaeridia* sp., *Lophosphaeridium* sp., *Multiplicisphaeridium* sp., *Veryhachium* spp., *Villosacapsula?* *setosapellicula*, *Visbysphaera* sp. (Pl. 1, figs. 7-16).

The acritarch assemblage is rather impoverished in species diversity being dominated by the veryachid forms (*Veryhachium* spp., *Villosacapsula? setosapellicula*), a typical feature at this age. As Vecoli (2008) refers, across the Ordovician-Silurian boundary, the presence of members of the *Veryhachium* and *Multiplicisphaeridium* complexes, as well as of netromorph acritarchs (*Leiofusa* spp.), is very common. The present assemblage includes large stratigraphic range species, Ordovician to the lower Silurian in age, *Veryhachium* spp. and *Leiofusa* sp. As well, includes a latest Hirnantian specie, *Villosacapsula? setosapellicula*, that disappear in the Hirnantian/Rhuddanian boundary. The first occurrence of *Visbysphaera* sp., at the mid upper Hirnantian level (*Normalograptus persculptus* Graptolite Biozone; *Spinachitina oulebsiri* Chitinozoan Zone), allows constrain the age.

It was also recovered from the samples, specimens of chitinozoans moderately preserved: *?Conochitina* sp.. Completes the assemblage and presented here for the first time, are the cryptospores *?Rugosphaera* sp., *Tetrahedraletes medinensis*, *Velatitetras retimembrana*, and *Dyadospora murusattenuata*. (Pl.1, figs. 1-6) These species have a very large stratigraphic range from the Upper Ordovician to the lowermost Devonian (Burgess, 1991; Rubinstein and Vaccari, 2004) with a limited use at the Ordovician-Silurian boundary, as it has been also described by Rubinstein and Vaccari (2004).

From the Ribeira Cimeira Formation one of the three samples collected was positive, yielding moderately preserved acritarchs, that includes *Veryhachium? trispinosum*, and a single chitinozoan specimen (*?Conochitina* sp.). No age determination was possible.

From the Casal Carvalhal Formation five samples were collected but they were barren in palynomorphs.

These data presented confirms previous determinations based on the Hirnantian brachiopod fauna from Ribeira do Braçal Formation (*Horderleyella? cf. bouceki*, *Plectothyrella* sp. and *Bracteoleptaena cf. polonica*: Young, 1985, 1987)).

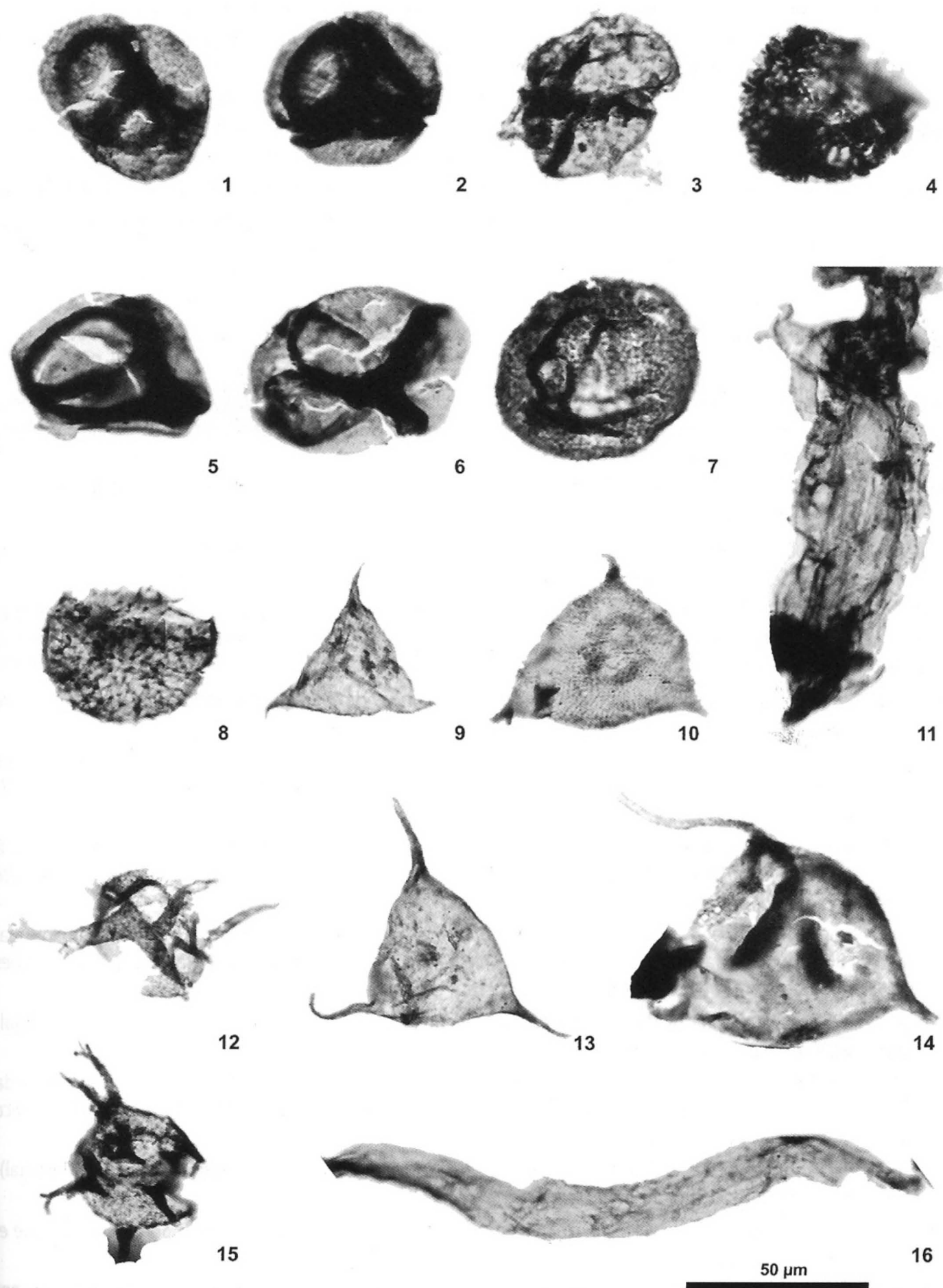
The cryptospores and acritarchs identified from these formations are the first insights to characterize the a Hirnantian microfauna in Portugal.

CONCLUSIONS

The following conclusions were reached from this study:

- This preliminary results obtained in the Ribeira do Braçal Formation indicates an acritarch assemblage assigned to the mid-late Hirnantian. These results confirm previous age determination based on macrofauna.
- The recovered assemblage could provide information to better understand and establish a more detailed acritarch biozonation for the Upper Ordovician-Lower Silurian interval.

Plate 1. Hirnantian cryptospores (1-6) and acritarchs (7-16) from the Ribeira do Braçal Formation, Buçaco syncline, central Portugal. Each specimen is referenced by sample number, slide number and microscopic coordinates. 1-2, *Velatitetras retimembrana* (Miller and Eames) Steemans, Le Hérisse and Bozdogan, 1996. Sample BU.D/RB5, slide 1(1), 1389–155; slide 1(2), 1164–109; 3, *Morphon Dyadospora murusattenuata* Strother and Traverse, 1979. Sample BU.D/RB5, slide 1(1), 1345–107; 4, *?Rugosphaera* sp. Sample BU.D/RB3, slide 1(1), 1334–205; 5-6, *Tetrahedraletes medinensis* (Strother and Traverse) emend. Wellman and Richardson, 1993. Sample BU.D/RB5, slide 1(1), 1087–149; sample BU.D/RB3, slide 1(1), 1179–226; 7, *Lophosphaeridium* sp. Sample BU.D/RB1, slide 2(1), 1233–181; 8, *Visbysphaera* sp. Sample BU.D/RB4, slide 1(2), 1350–132; 9, *Veryhachium? reductum* (Deunff) Jekhowsky, 1961. Sample BU.D/RB4, slide 1(2), 1379–135; 10, *Villosacapsula? setosapellicula* (Loeblich) Loeblich and Tappan 1976. Sample BU.D/RB5, slide 1(2), 1409–116; 11, 16, *Leiofusa* sp.; samples BU.D/RB5, slide 1(1), 1373–116 and BU.D/RB5, slide 1(1), 1145–202; 12, 15, *Multiplicisphaeridium* sp., samples BU.D/RB3, slide 1(1), 1393–119 and BU.D/RB5, slide 1(2), 1354–162; 13, *Veryhachium trispinosum* (Eisenack) Stockmans and Willièrè, 1962. Sample BU.D/RB5, slide 1(1), 1426–93; 14, *Veryhachium subglobosum* Jardiné, Combaz, Magloire, Peniguel and Vachey, 1974. Sample BU.D/RB5, slide 1(2), 1246–71.



- For the first time a cryptospore assemblage was recovered in the Ribeira do Braçal Formation.
- More detailed sampling of these three formations should be done, in order to better characterize the Hirnantian microfauna of the Buçaco Syncline.

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REFERENCES

- Brenchley, P.J., Romano, M. and Gutiérrez-Marco, J.C. 1986. Proximal and distal hummocky cross-stratified facies on a wide Ordovician shelf in Iberia. In R.J. Knight and S.R. McLean (eds.), *Shelf Sands and Sandstones*. Canadian Society of Petroleum Geologists Memoir, 11, 241-55.
- Burgess, N.D. 1991. Silurian cryptospores and miospores from the type Llandovery area, South-West Wales. *Palaeontology*, 34 (3), 575-599.
- Delgado, J.F.N. 1908. Système Silurien du Portugal. Étude de stratigraphie paléontologique. *Mémoires de la Commission du Service Géologique du Portugal*, Lisboa, 245 pp.
- Elaouad-Debbaj, Z. 1978. Acritarches de l'Ordovicien supérieur du synclinal de Buçaco (Portugal). Systématique, Biostratigraphie, Intérêt paléogéographique. *Bulletin de la Société Géologique et Minéralogique de Bretagne (C)*, 2, 1-101.
- Henry, J.L. 1980. Trilobites ordoviciens du Massif Armoricaïn. *Mémoires de la Société Géologique et Minéralogique de Bretagne*, 22, 250 pp.
- Henry, J.L. and Thadeu, D. 1971. Intérêt stratigraphique et paléogéographique d'un microplancton à Acritarches découvert dans l'Ordovicien de la Serra de Buçaco (Portugal), *Compte rendus de l'Académie des Sciences*, 272, 1343-1346.
- Henry, J.L., Melou, M., Nion, J., Paris, F., Robardet, M., Skevington, D. and Thadeu, D. 1976. L'apport de Graptolites à la zone à *G. teretiusculus* dans la datation de faunes benthiques lusitano-armoricaines. *Annales de la Société Géologique du Nord*, 96, 275-281.
- Henry, J.L., Nion, J., Paris, F. and Thadeu, D. 1974. Chitinozoaires, Ostracodes et Trilobites de l'Ordovicien du Portugal (Serra de Buçaco) et du Massif Armoricaïn: essai de comparaison et signification paléogéographique. *Comunicações dos Serviços Geológicos de Portugal*, 21 (2-3), 203-216.
- Mitchell, W.I. 1974. An outline of the stratigraphy and paleontology of the Ordovician rocks of Central Portugal. *Geological Magazine*, 111, 385-396.
- Oliveira, J.T., Pereira, E., Piçarra, J.M., Young, T. and Romano, M. 1992. O Paleozóico Inferior de Portugal: Síntese da estratigrafia e da evolução paleogeográfica. In J.C. Gutiérrez-Marco, J. Saavedra and I. Rábano (eds.), *Paleozoico Inferior de Ibero-América*. Universidad de Extremadura, Madrid, 359-375.
- Paris, F. 1979. Les Chitinozoaires de la Formation de Louredo, Ordovicien Supérieur du Synclinal de Buçaco (Portugal). *Palaeontographica Abt A*, 164, 24-51.
- Paris, F. 1981. Les chitinozoaires dans le Paléozoïque du sud-ouest de l'Europe. *Mémoires de la Société Géologique et Minéralogique de Bretagne*, 26, 496 pp.
- Paris, F. 1990. The Ordovician Chitinozoan biozones of the Northern Gondwana Domain. *Review of Palaeobotany and Palynology*, 66 (3-4), 181-209.

- Romano, M. 1982. The Ordovician biostratigraphy of Portugal – A review with new data and re-appraisal. *Geological Journal*, 17, 89-110.
- Romano, M., Brenchley, P.J. and McDougall, N.D. 1986. New information concerning the age of the beds immediately overlying the Armorican Quartzite in central Portugal. *Géobios*, 19, 421-433.
- Rubinstein, C. and Vaccari, N. 2004. Cryptospore assemblages from the Ordovician/Silurian boundary in the Puna Region, North-West Argentina. *Palaeontology*, 47(4), 1037-1061.
- Sá, A. 2005. *Bioestratigrafia do Ordovício do NE de Portugal*. PhD Thesis, Universidade de Trás-os-Montes e Alto Douro, 571 pp.
- Sequeira, A.J.D. *in prep.* *Carta Geológica de Portugal à escala 1:50 000. Folha 19-B (Coimbra-Penacova)*. Laboratório Nacional de Energia e Geologia, Lisboa.
- Soares, A.F., Marques, J.F. and Sequeira, A. 2007. *Carta Geológica de Portugal Folha 19-D (Coimbra-Lousã) à escala 1:50000. Notícia Explicativa da Folha 19-D (Coimbra-Lousã)*. Instituto Nacional de Engenharia Tecnologia e Inovação, Lisboa.
- Vecoli, M. 2008. Fossil microphytoplankton dynamics across the Ordovician–Silurian boundary. *Review of Palaeobotany and Palynology*, 148, 91–107.
- Wood, G.D., Gabriel, A.M. and Lawson, J.C. 1996. Palynological techniques-processing and microscopy. In Jansonius, J. and McGregor, D.C. (eds.), *Palynology: Principles and applications*. American Association of Stratigraphic Palynologist Foundation, 1, 29-50.
- Young, T. 1985. *The stratigraphy of the Upper Ordovician of Portugal*. PhD thesis, University of Sheffield. 394pp.
- Young, T. 1987. The Upper Ordovician of Central Portugal. *Gresbase field excursion*, 13 pp.
- Young, T. 1988. The lithostratigraphy of the upper Ordovician of central Portugal. *Journal of the Geological Society of London*, 145, 377-392.
- Young, T. 1989. Eustatically controlled ooidal ironstone deposition: facies relationships of the Ordovician open-shelf ironstones of Western Europe. *Geological Society, Special Publication*, 46, 51-63.