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Upper Visean brachiopods in the Natural History Museum, London: taxonomic revision, biostratigraphy and palaeoecology

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Background

The order Productida, comprising concavo-convex spinose brachiopods, is among the most widespread and diversified in the Carboniferous of western and eastern Europe (Muir-Wood & Cooper 1960). Much attention has been given to the taxonomy of the group for their abundance and relative easiness of identifying taxa based on external characters (morphology and ornamentation) which attracted the interest of British and Irish geologists attempting to obtain macro-fossils biostratigraphic zonations and correlation in the region (e.g. Vaughan 1905; Garwood 1913). Tens of genera and hundreds of species have been erected for the Productida in the British Isles and Ireland (e.g. Thomas 1914; Muir-Wood 1928) as well as in Belgium (e.g. de Koninck 1847; Demanet 1934) and western Russia (e.g. Sarycheva & Sokolskaya 1952), whose faunas share a lot of affinities with British-Irish ones.

Many productide genera are in need of revision as they are poorly defined and have been used as a "basket" for species showing a wide range of morphological variation, while many species erected in the XIX century still lack a proper generic attribution. This hampers the reconstruction of

brachiopod global palaeogeographic distribution, niche partitioning and faunal variation in the Mississippian, a critical time for the evolution of marine life during the onset of the Late Paleozoic Ice Age (LPIA), which seemed to have reached its acme with the glaciation of peripolar circle regions of southern Gondwana in the Middle-Late Mississippian (middle-late Visean to Serpukhovian stages; Isbell et al. 2012; Montañez & Poulsen, 2013; Isbell et al. 2021) triggering the Middle-Late Mississippian biodiversity crisis (M-LMBC), possibly ranked as the fifth most ecologically severe among the Phanerozoic mass extinctions (McGhee et al. 2012, 2013; Yao et al. 2022). Also, a better defined and updated taxonomy for the productides might be useful to resolve some global problems of correlation of the Upper Mississippian, though the use of productide-based biostratigraphic zonations and correlation have been strongly debunked in the last decades due to their long stratigraphic range and strong tendency to homeomorphy (Aretz et al.2020; Angiolini et al. 2021).

Studied material

During a period of six weeks at the Natural History Museum, London, I redescribed and studied the material on which Muir-Wood (1928) based her analyses to erect new species of British and Irish productides and to emend the diagnosis of known ones, including also many type specimens. In particular, I focused on the species attributed by Muir-Wood (1930) and Muir-Wood & Cooper (1960) to the genera *Antiquatonia* Miloradovich, 1945 and *Eomarginifera* Muir-Wood, 1930 of the Family Productidae Gray, 1840. The species of both genera are widespread in the upper Visean (Upper Mississippian) mud mounds of Derbyshire, UK (Carniti et al. 2022), which are the object of study of my PhD research project, and in several Upper Mississippian units in western and eastern Europe.

I also studied material of the Mundy and Tisley collections coming from units coeval and ecologically comparable to the mud mounds in Derbyshire: from microbial–sponge–bryozoan–coral reefs in the upper Visean of Yorkshire, England (Cracoean reefs; Brunton & Mundy 1988; Mundy 1994) and from comparable reefs in the upper Visean of northern Derbyshire (Brunton & Tilsley 1991). In particular I studied several specimens of species of *Antiquatonia* and *Eomarginifera* to further investigate the variability of the genera. Also I investigated specimens of species of small productides whose generic attribution is in need to be reconsidered: *Productus koninckianus* de Verneuil, 1845, *Productus arcuarius* de Koninck, 1843, and *Productus tortilis* M'Coy, 1844.

Preliminary results

1- The study of the specimens of species of *Antiquatonia* housed at NHM led to a redescription of the type species *A. antiquata* Sowerby, 1821 showing the possibility that *A. hindi* Muir-Wood, 1928, *A. hindi* var. *wettonensis* Muir-Wood, 1928, *A. sulcata* Sowerby, 1822 and *A. costata* Sowerby, 1827 are synoyms to *A. antiquata*. PCA (Principal Component Analysis) analysis run with PAST software (Hammer et al. 2001) showed that the five species might be included in a single Upper Mississippian species with a wide and continuous morphological variability (Fig. 2). The study of the material collected from Yorkshire by D.J.C. Mundy and from Derbyshire reefs by J.W. Tilsley showed that a wide variability is expressed among specimens collected from the same beds.
2- The redescription and study of the specimens of the species of *Eomarginifera* housed at NHM led to an emendation of the diagnosis of the genus to include species with moderate

ears and with a less regular disposition of halteroid spines with respect to the regular symmetrical six pairs of spines shown by the type species *E. longispina* Sowerby, 1814. *E. derbiensis* Muir-Wood, 1928, previously considered to be an uppermost Visean species (Brunton 1984), is restricted to the lower-middle Visean and it is likely the ancestor of all upper Visean species of *Eomarginifera*.

3- The study of the material in the Mundy collection from the upper Visean Yorkshire Cracoean reefs underscored that *Productus koninckianus* may represent a new genus similar to *Ovatia* Muir-Wood & Cooper, 1960 of the Monticuliferidae Muir-Wood & Cooper, 1960; *Productus arcuarius* may represent a new genus close to *Marginovatia* Gordon & Henry, 1990 of the Linoproductidae Stehli, 1954, characterised by a cincture and gutter anteriorly; *Productus tortilis* may represent a new genus similar to *Plicatifera* Chao, 1927 of the Productellidae Schuchert, 1929.

Future perspectives

The specimens identified as undetermined species of *Antiquatonia* collected from the upper Visean Derbyshire mud mounds, housed in the Museum of Palaeontology of the University of Milan, Department of Earth Sciences "A. Desio", Milan, Italy, will be included in the statistical analyses to complete the understanding of the variability of the species of the genus.

The revision of British and Irish species of *Antiquatonia* and *Eomarginifera* will led to a reevaluation of their differences with Russian and American species reported in the literature with an understanding of their stratigraphic and palaeobiogeographic distribution with possible implications for Upper Mississippian biostratigraphy and global ecological variation.

To assess the need to erect three new genera of small productides respectively based on *P. koninckianus, P. arcuarius* and *P. tortilis* further study of the literature and possibly study of the type material housed in the Muséum National d'Histoire Naturelle in Paris, France, will be performed.

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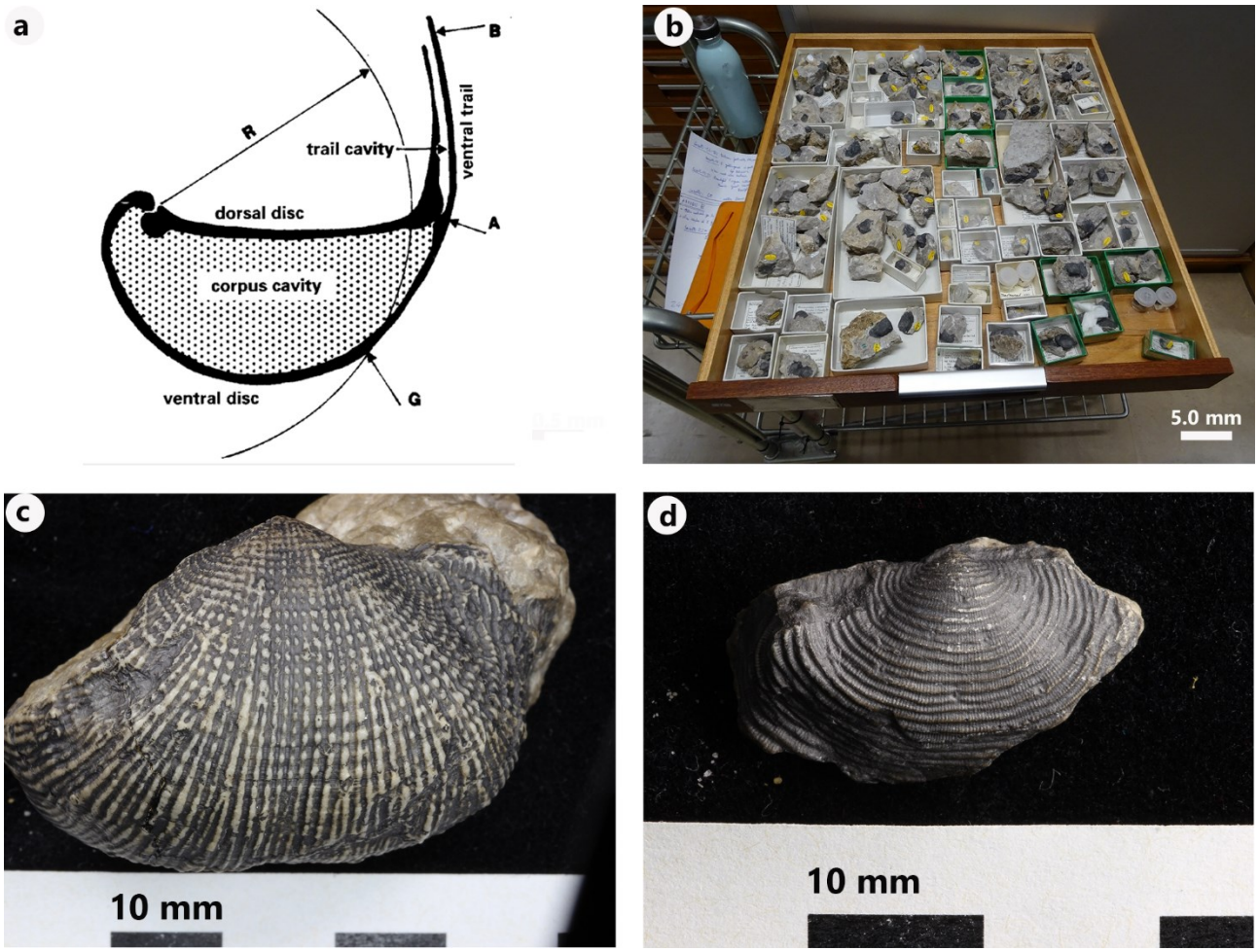

Figure 1: a- schematic transverse section of a productide brachiopod (after Brunton et al. 1995); b- one of the trays containing the Mundy brachiopod collection, Natural History Museum, London; c- the lectotype of *Antiquatonia antiquata*, type species of *Antiquatonia*, housed at the NHM; d- a specimen of *Productus tortilis* from the NHM collection.

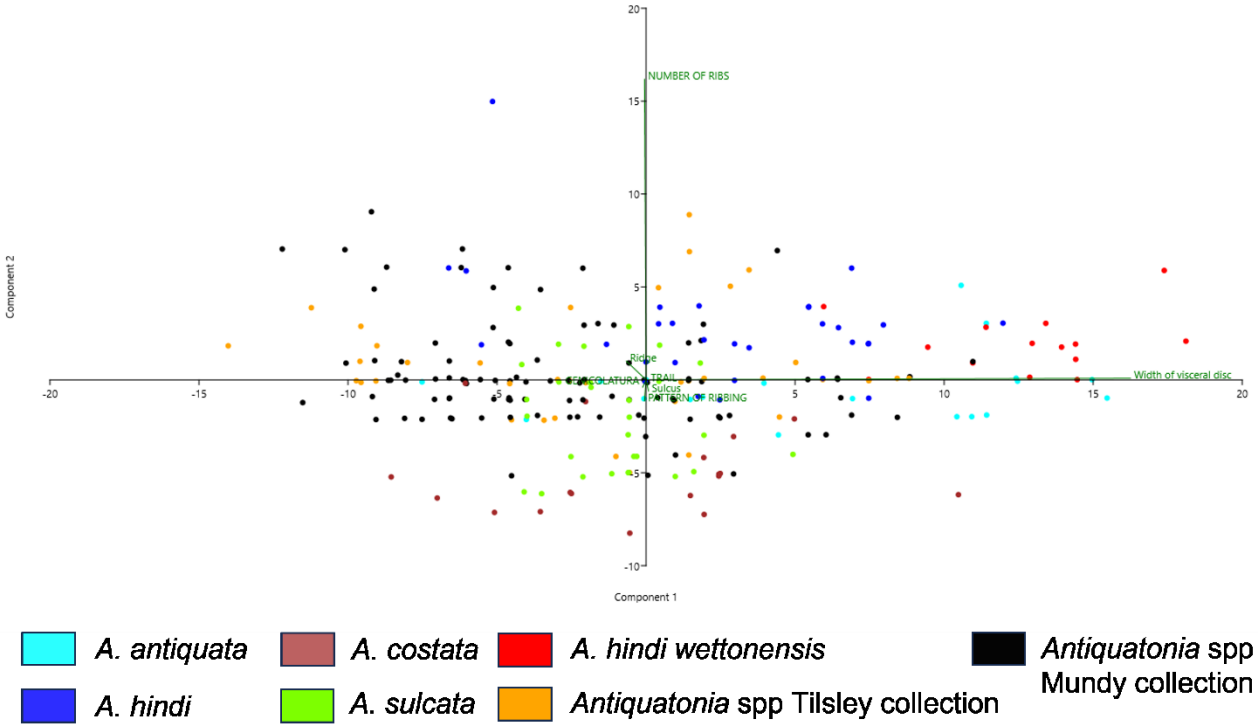

Figure 2: scatter plot of PCA analysis run for the species of *Antiquatonia* of Muir-Wood (1928) reference collection with type material of *A. antiquata*, *A. hindi, A. hindi wettonensis*, *A. sulcata,* and *A. costata*, and material labelled as *Antiquatonia* spp in the Mundy collection from Yorkshire Visean reefs and Tilsley collection from Derbyshire Visean reefs. PCA is based on seven coded characters: shell width (in millimetres), morphology of lateral ridge up flanks (absent, present, present and persistent up to anterior commissure), sulcus (absent, present only posteriorly, present up to anterior commissure), geniculation (angle of geniculation >120°, angle of geniculation <120°), trail (long, short), number of ribs (measured per 10 mm width at 25 mm from umbo), pattern of ribbing (ribs of uniform width; ribs of varying width). Scatter of points shows the difficulty to identify clusters and biplot axis shows the absence of relationships between the characters, suggesting the possibility that all specimens included in the analysis are representative of a single species *A. antiquata*.