Revision of three large species of *Barrettia* from Jamaica

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ABSTRACT. **This paper represents a revision of three multiple-fold hippuritid rudist bivalves (*Barrettia monilifera* Woodward, *B. multilirata* Whitfield and *B. gigas* Chubb) from the Campanian (late Cretaceous) of Jamaica. The differences between the species are investigated using differences in the construction of the outer shell layer of the RV, the myocardinal arrangement, the size and spacing of the beads in the rays of the RV, and the pore system in the LV. Two genera are recognised: *Barrettia* Woodward, type species *B. monilifera*; and *Whitfieldiella* gen. nov., type species *B. gigas*. *Barrettia* is characterised by a small (70-150°) P2-P1-PM angle, a large (100-200°) P1-PM-PT angle, and a reticulate pore system; whereas *Whitfieldiella* is characterised by large (170-220°) P2-P1-PM angle, a small (60-90°) P1-PM-PT angle, and irregular to denticulate pore clusters on pustules with imperforate bands around. The size and spacing of the beads is demonstrated to be an important means of distinguishing between species. Two species of *Barrettia*, *Barrettia monilifera* Woodward and *Barrettia multilirata* Whitfield, and one species of *Whitfieldiella*, *Whitfieldiella gigas* (Chubb), are recognised.**

An analysis of the shell microstructure of the Caribbean Hippuritidae indicates that this has no value in delineating subfamilies; thus Barrettinae Chubb, as revised by Grubić, and the recently erected genus *Caribbea* Grubić (which is synonymised with *Hippuritella* Douvillé because both have similar pore systems) are not recognised. *Gloria* Grubić is invalid, since the generic name is preoccupied by *Gloria* Barrande; the lack of knowledge of the morphology of the myocardinal features and the pore systems in its type species *Gloria vermunti* Grubić (= *Pironaea* cf. *peruviana* Vermunt), means that this species cannot be placed in a valid genus at the present time.

Key words: ***Barrettia*, *Whitfieldiella*, Hippuritidae, rudist bivalve, Cretaceous, Jamaica, systematic palaeontology.**

1. INTRODUCTION

Multiple-ray (or multiple-fold) hippuritid rudists were first discovered in the Back Rio Grande, a tributary to the Rio Grande of the Blue Mountains Inlier (**Figure 1**) of Jamaica by Lucas Barrett in 1860 and described by Woodward (1862) under the name *Barrettia monilifera*. Douvillé (1894, pl. XVII, fig. 6) illustrated a transverse section with a caption which when translated reads *"Section of the type individual of the genus and species, previously figured by Woodward. Photographic reproduction of a portion of the sample sent to the former School of Mines by the author."* Further material from central (Central Inlier) and western (Green Island Inlier) Jamaica was collected by F. C. Nicholas and monographed by Whitfield (1897) who recognized three species *Barrettia* cf. *monilifera*, *B. multilirata* Whitfield and *B. sparcilirata* Whitfield. Trechmann (1922) revised the rudists from the Barrettia beds of Jamaica and introduced several new varieties of *Barrettia multilirata*; in 1924, he introduced the genus *Praebarrettia* for Whitfield's *B. sparcilirata* believing it to form a primitive stage in the

evolution of the multiple-fold hippuritids. Boissevane and Mac Gillavry (1932) described specimens of *Barrettia sparcilirata* from Cuba and showed that the angle between lines joining the centres of PM-PT and PT-AT was different in the various forms of *Barrettia* (inclusive of *Praebarrettia* that they did not recognise as an independent genus) that had been described.

Chubb (1955) began his revision of the rudist fauna of Jamaica by a taxonomic revision of the material described by Whitfield (1897), introducing the name *Barrettia gigas* for the material identified as *B.* cf. *monilifera* by Whitfield. Chubb (1968, 1971) described various new species of multiple-ray hippuritids from Jamaica, including *Barrettia ruseae* and *Praebarrettia coatesi*. van Dommelen (1971) showed that *Barrettia* had pallial canals in the left (free) valve and that *Praebarrettia* did not. Since he was able to demonstrate that Chubb's *P. coatesi* had pallial canals in the left valve, this was transferred to the genus *Barrettia* and ray morphology was regarded as having little significance in distinguishing genera. van Dommelen (1971) introduced a further method of
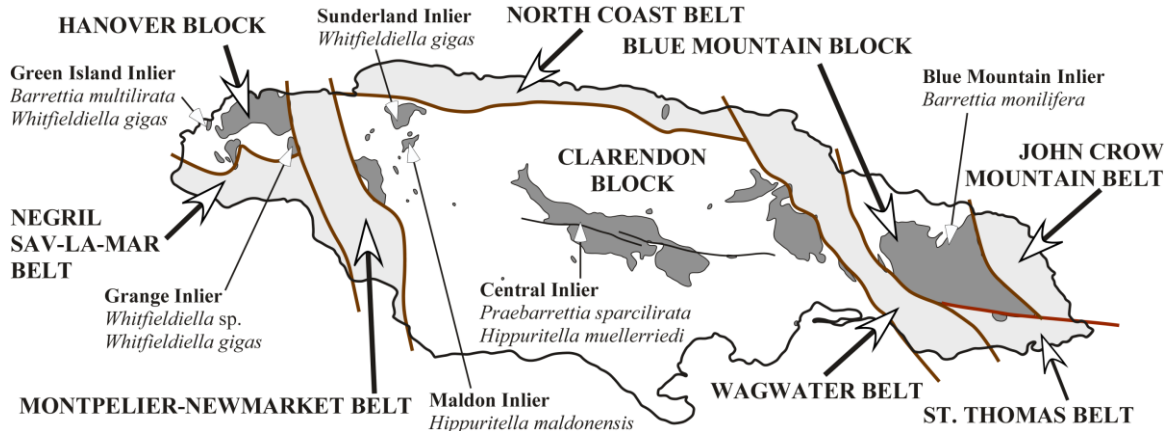
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Figure 1. Location of Cretaceous inliers of Jamaica that have yielded the material described in this paper. Cenozoic blocks and belts shown in capitals; inliers (with rudist occurrences) shown in bold sentence case.

studying the myocardinal structure, and used the position of the orthogonal projection of the posterior myophore onto the ligamental infold (that is beyond, at the tip, or on the infold), the infold being identified as the longest ray adjacent to the posterior tooth (as suggested by Boissevain and Mac Gillavry, 1932). Using the PM-PT-AT angle of Boissevain and Mac Gillavry (1932) and the PM projection, van Dommelen suggested three dentition types that separated *Praebarrettia* (Type B), primitive *Barrettia* (Type A) and advanced *Barrettia* (Type C). van Dommelen was less clear about the position of *B. monilifera*, *B. multilirata* and *B. gigas*, and included all these forms in *B. monilifera* s.l. (p. 90), yet he finally states on p. 93 that *"... if the view is accepted of* multilirata *and* gigas *being more that incidental responses to a particular local environment, then it will be necessary to restudy all material previously ascribed to* multilirata *and* monilifera.*"*

Rojas et al. (1996) suggested a threefold division of the *Barrettia* lineage based on material collected from Cuba and a reassessment of published records. They suggested three chronospecies: *B. coatesi* (Chubb) in the Santonian, *B. monilifera* in the Campanian and *B. multilirata-gigas* in the Maastrichtian, even though *B. multilirata* and *B. gigas* were already firmly dated as late middle Campanian in Jamaica (Jiang and Robinson, 1987; Jiang, 1993; Wiedmann and Schmidt, 1993).

Grubić (2004) undertook a revision of many of the hippuritid rudists of the Caribbean region based on material in European museums. He suggested that forms included in *Hippurites (Orbignyi)*, *Barrettia*, *Praebarrettia* and *Parastroma* had vertical canals in the outer layer of their right valves and used this to define, and re-diagnose, the monophyletic subfamily Barrettinae Chubb 1971.

He introduced two new genera, *Caribbea* (for American forms previously included in *Hippurites*) and *Gloria* (for American forms, previously included in *Pironiaea* and *Praebarrettia*, that had two cycles of infoldings). He also introduced several new species and subspecies names for small populations of material previously described under open nomenclature by Trechmann (1924) and van Dommelen (1971).

There is therefore great confusion regarding the three Jamaican species *Barrettia monilifera* Woodward 1862, *Barrettia multilirata* Whitfield 1897 and *Barrettia gigas* Chubb 1955; forms that have dentition type C according to van Dommelen (1971). In this paper these three species are described and shown to be distinct. Differences in the myocardinal-pillar arrangement and the pore systems indicates that *gigas* is not related to the other two species and is placed in a new genus, *Whitfieldiella*, which is described herein.

2. MORPHOLOGY OF MULTIPLE-FOLD HIPPURITID RUDISTS AND CRITERIA FOR GENERIC AND SPECIFIC RECOGNITION

The shell is divided into a right valve (RV or attached valve) and a left valve (LV or free valve), held together by the myocardinal elements. The myocardinal-pillar arrangement is demonstrated here to be important when placing multiple-fold hippuritid rudists within genera.

Right (attached) Valve (RV). This has an inner and outer layer; the outer layer is folded into the inner layer as three primary rays or infolds and a variable number of 'secondary' or additional rays (infolds). The primary infolds are now referred to as P0 (Ligamental infold, formerly L), P1 (formerly S) and P2 (formerly E) (e.g., Steuber, 1999).
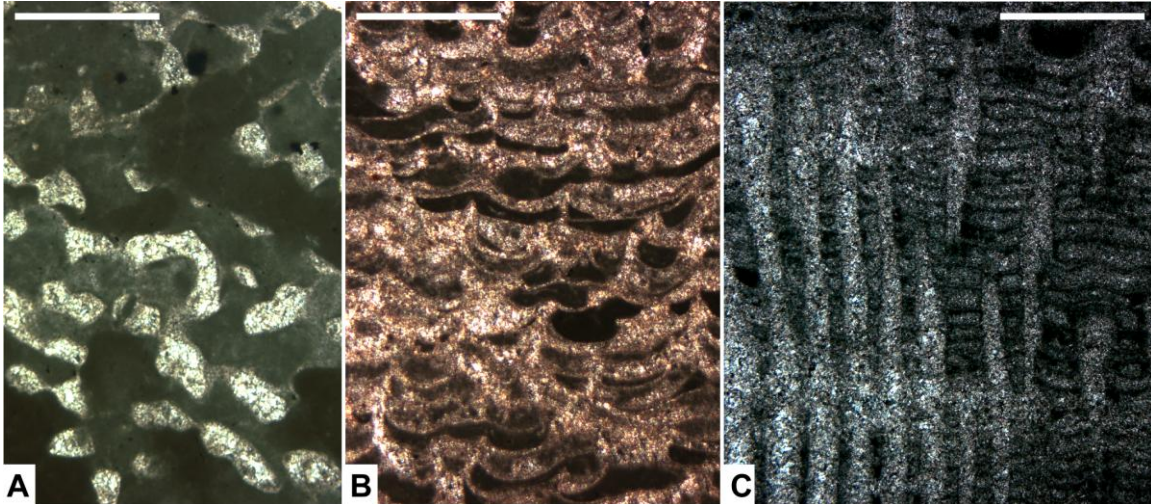
Figure 2. Microstructure of Caribbean hippuritid rudists. A-B: *Praebarrettia sparcilirata* **(Whitfield); A, transverse sections showing irregularly shaped pustules; B, tangental section showing that the pustules represent stacked micro-rhythms. C:** *Hippuritella maldonensis* **(Chubb); longitudinal section showing ghosts of microrhythms. Scale bars equal 1 mm.**

Grubić (2004) suggested that the outer shell layer of the RV contained vertical capillaries that penetrated the funnel plates, and that this defined the monophyletic subfamily Barrettinae Chubb, 1971, emend Grubić, 2004. Grubić (2004) based his interpretations of the outer shell layer on descriptions by Mac Gillavry (1937) and Chubb (1956) and reproduced Chubb's (1956, pl. 5, figs 4-6) illustrations of thin sections of '*Parastroma' maldonensis* Chubb in support of this. Mac Gillavry (1937) described the structure in *Hippurites mullerriedi* (Vermunt) [= *Hippurites ceibarum* Chubb] as *"... a system of funnel plates, which is undulated, but instead of prisma-cell walls there are only more or less radially directed walls, which start from the circumference towards the interior. Some of them reach the inner edge of the outer shell-layer, others not."* Chubb (1956, p. 22-23), with regard to *Parastroma maldonensis* [=*Hippuritella maldonensis* (Chubb)], stated *"... outer layer shows a structure which on weathered, freshly broken or polished surfaces appears to resemble that of a radiolite ... nearly horizontal or slightly tilted upwards, and vertical elements which run continuously through the funnel plates, and in hand specimen appear to resemble radial plates. Part of the polished section shows a structure that mimics a polygonal cell pattern, but in other parts the cells appear to be more scattered and are round or vermicular, while along the inner and outer margins of the layers the cells are elongated in a radial direction, the outer cells being much finer than the inner. Weathered surfaces of the funnel plates show raised granules, which are generally round or vermicular, but which take the form of radial ridges at the two margins." "In the horizontal section ... round, oval, kidney-shaped or vermicular bodies, evidently cross-sections of the vertical elements, are scattered over the section." "All*

these vertical elements are composed of crystalline calcite which appears to be secondary." "In both [radial and tangential] *sections the vertical elements average about 0.25 mm in width, and they appear to have originated not as pillars but as tubes, which have been filled with secondary calcite resembling that occupying the spaces between the funnel plates."* Thin sections of the outer shell layer of the RV of *Praebarrettia sparcilirata* (**Figure 2A-C**) and *Hippuritella maldonensis* (**Figure 2D**) indicate that the wall is constructed in a way very similarly to that of a radiolitid. It consists of funnel plates separated by radial muri, which, in both these species, have broken up to form pustules.

Grubić (2004) clearly misinterpreted the structure described by Mac Gillavry (1937) who made no mention of canals penetrating the funnel plates. Chubb's (1956) description is misleading as no canals are present. Consequently, a *"capillary microstructure"* consisting of *"funnel plates perforated and interconnected by capillary tubes"* (Grubić, 2004, p. 144) is not present in any hippuritid rudist from the Caribbean region. Therefore, Grubić's (2004) new genus *Caribbea* (type species *Orbignyi muellerriedi* Vermunt, 1937) is unnecessary, and there is no basis for using shell structure to define a separate subfamily Barrettinae. *Caribbea* is here regarded as a junior synonym of *Hippuritella* Douvillé, since the pore system of a Jamaican specimen of *muellerriedi* has polygonal to reticulate, not linear, pores (**Figure 3A**).

Recognition of the ligamental infold (P0). In relatively primitive multiple-ray hippuritids, the ligament (P0) can be identified as a prominent long infold (ray) close to the posterior tooth (Boissevane
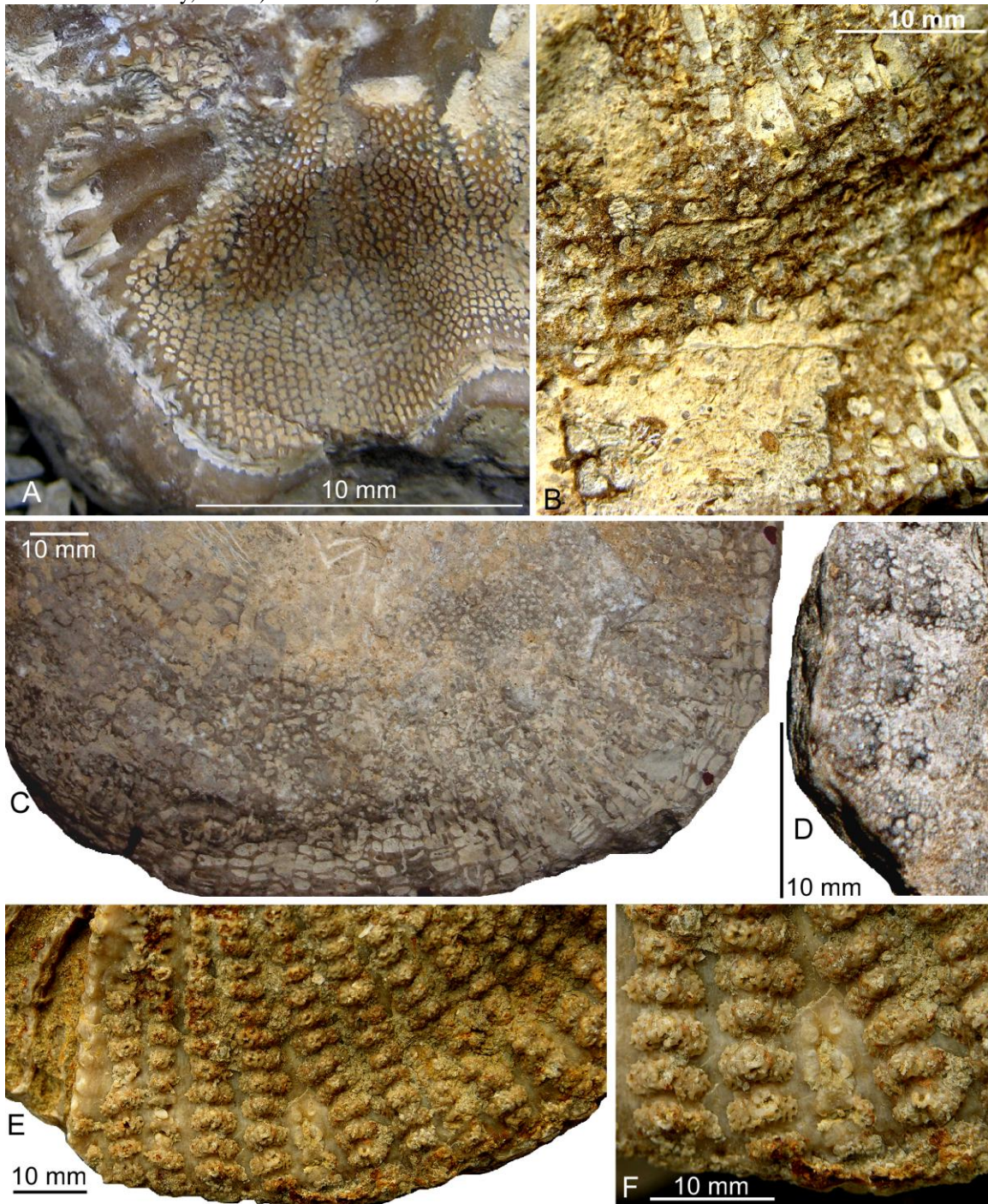
and Mac Gillavry, 1932). However, in more

Figure 3. Pores in Caribbean hippuritid rudists. A, polygonal to denticulate pores in *Hippuritella muellerriedi* **(UWIGM.2010.01.0001), Guinea Corn Formation (Upper Maastrichian), Central Inlier; B-C,** *Barrettia multilirata***, Haughton Hall Limestone (Middle Campanian), Green Island Inlier; B (UWIGM.2010.01.0002), double canals with canals separated by a bar with a small open ring in the middle (lower left); C (BMNH.PIMB.978), polygonal pores (centre right); D (UWIGM.2010.01.0003), reticulate pores on domes over each bead in** *Barrettia monilifera***, Back Rio Grande Formation (Middle Campanian), Blue Mountain Inlier; E-F (UWIGM.2010.01.0003), raised pustules with irregular pores separated by imperforate bands,** *Whitfieldiella* **sp. nov. (UWIGM.2010.01.0004), rudist limestone (Middle Campanian), Grange Inlier.**
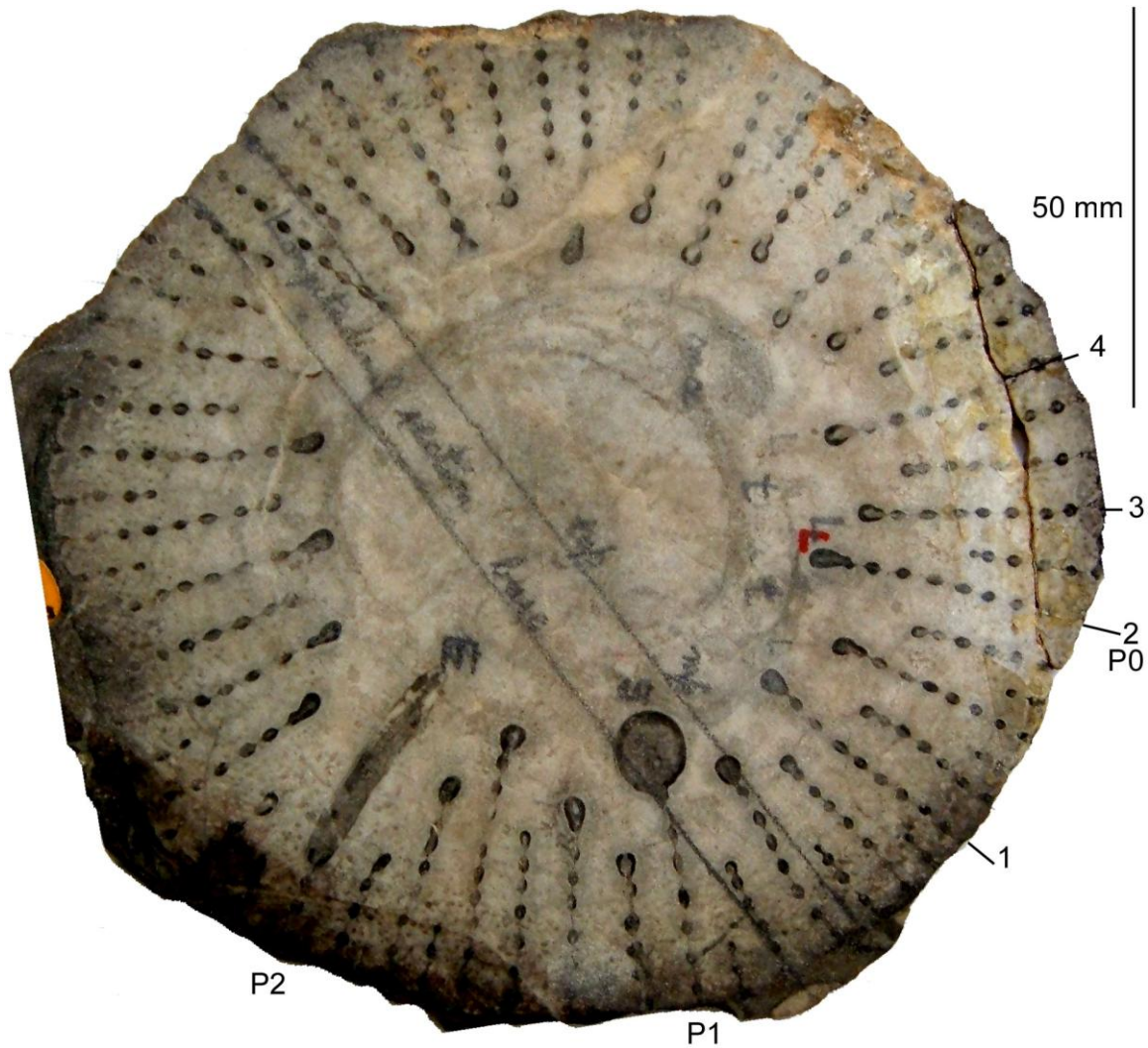
Figure 4. Transverse section through part of one of the syntypes of *Barrettia monilifera* **(BMNH.42861) showing the line of Woodward's (1862) original section as well as various attempts (mostly in pencil) to identify the ligamental infold; 1-4 are the various indicated identifications of the ligamental infold; P0, P1 and P2 are the ligamental infold, first, and second pillars, respectively, using criteria in this paper.**

advanced forms, the ligamental infold is no longer than other long infolds. In these forms Douvillé (1894, 1926) and Chubb (1971) identified the ligamental infold as the long infold that bisected PT and AT (**Figure 4**). However, by comparison with more primitive forms, Boissevane and Mac Gillavry (1932) and van Dommelen (1971) recognized that P0 (L) should be identified as the longest infold close to PT.

Number of infolds (rays) of the outer shell layer. Whitfield (1897), Chubb (1955, 1971) and Alencáster (1971) relied heavily on the number of infolds to distinguish between their species of *Barrettia*. van Dommelen (1971) produced a graph of number of infolds versus diameter for various species of *Barrettia* and *Praebarrettia*. This plot shows that there is insufficient variability in the

number of infolds to allow recognition of species as there is too much overlap. When just considering the three species described here, the two species of *Barrettia*, although not distinguishable at a particular size, have significantly more infolds than *Whitfieldiella gigas* (**Figure 5**).

Grubić (2004) suggested that the number of cycles of progressively shorter secondary infolds had taxonomic value; in his scheme *Barrettia* had 3 to 7 cycles, whereas his new genus *Gloria* had only two. *Gloria* Grubić 2004, type species *Gloria vermunti* Grubić 2004 (= *Pironaea* cf. *peruviana* Vermunt, 1937), is preoccupied by *Gloria* Barrande 1881, and is therefore unavailable. The number of cycles of secondary infolds is, however, also related to size; small forms (e.g., *Barrettia monilifera*) have low numbers of cycles (**Figure 6A**), larger forms
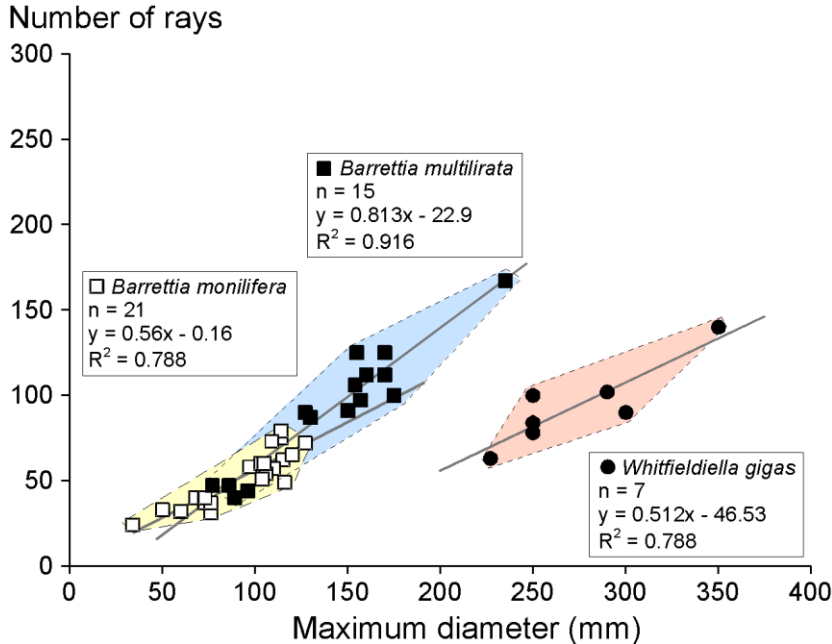
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Number of rays

Figure 5. Scatterplot showing number of rays versus maximum diameter in *Barrettia monilifera*, *B. multilirata* and *Whitfieldiella gigas*. Although *Barrettia* and *Whitfieliella* appear distinct, the two species of *Barrettia* cannot be separated.

more cycles (**Figure 6B-C**). Although obvious features in multiple-fold rudists, therefore, neither the number of infolds, nor the number of cycles of secondary infolds are considered to have high taxonomic value and they are both likely to increase throughout lineages that show phyletic size increase.

Grubić (2004) based some species on differences in the angles between the primary infolds, often in small populations or for single specimens. He used three criteria: P2-P1 was greater than P1-P0; P2-P1 and P1-P0 were more-or-less equal; and P2-P1 was smaller than P1-P0. When larger populations are available, as in the material described here (**Figure 7**), the range of variation in species is relatively large and shows significant overlap; these criteria therefore do not necessarily allow assignment of specimens to species.

Form of infolds of the outer shell layer. The different form of infolds (rays) originally led Trechmann (1924) to separate *Praebarrettia* (with simple infolds) from *Barrettia* (with moniliform infolds). Hence when Chubb (1968, 1971) described his new species *coatesi*, he placed it in *Praebarrettia* based on the simple shape of the infolds. Chubb (1971) carefully described the size of the beads in the various species of *Barrettia* he recognised, however, this has been overlooked by subsequent authors. Chubb also considered the spacing of beads as significant; his personal communication about a *Barrettia* from St. Croix in Whetten (1966, p. 209) states *"... the beads are much more widely spaced on the string than in the true*

Barrettia monilifera ..." Thus Chubb used both bead size and bead spacing to distinguish between his different species of *Barrettia*. Bead size, spacing and form (non-moniliform, sub-moniliform or moniliform) is very stable within populations and allows species (even single specimens) to be distinguished (**Figure 8A-C**).

Left (Free) Valve (LV). The LV is cap-like, and contains the pore system and supports the main myocardinal structures. The LV consists of an inner layer that may be dense or filled with pallial cannals, and an outer layer that contains vertical/transverse canals and the pore system. The myocardinal apparatus consists of the posterior (PT) and anterior (AT) teeth and the posterior (PM) and anterior (AM) myophores. The corresponding tooth in the RV is reduced to a support for the grooves receiving the teeth of the LV. The size, shape and orientation of the teeth has taxonomic value, as does the relative position of the posterior myophore (PM).

Boissevane and Mac Gillavry (1932) suggested that the angle formed between the centres of PT and AT and the centres of the PT and MP could be used to ascertain the degree of development of *Barrettia*. Using the progressive decrease in this angle, they suggested a hypothetical lineage of four species, which were from primitive to advanced *B. sparcilirata*, *Barrettia* sp. of Douvillé (1926), *B. monilifera*, and *B. multilirata*. They noted that in this progression the length of the ligamental infold decreased and it becomes equivalent to a 'normal' ray. Although this development was attractive, the stratigraphical distribution of species was
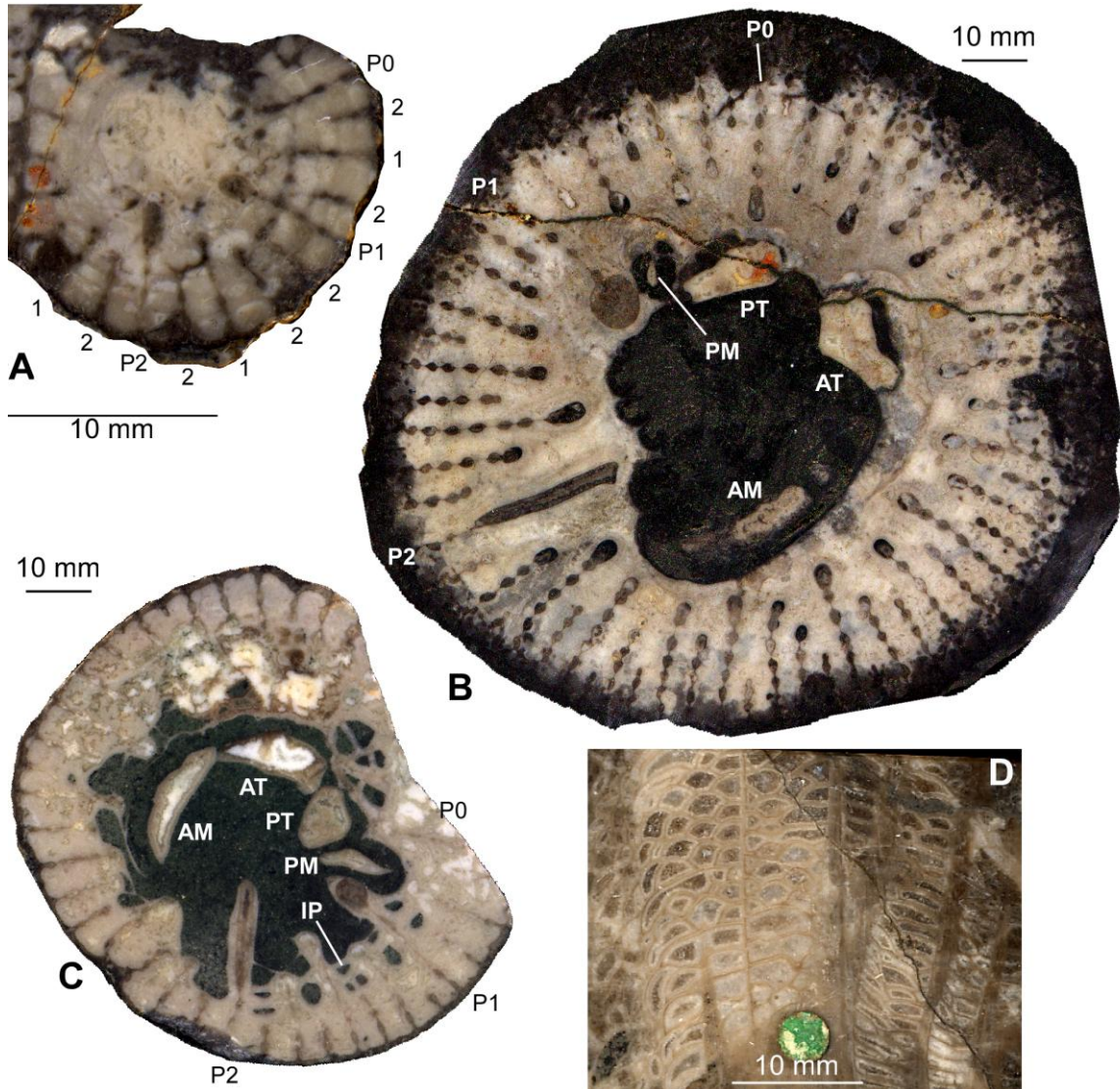
Figure 6. *Barrettia monilifera* **Woodward, 1862. A, transverse adapical section of juvenile (UWIGM.RUD.2006.222) showing primary rays (P0, P1 and P2) and two orders (1 and 2) of secondary rays. B (abapical view, UWIGM.RUD.2006.223) and C (adapical view, UWIGM.RUD.2006.216), transverse sections of adult specimens showing myocardinal structure and inter-ray partitions (C). D, tangential section (figured by Woodwrad, 1862, pl. 20, fig. 3) showing two or three large cells between rays (BMNH.42864). AM, anterior myophore; PM, posterior myophore; PT, posterior tooth; AT, anterior tooth, P0, P1, and P2, ligamental, first and second pillars respectively; IP, inter-ray partitions.**

significantly different to this scheme with *B. sparcilirata* being the youngest (Chubb, 1971).

van Dommelen (1971) used two criteria to define the myocardinal apparatus in Caribbean multiple-ray hippuritids. The first was the angle between AT-PT-PM (as used by Bosseivain and Mac Gillavry, 1932) and the second was the projection of PM onto L (P0). While clearly discriminating some species of *Barrettia*, these characters only record some of the variation in the myocardinal-pillar arangements. In particular, the

projection of PM onto L (P0) might be due to a repositioning of PM or a reduction in the length of L (P0).

The myocardinal-pillar arrangement is regarded as having a high taxonomic value in this paper and can be used to define separate evolving lineages. This can be characterised biometrically by measuring three angles between distinctive elements of the myocardinal-pillar system. The following elements can be recognised (**Figure 9**): centre of anterior tooth (AT); centre of posterior tooth (PT);
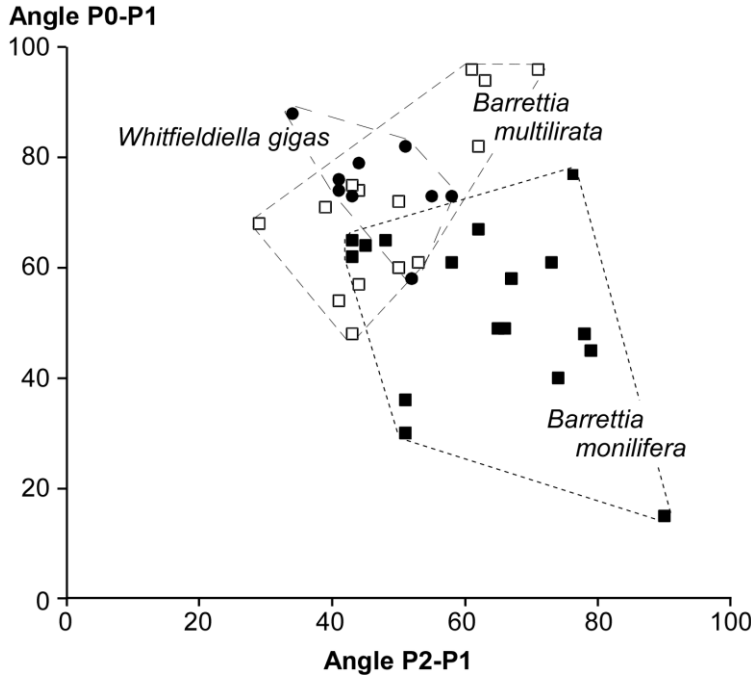
Figure 7. Scatterplot showing P2-P1 versus P1-P0 for *Barrettia monilifera*, *B. multilirata* and *Whitfieldiella gigas*. For *B. multilirata* and *W. gigas* angle P0-P1 is larger than angle P2-P1; but for *B. monilifera* angle P0-P1 may be larger, the angles may be equal, or angle P2-P1 may be larger. Although there are differences in the fields (outlined), there is too much overlap to use these criteria to place specimens within species or genera.
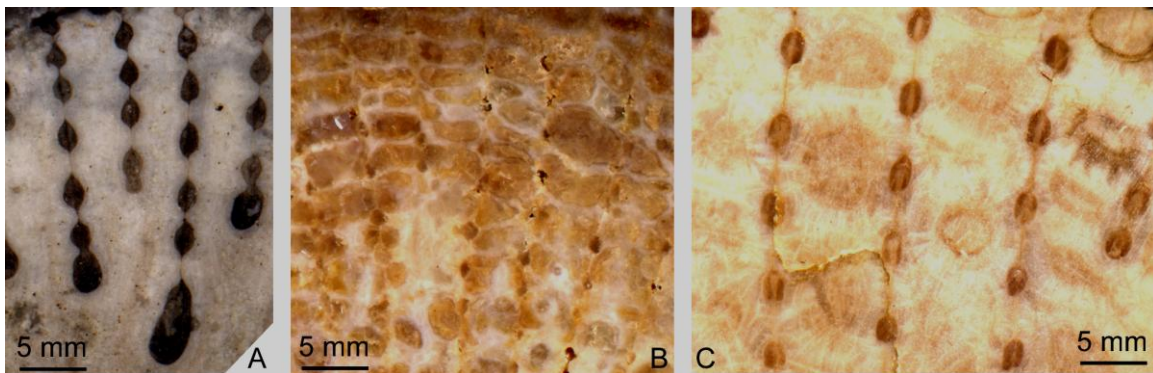

Figure 8. Form of infolds (development, size and spacing of beads) in *Barrettia monilifera* (A), *B. multilirata* (B) and *Whitfieldiella gigas* (C) shown at the same scale. Species are clearly distinguished using these criteria. Inter-ray partitions are visible in B (clear 'horizontal' lines connecting between rays) and C (circles in inter-ray spaces which are cement infills), but are not obvious in A.

centre of posterior myophore (PM); centre of first pillar (P1) or half the thickness of the knob from the tip of the knob if not circular; and radial tip of second pillar (P2). Using these features the following angles can be measured (**Figure 9**): P2-P1-PM, the angle between the tip of P2 and the centres of P1 and PM; P1-PM-PT, the angle between the centres of P1, PM and PT; and PM-PT-AT, the angle between the centres of PM, PT and AT.

The genera *Whitfieldiella* gen. nov. and *Parastroma* Douvillé are characterised by a large P2-P1-PM angle and a small P1-PM-PT angle. In contrast, *Barrettia* has a small P2-P1-PM angle and

a large P1-PM-PT angle. These angles clearly define separately evolving lineages (**Figure 10**).

The pore system has been seen in the two species of *Barrettia* described here and consists of a reticulate covering over the surface of the LV (**Figure 3B-D**). Although the pore system has not been seen in *Whitfieldiella gigas*, an undescribed form from the Grange Inlier shows it well (**Figure 3E**). *Whitfieldiella* is characterised by multiple slit-like pores on raised pustules with an imperforate zone around the pustule. The pore systems of *Barrettia* and *Whitfieldiella* are therefore different and this supports the erection of the new genus *Whitfieldiella*.
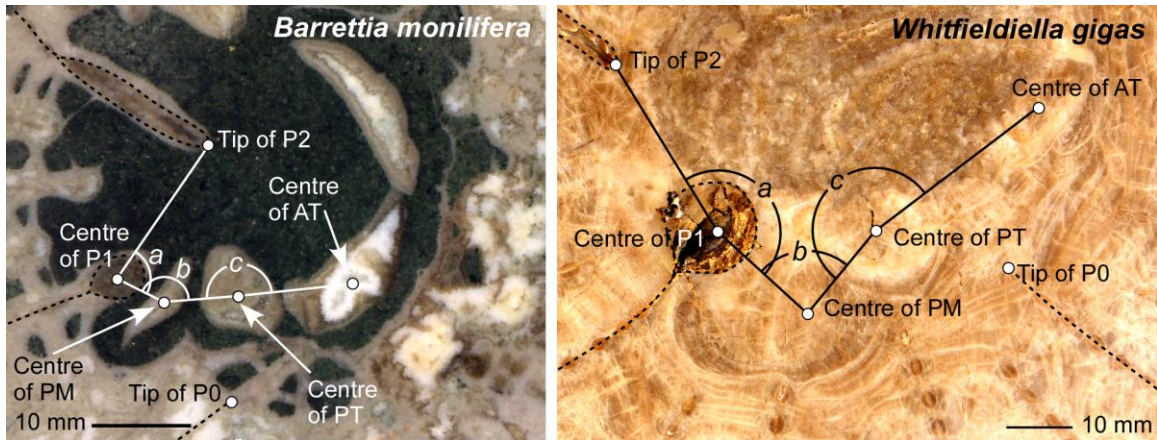
Figure 9. Pillar-myocardinal arrangement in *Barrettia monilifera* and *Whitfieldiella gigas*. The angles *a* (P1-P2-PM), *b* (P2-PM-PT) and *c* (PM-PT-AT) allow the distinction of different multiple-fold hippuritid lineages; note that angle *a* is close to 90° in *Barrettia* and close to 180° in *Whitfieldiella*.
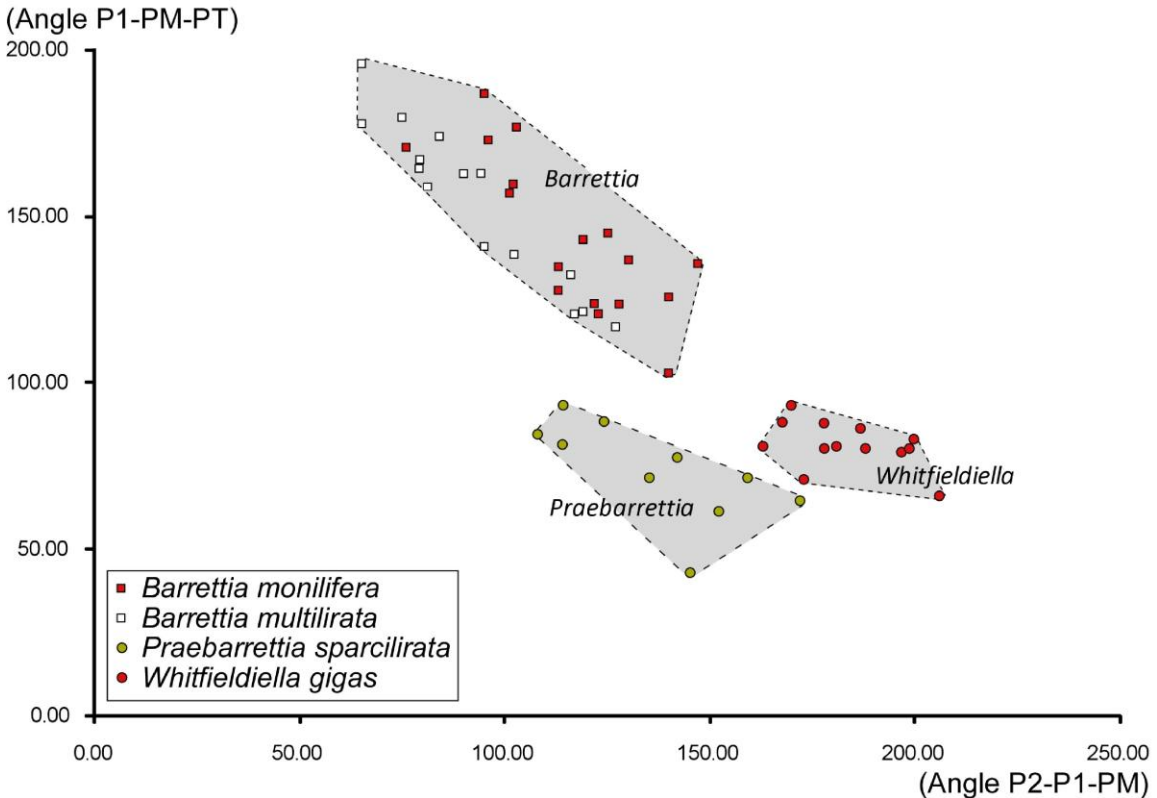

Figure 10. Scatterplot of pillar-myocardinal arrangements for *Barrettia*, *Whitfieldiella* and *Praebarrettia*. The three genera plot in separate fields with no overlap.

3. SYSTEMATIC PALAEONTOLOGY

The material utilized in this study includes material in existing collections, figured specimens, and extensive newly collected populations. Repositories for material are as follows: AMNH: American Museum of Natural History; BMNH: Natural History Museum London; NHML: Nationaal Natuurhistorisch Museum Leiden; UWIGM: University of the West Indies Geology Museum.

Family Hippuritidae Gray 1848

Four genera of American multiple-fold hippuritid rudists are recognised here: *Barrettia* Woodward 1862; *Praebarrettia* Trechmann 1924; *Parastroma* Douvillé 1926; and *Whitfieldiella* gen. nov. These genera can be distinguished based on differences in the myocardinal-pillar arrangements (**Figure 10**), the presence or absence of pallial canals in the inner layer of the LV, and the pore systems (**Table 1**).

Table 1. Diagnostic characters of American multiple-fold hippuritid bivalves

	BARRETTIA	*WHITFIELDIELLA*	*PRAEBARRETTIA*	*PARASTROMA*
Dentition	*Barrettia*-like	*Whitfieldiella*-like	*Praebarrettia*-like	*Whitfieldiella*-like
Multiple rays	Present	Present	Present	Secondarily lost
RV outer shell	Compact?	Compact?	Funnel plates with pustules	Compact?
LV Pallial canals	Present	Present	Absent	Present
Pores system	Reticulate	Pustules with imperforate areas	Reticulate	Reticulate
Tabulae	Coarse vesicular	Fine vesicular	Coarse vesicular	Fine vesicular

Genus *Barrettia* Woodward 1862

Diagnosis. Multiple-fold hippuritid rudist with pallial canals in the inner layer of the LV, P2-P1-PM ranging from 65° to 147°, P1-PM-PT ranging from 103° to 196°, PM-PT-AT ranging from 132° to 171°, a coarse vesicular structure in the inner layer of right valve, and multiple reticulate pores over each bead in the LV.

Type species. *Barrettia monilifera* Woodward, 1862, by monotypy. Upper Middle Campanian, Back Rio Grande Limestone, Back Rio Grande, Portland, Jamaica.

Species included. *Barrettia coatesi* (Chubb 1968) (=*B. macgillavryi* Grubić 2004), *B. ruseae* Chubb 1968, *B. dommeleni* Grubić 2004, *B. monilifera* Woodward 1862, and *B. multilirata* Whitfield 1897. Several new species await description.

Stratigraphical Range and Geographical Range. Late Santonian (first, *Barrettia* sp. nov. A, Jamaica) to Early Maastrichtian? (last, *Barrettia* sp. nov. B, Ozocaultar Formation, Mexico = *Pseudobarrettia* of Müllerried, 1931, and Chubb, 1959). Recorded from Jamaica, Puerto Rico, Cuba, Haiti, Mexico (Chiapas) and California (Chubb, 1971; van Dommelen, 1971; Filkorn, 2005).

Discussion. The material described by Filkorn (2005) as *Praebarrettia sparcilirata* from California shows a myocardinal-pillar arrangement typical of *Barrettia* and not *Praebarrettia*. This material is here assigned to the genus *Barrettia*, and will be described elsewhere.

Barrettia monilifera Woodward, 1862
Figures 3D, 4, 6A-D, 8A, 9.

v*. 1862 *Barrettia monilifera*: Woodward, p. 372-378, pl. 20, figs 1-4; pl. 21, Fig. 5.
v. 1894 *Barrettia monilifera* Woodward; Douvillé, p. 110, pl. 17, Fig. 6.
v. 1897 *Barrettia monilifera* Woodward; Whitfield, only reproduction of Woodward's pl. 20-21.
v. 1903 *Orbignya monilifera* Woodward; Toucas, p. 47, text-Fig. 83.

v. 1932 *Barrettia monilifera* Woodward; Boissevane and Mac Gillavry, fig. 3c.
v. 1971 *Barrettia monilifera* Woodward; Chubb, p. 208-210, pl 51, figs 1-3, pl. 52, figs 2-3, text-Fig. 8.
v. 1971 *Barrettia monilifera* Woodward; van Dommelen, text-Fig. 7C, 6E; Text-Fig. 9A.
v. 2004 *Barrettia monilifera* Woodward; Grubić, p. 160, pl. 5, fig. 2.

Diagnosis. A *Barrettia* with an advanced myocardinal-pillar arrangement, a short ligamental ray, a moderate ray density, moderately large round beads, and thin, irregular inter-ray partitions; pores of left valve on raised domes over each bead.

Type specimen. The type series is in the Natural History Museum, London. The original figure of Woodward (1862, pl. 21, Fig. 5) represents a transverse section that cuts through the body chamber and shows the teeth in position; it is not amongst the material in the Natural History Museum. BMNH 42861 is the transverse section that was figured by Douvillé (1894) and Chubb (1971) and was stated by Douvillé (1894) to be a section of the 'type individual' that was sent to him by Woodward. It would appear that the part of the specimen that was figured by Woodward (1862) is missing, but another part of the same individual, as figured by Douvillé (1894) is represented by BMNH 42861. Since all this material is part of the original type series of Woodward (1862), there is no problem with the interpretation of the species.

Material. Abundant material collected over the last five years from the Back Rio Grande Formation of the Back Rio Grande, Blue Mountains Jamaica (Mitchell and Ramsook, 2009), including: UWIGM.RUD.2006.214-227 and 2010.01.0003.

Description. Right valve cylindro-conical reaching a maximum diameter of 115 mm. Specimens grew singly or in small bouquets numbering up to seven specimens. The outer layer is about 1 mm thick and is folded into the inner layer as a serious of rays. The external ornament consists of regular costae, with the grooves between costae corresponding to infolds (rays). In adult specimens the number of rays ranges from 49 to 79. The rays are moniliform, the beads are typically circular to radially elongated, and constrictions between beads are well-

developed. The beads have diameters ranging from 0.9 to 1.8 mm in width, and are separated by distances of 2.7 to 6.2 mm (usually between 3 and 4 mm). The ligamental ray is no longer than other primary rays, and can be identified as the longest ray closest to PT; it has a regularly circular knob. The termination of P2 is represented by a more-or-less parallel-sided radially elongated knob with a length ranging from 13 to 28 mm in adults. P1 is circular to gently radially elliptical with a diameter of 4.0 to 5.5 mm. The knobs of other rays are more-or-less circular with the knob (typically 3 mm) larger than the beads on the ray. The rays are raised on the commissural surface. The inner shell layer contains inter-ray partitions. These are not obvious on typical transverse cross-sections because there is little contrast between the calcitic replacement of the inter-ray partitions and the calcite cement filling the inter-ray regions. When sections are cut close to the commissural surface the contrast is obvious between the calcite replacement of the inter-ray partitions and the dark micritic sediments infilling the inter-ray spaces (**Figure 6C**). The arrangement of tabulae between the inter-ray partitions is difficult to recognise on transverse or longitudinal sections due to the calcite cements, but is visible in one of Woodward's (1862, pl. 20, fig. 3) specimens (**Figure 6D**). This shows two rows of cells concentrically within each inter-ray region.

Complete or fragmented examples of four LVs are available and show the pore system. The left valve forms a low cone. The myocardinal structure of the left valve is preserved in place within numerous RVs. The posterior myophore is elliptical and radially elongated; the angles of the myocardinal-pillar elements are as follows: P2 P1 PM ranges from 76˚ to 147˚ (mean = 116.1˚, SD = 18.84˚, N = 17); P1-PM-PT ranges from 103˚ to 187˚ (mean = 143.9˚, SD = 23.34˚, N = 17); and PM-PT-AT ranges from 132˚ to 171˚ (mean = 116.1˚, SD = 12.58˚, N = 16). The posterior tooth (PT) is large and only slightly smaller than the anterior tooth (AT). The left valve contains radially orientated pallial canals within the ridges of the LV which fit into the inter-ray grooves of the RV. Each bead in the RV is overlain by a vertical canal that penetrates the inner layer of the LV; these canals pass up into concentrically elongated double-cavities. Above the double-cavity is a dome-shaped covering containing numerous small polygonal to denticulate (reticulate) pores (**Figure 3**).

Geographical and stratigraphical distribution. *Barrettia monilifera* occurs abundantly in the lower part of the lower limestone member of the Back Rio Grande Formation (late Middle Campanian),

Back Rio Grande, Blue Mountain Inlier (Mitchell and Ramsook, 2008). There are no reports of the species from elsewhere with certainty. Material identified as *B. monilifera* from Cuba, Puerto Rico, St. Croix and elsewhere from Jamaica belongs to various other species of *Barrettia*; these other species will be described elsewhere.

Discussion. Whitfield (1897) placed material collected from Green Island in *B.* cf. *monilifera*, but Chubb (1955) demonstrated that this material was not conspecific with *B. monilifera* and erected the new species *Barrettia gigas* for it. *B. monilifera* is distinguished from *B. coatesi*, *B. ruseae* and *B. dommeleni* by the presence of inter-ray partitions, the shorter ligamental infold and the well-developed beads giving fully moniliform rays.

Barrettia multilirata Whitfield, 1897
Figures 3B-C, 8B, 11.

v* 1897 *Barrettia multilirata*, n. sp.: Whitfield, p. 244; pl. 33-35.
v. 1922 *Barrettia* cf. *multilirata*, typical form (?): Trechmann, p. 511; pl. 19, fig. 1.
v. 1922 *Barrettia* cf. *multilirata*, Var. *cylindrical* nov.; Trechmann, p. 511; pl. 20, fig. 3.
v. 1922 *Barrettia* cf. *multilirata*, Var. *conica*, nov.; Trechmann, p. 511; pl. 17, fig. 1a, b.
v. 1955 *Barrettia multilirata* Whitfield; Chubb, p. 12-13.
v. 1971 *Barrettia multilirata* Whitfield; Chubb, p. 211-213; pl. 54, figs 1-4; pl. 55, fig. 2; text-figs 8-10.
. 1971 *Barrettia* cf. *multilirata* Whitfield; van Dommelen, pl. 10, fig. 2.
v. 2004 *Barrettia multilirata* Whitfield; Grubić, p. 162, excluding pl. 7.
v. non 2004 *Barrettia multilirata* Whitfield; Grubić, pl. 7 = *Whitfieldiella gigas* (Chubb).

Diagnosis. A species of *Barrettia* with an advanced myocardinal-pillar arrangement, a high ray density, abundant small narrow beads, and well-developed inter-ray partitions; pores of left valves on a continuous thin covering.

Type specimen. Whitfield (1897) provided three figures of this species which are parts of the same specimen. This specimen (AMNH No. 9666/1) is therefore designated as lectotype here.

Material. Abundant material from the Green Island Formation of the Green Island Inlier preserved in numerous museums, including: AMNH No. 9666/1; UWIGM.RUD.2006.200, 2006.200b, 2006.201, 2006.203-4, 2006-228-230.
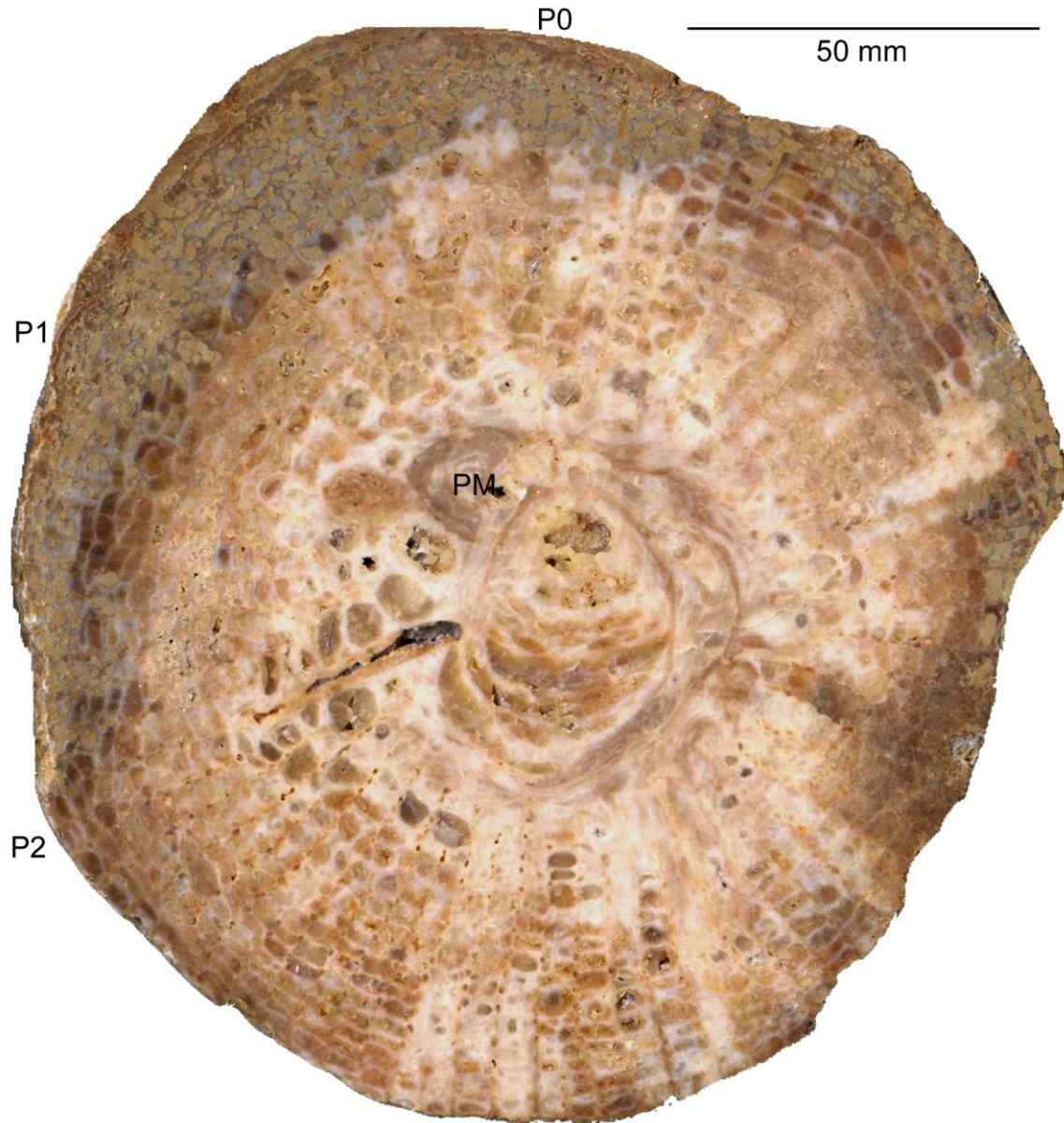
Figure 11. *Barrettia multilirata* **Whitfield (UWIGM.RUD.2006.228). Transverse section of a specimen from the Haughton Hall Limestone, Green Island, Hanover, Jamaica. The small beads and obvious inter-ray partitions are clearly visible.**

Description. Right valve cylindrical to conical reaching a maximum diameter of 184 mm. Specimens generally grow as isolated individuals and not as bouquets. The outer layer is up to 1 mm thick, but is generally poorly preserved on weathered specimens. It is folded into the inner layer as numerous rays, which number 154 to 184 in adult specimens. The rays are moniliform with numerous small beads with diameters of 0.8 to 1.2 mm, and with bead centres separated by 0.7 to 4.4 mm (usually between 2 and 3 mm). The ligamental ray (P0) is of the same length as the 'normal rays' and can only be identified as the longest ray adjacent to PT. P1 is circular with a diameter of 9 mm; P2 is elongated with parallel sides, its length ranges from 21 to 38 mm. The inner shell layer is composed of closely spaced vertical inter-ray partitions with moderately spaced concave tabulae between; the tabulae have a spacing of about 1 mm. The rays are raised on the commissural surface with the depressions between divided up into inter-ray spaces.

Left (free) valves are low cones. The myocardinal structure of the left valve is preserved

in place within several right valves and shows a typical advanced *Barrettia* arrangement. The angles for the myocardinal-pillar elements are as follows: P2-P1-PM ranges from 65° to 127° (mean = 92.5°, SD = 19.89°, N = 15); P1-PM-PT ranges from 117° to 196° (mean = 154.5°, SD = 24.21°, N = 15); and PM-PT-AT ranges from 135° to 170° (mean = 156.1°, SD = 10.88°, N = 14). The posterior myophore is broadly circular. The posterior tooth (PT) is relatively large, and close to the size of AT and P1. The left valve contains radially orientated pallial canals. The rays are overlain by a system of vertical canals, these become 8 shaped and finally develop a cross bar with a small ring in the middle. This structure is overlain by a fine polygonal mesh (**Figure 3**).

Geographical and stratigraphical distribution. *Barrettia multilirata* occurs abundantly in the late Middle Campanian Green Island Formation at Green Island, Hanover.

Discussion. *Barrettia multilirata* is distinguished from *Barrettia monilifera* by its more numerous rays (although this may be an artefact of size), its more closely spaced smaller beads, and its more obviously developed inter-ray partitions. The two species may have lived at the same time or may be ancestor (*B. monilifera*) and descendent (*B. multilirata*); unfortunately the associated fauna is insufficient to determine the relative stratigraphical distribution of the two species. Trechmann (1922) erected two named varieties, but since these occur at the same horizon and grade into one-another, they are regarded as intraspecific variations of a single species herein. Specimens assigned to *Barrettia multilirata* from Cuba by Rojas et al. (1996) belong to species of *Whitfieldiella* and will be described elsewhere.

Genus *Whitfieldiella* gen. nov.

Diagnosis. Multiple-fold hippuritid rudist with pallial canals in the inner layer of the LV, P2-P1-PM ranges from 163° to 206° (mean = 183.7°, SD = 13.70°, N = 13), P1-PM-PT ranges from 67° to 94° (mean = 81.9°, SD = 6.95°, N = 14); and PM-PT-AT ranges from 160° to 212° (mean = 183.6°, SD = 14.58°, N = 14), a fine vesicular structure in the inner layer of right valve, and irregular to reticulate pores on pustules separated by imperforate bands in the LV.

Type species. *Whitfieldiella gigas* Chubb 1955 (=*Barrettia* cf. *monilifera* Whitfield 1897), Middle Campanian, Haughton Hall Formation, Green Island, Hanover, Jamaica.

Species included. *Whitfeildiella gigas* (Chubb 1955), together with various undescribed forms from Puerto Rico, Cuba and Jamaica.

Stratigraphical Range and Geographical Range. Early Campanian (earliest, *Whitfieldiella* sp., Jamaica and Puerto Rico) to Late Maastrichtian (last, *Whitfieldiella* sp., Jamaica and Cuba). Recorded in Jamaica, Puerto Rico, Cuba and Mexico (Chiapas).

Discussion. *Whitfieldiella* is distinguished from *Barrettia* by its different myocardinal-pillar arrangement (**Figures 9-10**), its closely spaced tabulae in the inner layer of the RV, and its different pore system.

Whitfieldiella gigas (Chubb 1955)
Figures 3E-F, 8C, 9, 12.

v* 1897 *Barrettia monilifera* Woodward, in part (excluding Woodward's material); Whitfield, pl. 27-32.

v. 1922 *Barrettia* cf. *monilifera* S. P. Woodward; in part, Trechmann, p. 510-511, pl. 20, figs 1, 2 [non pl. 19, figs 2a, b = *Parastroma trechmanni* (Chubb)].

v. 1955 *Barrettia gigas*, new name; Chubb, p. 9-12.

v. 1971 *Barrettia gigas* Chubb; Chubb, p. 210-211, pl. 52, fig. 1, pl. 53, figs 1-3.

v. 1971 *Barrettia gigas* Chubb; Alencáster, p. 63, pl. 13, figs 1-4.

v. 2004 *Barrettia multilirata gigas* Chubb; Grubić, p. 163.

v. 2004 *Barrettia multilirata* Whitfield; Grubić, pl. 7.

? 2004 *Barrettia monilifera robusta* subsp. nov.; Grubić, p. 161, pl. 6, fig. 2.

Diagnosis. A very large species of *Whitfieldiella* with a short ligamental ray, full moniliform rays, well-developed inter-ray partitions and relatively large and widely spaced beads.

Holotype. Holotype nominated by Chubb, 1955, as specimen shown on Whitfield's (1897) plate 27, fig. 1 and pl. 28 (AMNH No. 9665/1).

Material. Material including: AMNH 36572-36573 and UWIGM (RUD.2010.0005) from the Haughton Hall Formation, Green Island, Hanover, Jamaica, and the Stapleton Formation, St. James, Jamaica.

Description. Right valve is cylindrical to conical reaching maximum diameters of 350 mm. Specimens generally grow as isolated individuals and do not form bouquets. The outer shell layer is up to 1 mm thick, but is generally poorly exposed since most specimens are heavily weathered. The outer shell layer is folded into the inner shell layer forming numerous rays, which number 78 (250 mm
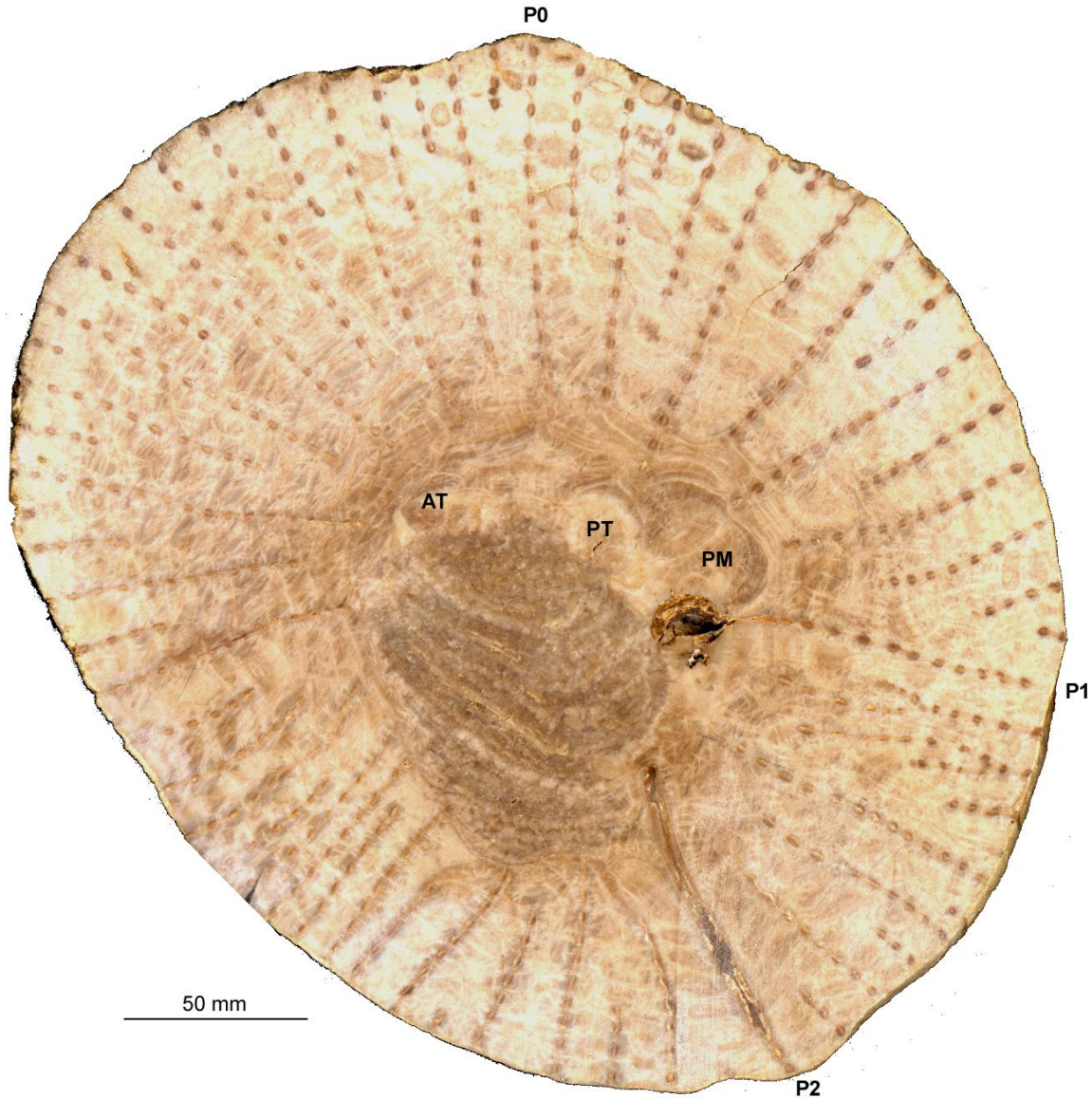
Figure 12. *Whitfieldiella gigas* **(Chubb) (UWIGM.2010.01.0006). Transverse section of specimen from the Haughton Hall Limestone, Green Island, Hanover, Jamaica. The large beads are clearly visible and the calcite cement infils of the inter-ray spaces are seen as eliptical areas between the rays.**

diameter) to 140 (350 mm diameter) in adult specimens. The rays are moniliform with numerous moderate sized elliptical beads with their length a little greater than their width, lengths range from 1.9 to 2.9 mm; bead centres are separated by 3.6 to 5.8 mm (**Figure 8**). The ligamental ray is of the same length as the 'normal rays' and can only be identified by its position close to PT. P1 is circular with a diameter of 12 mm; P2 is elongated with parallel sides, its length ranges from 20 to 50 mm. The inner shell layer is composed of closely spaced vertical inter-ray partitions with closely spaced concave tabulae between; the tabulae have a

spacing of about 0.25 mm. The rays are raised on the commissural surface with the depressions between divided up into inter-ray spaces.

Left (free) valves are low cones. The myocardinal structure of the left valve is preserved in place within several right valves. The angles for the myocardinal-pillar elements are as follows: P2 P1 PM ranges from 163° to 206° (mean = 183.7°, SD = 13.70°, N = 13), P1-PM-PT ranges from 67° to 94° (mean = 81.9°, SD = 6.95°, N = 14); and PM-PT⁻AT ranges from 160° to 212° (mean = 183.6°, SD = 14.58°, N = 14). The posterior myophore is broadly circular. The

posterior tooth (PT) is relatively large, and close to the size of AT and P1. The left valve contains radiating pallial canals. The rays are overlain by a system of vertical canals; the pore system has not been seen in this species.

Geographical and stratigraphical distribution. Found in the Haughton Hall and Stapleton Limestones of the Green Island and Sunderland Inliers, respectively. These limestones have been placed in the upper Middle Campanian based on nannofossil (Jiang and Robinson, 1987) and larger foraminifer (Krijnen et al., 1993) evidence. Similar forms were illustrated by Alencáster (1971) from Chiapas, Mexico.

Discussion. Grubić (2004) figured a new drawing which he attributed to *Barrettia multilirata*; this specimen was cited as the specimen figured by Whitfield, 1897, plate XXXIV, but appears to be the specimen figured by Whitfield, 1897, on plate XXVII figure 1 under the name *Barrettia* cf. *monilifera* Woodward, and nominated as holotype of *Barrettia gigas* by Chubb (1955). Grubić (2004) erected *Barrettia monilifera robusta* on an incomplete specimen collected by van Dommelen from Puerto Rico. Based on the drawing, the relationship between P1, P2 and PM indicates it is a species of *Whitfieldiella*, but it is specifically indeterminate since the ligament is not preserved. The name *Barrettia monilifera robusta* should therefore only be applied to this specimen, which is tentatively placed in synonymy with *W. gigas* here.

A small species of *Whitfieldiella* occurs in the Grange Inlier of Westmoreland, Jamaica. Several specimens of this species, which will be described elsewhere, have the pore system preserved. Each vertical canal is overlain by a pustule which consists of two flaps that extend out concentrically. The flaps contain irregular to reticulate pores, whereas the areas between the pustules are imperforate (**Figure 3**).

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