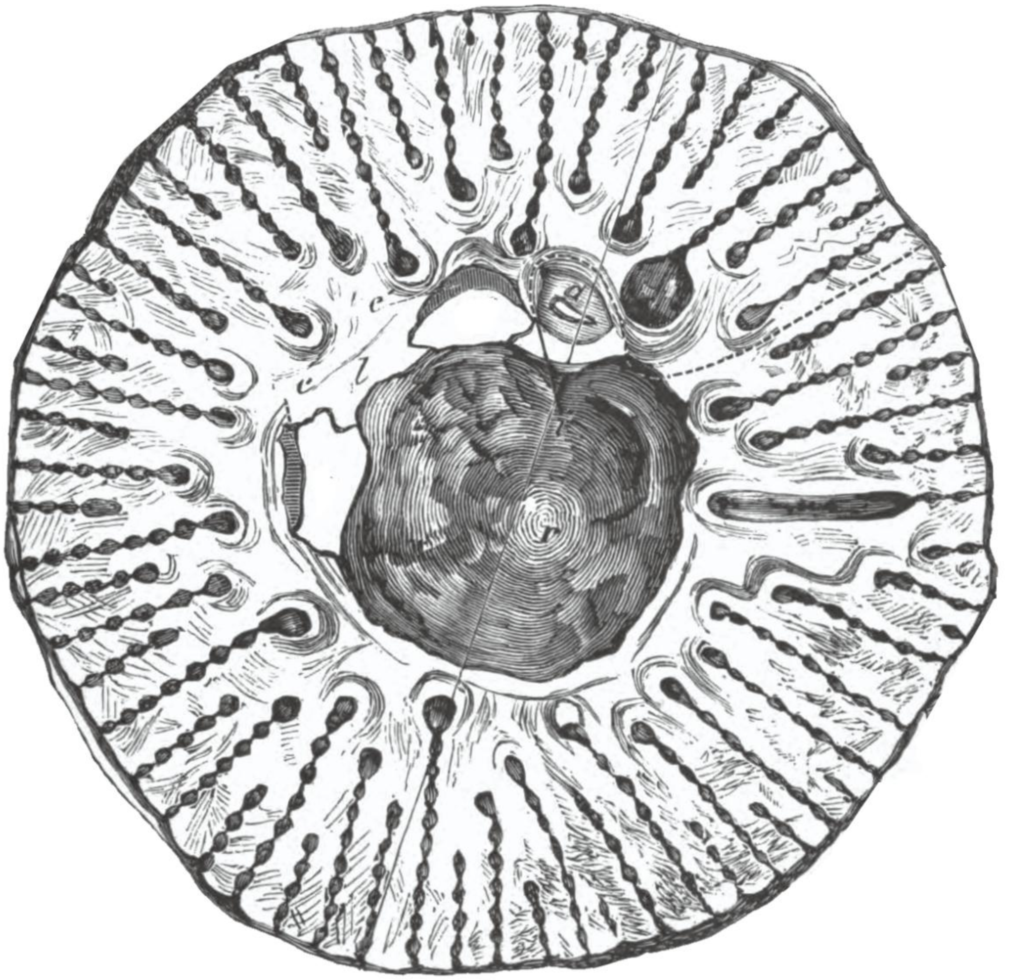
The Ninth International Congress on Rudist Bivalves

18th to 25th June 2011

Kingston, Jamaica

Abstracts, Articles and Field Guides



Editor: Simon F. Mitchell
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Dedication. Lawrence John Chubb came to Jamaica in 1950 with the aim of retiring. Instead, he worked for the next twenty years on the Cretaceous succession and particularly the rudist bivalves. This work culminated in 1971 in the publication of his memoir *"Rudists of Jamaica."* This volume was published 40 years ago and it is fitting that the Ninth International Congress on Rudist Bivalves should be held in Kingston to commemorate this achievement.

Contents

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Rudist bivalves in Jamaica: from Barrett and Sawkins to Chubb

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The Discovery of Rudists in Jamaica

Rudist bivalves were discovered in Jamaica early during the First Geological Survey, a survey commissioned by the Colonial Government in Jamaica and the Home Government in London that was undertaken to determine the economic mineral resources of the island. The director of the survey, Mr. Lucas Barrett, and his assisitant, James Gay Sawkins, began their survey in St. Thomas in the East (now the Parish of St. Thomas), and in the banks of the Plantain Garden River, some 3 miles west of Bath, they discovered several thin limestones that contained specimens of Cretaceous fossils included hippurites (not *Barrettia*, as is often stated, but rudists *sensu lato*, since the name 'hippurites' was at that time used for most rudists), *Inoceramus* and *Nerinaea*, and demonstrated that these rocks were of Cretaceous age (Barrett, 1860). The founder of Jamaican Geology, Sir Henry De la Beche, had formerly mapped the area and had included the rocks in which the rudists were found as the Transition Series which was then attributed to the Palaeozoic (De la Beche, 1827); but even De la Beche (1830) whould admit that this age was based on gross mineralogy and had little value. Yet the notice published in the *Quaterly Journal of the Geological Society* by Barrett was not the first fossil record that De la Beche's suggestions of age were wrong, for James Gay Sawkins had reported a Cretaceous coral (*Caryophyllia centralis*) in rocks below the so-called Coal Measures several years before (Sawkins, 1856).

After mapping St. Thomas in the East, Barrett and Sawkins split up – Sawkins would survey the eastern part of the parish of Portland, whilst Barrett would survey the western part of the same parish. It was Barrett, whilst exploring the western area of the Back River (Back Rio Grande) who discovered a limestone in January 1861 with the remarkable fossil that once transported back to England, and investigated by S. P. Woodward (1862; **Figure 1**), would be described as *Barrettia monilifera* (the generic name *Barrettia* was taken from Barrett, although apparently much to his dislike: Annonymous, 1863).

Barrett died at the end of 1862 in a diving accident and Sawkins was promoted to Director of the Survey. The Director of the Geological Survey for the survey of Trinidad which was undertaken before that of Jamaica, George Parks Wall, was in Jamaica (probably involved with the Jamaican copper mining companies), and was temporarily employed in the position of Assistant Geologist. Wall had made extensive collections of corals (Duncan and Wall, 1865) and rudists (Chubb, 1980) in Clarendon, and upon leaving Jamaica he took these specimens back to London where they were lodged in the British Museum. Sawkins, together with his assistants – George Parks Wall, Arthur Lennox, and Charles Barrington Brown – were also to make collections of fossils including rudists, but lack of resources in the colony of Jamaica and/or from the Colonial Office in London meant that none of these specimens was ever sent to London (Sawkins and Brown, 1867). These specimens, which were subsequently referred to as the 'Sawkins and Brown collection', were used to establish a Geological Museum in Spanish Town in 1866 or 1867, and in 1879, with other collections, went to form the nucleus of the Institue of Jamaica (Kaplan, 1996).

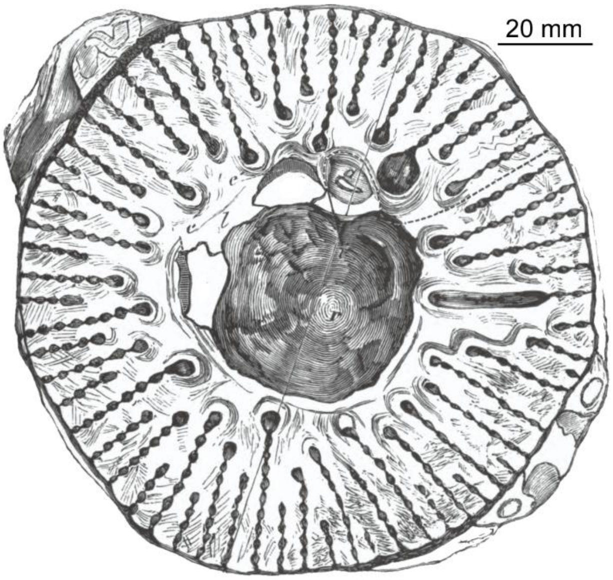

Figure 1. The original cross-section of *Barrettia monilifera* Woodward (1862, plate II, fig. 5). This section (which can no longer be traced) shows the two pillars, the posterior myophore fitting into a socket, and the two teeth fitting into slots. Mitchell (2010, fig. 6B) illustrated an almost identical specimen from the type locality.

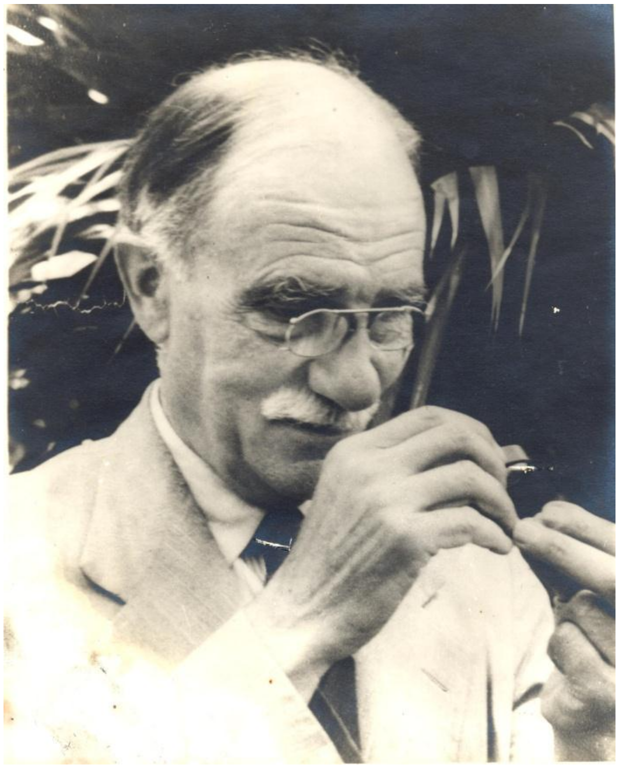

Figure 2. Charles Taylor Trechmann (1885-1964) from a photograph in the University of the West Indies Geology Museum (date unknown). Trechmann collected and described the rudists of Jamaica and produced two important papers in 1922 and 1924.

New Rudist Localities: Logie Green and Green Island

Following the Sawkins' survey, rudist bivalves would receive virtually no interest in Jamaica for the next 30 years. The construction of roads in the late 1890s, cut through some of the Cretaceous limestones, and rudist specimens found their way to the Institute of Jamaica, where the curator, Mr. Duerden, who had geological experience, recognized their importance (*The Gleaner*, 29th January 1898). Mr. F. Nicholas, from New York, now made collections of the rudists form the Cretaceous rocks (specifically Logie Green, in Clarendon, and Orange Cove, in Hanover).

Not being familiar with rudists, Nicholas forwarded his material to the American Museum of Natural History in New York, where R. P. Whitfield, the curator, was to work on this material. Whitfield (1897a) described a whole range of rudists: the huge barrel-shaped specimens of *Durania*, the coiled caprinids, and the small *Radiolites*. But it was with *Barrettia* that Whitfield had his greatest problem – he did not think it was a rudist but believed it to be a coral (Whitfield, 1897b). The leading expert on rudists at the time, H. Douvillé (1898), wrote a short review of Whitfield's work, stating that *Barrettia* was a rudist, and bemoaning the fact that no sections were given of the other forms.

Gentlemen Geologists

Another twenty years, or so, would ellapse, during which the Great War saw major loss of life and devastation in Europe, until the next investigations of Jamaican rudists would begin. Charles Taylor Trechmann (**Figure 2**) was an independently weathly Englishman; his money had come from his father's cement company (Donovan, 2010). He spent his summers in England but would travel during the cold winter months. His first trips, associated with the British Society for the Advancement of Science, were to Australia and New Zealand (*Evening Post [New Zealand]*, 13th November 1914). But in 1921, he began regular visits to the West Indies – Trinidad, Barbados and Jamaica; but it was with Jamaica that rudists, as well as other fossils, became important and eventually the geology too. Each trip would see him collecting different areas, or returning to areas that had previously proved productive. Trechmann was a fossil man, and above all he used his fossils to date the rocks: De la Beche had promoted general rock types, Barrett and Sawkins had assigned periods, but it was Trechmann who used Jamaican fossils to try and place Jamaican rock units within European stages. In 1921 he returned to Orange Cove in Hanover to look for *Barrettia*, but not finding it he found a local man who had seen F. C. Nicholas collecting there 25 years before – the *Barrettia* location was at Haughton Hall not Orange Cove! His paper redescribing *Barrettia* (Trechmann, 1922) was published the following year. In 1923, he collected extensive material from Logie Green – most of Whitfield's described species – but a whole lot more (F. C. Nicholas' collections in the American Museum of Natural History contain specimens of all these species, but none were described); now Trechmann describes such distinctive forms as: *Biradiolites rudissimus*, *Biradiolites jamaicensis* and *Coralliochama radiolitiformis*. Trechmann also had travelled extensively through France, Austria and Persia; and the knowledge he had gained of European rudists allowed him to recognize that various Jamaican forms were highly distinctive – in 1924 he named *Titanosarcolies*, *Antillocaprina*, and *Praebarrettia*. In 1924, Charles Aldred Matley arrived in Jamaica to begin the Second Government Geological Survey – this time it was for water rather than for mineral resources. Sawkins (1869) had recorded a mineral spring in St. Ann's Great River and so Matley now studied this spring. In doing so, he discovered that it was seeping methane and suggested the presence of petroleum underneath. Although Matley's survey was to be short-lived, he made a rapid investigation of the Cretaceous rocks in St. Ann before he left Jamaica; here he found a Cretaceous limestone from which Trechmann identified Maastrichtian rudists.

Figure 3. Lawrence John Chubb, reproduced from the *Journal of the Geological Society*, volume 13, photograph facing p. 2.

The Third Geological Survey and Chubb's Rudists

The Second World War would intervene before the resumption of studies on rudist bivalves. Professor Verners A. Zans was selected to head the new Geological Survey and arrived in Jamaica in October of 1949. On the 10th of January 1950, Dr. Lawrence John Chubb (**Figure 3**), aged 62, and his wife arrived in Jamaica on Sabbatical leave from University College London, with thoughts of retirement in Jamaica's pleasant climate (Robinson, 1973; *The Gleaner*, 11th January 1950). This was not to be, and later that same year he was appointed as Geologist in the new Geological Survey.

Chubb now took on the task of trying to make sense of the Jamaican Cretaceous with its limestones full of rudists. He began by studying specimens preserved in the museum at the Institute of Jamaica, Whitfield's type specimens preserved in the American Museum of Natural History, the Matley and Stephenson Collections at the United States National Museum, and the Barrett, Trechmann and Woodward Collections in the British Museum of Natural History (Chubb, 1955a). As mapping of Jamaica progressed, collections of fossils were also made by the mapping geologists and worked on by Chubb. Chubb's first paper on rudists was a revision of Whitfield's Jamaican species (Chubb, 1955a). Following this, he described a range of rare or unusual specimens from Jamaica (Chubb, 1956a, b) and extended his ideas to other Caribbean islands (Chubb, 1956c).

Chubb also brought to Jamaica his knowledge of the Geologists' Association and of publicizing geology. In 1955, Chubb, together with other Survey geologists, other professional geologists, and various interested amateurs, formed the Jamaica Group of the Geologists' Association. The augural meeting was held on Friday the 7th of October, and Lawrence Chubb was elected the first Chairman (*The Gleaner*, 10th October 1955).

The International Geological Congress was held in Mexico in September 1956, and this provided Chubb with an opportunity to visit Mexico. Following the Congress, Chubb examined the succession in Chiapas where he made rudist collections and redescribed the succession (Chubb, 1959). In 1957 Chubb became Deputy Director of the Geological Survey.

Because of his knowledge of rudists, Chubb also received collections of specimens from geologists working elsewhere in the Caribbean. Peter H. Matson was mapping south-western Puerto Rico, and sent his material to Chubb for identification. Chubb's identifications were critical for assigning ages to the rocks of Puerto Rico, although too few rudists were sent to Jamaica to accurately assign ages to all of the limestone units. From St. Croix, Chubb received rudists from the Judith Fancy Formation collected by John T. Whetten; this was an interesting assemblage for Chubb, *Barrettia* with *Titanosarcolites* occurring together! This was something that he had argued with Trechmann about many times, Chubb maintained that *Barrettia* and *Titanosarcolites* had separate ranges indicating the Campanian and Maastrichtian, repectively; whereas Trechmann reported that he had found them together in the Stapleton Limestone in the Sunderland Inlier of western Jamaica (Chubb, 1955b; Trechmann, 1960). Chubb's comment included in Whetten's thesis was that the occurrence of *Barrettia* and *Titanosarcolites* together might indicate a series of 'passage beds' between the Campanian and Maastrichtian. But in Chubb's copy of Whetten's (1961) thesis he wrote *"When I wrote this I did not realize that the fossils came from a conglomerate and were therefore probably reworked."*

At the Annual General Meeting of the Jamaica Group of the Geologists' Association in 1959, it was decided to break the link with the Geologists' Association (Robinson, 1980). At the start of 1860, the Geological Society of Jamaica was born, with a new constitution, and Lawrence Chubb as the first president. The following year, Chubb resigned as president at the age of 73.

Following the sudden death of Verners Zans from a heart attack on the 5th of September, 1961, Chubb was promoted to the position of acting Director of the Geological Survey (Chubb and Williams, 1961). In 1963, Lawrence Chubb retired from the Geological Survey and became a Research Associate in the newly formed Department of Geology at the University of the West Indies. But the following year his wife died and he returned to England. His return to England was not what he expected, and he decided he liked Jamaica. He returned to Jamaica and became an Honouray Consultant in the Department of Geology at the University. It was here that he worked on his monograph of Jamaican rudists, but work was slow.

By 1967, new work was progressing on the Cretaceous of Jamaica. Henry Mac Gillavry, who had published on the Cuban rudists in 1937, had a new set of students (H. van Dommelen and Jan Krijnen) working in the Caribbean. The group visited Jamaica in 1967 where they met with Chubb. Chubb's monograph was still not complete, and so he submitted brief descriptions of the new species to the *Journal of the Geological Society of Jamaica* – the article was published in 1968 (Jung, 1970).

Three more years were to pass before finally Chubb's monograph "*Rudists of Jamaica*" would appear in print (**Figure 4**). Its date of publication is given as the 17th of September, 1971, and in it he describes 71 species from Jamaica. Two other important monographs on Caribbean rudists also appeared the same year: Gloria Alencáster de Cserna's "*Rudistas del cretacico superior de Chiapas*," and H. van Dommelen's "*Ontogenetic, phylogenetic and taxonomic studies of the American species of* Pseudovaccinities *and of* Torreites *and the multiple-fold Hippuritids*."

Lawrence Chubb died on the 12th of October, 1971, less than a month after the publication of his monograph. There is no copy of his monograph in the Lawrence Chubb Papers in the West Indies Collection of the University of the West Indies Science Library, nor, for that matter are there copies of the other two works published the same year (Donovan, 1988). Lawrence Chubb lived to see his work published, but probably never saw a copy of the final printed version.

Acknowledgements. *We thank Richard Coutou for reviewing this manuscript and making valuable suggestions for improvements.*

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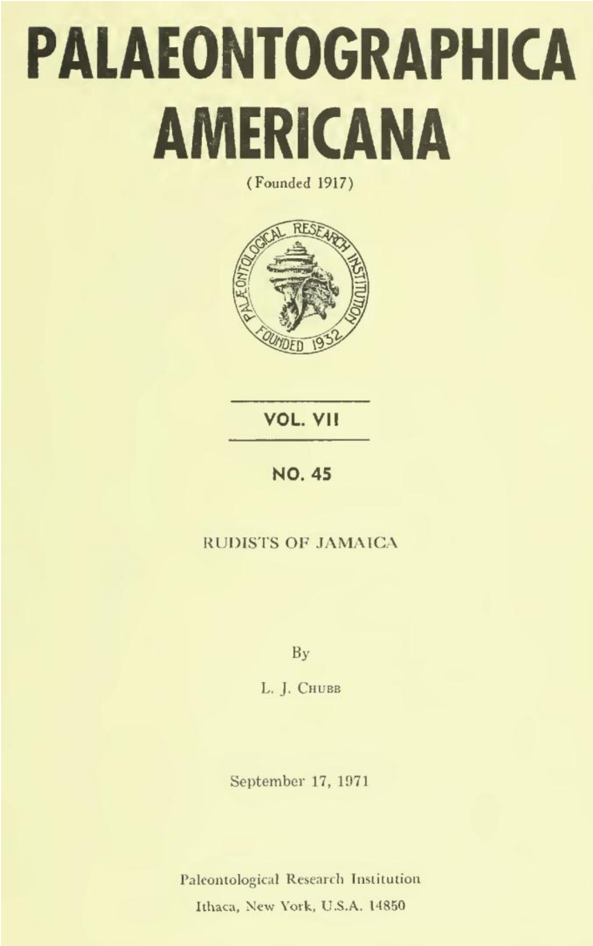

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RUDISTS OF JAMAICA

By
L. J. CHUBB

September 17, 1971

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Figure 4. Cover of Chubb's monograph *"Rudists of Jamaica"* published on the 17th of Spetember 1971; Chubb died on the 12th of October 1971 less than a month after its publication.

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Abstracts: orals (O) and posters (P)

O1. **Rudist higher taxa for the revised Bivalvia volumes of the Treatise on Invertebrate Paleontology**

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Following revision, including nomenclatural corrections according to ICZN rules, the higher taxonomic classification of rudists below has been agreed with Joe Carter (Lead Editor), for the revised Bivalvia volumes of the 'Treatise…' and is proposed here for final review and approval at ICRB 9. Most of the taxa are monophyletic, according to current phylogenetic analyses, though a few paraphyletic taxa (indicated by '!') are retained for groupings that include genera regarded as ancestral to other listed taxa (and further analysis may identify others as being paraphyletic). Polyphyletic taxa have been avoided, as far as present understanding allows. Also included are key diagnostic characters [in square brackets; plus further comments in italics]. Shared derived character states (synapomorphies) are emphasized (*) for monophyletic taxa, though allowance must be made for exceptions due to secondary modification (just as snakes are regarded as 'tetrapods', despite their lacking legs); paraphyletic taxa are defined by primitive character states. References (in J. G. Carter et al., Annotated Bibliography of the Bivalvia, in prep.) will be listed at the meeting. Abbreviations: am, anterior myophore; at, anterior tooth; ct, central tooth; LV, left valve; ol, outer shell layer; pm, posterior myophore; pt, posterior tooth; RV, right valve.

Suborder HIPPURITIDINA Newell, 1965 [ol of fibrillar prismatic low-Mg calcite*, primitively thin (~1 mm), and primitively thick aragonitic inner shell that includes teeth and myophores; = all 'rudists'].

Superfamily Requienioidea Kutassy, 1934 [Attached by LV*, 'normal' dentition comprising two unequal teeth in RV (pt >> at) straddling one ct in LV (plus small incipient tooth at posterior end of ligament in LV); shells limited to prosogyral spirogyrate growth by external parivincular ligament]: 1, Family Requieniidae Kutassy, 1934 [strongly inequivalve, with coiling axis of LV at small angle to commissural plane so that umbo coils across it*, generating extended basal surface along anterior flank; (ol thickened* in more derived taxa); two subfamilies, Requieniinae and Matheroniinae, proposed by Bob Scott]; 2, Family Epidiceratidae! Rengarten, 1950 [sub-equivalve to inequivalve with LV coiling axis at high angle to commissural plane such that umbones coil away from it; stem grouping of three genera].

Superfamily Radiolitoidea d'Orbigny, 1847c [Attached by RV* (+ ligament invaginated*, allowing uncoiled growth of valves, in all but Diceratidae; and 'inverse' dentition* consisting of two main teeth in LV and one (ct) in RV in all except *Diceras* (see below))]: 1. Family Radiolitidae d'Orbigny, 1847c [Crescentic myocardinal arc in LV has straight, sub-equal at and pt straddling reduced ct ridge in RV, plus projecting am and pm both facing outwards onto inner wall of RV*; ol much thickened*, with two differentiated radial bands on postero-ventral flank* (+ celluloprismatic mesostructure* in ol of at least RV in most genera); largest rudist family, but subdivision into phylogenetically supported subfamilies still to be achieved]; 2, ?Family Antillocaprinidae MacGillavry, 1937 [Ligamentary infolding absent*; ol reduced to thin skin, and capillary-like pallial canals present throughout thick inner shell in both valves*; ct socket restricted so that pt is adjacent to body cavity*; Caribbean endemics, possibly derived from Caprinuloideinae, fide Simon Mitchell]; 3, Family Caprinidae d'Orbigny, 1847d [LV pm rooted on posterior valve wall and separated from body cavity by large endomyophoral cavity limited internally by salient lamina running from at to postero-ventral margin*; relatively primitive 'inverse' dentition with teeth still unequal in LV (at >> pt); (+ pallial canals* in inner shell of one or both valves in all but a few primitive genera)]; 3a, Subfamily Caprininae d'Orbigny, 1847d [RV pm a projecting vertical plate separated from posterior valve wall by a narrow ectomyophoral cavity and reaching into LV, where it faces outward onto inner face of LV pm*; canals absent or sparse in RV, except in *Offneria*]; 3b, Subfamily Caprinuloideinae Damestoy, 1971 [LV pm projects into endomyophoral cavity in RV, where it faces outwards onto posterior wall of RV*; canals, when present, in both valves; subfamily limited to Caribbean-Pacific]; 4, Family Caprinulidae Yanin in Menner, ed., 1990 [myocardinal apparatus analogous to Caprininae, though LV pm projects into broad ectomyophoral cavity in RV to face inwards onto wall-like pm*; (pallial canals* present in *Neocaprina* and *Caprinula*; previously placed in Caprinidae, but probably derived from *Sellaea*)]; 5, Family Caprotinidae Gray, 1848 [spatulate pm in LV linking pt to lamina running from at to postero-ventral margin, and partly separated from posterior wall by ectomyophoral cavity, faces onto up-tilted pm ledge in RV*; only two genera, of unclear origins]; 6, Family Diceratidae! Dall, 1895a [primitive external parivincular ligament limits shell to spirogyrate growth; shell sub-equivalve to inequivalve, with prosogyral umbones directed away from commissural plane; two stem genera, *Diceras* (with primitive 'normal' dentition, as in Requienioidea), and *Valletia* (with shortened ligament, loss of at in RV and two unequal teeth in LV (at >> expanded incipient pt))]; 7, Family Hippuritidae Gray, 1848 [ol thickened*, with two infolded pillars in RV matched by oscules in LV*, plus radial canals within ol of LV opening via pores to exterior*; subdivision into phylogenetically supported subfamilies still to be achieved]; 8, Family Ichthyosarcolitidae Douvillé, 1887c [ol thinned and inner shell layer of both valves with capillary-like pallial canals*; 'radiolitiform' myocardinal apparatus*; single genus, *Ichthyosarcolites* (may be derived caprinuloideinid)]; 9, Family Monopleuridae! Munier-Chalmas, 1873 [Capuloid to low-domed LV* with two subequal teeth (at > pt)* straddling erect ct in RV; myophores extend ventrally from hinge plates, with adductor insertion surfaces oriented either parallel to commissural plane, or (*) with one or both LV myophores projecting down into RV so as to face onto their depressed counterparts there; (ol thickened* in some genera)]; 10, Family Plagioptychidae Douvillé, 1888a [essentially similar to #11, though with more extended, coiled LV*, containing pallial canals around anterior, ventral and posterior margins*]; 11, Family Polyconitidae! MacGillavry, 1937 [operculiform to low-domed LV; ol thickened, especially in RV*; subequal teeth in LV (at > pt) straddling erect ct in RV; LV pm a reflexed plate connecting pt to salient ridge running from at to postero-ventral margin*, with ectomyophoral cavity tucked behind it*, and facing down onto ledge-like or depressed pm in RV]; 12, ?Family Trechmannellidae Cox, 1934 [RV ol thickened (*?); ligamentary infolding absent*; inner shell canaliculate throughout in both valves*; pt dorso-ventrally flattened, flanking body cavity and separated from dorsal margin by small accessory cavity*; LV pm adjacent to body cavity, projecting down, and facing outwards, into recess or socket in posterior wall of RV*; name retained in place of Dictyoptychidae Skelton, 1993, despite '*Trechmannella* Cox, 1933' being a junior synonym of *Dictyoptychus* Douvillé, 1905, according to ICZN article 40.1 – sorry!].

O2. A late Jurassic–earliest Cretaceous primitive uncoiled rudist from southwest Japan and its significance for the early evolutionary history of rudists

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Rudists from the Torinosu-type limestones in Southwest Japan, of Late Jurassic–earliest Cretaceous age, have provided new stratigraphic and palaeobiogeographic information on the western Pacific at that time (Sano, S., and P. W. Skelton. 2010. *Epidiceras* (Bivalvia, Hippuritoidea) from the Tithonian–Berriasian Torinosu-type limestones of the Sakawa area, Southwest Japan. *Turkish Journal of Earth Sciences* **19**, 733–743). Since the preliminary report of small uncoiled form (*Monopleura* sp.) from the Shirokawa area of western Shikoku (Sano, S., P. W. Skelton, M. Takei and A. Matsuoka. 2007. Discovery of Late Jurassic rudist bivalves from the Torinosu-type limestone blocks in the Oriai Formation of the Imaidani Group in the Shirokawa area, Ehime Prefecture, Southwest Japan. *Journal of the Geological Society of Japan* **113**, 500–503), similar uncoiled rudists have been discovered from various localities in the Shirokawa and Sakawa areas in Shikoku Island, and the Yura area in Honshu Island (southern Central Japan). They are usually crowded in autochthonous clusters, with calcimicrobes (*Bacinella*) filling the spaces between rudist individuals.

Study of these Japanese specimens and comparison with other primitive right valve-attached rudists (*Valletia auris* Favre from the French Jura, *Monopleura taurica* Pchelintsev and *M. crimica* Yanin from the Crimea, and *Valletia* sp. from Bau, Borneo Island, Malaysia) reveal that these rudists are closely similar to each other in the following characters: small size (1 cm to 2-3 cm in commissural diameter); strongly inequivalve condition, with, usually, a low cap-shaped left valve and an incipiently uncoiled, prosogyral right valve); unequal to sub-equal teeth (anterior tooth larger than posterior tooth) in the left valve; and relatively short or invaginated ligament. These rudists probably represent a single lineage (*"Valletia" auris* form), and had a cosmopolitan distribution across the Old World in the Late Kimmeridgian to Berriasian time, as with *Epidiceras speciosum* and *E. guirandi*. Since this "*Valletia*" *auris* form can be considered as a possible rootstock of all uncoiled rudists, its further comparison with primitive coiled forms (*Diceras* and other *Valletia*) and the earliest genera of two uncoiled lineages (*Pachytraga* and post-Berriasian *Monopleura*) could provide a key to reconstructing the evolutionary origins of the major clade of right-valve attached rudists ('Radiolitoidea' in the proposed classification for the revised Bivalvia volumes of the *'Treatise on Invertebrate Paleontology'*).

O3. Interpreting *Texicaprina* and its relationship with other Albian 'Caprinuloidids'

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Coogan (1973) introduced the genus *Texicaprina* with the type species *Sabinia vivari* Palmer and then stated *"The illustrations of* Texicaprina vivari *(Palmer) which are reproduced here as Plate 3, figures 1-3, do not show adequately the characters which make this species a Texicaprina. Examination of Palmer's types at the California Academy of Science shows that they are badly recrystallized internally, but otherwise appear to be the same species as found in the Edwards Limestone in central Texas."* Coogan (1973) seems to base much of his description of *Texicaprina* on *Sabinia kugleri* Bouwman from Trinidad which is preserved as specimens free from matrix where the teeth, sockets and myophores have been illustrated. Since the type specimens of *Sabinia vivari* are too-badly preserved to serve in fixing the genus *Texicaprina*, the genus *Texicaprina* is considered indeterminate here.

For this study, virtually all the previously described Albian specimens of caprinuloidid/coalcomanid rudists have been examined and photographed. This allows the illustration of the important points that allow the group to be classified into genera. The following morphological features are considered important at the genus level:

1. The form of the ligament. In early forms the ligament is represented by a prominent groove and a comma-shaped invagination close to the posterior tooth. In later forms, the external groove is lost and only the comma-shaped invagination remains.
2. The form of the myophores. Early forms have blade-like myophores; later forms have the anterior myophore broken up as a series of protuberences separated by pallial-canal-bearing 'slots'.
3. The distribution of pallial canals. These range from a marginal band in early forms and show a progressive invasion of canals into the inner shell layer and into some of the myocardinal structures.
4. Cross-sectional shape of the valves. This is rounded in earlier forms, rounded, square or rectangular in later forms.

During the Albian there is a progression from rounded forms with a ligamental groove, blade-like myophores and a single row of pallial canals (e.g., *Coalcomana*); to rounded forms with no ligamental groove, and the anterior myophore formed by a series of blebs. The later invites a comparison with early 'antillocaprinids' with the bleb like anterior myophore giving rise to the anterior myophore and the additional toothlets in certain derived forms.

O4. *Vaccinites marticensis* (Douvillé, 1891) and some insights on Coniacian-Santonian hippuritids evolution

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Vaccinites marticensis was first reported by Douvillé 1891 (Douvillé, H. 1891. *Mémoires de la Société géologique de France. Paléontologie* **1**, 1-31 + 1-3) from Val d'Aren, Var, France as *V. corbaricus* (race *marticensis*). Toucas (1904 [Toucas, A. 1904. *Mémoires de la Société géologique de France. Paléontologie* **12**, 65-128 + 8-17]) recognized it as a valid species, illustrated two transverse sections of the right valve and a picture of the left valve, and included it in one of his *Vaccinites* groups or evolutionary lineages, the *V. dentatus* Group. The species has been reported from southern France and northern Spain; a poorly preserved transverse section of a right valve from Serbia was attributed also to this species by Pašić (Pašić, M. 1957. Geoloski Institut 'Jovan Zujović' *Posebna Izdana* **7**, 208 pp. + 38 pl. + 1 map).

Subsequent taxonomic and evolutionary studies on the genus have challenged the validity of many of the *Vaccinites* species considered by Toucas and also of some of the evolutionary lineages he recognized within (See: Bilotte, M. 1985. *Strata* (2) **5**, 438 pp; Vicens, E. 1992. *Geologica Romana* **28**, 119-161; Simonpietri, G. 1999. Ph. D. Thesis, Université de Provence, 181 pp. + 42 pl. + 31 annex).

The study of numerous specimens of *V. marticensis* from different fossil localities in south-central Pyrenees allowed us to characterize the morphologic features of both valves and their intraspecific variability, to differentiate it from other species, and to bracket its stratigraphic distribution with the inoceramid and ammonites zonations. We conclude that *V. marticensis* is a valid and biostratigraphically useful species.

Moreover, we observed that many *Vaccinites* species, but also species of other hippuritid genera, significantly split during the Coniacian and Santonian. Many of these species may finally appear as valid species after characterizing all their morphologic features, not only the biometric data on the infolds of the inner shell layer, but also as useful species after precisely bracketing their stratigraphic distribution, as we did with *V. marticensis*. Consequently, we postulate that another evolutionary model should better contribute to the understanding of the hippuritids evolution, instead of the lineal parallel evolutionary model considered until now by most authors. Also, the stratigraphic value of hippuritid species should become enhanced.

O5. **The state of the knowledge of the genus *Pseudopolyconites***

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The late Campanian lithological and faunal succession cropping out in the zone of Bačevica and Vrbovac (Eastern Serbia) has been examined after many field investigations. The scope of the latest investigations has been mainly aimed at finding examples of the rudist genus *Peudopolyconites*. Several dozens of specimens of this rudist bivalve have been found and more than 90% of them have been recovered in a small area where a rich monospecific assemblage has been observed. The individuals are always isolated, not reworked, mostly in growth position and fully articulated. The finding of *Pseudopolyconites* outside this small area is undoubtedly rare. Moreover, the level rich in these specimens occupies a precise stratigraphic position along the Bačevica section. Thus, this research strengthens the conviction that all the 18 (or 20?) instituted species may be regarded as simple eco-morphotypes.

Other examples of *Pseudopolyconites* have been found within mixed carbonate-siliciclastic or volcanoclastic late Campanian successions (e.g. Eastern Serbia, Bulgaria and Turkey) and also within coeval carbonate successions cropping out in Apulia (Southern Italy), Friuli (NE Italy), W. Slovenia, Croatia, etc. Consequently, new species classified mainly on the base of one criterion only (i.e., the change in shape of the ligamental ridge near the commissure of the genus in question) were instituted. It is emphasized that, in spite of laborious researches carried out in Beograd, the original paleontological material in many of the fore-mentioned cases has not been found, thus making comparative analysis impossible between the holotypes and new isotypes.

Pejović and Sladić-Trifunović (1977) recognized Santonian-early Campanian ancestral representatives of the genus *Pseudopolyconites* in a giant olistolith at Lesak (Serbia) and in the coeval Gosau-type facies of Dealul Magura (Apuseni Mountains, Rumania). The material illustrated by the two Serbian rudistologists shows many of the characteristics of the *Pseudopolyconites* genus but unfortunately the original examples in the first case seem to have vanished; moreover, at present the Serbian locality is interdicted. Our research carried out in the Rosia area (Dealul Magura) has been unproductive till now but the holotype of *P. hirsutus* is at the Geological Museum of Bucharest.

Pseudopolyconites shows a wide distribution in the late Campanian transgressive mixed siliciclastic-carbonate successions in Turkey, from the Istanbul zone (NW of Turkey), Tuz Lake basin (Central Anatolia) to Antakya area (Southeastern Anatolia). The Turkish specimens of this genus are well-preserved, isolated, generally large and in growth position giving possibility to observe all internal and external characteristics of both valves.

Sladić-Trifunović (1980) named Pseudopolyconitidae a new family (sic) within the Hippuritacea superfamily. According to this Author (2004) both the genera *Fundinia* and *Kurtinia* can be regarded as members of the family. But, both *Fundinia* and *Kurtinia* have no tubular excrescences emerging from the shell wall which are the most remarkable elements in the structure of the *Pseudopolyconites*. To sum up, the treatment of the phylogenetic relationships within the Pseudopolyconitiidae is still much too tentative and inaccurate and so is beyond our comprehension.

O6. Exceptionally preserved hippuritid rudists from Puerto Rico – a new analysis of the New World hippuritids

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Multiple-ray hippuritid rudists, exemplified by *Barrettia* Woodward, are amongst the most distinctive fossils of the late Cretaceous of the New World, with numerous forms having been described. Preservation, however limits the description of full morphological features of these forms; either, because they are encased in hard rock and can only be investigated by cutting sections, or because of incomplete or poor preservation. Critical features that have not been described for many genera include full details of their dentition and particularly the form of their left valve pore systems. Norman Sohl's studies of New World Cretaceous gastropods led him to collect vast quantities of material from Puerto Rico, much of which resides in the United States National Museum collection at the Smithsonian Institute in Washington D.C. Amongst this material is a large collection of silicified material from the El Rayo Formation of Puerto Rico. In 2009, the two senior authors of this paper were able to carry out a detailed analysis of this material. This unique collection includes exceptional specimens of rudist bivalves with the shell partially to completely silicified. It presents an unrivalled opportunity to understand the morphology of various rudists, particularly the hippuritids, which are represented by three species belonging to three different genera: *Caribbea*, *Laluzia* and *Parastroma*.

Caribbea Grubic. This is a hippuritid with two primary infolds (P1 and P2) and an incipient ligamental ridge (infold). The PT and AT have ridges that fit into channelled grooves (sockets) on the CT and inner shell layer of the RV. The posterior myophore fits into an embayment in the inner shell layer; the anterior myophore is attached directly to the unmodified inner shell layer. The outer shell layer of the RV is composed of funnel plates that are separated by irregular dendritic radial muri or pustules. Pallial canals are absent in the inner layer of the LV. The radial canals of the LV are overlain by a pore system characterized by thin-walled irregular to polygonal canals that are subdivided to form porules by trabeculae. The pores are irregularly arranged in the central part of the LV, but form radial lines over narrow radial canals in the limbal zone.

Laluzia Götz and Mitchell. This is a hippuritid with three primary infolds (P0, P1 and P2) and multiple secondary infolds. The PT and AT have ridges that fit into channelled grooves (sockets) on the CT and inner shell layer/PM lamella of the RV. The PM fits into an embayment in the inner shell layer that is separated from the body cavity by a lamella; the anterior myophore is attached directly to the unmodified inner shell layer. The outer shell layer of the RV is composed of funnel plates that are separated by irregular dendritic radial muri. Pallial canals are absent from the inner shell layer of the LV. Vertical canals penetrate the outer zone of the LV above the rays, and radial canals occur in the inner zone. The pore system consists of irregularly distributed, thick-walled irregular pores.

Parastroma Douvillé. A multiple-ray hippuritid in which the rays have been lost except for the knobs of P1 (round) and P2 (parallel sided) which are isolated (in transverse sections) within the complex inner shell layer of the RV. The inner shell layer consists of radial and concentric partitions and tabulae which are arranged to provide a series of radial ridges and furrows on the apertural surface. The PT and AT fit into embayments on the margin of the body cavity, the short conical PM fits into a socket, covered with connellae, embedded in the inner shell layer, and the AM attaches to a ledge bearing connellae on the margin of the inner shell layer. The LV has strongly developed buttresses, and a series of double vertical canals that open adapically into rectangular fields that are overlain by an intricate domed mesh formed of delicate trabeculae.

We use the new information, coupled with information from various other hippuritids from the New and Old World to understand the evolution of American hippuritids.

O7. Changing the dynamic of a rudist collection

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Research collections in museums form a vital part of the scientific resource for paleontologists. Such collections are not a static resource but one that changes over time. The changes may be the result of incoming specimens but more often stem from increased curation of the collection, research activity, or the use of new techniques. The rudist collection at the Non-vertebrate Laboratory of the Texas Natural Science Center illustrates these collection dynamics.

Between 2002 and 2005 the collection size expanded. Very little could be attributed to new field collection. Change resulted from the creation of a taxonomic rudist section which required an extensive search and inventory to find the location of specimens. Additional research visitors brought their expertise, recognizing many specimens as being rudists. By 2008 single rudists evolved into groups collected from the same sections, sliced specimens found their relatives and the specimens were linked to papers, original photographs and acetate peels. The collection was becoming a much more useful resource.

From 2005 to 2011 there was another change, this time in diversity. Some was the result of new collecting but mainly came from the expanded and updated taxonomy, enabled by a rudist congress, grant supported research identification, and developing expertise in-house. The fraction of the collection merely classified as being a rudist shrank in size. This change has great relevance providing a far more accurate picture of the strengths of the collection.

More recent changes reflect the use of new techniques to examine specimens, particularly the use of computed tomography and other imagery. These are building up a digital collection of image data, easy to access from a distance. The online portion of the collection not only provides searchable data related to individual specimens, it also places those data into an exciting new environment. Georeferenced specimen collection localities are related geographically, geologically, and with the aid of geo-rotation related to deep time plate positions.

O8. **Provenance, use and interpretation of the Rudist Collections at the University of the West Indies Geology Museum (UWIGM)**

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The study of rudist bivalves in Jamaica and the Caribbean has been taking place since the mid 1800s with Woodward (1862) who studied *Barrettia*; Whitfield (1897a, b) who also studied *Barrettia*, which he did not believe it was a rudist, other 'typical' rudists; Trechmann (1951) who studied various groups and deposited collections in many museums around the world including Natural History Museum London and the Institute of Jamaica (IOJ); Chubb (1955, 1968, 1971) in his revision of rudists of Jamaica viewed the Trechmann collection at the IOJ where he added his notes to some of Trechmann's original labels. Recent work (1998 to present) carried out by Mitchell, Gunter and Ramsook has develloped the regional aspects of this bizarre group building on the work of those before, but also bringing into sharp focus the role of the UWIGM collections in educating other workers about Jamaican rudists.

The UWIGM, through initial acquisitions and through the transfer of material from the Institute of Jamaica, the Geological Survey Department and the Department of Geography and Geology research collections (through staff and graduate students) have a collection of material that shows the abundance and diversity of rudist species in Jamaica as well as parts of the Caribbean and Central America.

This paper illustrates the provenance of the collections and how its use has helped in the definition, characterization and revision of species and nomenclature. An effort is made here to document the items in the collection and link them to various publications both new and old in order to show how the groups and specific species have been interpreted over time.

O9. **Rudist biozonation of the Upper Cretaceous (Upper Turonian – Maastrichtian) of the Mediterranean Tethys and the Arabian Plate**

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Rudist biozones have been established for the Upper Turonian – Maastrichtian of the Mediterranean Tethys and the Arabian Plate. These biozones are based on ranges of taxa derived from occurrences at localities that have been age-dated with strontium isotope stratigraphy. Numerical ages have been obtained for 80 localities, with a focus on species-rich occurrences, and/or type localities of species with a wide geographical distribution. In total, more than 380 samples have been analysed, and more than 200 Sr-isotope ratios have been used to derive numerical ages after screening for diagenetic alteration.

Biozones are based on relatively few taxa that are abundant, have a well-established taxonomy, and are easy to identify. Most zones are interval zones, defined by the first occurrence of the nominal taxon. Seven biozones are introduced for the Upper Turonian to Maastrichtian of the Mediterranean Tethys, and three biozones are defined for the mid-Campanian to Maastrichtian of the Arabian Plate. Biostratigraphic resolution is improved by phyletic size increase demonstrated for several species of hippuritids, and by associations of characteristic taxa. Interestingly, ranges of Turonian-Santonian species are significantly shorter when compared to species that originated in the Campanian.

Many taxa previously considered to indicate the Maastrichtian range as low as the lower Campanian, while some species that were thought to be of Santonian-early Campanian age have significantly older occurrences. No proven records of the genus *Vaccinites* appear to exist after a mid-Campanian-extinction event in the Mediterranean Tethys, but the genus ranges into the Upper Maastrichtian of the Arabian Plate.

The numerical ages for a large number of key localities of Tethyan carbonate platforms have important implications for stratigraphical ranges of associated biota, such as benthic foraminifera and calcareous algae.

O10. **American rudist zones for the Turonian to Maastrichtian time interval**

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A revision of the rudist faunas of the late Cretaceous of the American region based on extensive new collections (Jamaica, Puerto Rico) and the examination of museum collections has resulted in a zonation scheme for the Turonian to Maastrichtian of the tropical American region. The scheme has its greatest application in the 'core tropics' but may be applicable at some higher latitudes. The correlation of the rudist zones to the chronostratigraphy is based on a combination of other biostratigraphically important fossil groups (foraminifers, nannofossils; ammonites, crinoids; inoceramids) together with Sr-isotope values. The scheme is simply highlighted here:

Late Turonian: *'Hippurites'* – Mexico

Coniacian: *Vaccinites* spp. – Mexico

Late Santonian: *Barrettia praecoatesi* – Jamaica; Cuba?

Early Late Campanian: *Barrettia coatesi*; *B. ruseae*; *Whitfieldiella luceae*; *Vaccinites muellerriedi* – Jamaica; Puerto Rico; Cuba

Late Early Campanian: *Barrettia dommeleni*; *Barrettia irregularis*; *Whitfieldiella catherinei*; *Macgillavryia nicholasi* – Jamaica; Puerto Rico

Early Middle Campanian: *Barrettia douvillei*; *Parastroma sanchezi*; *Whitfieldiella* sp.; first *Titanosarcolites* sp.; *Chiapasella cubensis*; *Macgillavryia nicholasi* – Puerto Rico; Cuba; St Croix

Late Middle Campanian: *Barrettia monilifera*; *Whitfieldiella gigas*; *Parastroma trechmanni*; *Titanosarcolites* sp.; *Chiapasella cubensis*; *Macgillavryia nicholasi* – Jamaica; Chiapas

Early Late Campanian: *Whitfieldiella zansi*; *Parastroma guitarti*; *Titanosarcolites* sp.; *Chiapasella cubensis*; *Macgillavryia nicholasi* – Jamaica; Puerto Rico; Cuba; San Luis Potosi

Late Late Campanian: *Laluzia peruviana*; *Caribbea muellerriedi*; *Parastroma guitarti*; *Titanosarcolites* sp. ; *Macgillavryia nicholasi* – Puerto Rico; Cuba; San Luis Potosi

Early Maastrichtian: *Laluzia armini*; *Caribbea muellerriedi*; *Titanosarcolites* sp.; *Macgillavryia nicholasi*; *Tampsia* – Jamaica; San Luis Potosi; Cuba

Early Late Maastrichtian: *Caribbea muellerriedi*; *Titanosarcolites giganteus*; *Chiapasella radiolitiformis*; *Macgillavryia nicholasi* – Jamaica

Mid Late Maastrichtian: *Caribbea maldonensis*; *Praebarrettia sparcilirata*; *Titanosarcolites*; *Chiapasella aguilae*; *Macgillavryia nicholasi* – Jamaica

Late Late Maastrichtian:*Caribbea* sp. nov.; complex *Titanosarcolites*; *Macgillavryia nicholasi* – Jamaica.

O11. **The biostratigraphy of the Maldon Inlier, parish of St. James, north-western Jamaica**

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The biostratigraphy of the Maldon Inlier in the parish of St. James is described and discussed. The Upper Maastrichtian succession consists predominantly of mudstones (and subsidiary sandstones) with intervening rudist-bearing limestones. The limestones of the inlier yield a distinct rudist fauna characterized by the recumbent genera *Parasarcolites* and *Titanosarcolites* with diverse colonial corals. Collections indicate at least two species of *Titanosarcolites* are present in the inlier along with other potentially novel antilocaprinid rudists collected in particular from the stratotype of the Maldon Formation at Shaw Castle. The mudstones and sandstones contain fossiliferous horizons with non-rudist bivalves, solitary corals, gastropods, echinoids, brachiopods, foraminifers and ostracods, amongst others. The relatively simple structural geology, well-defined lithostratigraphy and age dates provided by strontium isotope ratios make the Maldon Inlier highly useful as a regional biostratigraphical reference point.

O12. Albian Sea Level Cycles and Rudist Evolution

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The Albian in the Tethys was a time of great diversity change and is a laboratory to evaluate processes affecting diversity. Many Albian groups of organisms experienced evolutionary diversification. Species diversity is directly related to habitat area. Rudist generic diversity is correlated with long-term Albian sea-level cycles, which controlled the area of marine habitats. The Caprinidae clade diversified during the Barremian to Early Aptian but their numbers were depleted following OAE1a. They diversified again beginning in the Early Albian and through the Cenomanian when they became extinct at OAE2. Albian generic diversity is most evident in the Caribbean Province rather than in the Old World area of the Mediterranean and Middle East because widespread long hiatuses interrupt the Albian section.

At least eleven Albian deepening-shallowing depositional cycles are recorded on the Texas Comanche shelf. Nearshore transgressive facies siliciclastics are overlain by offshore deeper water marls. Maximum flooding and cycle turnaround are indicated by marl with ammonites and diverse mollusks and echinoids. Shoaling facies are rudist buildups, carbonate grainstone, mixed evaporite-mudstone, and shelf wackestone. The top surfaces of some cycles are iron-stained, bored hardgrounds. During the 15.5 myr to 11.6 myr long Albian Age long-term sea level flooded approximately 40 x 106 km^2 of continental area, an increase of 60%. During this same time the number of rudist genera increased from 9 to 19, an increase of 47%. 1) Generic rudist diversity increased during the time of maximum flooding, and 2) diversity increased as the frequency of cycles increased during the Late Albian. Sea level rise increased the area of marine habitats and rudists diversified into those habitats. This conclusion is tested by the increase in the number of ecological morphotypes through the Albian.

Albian Caprinidae were either elevators or recumbents, and some species adapted to both habits. These two morphotypes were well adapted to the shelf margin, ramp and inner shelf. During the Early Albian three elevator to recumbent genera were part of the shelf and shelf margin bioherm paleocommunities along the Texas and in southwestern Mexico. During the Middle Albian three elevator to recumbent genera, *Caprinuloidea*, *Planocaprina* and *Texicaprina* formed shelf margin to inner shelf buildups in Texas and Mexico. The greatest increase in Caprinidae genera and species occurred during the Late Albian following the expansive continental flooding of North America. The elevator caprinids *Guzzyella*, *Jalpania*, and *Muellerriedia* diversified in shelf bioherms upon the Mexican island arc atolls. On the Gulf Coast shelf margin and inner shelf the elevator-recumbent *Kimbleia* and the elevator *Mexicaprina* were new genera. The record of Caprinidae diversification in the Mediterranean region is incomplete because of tectonic effects resulting in widespread intra-Albian hiatuses and the encroachment of siliciclastic facies.

O13. Foraminiferal biostratigraphy and palaeoenvironmental analysis of some late Cretaceous basinal successions of Jamaica

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St. Ann's Great River and the Grange Inlier together, expose a ~2,000 m thick Coniacian to Maastrichtian sedimentary succession. These successions contain macrofossils (ammonites, inoceramids, crinoids and some rudists), microfossils and nannofossils that allow correlation with stage stratotypes. More than 30 species of planktic foraminifers have been identified including forms of high biostratigraphic significance. Six biostratigraphic zones based on foraminifer biovents are recognised. The zones identified are: *Dicarinella primitiva*, *Dicarinella concavata*, *Pseudotextularia nuttali* and the *Sigalia carpatica* interval zone, *Sigalia decoratissima* total range zone, *Globotruncana ventricosa* interval zone and the extinction of the *Sigalia* group. Palaeo-water depth is calculated using regression analysis (van der Zwaan 1990) and shows a shallowing upward trend from lower bathyal (1,200 m) to upper shelf/neritic (136 m).

Rudist bivalves in growth position occur at three intervals in the succession. In the Clamstead Formation (*Uintacrinus socialis* zone of the lower Upper Santonian) rare specimens of *Barrettia* sp. nov. (in growth position) and *Antillocaprina* cf. *occidentalis* (Whitfield) (reworked) are found. The in situ assemblage occurs with solitary corals, inoceramids and ammonites, but no algae. The second level occurs at the base of the Drax

Hall Formation (upper Middle Campanian) where rare *in situ* and common reworked rudists are present. The fauna includes *Barrettia multilirata* Whitfield, *Plagioptychus* sp., *Durania* sp. and can be equated to the classical Haughton Hall Formation rudist beds at Green Island in Western Jamaica. The upper interval with rudists is the Lime Hall Limestone (attributed to the upper Upper Campanian here) which contains an abundant assemblage of *Whitfieldiella* sp. nov., *Bournonia cancellata* (Whitfield); *Biradiolites rudissimus* Trechmann; *Macgillavryia nicholasi* (Whitfield); *Antillocaprina* sp., and *Plagioptychus* sp. The foraminiferal palaeowater-depths suggest that rudist bivalves were not strictly restricted to the shallow shelves, but could survive, albeit in small numbers, in deeper clastic environments.

O14. Rudist palaeobiogeography in relation to the Pacific in the Late Jurassic and Early Cretaceous

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The record of Late Jurassic to Early Cretaceous rudist evolutionary history in relation to the Pacific can be split into four phases:

1. By Tithonian to Berriasian times, a cosmopolitan rudist fauna of low diversity extended along the Atlantic-Tethyan belt, from at least Nova Scotia to Japan, including *Epidiceras* species, of large and small shell size, and small, primitive uncoiled rudists currently placed in either *Valletia* or *Monopleura*. No rudists of this age are yet recorded from Pacific seamounts, nor can their presence there be inferred, as the lack of E-W provincialism precludes identification of disjunct endemism either side of the Pacific.
2. No definitely Valanginian-Hauterivian rudists are known from the Caribbean, Pacific or Japan.
3. E-W rudist provincialism began in the Barremian-Early Aptian, with caprinuloidinid caprinids evolving in the Caribbean province, and also in the Early Aptian Pacific (e.g., *Conchemipora*, Resolution Guyot). Meanwhile, some caprininid genera were more cosmopolitan, extending from the western Tethyan to the Caribbean regions, e.g., *Caprina*, *Offneria*, although some provincialism is recognized at the species level (as well *Pseudocaprina* in the Caribbean). The discovery of internal moulds of *Pachytraga* in calcareous sandstones of probable Barremian age in the Osaka Formation in Japan suggests immigration from a Pacific refuge, given the absence of the genus from the Atlantic/Tethyan region for most of the Barremian. A corresponding age for the earliest rudists recovered from Pacific seamounts is consistent with this hypothesis. Another internal mould from the Osaka Formation, of possible Aptian age, reveals multiple rows of canals in the right valve and a caprinuloidinid-type myocardinal arrangement, providing the oldest record of a complete trans-Pacific faunal connection. This phase coincided with the acme of the first major episode of Cretaceous superplume-related volcanothermal edifice-building in the Pacific.
4. The Late Aptian-Albian saw significant Pacific involvement in rudist evolution. We recognize three new polyconitid taxa of Late Albian age: two, from seamounts, are of elongate elevator morphotype; a third, from Cebu and Japanese Seamounts (collaboration with Yasuhiro Iba), is a canaliculate derivative of Late Aptian *Praecaprotina*, known from Japan and Daiichi-Kashima Seamount. Moreover, certain polyconitid taxa described from Mexico (*Tepeyacia*), Japan (*'Caprina' uwajimensis*) and the Pelagonian Platform (*?Horiopleura juxi*) are united by possession of a tightly pleated outer shell layer. Meanwhile, revision of *Caprina mulleri*, from Mid-Pacific guyots, confirms its original generic attribution, emphasizing similarities with the co-eval *C. choffati* from Iberia, and Cenomanian C. adversa, hence a disjunct Late Albian distribution of the genus in the Mediterranean Tethys and the Pacific.

These distributional data indicate that Pacific seamounts hosted rudist associations from at least the Barremian, allowing complete trans-Pacific links among certain taxa during the Aptian. Thereafter, the Pacific remained an important rudist faunal province to the Late Albian, with taxa derived from both the western Pacific (despite the demise of Japanese platforms by then) and Mediterranean Tethyan areas.

O15. Facies diversification and rudists during OAE 1a – a case study of Lower Aptian platform carbonates on the island of Vis (Adriatic Sea, Croatia)

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The Early Aptian (Early Cretaceous) was a time of significant environmental change affecting low-latitude Tethyan carbonate platforms. The Adriatic-Dinaridic Carbonate Platform domain (ADCP) was the largest shallow-water platform domain in the peri-Adriatic region. While pre-Aptian successions of the ADCP are dominated by intertidal environments, the beginning of the Aptian marked the onset of subtidal, more open-platform environments, characterized either by *Lithocodium-Bacinella* or skeletal, rudist-rich facies. Apart from the northern (marginal) part of the ADCP that is characterized by rudist-coral-stromatoporoid communities which flourished within a high-energy belt, other areas of the platform are characterized by oligospecific associations of *Toucasia* and *Requienia*. *Offneria*-bearing high-energy deposits are to date reported just from a few occurrences.

An excellent exposure of Lower Aptian shallow-water carbonates is found on the island of Vis (Dalmatia, Croatia). The Lower Aptian facies stacking within a ca. 90 m thick succession is probably the most lithologically diversified intra-platform succession in Croatia. It is characterized by thick-bedded dolostones, thin-bedded marly limestones, dolomitized mud-mounds, rudist- and chondrodontid-rich sedimentary bodies including high-energy *Offneria* shoals, orbitolinid tempestites, chert horizons, and algal-rich subtidal facies. Transitions within the facies are mostly sharp.

A thick-bedded dolostone unit comprises the lowermost 30 m of the succession. *Lithocodium-Bacinella* and *Palorbitolina* are observed in limestone lenses that escaped dolomitization. The dolomitized unit is recognized as equivalent to the Lower Aptian Kanfanar unit (Istria). Above the dolostone unit, ca. 60 m of limestone with diverse facies characterize the rest of the Lower Aptian succession. Integrated biostratigraphy and isotope chemostratigraphy (carbon, strontium) reveal the Lower Aptian age of the strata deposited during OAE 1a. Sr-isotope ratios of requieniid shells from 15 horizons within the limestone unit, indicate similar Early Aptian numerical ages (Bedoulian, 123 Ma). This is slightly younger than the recently improved age of the *Lithocodium-Bacinella* unit of the Istrian reference sections at Kanfanar (124-125 Ma), implying larger accommodation space (approx. 70 m) during the Early Aptian at the Vis locality, or less erosion during subsequent Aptian-Albian subaerial exposure.

Although the ADCP obviously experienced a prominent relative sea-level rise at the beginning of the Early Aptian and during OAE 1a, intraplatform thickness variations of up to 70 m are the result of synsedimentary tectonics. Our data from the island of Vis show that significant facies diversification was triggered by OAE 1a, while facies stacking pattern was driven by coeval sea-level changes. However, shallow-water carbonate deposition has been continuous during and after the OAE 1a, up to the regional Aptian-Albian emergence.

O16. Cyclic rudist settlement on an Aptian continental margin of Northern Iberia

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Hard and dense red rudist limestones were long-termed exploited at several localities between Bilbao and Zarauz (Northern Spain). Due to mining by the cable method in several outcrops nearby the village Eren□o large smooth plains could be studied in great detail. More than 30 units with rudists in life position could be recognized. The rudist associations built elongate patches surrounded by muddy sediment. Due to reoccurring disturbances, probably caused by tectonic movements, the patches could not survive. After a period with muddy sedimentation and the deposition of floatstones a strong recolonization took place. Probably a reef barrier separated the restricted rudist environments from the ocean.

O17. Quantitative Palaeobiology, Reproduction and Seasonality in *Biradiolites mooretownensis*

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Up to the Late Cretaceous, rudist bivalves were the dominant benthic carbonate producers on tropical to sub-tropical carbonate platforms. Yet questions concerning the biology of rudist bivalves remain unanswered to a large extent. In this study a densely packed bouquet of the small radiolitid rudist *Biradiolites mooretownensis* Trechmann has been examined in terms of reproduction, growth, and seasonality. The sample originates from the Rio Grande Limestone (Lower Maastrichtian) in the Blue Mountain Inlier of Jamaica, which developed in a shallow marine setting along the margin of the Caribbean plate. It has been influenced by island arc volcanism and crops out as impure, volcaniclastics-rich limestones. Three-dimensional, high-resolution, quantitative analysis allows detailed evaluation of an *in situ* rudist association. The true-colour tomograms were produced in the Heidelberg Grinding Tomography laboratory using a G&M MPS 2R 300S precision grinding machine in combination a high-resolution flat bed scanner. Along with this study a total of 1.237 consecutive tomograms with a vertical spacing of 0.1 mm have been produced and digitally measured for coverage, packing density, spat density, survival time and mortality, accommodation space and ontogeny. Furthermore, growth rates, reproduction and cyclicities have been analysed using isotope analysis and statistical software.

As results, the bouquet shows constant coverage of about 60%, stable packing density of 3.2 individuals per cm2 and continuous occurrences of spat. Time series analysis (spectral analysis) using PAST software reveals a cyclic occurrence of spat every 14.9 mm in vertical growth. $\delta^{18}O$ isotope analysis of the outer shell material shows a temperature cyclicity of 14 mm. In consequence, reproduction following annual cycles can be assumed. Population dynamics of the species *Biradiolites mooretownensis* Trechmann show a mortality rate of 46.4% in the first 3 mm of vertical growth. Over 93% of the initial spat dies before the adult age of 15 mm shell height or 1 year, respectively. Two mortality peaks in the juvenile's life at 4 mm and 10-15 mm shell height either represent important obstacles in the ontogenic development of the species or reflect external influences. Furthermore, the chance of surviving the first year is directly connected to the space available for settlement. In average, settlers that outlive the first year initially had 9.3% more space available than spat perishing within the first year.

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O18. Contrasting patterns in rudists and corals from the uppermost Mastrichtian of Jamaica

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The Jamaican Cretaceous succession includes rich associations of corals and rudists of latest Maastrichtian age exposed in several inliers across the island. Large collections with 1000's of specimens from different Jamaican inliers has allowed for a comparison of local the distribution patterns of these two important components of the benthic fauna.

As a whole, species richness in the late Cretaceous coral fauna of Jamaica is as high as at any subsequent time. Coral diversity, the relative abundance of coral taxa and the distribution of coral growth forms all show considerable variation between different lithostratigraphic units and inliers. This high beta diversity in the Jamaican coral fauna contrasts markedly with patterns seen in rudist bivalves. Rudist faunas are relatively homogenous across different inliers with little differences in richness, diversity or relative abundance between units.

These contrasting patterns suggest that the composition and structure of coral and rudist communities was largely controlled by distinct paleoecologic factors in the latest Cretaceous.

O19. Calcite / aragonite ratios in rudist bivalves: Quantitative data based on serial grinding tomography

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Rudist shells are composed of an outer calcitic and an inner aragonitic shell layer but the relative proportion of calcite and aragonite varies distinctly between families and probably even at the genus level. These variations are linked to the macro evolutionary history of rudist bivalves, which is characterized by quick radiations punctuated and finally terminated by extinction events. Detailed studies of these taxonomic mineralogical shifts are not available due to the lack of a method to obtain reliable quantitative data.

This presentation is focused on the first quantitative data of calcite / aragonite (C/A) ratios of rudist bivalves, quantified with a new tomographic method, based on automatic serial grinding and digital scanning. This method supplied more than 2000 tomograms with a horizontal resolution of 1200 dpi and a vertical resolution between 51 and 254 dpi. In all this data the calcite and aragonite layers were optically analyzed and then quantified with proprietary software. We calculated the C/A ratios of the families Requieniidae, Caprinidae, Monopleuridae (parafamily), Polyconitidae (parafamily), Plagioptychidae, and Hippuritidae. For example, *Toucasia carinata* has a C/A ratio of 2.55, *Coralliochama orcutti* has a C/A ratio of 0.6, *Polyconites hadriani* has a C/A ratio of 1.19 and a specimen of *Vaccinites sulcatus* has a C/A ratio of 2.76. These results were evaluated statistically to show that each rudist bauplan has a minimal vertical resolution that still provides reliable data.

Quantitative, volume based C/A ratios allow a better differentiation between aragonite dominated and calcite dominated rudists. In the future, C/A ratios might even act as proxy for acidification events in the Cretaceous. C/A ratios could also unravel adaptation strategies of reefal ecosystems to environmental change in general.

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O20. Quantification of the calcite and aragonite fluctuations in *Polyconites hadriani* from the Lower – Middle Aptian of Iberia

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The species *Polyconites hadriani* Skelton et al., 2010 is the oldest known species of the genus *Polyconites*. It appeared in Iberia in the middle Early Aptian coinciding with the carbon cycle perturbation (OAE1a) most probably evolving from the genus *Horiopleura*. During the latest Early Aptian the aragonitic dominated rudists (principally, caprinids) became less abundant and more calcitic rudists (*Polyconites* and *Toucasia*) dominated carbonate platforms in Iberia. The thickened calcitic shell layer (relative to the aragonitic inner shell) of *Polyconites hadriani* compared with its ancestor (*Horiopleura*) could have been an evolutionary response to environmental change. Therefore the aim of the present study is the quantification of the calcite to aragonite ratio in the *P. hadriani* - *P. verneuili* lineage through time.

The studied specimens are from the Galve sub-basin of the western Maestrat Basin and from the South Iberian basin of the eastern and southern Iberian Chain respectively. The ages of the currently investigated specimens range from the latest Early Aptian (Dufrenoyia furcata biozone) to the early Middle Aptian (Epicheloniceras martini biozone). The chronostratigraphy is based on strontium isotopes and biostratigraphy (ammonites, foraminifers and rudists).

Transverse tomograms through *Polyconites hadriani* are obtained with a grinding tomography method. These tomograms are stacked to yield three dimensional reconstructions and calcite / aragonite (C / A) ratio quantifications. In each tomogram aragonite and calcite are manually digitized and subsequently quantified with proprietary software (GeoPL). Statistical analyses show that 35 transverse tomograms at least are needed for reliable C / A measurement in *Polyconites hadriani*.

First results in specimens of the same age show that the intraspecific variability is small, even when the specimens are from distant localities. A preliminary trend shows that the C / A ratio decreases from the latest Early Aptian to the early Middle Aptian. These results indicates that biocalcification in rudists may have been sensitive to short time seawater chemistry fluctuations (e.g. pH). Further analysis and more samples are needed to provide information about the ability of *Polyconites hadriani* to adapt to environmental change.

O21. Biofacies analysis and de positional model of a Lower Aptian carbonate platform: a case history on platform recovery in Iberia after OAE 1a.

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The Villarroya de los Pinares Fonnation, in the Galve sub-basin of the western Maestrat Basin, eastern Iberian Chain, is essentially made up of platform carbonates with abundant rudist bivalves and corals, sandy limestones and oolitic and bioclastic grainstones and packstones. It spans the upper part of the Dufrenoyia furcata biozone (of latest Early Aptian age) and in some parts the lower part of the Middle Aptian. The Villarroya de los Pinares Formation marks the end of the latest Early Aptian Tethyan-wide regression that culminated with subaerial exposure in the central Galve sub-basin, and, in proximal platform and platform-margin settings, the start of the Middle Aptian transgression.

ln the central part of the Galve sub-basin, the western side of the Miravete fault, striking NNW-SSE, affords two well exposed platform successions of latest Bedoulian age: a highstand platform (Camarillas-Loma del Morron platform), extending at least 5 km, from north of the village of Camarillas to Las Mingachas platform-to-basin transition area, and a succeeding Iowstand small platform (Las Mingachas platform) constructed downslope in the former basin. The two platforms here had a flat-topped non-rimmed depositional profile showing similar biofacies. The internal platform top biofacies comprise repeated metre-scale cycles each consisting of orbitoline-rich marl passing up to more resistant nodular bioclastic floatstone dominated by the requieniid rudist *Toucasia*. In the platform margin limestones clusters of closely packed *Polyconites hadriani* are joined by both branching and domal corals, as well as the oyster-like *Chondrodonta glabra* and nerineid gastropods. In Las Mingachas platform, where the massive rudist- and coral-rich platform limestones pass laterally into the slightly more marly and recessive clinoforms of the upper slope facies, *Polyconites* is especially abundant. Basinwards these slope deposits pinch out into basinal marls with orbitolinids and ammonoids, containing *Toucasia*-rich debris-flow deposits. The prevalence of polyconitids in the platform margin facies, in particular, makes a striking contrast with early Bedoulian platforms, and heralds the widespread proliferation of this group across the Tethyan Realm through the Late Aptian and thereafter.

P1. Rudist higher taxa for the revised Bivalvia volumes of the Treatise on Invertebrate Paleontology (Oral and Poster)

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See Abstract O1.

P2. First record of *"Immanitas" rotunda* Palmer from northern California, U.S.A? (a preliminary report)

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The presence of a Late Albian canaliculate rudist in northern California, U.S.A. was only recently recognized (Iba, Y. et al. 2009. First record of Late Albian canaliculate rudist from northern California and re-assessment of *Durania? californica* Anderson, 1958. *Cretaceous Research* **30**, 540–546). Its systematic assignment, however, remains unsolved. Here we describe another specimen from northern California, previously deposited in the California Academy of Sciences (CASG 60852), and found to be similar to the poorly-known canaliculate rudist, *"Immanitas" rotunda* Palmer. This latter species had been known only from a single incomplete specimen (a short fragment) recovered from Colima Province, Mexico (Palmer, R. H. 1928. The Rudistids of Southern Mexico: *Occasional Papers of the California Academy of Science* **14**, 137 pp.) and one other tentatively-assigned specimen (*I.* sp.?, cf. *I. rotunda*) from a well in Texas (Coogan, A. H., 1977.

Early and middle Cretaceous Hippuritacea (rudists) of the Gulf Coast. In: Bebout, D.G., Loucks, R.G. (Eds.), *Cretaceous Carbonates of Texas and Mexico, Applications to Subsurface Exploration. Report of Investigations*, **89**. Bureau of Economic Geology, University of Texas, Austin, pp. 32–70). Although its affinity to the genus *Immanitas* has been questioned in many previous studies, including that of Palmer (1928, *q.v.*), its re-investigation has remained outstanding.

The specimen reported here was recovered from the conglomerate bed of the Upper Chickabally Mudstone Member of the Budden Canyon Formation on the northern side of Northern Cottonwood Creek. This locality is probably the same as, or very close to the rudist localities of Iba et al. (2009, *q.v.*). Thus the Late Albian (the Mortoniceras perinflatum zone) age is likewise supposed for this specimen.

The specimen is an incomplete right(?) valve of a large individual; the shell is almost completely filled with small, tabulate, polygonal canals except for a single row of pyriform canal along some part of shell margin; the body cavity is small; a U-shaped white re-crystallized part, which is filled with relatively large polygonal canals in some parts, occurs in the centre of the shell, situated possibly dorsal to the body cavity. These characters, excepting the pyriform canals, are concordant with the original description of *"Immanitas" rotunda* by Palmer (1928, *q.v.*), though the presence of tabulae in the body cavity is not yet recognized in the Californian specimen.

Such specimens, showing similarity to *"Immanitas" rotunda*, may provide an opportunity to recognize the morphological characters of the species and to resolve its affinity. In addition, they may point to a faunal link between northern California, Central Mexico and possibly Texas in Late Albian times.

P3. A new genus of polyconitid rudists from Japan and Greece

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Horiopleura? *juxi* Steuber, 1999 (Steuber, T., 1999. *Special Papers in Palaeontology* **61**, 1-229), described from the Aptian of Beotia, Greece, was considered to be a new species based on characteristic infoldings of the outer shell layer, while the cardinal characters are similar to those of *Horiopleura*.

Caprina uwajimensis Shikama and Tanabe, 1970 (Shikama, T., Tanabe, K., 1970. *Science Reports, University of Yokohama, Section* **II**, 1970: 49-58), was reported from the Ehime prefecture of Shikoku, Japan, and believed to be of Santonian age. Re-inspection of the type material has shown that the two species have identical diagnostic characters. The perceived canals of *C. uwajimensis* are the same infoldings of the outer shell layer as in *H. juxi*, so that the species should not be included in the Caprinidae, in which canals are developed in the inner shell layer, and the outer shell layer is particularly thin. Based on these specimens from Greece and Japan, a new genus of the Polyconitidae is described, with the type species *C. uwajimenis*.

The localities in Greece and Japan both have a complicated stratigraphical setting. The Greek specimen was found loose in ophiolitic conglomerates with abundant large limestone blocks that contain Aptian benthic foraminifers and corals. The type locality of *C. uwajimenis* is now considered to be in the Coniacian part of the Uwajima Group, although the occurrence of possible Early Cretaceous "oysters" in the rudist limestone (Shikama and Tanabe, 1970, *q.v.*) argues for the Early Aptian Chikanaga Formation as the rudist-bearing stratum.

To obtain independent evidence for the age of the specimens, samples of low-Mg calcite of shells from Japan and Greece were analysed for Sr-isotope ratios. The outer shell layer of *H. juxi* proved to be diagenetically altered so that no reasonable numerical age can be derived, while the Sr-isotope ratios of two samples of *C. uwajimensis* are believed to represent the original seawater composition. However, the derived numerical age is inconclusive and would be consistent with the Latest Bedoulian, the Early Albian, or the Late Turonian/Early Coniacian. A Late Cretaceous age is considered to be highly unlikely, as typical tropical Tethyan biota are absent from Japan after the mid-Cretaceous (Iba, Y., Sano, S., 2007. *Palaeogeography, Palaeoclimatology, Palaeoecology* **245**: 462-482). The Late Bedoulian age would match with the age of the associated biota in Greece, although the new genus appears to be rather derived compared to other polyconitids of the Mediterranean Tethys.

P4. New Albian canaliculate polyconitid rudist from the Pacific

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Spatio-temporal change in the distribution of rudists and other Tethyan biota provides clues for reconstructing the paleobiogeographic and paleoclimatic history of the Cretaceous Pacific, including, in particular, the stepwise demise of that biota in the Albian (Iba, Y., and S. Sano. 2007. *Palaeogeography, Palaeoclimatology Palaeoecology*, **245**, 462–482; Iba, Y. et al. 2011. *Geology*, **39**, 483–486). A rudist of Late Albian age from Cebu Island, Philippines (Wolcke, F., and J. Scholz. 1988. *Mitteilungen aus dem Geologisch-Paläontologischen Institut der Universität Hamburg*, **H. 67**, 121–133; Masse, J.-P. et al. 1996. *Comptes rendus de l'Académie des sciences*. Série **2**, v. **322**, 973–980), provides a unique window to study the paleobiogeography of the Central Pacific at that time. Masse et al. (1996, *q.v.*) had already noted its possible similarity with Japanese forms then referred to *Pachytraga*, but later re-assigned to *Praecaprotina* (Skelton, P. W., and J.-P. Masse. 1998. *Géobios, Mém. Spéc.* **22**, 331–370), a polyconitid genus of Late Aptian–Albian age described from Japan and Daiichi-Kashima Seamount, now located in the western Pacific. However, further systematic and paleobiogeographic studies of the Cebu rudist awaited completion.

During the paleobiogeographic study of the Pacific, one of the authors, Yasuhiro IBA, recently collected additional rudist material from reddish tuffaceous limestones in Cebu Island, including one of the localities of Masse et al. (1996, *q.v.*). Study of these specimens has revealed an essentially *Praecaprotina*-type morphology, though with the addition of a number of thin radial partitions in the broad ectomyophoral cavity of the left valve, forming a single row of large, simple canals there. Thus the Cebu form can be interpreted as a canaliculate derivative of *Praecaprotina*, indicating that the polyconitids gave rise to a distinct clade of canaliculate rudists, probably endemic in the Pacific, in the late Albian. It is interesting to note that another clade of canaliculate rudists, the *Neocaprina–Caprinula* lineage, evolved almost at the same time in the NE African region, with an analogous mode of canal development, i.e., by the subdivision of large ectomyophoral cavities (Steuber, T., and M. Bachmann. 2002. *Palaeontology*, **45**, 725–749).

Moreover, cladistic analysis of rudists performed by Skelton and Smith (2000: Skelton, P. W., and A. B. Smith 2000, in *The evolutionary biology of the Bivalvia. Geological Society Special Publication* **177**, 97–127) has suggested a polyconitid origin for the plagioptychids. Derivation of the Plagioptychidae from the Cebu polyconitid or related form can be supposed, with ventral-ward extension of canals around the margin of the left valve, though the record of plagioptychids indicates a significant gap between the age of the Cebu form (Late Albian) and that of the first plagioptychids (Late Turonian). This evolutionary hypothesis thus needs further research.

P5. First unambiguous records of Barremian *Pachytraga* from Southwest Japan

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Pachytraga is the earliest genus of the Caprininae, which flourished in the Mediterranean Tethys and Middle East in the Hauterivian and Early Aptian (Skelton, P. W., and J.-P. Masse. 1998. *Géobios, Mém. Spéc*. **22**, 331–370). Because Hauterivian *P. tubiconcha* and Early Aptian *P. paradoxa* have been considered as chronospecies, the absence of this genus from the known record for most of the Barremian is an enigma, and possible controls on its restriction to some unknown refugium have been discussed by Masse and Fenerci-Masse (2008: Masse J.-P., and M. Fenerci-Masse. 2008. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **269**, 54–65).

Since *Pachytraga japonica* previously described from the Akaishi Mountains in Central Japan and the Osaka area in western Kyushu are now assigned to the polyconitid rudist *Preacaprotina*, the existence of *Pachytraga* in Japan had been denied only a few years ago (Sano, S. et al. 2008. *Abstracts of Eighth International Congress on rudists*, **40**). However, investigation of "*Pachytraga japonica*" from the Sanchu Cretaceous near Tokyo, reported by Ichise (Ichise, M. 2008. *Earth Evolution Sciences (University of Tsukuba)*, **2**, 39–65), and newly-collected specimen from the Osaka area reveals that these specimens indeed belong to *Pachytraga*, and represent its first unambiguous record outside the Mediterranean Tethys and Middle East.

The age of the *Pachytraga*-bearing strata in Southwest Japan is still controversial. However, all age-diagnostic ammonoid fossils in the strata both of Sanchu and Osaka areas clearly indicate a Barremian age, though the finding of *Praecaprotina* and a relatively advanced caprinuloidinid from the Osaka area suggests a younger age (possibly Aptian), and complex geologic structures in this area are suspected.

Three internal moulds of left valves of *Pachytraga* have been studied. The size of the Japanese *Pachytraga* (antero-posterior commissural diameter, at about 30 mm) is just above the size range of *P. tubiconcha* shown in Skelton and Masse (1998). Furthermore, the specimen from Osaka shows one derived character known in some specimens of *P. paradoxa* (small antero-dorsal canals), and one possibly autapomorphic character (anterior myophore relatively recessed with only narrow connection to the base of the anterior tooth), as well as a relatively lower-domed left valve. Thus this form could be an endemic Northwest Pacific-margin offshoot from the main *Pachytraga* lineage, within the 'gap' in the latter's known stratigraphical record in the Mediterranean/Middle Eastern Tethyan province (Masse and Fenerci-Masse, 2008). The discovery of Barremian *Pachytraga* in Japan indicates that the evolutionary history of *Pachytraga* is more complicated than previously thought, and should be discussed considering its much wider distribution expanded to the Pacific.

P6. A new requieniidae from El Abra Formation, Aquismon Quarry, Tanilul, San Luis Potosí, Mexico

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El Abra Formation limestones are known by the diversity of their rudist fauna and particularly by the Caprinuloideinae, Requieniidae being less diversified. In the quarry fronts of Aquismon Quarry, at Tanilul, were these rocks are exploited, we observed the presence of abundant sections of a Requieniidae showing internal features, particularly its posterior myophore lamina, different from those of any other known genus of this rudist family. Thus, in our opinion and after comparison with *Toucasia*, *Pseudotoucasia*, and *Apricardia*, the proposal of a new genus seems justified.

The new Requieniidae is easy to recognize by the development of a pedicle-supported posterior myophore lamina, with a 'T' form, in both the right valve (free valve) and the left valve (attach valve). This morphology reminds that of the posterior myophore lamina of the right valve in *Pseudotoucasia*; as in *Apricardia*, the pedicle of the myophore lamina is practically orthogonal to the inner surface in both valves.

P7. Santonian Hippuritidae from south-central Pyrenees, Spain

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A detailed description of the morphologic characters of some Santonian hippuritid species, with particular emphasis on their ontogenetic and intraspecific variability, is presented. Considered characters comprise: (1) the external morphology; (2) the infoldings of the outer shell layer and (3) the myo-cardinal apparatus, as observed on transverse sections of the right valve in specimens with both valves, close below the commissure (ontogenetic variations of the infoldings observed on serial sections); and (4) the canal-and-pore system of the left valve.

Considered taxa comprise: two species of

Hippuritella Douvillé, 1908, *Hippuritella maestrei* (Vidal, 1878) and *Hippuritella toucasi* (d´Orbigny, 1850); five species of *Hippurites* Lamarck, 1801, *Hippurites matheroni* Douvillé, 1893, *Hippurites microstylus* Douvillé, 1895, *Hippurites praecessor* Douvillé, 1895, *Hippurites socialis* Douvillé, 1893, and *Hippurites sublaevis* Matheron, 1842; and three species of *Vaccinites* Fischer, 1887: *Vaccinites beaussetensis* Toucas, 1904, *Vaccinites galloprovincialis* (Matheron, 1842), and *Vaccinites giganteus major* Toucas, 1904. Two *Vaccinites* left by now in open taxonomy have been also considered.

Observations are made on about one thousand well preserved specimens from several well correlated Santonian fossil localities in south-central Pyrenees, including the type locality of some of the considered species.

P8. Cyclic rudist settlement on an Aptian continental margin of Northern Iberia (Oral and Poster)

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See Abstract O17.

P9. The rudist faunal assemblages of Bacevica-Vrbovac (eastern Serbia): correlations with those found in Turkey

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Due to the almost complete disappearance of the holotypes and paratypes of the rudist bivalves recovered first by Milovanović and then by Sladić-Trifunović in the vicinity of the famous fossiliferous localities of Bačevica and Vrbovac (Eastern Serbia), extensive field investigations have been carried out in this area with the aim (i) of re-forming the collection of rudists which originally included new genera and numerous new species and (ii) of describing the lithological and faunal succession.

The Bačevica section is inserted within andesitic tuffs and lavas and consists of a lower part organized in lithological couplets made of a limestone breccias lower unit and a silty limestone fossil rich upper unit. The upper part of the section consists mainly of more or less weathered pyroclastic sandstones, siltstones and pebbly quartzic sandstones with well rounded quartz clasts while limestone represents a rare, occasional lithology.

An alternation of low diversity assemblages of rudist bivalves and much richer assemblages of the same characterises the upper part of the Bačevica-Vrbovac section. Some species and genera not previously recorded at Bačevica by the Serbian rudistologists have been collected, among these the discovery of the rudist bivalve *Balabania acuticostata* is remarkable. It is stressed that, due to the shortage of the cropping out strata, the assessment of this part of the section and the field relationships of the outcrops is still unclear. At present ten/eleven fossiliferous levels have been tentatively recognized.

Due to the reduced thickness of the upper part of the Bačevica-Vrbovac section which may be estimated about 40 metres thick, some rudist assemblages seem to occupy a really precise stratigraphic position within the section. In particular (i) an assemblage made solely of abundant large specimens of *Pseudopolyconites*, (ii) a pair of diverse assemblages characterised by different species of *Pironaea* and (iii) two rich diverse assemblages at the top of the section with examples of *Radiolites angeiodes*, *Branislavia bacevicensis*, *Balabania acuticostata*, *Pseudosabinia klinghardt* and other rudists are worth mentioning. In particular, the last assemblage is curiously characterised by the abundance of specimens showing tubules and well-developed pseudo-canals in their upper valves. Moreover, these rudist bivalves also share a rather distinctive bulbous-headed ligamentary infolding and a fine scale polygonal cell pattern in addition to the pseudo-canals.

The late Campanian-Maastrichtian transgressive mixed siliciclastic-carbonate sequences are well exposed in the different regions of Turkey such as Pontides (Northern Turkey), central, eastern and southeastern Anatolia. The Bačevica-Vrbovac section, lithologically, seems to resemble those of Pontides due to the outstanding presence of volcanic rock support in the succession if compared with other regions of Turkey. The rudist faunal composition of Pontides also shows no similarities with the one of Bačevica-Vrbovac . But, the faunal succession of Bačevica-Vrbovac shows strong analogies with other coeval transgressive mixed siliciclastic-carbonate successions of the Hamiana-Polatli and Tuz Lake basins of the Central Anatolia and Malatya basin of Eastern Anatolia.

P10. Depositional and Paleoenviron-mental Settings of the Early Albian limestones in the Greater Antilles

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Island arc tectonism in the Lower Cretaceous to middle Eocene has been well recorded in a series of volcano-sedimentary sequences in the Greater Antilles. Extensive deformation, associated with volcano-tectonic activity in an active margin, has led to chaotic and undifferentiated stratigraphic sequences, making difficult the detailed identification and correlation of those sedimentary units. Recent studies have focused on the recognition of carbonate depositional periods using rudistid bivalve associations. However, correlations of these fossil assemblages have not been accomplished throughout the Caribbean region. This study is undertaking an unprecedented high definition chemostratigraphic ($\delta^{13}C_{CARB}$ and $\delta^{13}C_{org}$) analysis of limestones where the *Coalcomana-Caprinuloidea* rudist assemblage (Early Albian) is exposed across the Greater Antilles (Dominican Republic and Puerto Rico). Preliminary chemostratigraphic profiles suggest that the timing of carbonate deposition was synchronous across the Caribbean, at least in the Dominican Republic and Puerto Rico, during the Early Albian. The chemostratigraphic framework is being used to constrain the timing and impact of ocean circulation of mid-Cretaceous carbonate deposition in the Caribbean region.

Mid-Cretaceous paleoceanography is thought to be dominated by superheated and hypersaline conditions that developed in the central paleo-tropics, the Supertethys oceano-climatic zone. These paleoceanographic conditions are being investigated using stable isotope ($\delta^{18}O$) thermometry and fluid inclusion analyses. The Epstein et al. (1953) equation provides the means to determine the sea surface temperatures of Cretaceous tropical oceans in the Caribbean region. Assumptions such as -1.2‰ $\delta^{18}O_{water}$ and constant salinities are used in the equation to develop sclerochronologic profiles on preserved rudists and oysters shells. Preliminary results suggest that the Mid-Cretaceous sea surface temperatures were 3 to 5°C warmer than today. Fluid inclusions preserved in submarine cement are used to measure sea surface salinities of Cretaceous seawater in the Caribbean. Salinities are calculated using the final melting temperature (Tm ice) of frozen inclusions. Preliminary results of fluid inclusions derived salinities indicate 37 to 41 ppt dissolved salt in water. Fluid inclusion data will help us to determine isotopic fractionation within mollusk shells and submarine cements more efficiently, enabling a temperature correction from oxygen isotope data.

P11. Cenomanian recumbent rudist facies from the Premantura, Istria, Northwestern Croatia

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Adriatic carbonate platform deposits with shallow water fossil assemblage and Cenomanian stratigraphic characteristics crop out at Premantira locality. Fauna include ichthyosarcolitids, caprinids, radiolitids, as well as other macrofossils. Stratigraphic age as well as shallow water conditions of the rudist fauna is consistent with micropaleontological data. Sedimentologically, these limestones are predominantly rudstones-floatstones which contain monospecific to polyspecific rudist comunities.

This Cenomanian depositional environment with recumbent rudists was dispersed throughout different parts of the Adriatic carbonate platform (Korbar, T., Fuček, L., Husinec, A., Vlahović, I., Oštrić, N., Matičec, D. & Jelaska, V. (2001): Cenomanian Carbonate Facies and Rudist along Shallow intraplatform Basin Margin-the Island of Cres (Adriatic Sea, Croatia). *Facies*, **45**, 39-58; Mamužić, P., Polšak, A., Grimani, M., Šimunić, A. & Korolija, B. (1979): Detaljni geološki stup kroz naslage cenomana sjeverno od Vela Luke na otoku Korčuli (Detailed geological column of Cenomanian northern from Vela Luka, Island of Korčula). *Geološki vjesnik*, **31**, 91-103; Mamužić, P., Polšak, A., Grimani, M., Šimunić, A. & Korolija, B. (1981): Detaljni geološki stup kroz naslage cenomana i turona u zapadnom dijelu otoka Hvara (Detailed geological column through deposits of

Cenomanian and Turonian in western part of Hvar Island). *Geološki vjesnik*, **33**, 49-57; Mamužić, P., Polšak, A., Grimani, M. & Korolija, B. (1982): Geološki stup kroz naslage cenomana i donjeg turona u središnjem dijelu otoka Cresa (Geological column through Cenomanian and Lower Turoniana in the middle part of Cres Isaland). *Geološki vjesnik*, **35**, 65-70), and presumably imply a regional character of this facies.

P12. Campanian Rudist-bearing shallow-water deposits of Northern Croatia and Slovenia

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In northern Croatia (Medvednica, Kalnik and Žumberak Mts. with D. Orešje, G. Orešje, Sv. Martin and Brašljevica localities) and in the northeast Slovenia (Pohorje Mt. with Stranice locality) a Campanian (Pleničar, M. & Šribar, Lj. 1992. Le Récif de rudistes près Stranice (NO de la Yougoslavie). *Geologica Romana*, **28**, 305-317; Moro, A., Ćosović, V., Benić, J. & Dokmanović, J. 2010. Taxonomy of rudists from the Campanian transgressive Sediments of Brašljevica, Donje Orešje and Sv. Martin, Northern Croatia. *Turkish Journal of Earth Sciences*, **19**, 613-633) shallow water sequence overlies basement rocks (Triassic and Jurassic sediments).

Two developments of shallow water sediments are present. At Stranice and G. Orešje localities, clay-rich marly sediments successively pass into limestones. Within rudist communities, individuals of radiolitids, vaccinitids, hippuritids and hippuritellas occur at Stranice locality, while in G. Orešje locality specimens of hippuritids, vaccinitids, plagioptychids and radiolitids are present. Second development, of D. Orešje, Sv. Martin and Brašljevica localities, starts with limestones which could vertically pass into marls with nannofossils or in limestones with pelagic fossils. Rudist fauna comprise generally vaccinitids, while other rudist could be minorly and sporadically present.

The depositional setting of localities may be considered as a result of sea-level rise which resulted with flooding of the paleorelief. Different facies developement are probably the result of more or less pronounced paleorelief conditions which could outcome in the specific rudist comunities.

P13. When X-rays fail: A new grinding tomography method for low density contrast samples

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The tomography of fossils is based on the production of numerous sequential high resolution pictures (tomograms) that form the base for a later three dimensional evaluation. X-ray CT proved to be the most successful method in tomography but has limitations in low density contrast samples (e.g. carbonate shells in limestone). Here, we describe a technique that can produce high resolution, true color images in limestone samples.

The method is based on automatic serial grinding and serial scanning. The working process starts with embedding the samples in a mold with epoxide resin. The hardened block is then polished by a precision surface grinding machine. After each polishing step, the surface is scanned in a water quench by a custom built high resolution scanner. This method provides a maximum resolution of 2400 dpi (horizontally) and 10 µm (vertically). Sample sizes can vary between 1 mm^3 and 15 x 15 x 30 cm. The productivity of this method is linked to resolution and sample size, and varies between 5 and 38 tomograms per hour. The main advantages of the method are: fast production of true color and high resolution tomograms, capability of processing samples of various sizes, as well as multiple samples in one block. Apart from 3D shape reconstruction of fossils with DICOM software (OsiriX), sedimentary structures, fractures and porosity; the outstanding image quality makes even new applications possible such as the quantitative evaluation of paleobiological entities in reefs (e.g. spat density), or volume based calcite / aragonite ratio measurements, among others.

P14. Stratigraphy of Jurassic-Cretaceous rudist genera

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Stratigraphic ranges of all genera of the Hippuritidina are presented, based on first and last occurrences of genera at localities with a defined age related to the 2004 Geologic Time Scale. Correlation of occurrences with ammonite zones has been established using various methods. Conventional biostratigraphy, i.e. direct or indirect correlation with ammonoid-bearing deposits has been used for most the Jurassic – early Cretaceous taxa. Graphic correlation was used for many Aptian-Cenomanian genera, and correlation based on numerical ages derived from strontium isotope stratigraphy was used for Late Turonian – Maastrichtian taxa. These methods are discussed, and the precision of stratigraphic correlation is evaluated. Sr-isotope stratigraphy resulted in significant revision of previously accepted ranges, particularly for Campanian-Maastrichtian genera.

The range charts reflect the well-known extinction events at the Early/Late Aptian boundary, during the Albian/Cenomanian transition in the New World, and at the end of the Cenomanian in the Old World. Although these extinction events are not further discussed in the present contribution, the range charts will be an important resource for further research in evolutionary patterns of the Hippuritidina.

P15. Allochthonous resedimented rudists as stratigraphic indicators in “platform- to-basin” deposits – an example in east-central Mexico

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During the Cretaceous, in the east-central portion of Mexico, carbonate rocks of contrasting environments were deposited. On the so-called Valles-San Luis Potosi Platform (VSLPP) shallow-water carbonates including a rudist-reef rim were deposited. The age of this platform ranges from Aptian to Maastrichtian, westward from the platform is the Central Mexico Mesozoic Basin (CMMB) that includes more than 1000 m of deep-water sediments, mostly pelagic carbonates. The sedimentary rocks of the CMMB have ages from Late Paleozoic (?) until end of Cretaceous.

Between both paleogeographic structures, there is a belt of mixing facies of a slope zone. The rock sequences exposed in the transition area among the western margin of the VSLPP and the CMMB have a predominantly allochthonous origin, which is produced by mass movements (carbonate breccias in form of debris flows) and turbidity currents. Because mixtures of autochthonous sedimentation and the continuous supplies of clastic material from the shallow waters areas controlled these transitional sequences, its stratigraphic relationships are very chaotic. On the other hand, eustatic movements caused a great mobility with progradations and retrogradations of the margins in the platform, causing interference and crowding of facies and lithologies of different ages. Finally, all these successions were strongly affected because of the laramide deformation with faulting, folding and thrusting, and commonly it is not easy to identify the stratigraphic position of these slope-deposits.

The clast-analysis of the carbonate breccias shows that there is a great amount of bioclasts and reworked fossils, which are important examples of rudists. Rudists were the main bio-constructors on the VSLPP and their range of ages goes from Albian to Maastrichtian. In general, there are two different groups of breccias - carbonate breccias (rudstones) and marly-silty breccias (floatstones). The stratigraphic position allows us to recognize that carbonate breccias are older, by the collection of redeposited *Immanitas anahuacensis* Palmer, *Kimbleia capacis* Coogan and *Mexicaprina cornuta* Coogan, it was possible to set the upper limit of these breccias in the Cenomanian. Overlying the Albian Cenomanian breccias, there are powerful layers of calcareous debris flows (likewise carbonate breccias) rich in bioclast and reworked fossils, including the above examples and the probable presence of *Hippurites resectus* Defrance, and *Vaccinites macgillavryi* Palmer, in which boundaries belong to the Santonian deposits.

Younger breccias show a marked change in lithology, they become silty-marly breccias with well-preserved clasts and redeposited rudist-fossils in a mud-supported fabric. *Vaccinites vermunti* Mac Gillavry and *Potosites tristantorresi* Pons et al. were identified here and it was possible to define a Campanian breccias sequence.

Based on the study of re-deposited rudists it was possible to construct a coherent stratigraphic succession of slope deposits with respect to their counterparts from basin to the west and platform to the east.

P16. Microfossils, paleoenvironments and biostratigraphy of the Mal Paso Formation (Cretaceous, Upper Albian), State of Guerrero, Mexico

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Microfossils from an outcrop of the coral reef and rudist-bearing calcareous upper member of the Mal Paso Formation just north of Chumbítaro, State of Michoacán, Mexico, indicate a deepening trend and transition from nearshore through outer shelf depositional environments upward through the sampled stratigraphic interval. The microbiota is mostly composed of species of calcareous algae and foraminifera. The identified calcareous algae are: *Pseudolithothamnium album* Pfender, 1936; *Cayeuxia kurdistanensis* Elliott, 1957; *Acicularia americana* Konishi and Epis, 1962; and *Dissocladella* sp. cf. *D. savitriae* Rama Rao and Pia, 1936. The species of foraminifera are: *Nezzazata* sp. cf. *N. isabellae* Arnaud-Vanneau and Sliter, 1995; *Buccicrenata subgoodlandensis* (Vanderpool, 1933); *Cuneolina parva* Henson, 1948; *Pseudolituonella* sp.; *Praechrysalidina* sp.; and *Rotalipora appenninica* (Renz, 1936). In addition, a species of stromatoporoid is illustrated and an indeterminate tube-shaped calcitic microorganism is described as an incertae sedis. From the base of the section upward, four biofacies are defined by the co-occurrences of these taxa: a benthic foraminiferal assemblage, a coral assemblage, a caprinid - dasycladacean assemblage, and a coral - miliolid assemblage. This report documents the first detailed examination of the microbiota of the calcareous upper member of the Mal Paso Formation. These data supplement earlier paleoenvironmental interpretations based on studies of scleractinian corals, rudists, and other mollusks, and carbonate facies relationships.

The combined stratigraphic ranges of the microfossil species identified from this measured section of the Mal Paso Formation support an age determination of Late Albian. The occurrence of *Rotalipora appenninica* (Renz, 1936), a planktic foraminiferan, in the uppermost portion of the exposed stratigraphic section indicates a marked deepening of the depositional environment which can be correlated with the onset of the global Late Albian marine transgression and drowning of Tethyan carbonate platforms that is known as the *R. appenninica* - event. A Late Albian age was also suggested by previous studies of the same stratigraphic section, particularly the species of the rudist bivalve genus *Mexicaprina* Coogan, 1973.

P17. The structure of a hippuritid reef. *Hippurites radiosus* from L'Espà, south–central Pyrenees

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This study has been focused in L'Espà reef (Berguedà, Catalonia, Spain), a relatively large outcrop (nearly 20 m thick) with abundant rudist specimens together with a clear sedimentological context. The faunal composition, structure, and zoning are clearly exposed, details become evident, and most observations can be quantified. This site also displays a vertical lithologic variability indicating environmental changes through the sedimentary sequence, which can assist the relationship between energy in the environment and rudist position.

Hippurites radiosus is the main component; other rudists, such as *Hippuritella lapeirousei*, *Hippuritella* sp. and *Plagioptychus* sp., together with branching and massive colonial corals, are far less abundant. In the distal setting, rudists are reworked as large bunches of grouped specimens, with scarce weathering and preserving both valves articulated. In the halfway, reworked, isolated, and flat-lying specimens are abundant. In the proximal setting, specimens tend to be vertical. Above, a calcarenitic unit displays few specimens, most of them highly reworked and, in the uppermost part, a lagoonal unit, with scarce rudists, is developed.

Observations on the orientation of specimens were plotted in several ways, including stereographic projections that indicate even the dipping of the reef wall.

P18. Cenomanian rudists from platform margin to lower slope settings. Sant Gervàs-Sopeira area, south-central Pyrenees, Spain.

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During the Cenomanian, the region was influenced by a syndepositional normal fault beneath a platform margin that created a steep depositional relief and resulted in the deposition of megabreccias. Two depositional sequences are distinguished, UK-1 and UK-2 (Drzewiecki, P. A., Simo, J. A. 2000. *Sedimentology* **47**, 471-495). The platform sediments, developed eastwards of our study area, correspond to the Santa Fe Formation; a Lower Santa Fe Limestone and an Upper Santa Fe Limestone were distinguished in literature, respectively corresponding to UK-1 and UK-2. The westwards deeper reworked deposits of the Santa Fe Formation were known as the Santa Fe Breccia, sometimes also distinguishing two units, the lower and the upper. The underlying sequence UK-1 has relatively few reworked deposits, suggesting that the depositional slope was more gentle, and the fault less active. During the deposition of UK-2, rudist biostromes and carbonate shoals accumulated on the margins and margin derived megabreccias bypassed the upper slope.

Rudists studied comprise taxa of the Ichtyosarcolitidae, Caprinidae and Radiolitidae families corresponding to both the rudist biostromes of the platform margin (Sant Gervàs) and the megabreccias of the lower slope (Sopeira).

P19. Biostratigraphy and Sequence Stratigraphy of Rudist-bearing Cretaceous Platform in North Sinai, Egypt

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Two rudist-bearing Cretaceous successions have been studied at Gabal Raghawi and Gabal Yelleg of north Sinai. Orbitolinid foraminifera, calcareous algae, ammonites, rudists and non-rudist bivalves have been used to construct high resolution biostratigraphic zonation scheme. At Gabal Raghawi, nine rudist levels are recorded in the Late Barremian through Early Cenomanian deposits. *Toucasia carinata* and *Horiopleura* sp. is the oldest rudist level distinguished for the first time from north Sinai. This level is associated with *Palorbitolina lenticularis*, which suggest a Late Barremian-Early Aptian age. Ten rudist levels are recognized with in the Late Albian-Turonian interval in Gabal Yelleg succession. Thirteen depositional sequences were also identified in the Late Barremian-Turonian sucession. The lower part of the platform (Late Barremian-Early Albian) is characterized by high siliciclastic inputs and poor rudist assemblages. However, the upper part of the platform that coincides with the Middle Albian-Turonian interval is distinguished by high carbonate and rudist contents. TST deposits are dominated by orbitolinid foraminifera and ammonites and HST deposits are dominated by rudists and calcareous algae.

Field Trip 1: Lower Cretaceous rudists of the Benbow Inlier, central-north Jamaica (Saturday, 18 June 2011).

Leaders: Simon F. Mitchell and Rupert Green

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Introduction

Jamaica contains by far the best record of Lower Cretaceous rudist bivalves in the arc rocks on the Caribbean Plate. Cretaceous rocks in Jamaica are exposed as a series of inliers, surrounded by younger rocks (**Figure 1**). The Lower Cretaceous succession consists of limestones intercalated with volcanic rocks (lavas) and volcaniclastic sediments and is exposed in the Benbow Inlier in the parish of St. Catherine (Brown and Mitchell, 2010). Four main limestone units are present, all of which contain carbonate platform facies and yield rudist bivalves and gastropods. This report is based on Brown and Mitchell (2010) with updates particularly on the faunas of the limestones.

Stratigraphy

The Benbow Inlier is a fault-bounded area of Cretaceous rocks situated on the north-eastern margin of the Clarendon Block (**Figures 1, 2**). Recent revisions of the stratigraphy have been published by Brown and Mitchell (2010) and the geochemistry of the igneous rocks by Hastie et al. (2007, 2008).

The stratigraphic succession present in the inlier has a thickness of some 6,500 m and includes thirteen formations (the lower nine placed in the Devils Racecourse Group) ranging in age from Valanginian or Hauterivian to Cenomanian or Turonian. The succession of fossils is shown in **Figure 3**.

Jubilee Formation (Hauterivian)

The Jubilee Formation (equivalent to: the Copper, Bonnet and Philipsburg limestones) includes the lowest limestones within the inlier. The formation rests upon the volcaniclastic sedimentary rocks of the Redwood Formation, which in turn rest upon the basaltic andesites and dacites/rhyolites of the Cistern Formation.

The Jubilee Formation consists of some 100-375 m of compact, very hard, dark to medium grey limestones interbedded with mudstones and volcanically derived sandstones and conglomerates. A single lava flow is present near the base of the formation. Limestone beds are generally massive and bedding is poorly developed. The limestones range from micrites and biomicrites at lower levels to wackestones and packstones at higher levels.

The macrofossil assemblage contains rudist bivalves, nerineid gastropods, colonial corals (Löser et al., 2009), echinoids, foraminifers (Vila et al., 1986; Skelton and Masse, 1998) and alage (Vila et al., 1986).

Rudists. The rudist bivalve assemblage (Skelton and Masse, 1998) is dominated by *Retha tulae* (Felix) (**Figure 4A-C**), which appears to be restricted mainly to the uppermost beds.

Polyconitid rudists, tentatively assigned to *Pseudopetalodonta* sp. are also present.

Other fossils. An important assemblage of colonial corals has recently been described from the formation by Löser et al. (2009).

Gastropods (**Figure 4D-F**) include *Neoptyxis galatea* Coquand and *Brouzetia* sp. *Neoptyxis galatea* is now regarded as of Hauterivian age (Calzada, 1992).

Foraminifers (*Coscinophragma* sp., *Miliola* sp., *Nautiloculina* sp., *Lithocodium aggregatum* Elliot, *Daxia* cf. *minuta* Laug & Peybernes and *Vercorsella* sp.) and algae (*Acicularia* sp. A) indicate a Hauterivian age (Vila et al., 1986; Skelton and Masse, 1998).

Benbow Formation (Barremian)

The Jubilee Formation is succeeded by a thick sequence of shales, sandstones and conglomerates (Boozy Ridge Formation), above which is the Benbow Formation of Matley and Raw (1942). The Benbow Formation consists of 400 m of very hard, compact dark blue-grey biomicrite, locally rich in rudists, gastropods and corals, with smaller numbers of chondrodonts and columnar stromatolites. Exposures are for the most part unyielding to rock hammers, and as such, macrofossils can only be studied on weathered surfaces.

Rudists. The rudist fauna includes *Retha tulae* Felix in the lower part, and *Amphitriscoelus primaevus* Pantoja-Alor, Skelton & Masse in the upper part. The rudist *Retha tulae* has an age range of Hauterivian (herein) to early Barremian (Skelton and Masse, 1998) whereas *Amphitriscoelus primaevus* is of late Barremian age (Pantoja-Alor, Skelton & Masse, 2004).

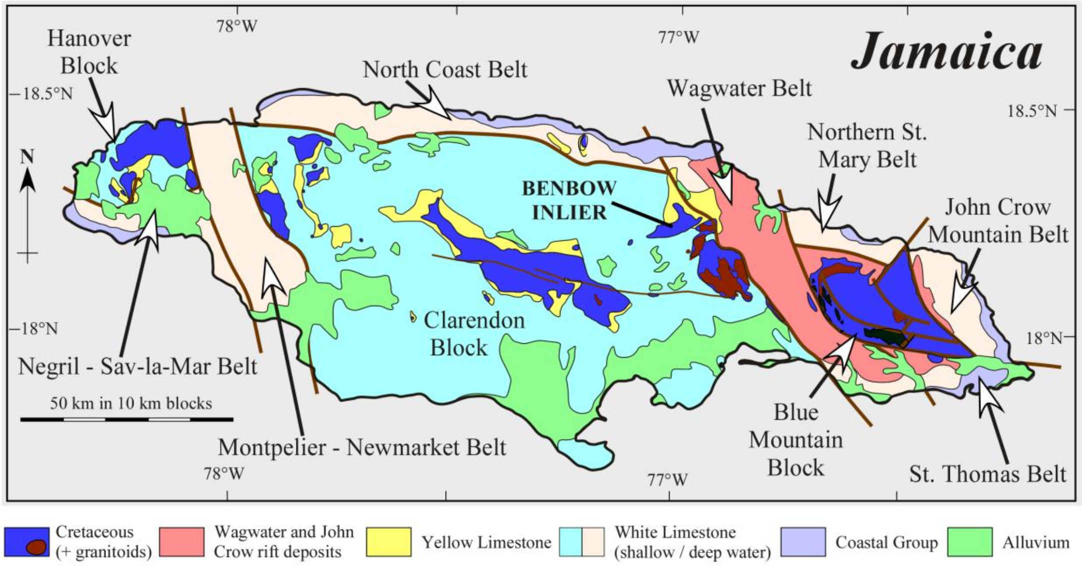

Figure 1. Geological map of Jamaica showing the location of Cretaceous inliers (dark blue/black), their relationships to the late Neognere block and trough structure, and the location of the Benbow Inlier.

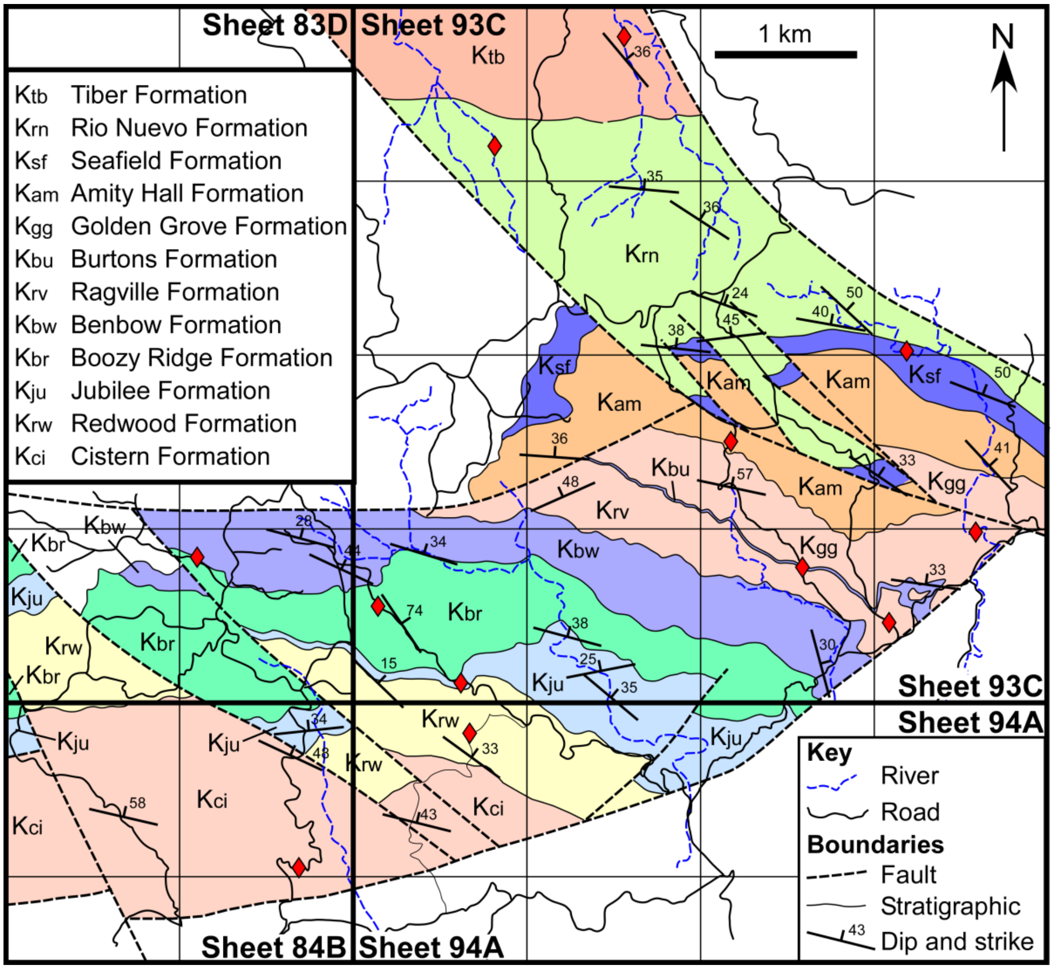

Figure 2. Geological map of the Benbow Inlier covering parts of 1:12,500 sheets 83D, 84B, 93C and 94A. Rocks younger than the Cretaceous are uncoloured. Type sections of formations are indicated by diamonds.

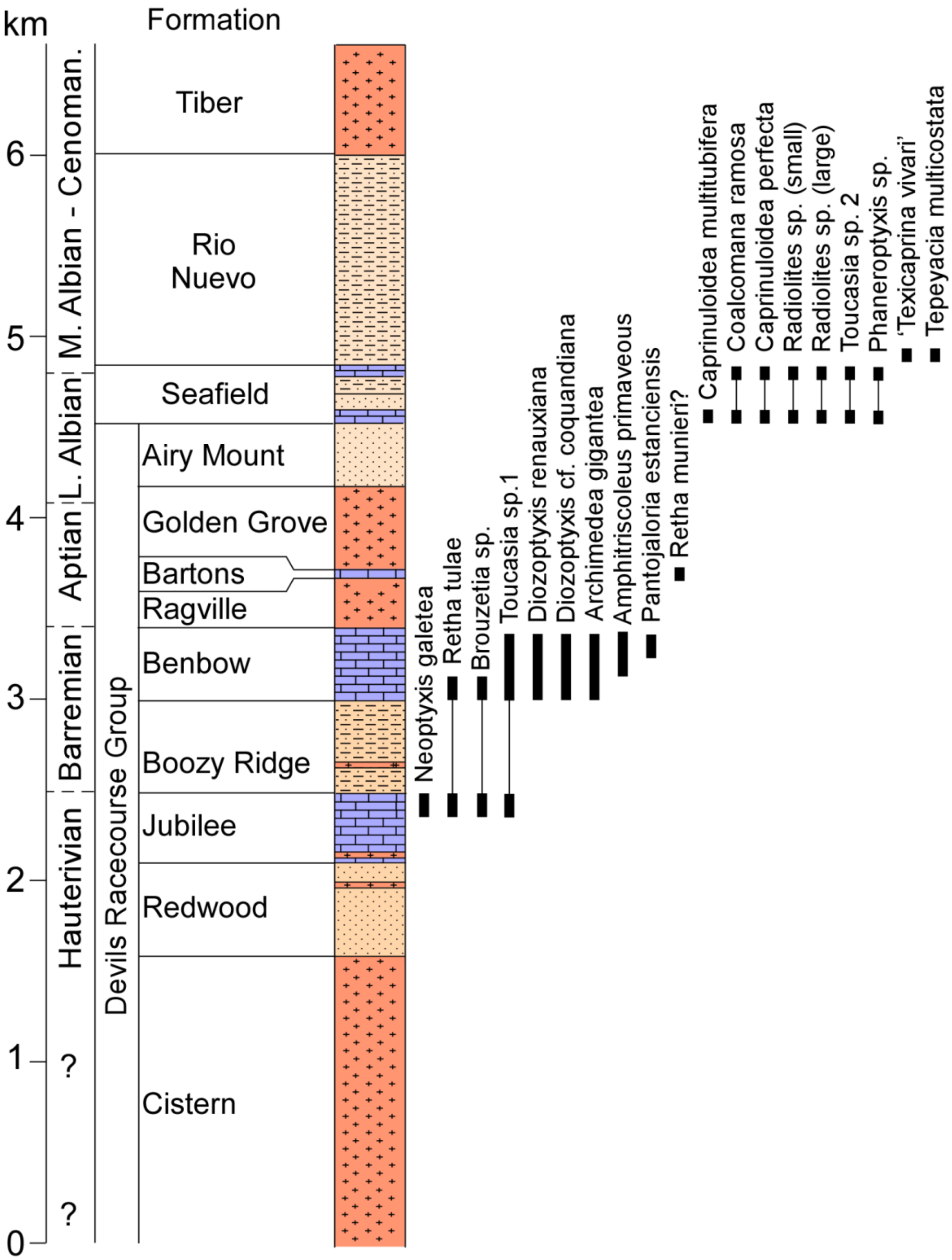

Figure 3. Stratigraphic distribution of selected macrofossils (rudists and gastropods) in the Benbow Inlier.

Large rudists with a single row of large pallial canals are *Pantojaloria estanciensis* Pantoja-Alor, Skelton & Masse. Other rudists include small specimens of *Toucasia* sp.

Other fossils. The gastropods *Diozoptyxis renauxiana* (d'Orbigny), *D.* cf. *coquandiana* (d'Orbigny) and *Archimedea gigantea* (d'Hombre-Firmas) occur in the Benbow Formation (Norman Sohl in Khudoley and Meyerhoff, 1971).

The bivalve *Chondrodonta glabra* is locally abundant forming shell beds, but appears to be confined to the upper part of the formation.

Benthic foraminifers: *Neotrocholina friburgensis* (Guillaume and Reichel), *Choffatella decipiens* Schlumberger, *Citaella* sp., *Cuneolina tenuis* Velic-Gusic, *Pseudocyclammina hedbergi* Maync and *Miliola* sp.; and algae: *Salpingoporella katzeri* Conrad & Radoicic, *Salpingoporella melitae* Radoicic, *Hetersporella*

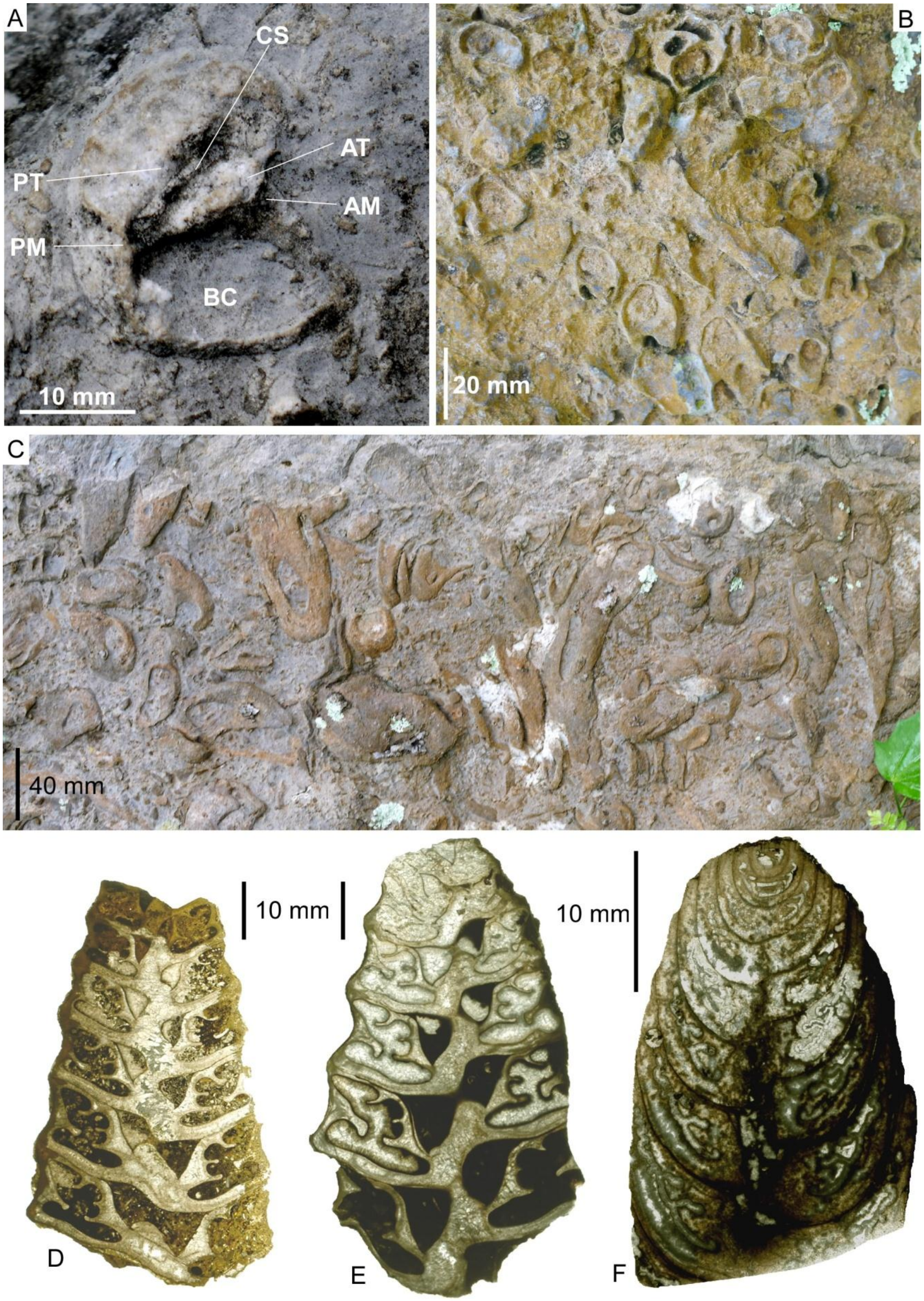

Figure 4. Rudists and gastropods from the Jubilee Formation. A, *Retha tulae*, LV, Stop 1. B-C, *Retha tulae* from Jubilee SDA Church. D-E, *Neoptyxis galatea* Coquand from Jubilee SDA Church. F, *Brouzetia* sp. from Jubilee SDA Church.

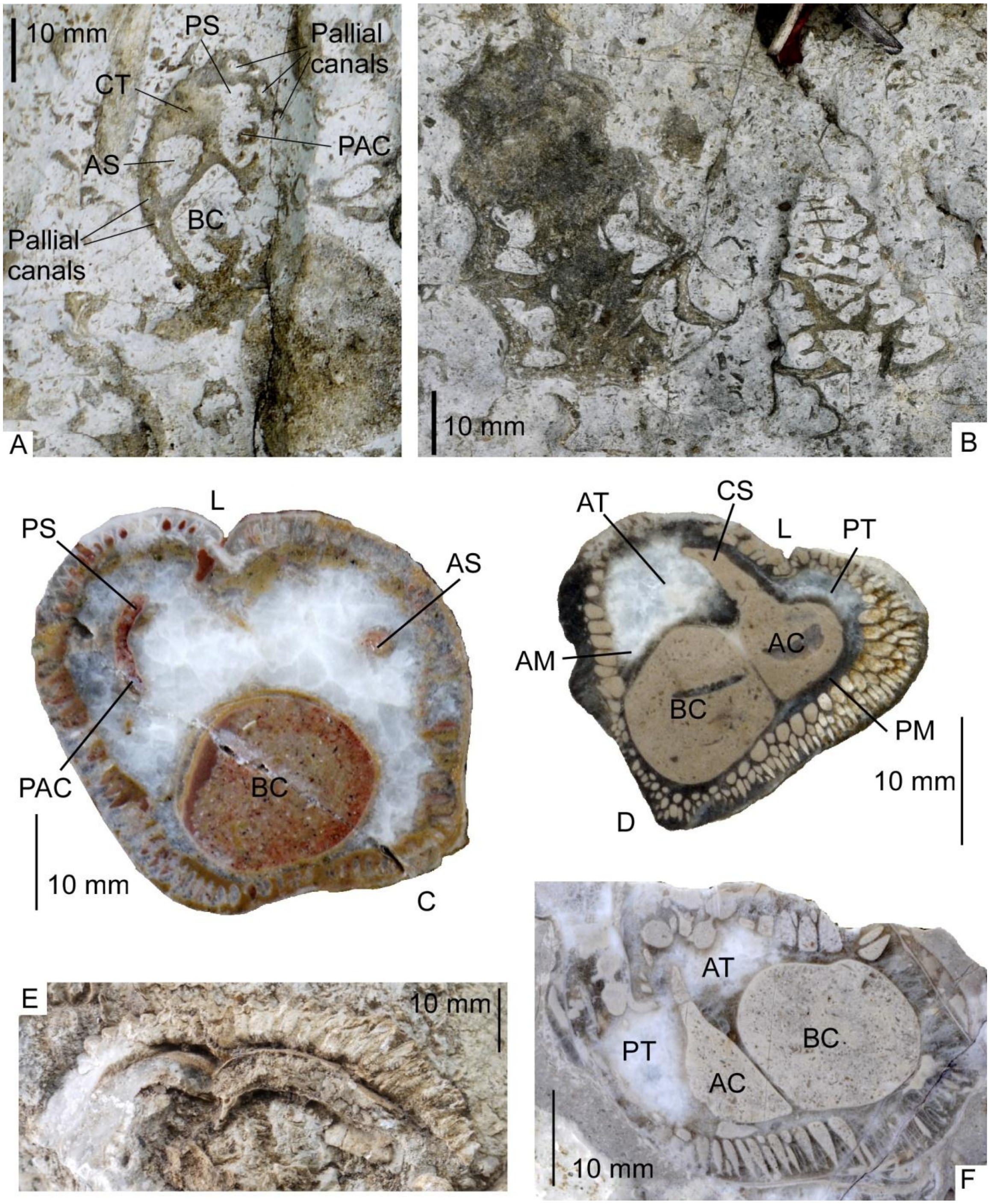

Figure 5. Rudists and gastropods from the Benbow and Seafield Limestones. A, *Amphitriscoelus primaevus* Pantoja-Alor, Skelton & Masse from the upper part of the Benbow Limestone at Stop 2. B, *Diozoptyxis renauxiana* (d'Orbigny) and *D.* cf. *coquandiana* (d'Orbigny) from the upper part of the Benbow Limestone at Stop 2. C, F, *Coalcomana ramosa* (Boehm) from the Seafield Limestone. D, *Caprinuloidea perfecta* Palmer from the Seafiled Limestone. E, *Radiolites* sp. from the Seafield Limestone.

lemmensis Bremier, *Salpingoporella appenninica* De Castro and *Actinoporella* sp.; are common in the Benbow Formation and indicate an age range from Early to Late Barremian (Pisot et al., 1986; Vila et al., 1986; Skelton and Masse, 1998).

Burtons Formation (Early Aptian?)

The Benbow Formation is followed by a succession of basaltic pillow lavas (Ragville Formation); the lavas are then overlain by a thin limestone unit, the Burtons Formation.

The Burtons Formation (Brown and Mitchell, 2010) is a thin limestone unit that can be mapped across much of the inlier from Burtons towards Guys Hill. It consists of 8 m of hard dark grey micritic limestone. Exposures are relatively poor except at the type locality. Fossils are scarce and are limited to rudists.

Rudists. Although scarce, some fossils do occur in the Burtons Formation, and *Retha munieri* (Matheron) is tentatively identified. If this identification is correct, this would suggest a late Barremian or Early Aptian age for the Burtons Formation (Skelton and Masse, 1998). The Burtons Formation may represent the local expression of the Early Aptian limestone that yields *Amphitriscoelus waryingi* Harris and Hodson in Trinidad (Harris and Hodson, 1922) and Mexico (Alencáster and Pantoja Alor, 1996).

Seafield Formation (Early Albian)

The Burtons Formation is succeeded by a further pile of pillow lavas (Golden Grove Formation) and a series of volcaniclastic sedmintary rocks (Airy Mount Formation). Above this are the limestones of the Seafield Formation, followed by a thick series of dark grey shales (Rio Nuevo Formation) and finally conglomerates with intercalatued lava flows (Tiber Formation).

The Seafield Formation is the highest limestone unit in the Benbow Inlier and consists of a 320 m-thick sequence of limestones interbedded with mudstones, shales and conglomerates. Two separate limestones have been tentatively distinguished, but have similar characteristics and may represent the same unit duplicated by faulting. The pale greyish-brown limestones contain abundant bioclastic material including rudists, rudist fragments, corals, gastropods and echinoid spines.

Rudists. The rudist fauna includes common coalcomanid rudists including: *Coalcomana ramosa* (Boehm), *Caprinuloidea perfecta* Palmer and *C. multitubifera* Palmer. The *Coalcomana-Caprinuloidea* rudist assemblage is widespread in the early Albian across the American region being found in Puerto Rico (Skelton, 1996), the Dominican Republic (Myczyński and Itturalde-Vinent, 2005), Cuba (Thiadens, 1936), Mexico (Boehm, 1898; Alencáster and Pantoja Alor, 1986) and Texas (Scott, 2002).

Examples of "*Texicaprina vivari* (Palmer)" have also been collected from volcaniclastic sedminets overlying the Seafield limestone and from loose blocks of limestone in the Tiber River. This suggests that the Seafield Formation may extend up into the middle Albian (Scott, 2002).

Radiolitid rudists also occur. A small species tentatively assigned to *Radiolites* is fairly common, and larger specimens also tentatively assigned to *Radiolites* have been collected (**Figure 5E**). The polyconitid rudist, *Tepeyacia multicostata* Chubb, has been found in volcaniclastic sedimentary rocks above the Seafield Limestone where it is associated with *'Texicaprina' vivari* (Chubb, 1971). Some beds in the Seafield Limestone are also characterized by coquinas of *Toucasia* sp.

Other fossils. Silicified gastropods occur in some blocks within a fault zone. They are identified as *Phaneroptyxis* sp.

Foraminifers are represented by *Mesorbitolina texana* (Roemer) (reported as '*Orbitolina oculata*' by Jiang and Robinson, 1987). The radials of echinoids are also common.

Field Stops

All the limestones in the Benbow Inlier are extremely hard, and the collection of fossils cannot be done except using sledge hammers (and even then it is difficult). It may be possible to collect loose blocks that show some of the fauna, but many of these are large. The best way to make a record is to photograph specimens. If there are specimens that should be collected, the UWIGM will facilitate the collection of the specimens following the field trip.

Stop 1: Jubilee Formation at Copper (GPS 18°13.194; 077°00.197)

Exposures of the Jubilee Formation at Copper (the type locality for the Copper Limestone) contain common rudists, but at this time the fields are covered with bush. A loose block of limestone on the roadside, fallen from somewhere in the lower part of the formation, contains small specimens of *R. tulae* (**Figure 4A**).

Stop 2. Benbow Limestone, Mrs Settal's Yard near Middlesex (GPS 18°14.317; 077°01.894)

These exposures in the upper part of the Benbow Limestone contain good fossil assemblages, and are intercalated in a thick sequence of limestone with few fossils. The rudist *Amphitriscoelus primaevus* (**Figure 4**) is abundant, and occurs in rudstone and floatstone beds, as well as in *in situ* growth fabrics; scattered specimens of *Toucasia* sp. may also be present. The gastropod *Diozoptyxis renauxiana* together with other gastropods occurs in some of the rudist floatstones, and there is a bed full of articulated *Chondrodonta glabra* Stanton.

Stop 3. Jubilee Limestone, Jubilee SDA Church (GPS 18°13.475; 076°59.361)

The Jubilee Formation exposed at the Jubilee SDA Church shows a section similar to that in the overgrown fields at Copper. The rudist *Retha tulae* occurs as beautiful growth fabric at the top of a limestone bed, and abundant blocks from this level can be seen. Associated fossils include nerinacean gastropods and examples of a polyconitid rudist bivalve. A volcaniclastic sandstone overlying the *Retha tulae* bed contains abundant examples of the Hauterivian gastropod *Neoptyxis galatea*; whereas the overlying limestones are rich in corals similar to those described by Löser et al. (2009).

Stop 4. Jubilee Limestone, near Jubilee Town (GPS 18°13.337; 076°59.169)

Loose blocks of limestone from the Jubilee Formation contain abundant shell debris including nerinacean gastropods and rudists (*Retha tulae*).

Stop 5. Seafiled Limestone, between Rosselle and Seafield (GPS 18°14.990; 076°58.487)

Outcrops of Seafield Limestone occur in the field at this locality. This is in the upper part of the Seafield Formation and a range of rudists can be found, including: *Coalcomana ramosa*, *Caprinuloidea perfecta*, *Radiolites* sp. (small), and *Toucasia* sp.

Stop 6. Benbow Limestone at fording in tributary to the Knollis River on road between Rio Mango and Burtons (GPS 18°13.564; 076°57.527)

The section here contains a series of rudist bearing limestone beds. The succession includes rudstones and floatstones with *Amphitriscoelus primaevus*, limestones with small specimens of *Toucasia*? sp. (small), and *in situ* fabrics with abundant articulated *Chondrodonta glabra* Stanton.

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Field Trip 2: Campanian and Maastrichtian rudists of Central and western Jamaica (Thursday, 23 to Saturday, 25 June 2011)

Leaders: Simon F. Mitchell[1], Gavin Gunter[2] and Jason Fisher[1]

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Introduction

Road construction and water supply projects in the 1890s led to the discovery of important rudist-bearing limestone localities in central and western Jamaica (*The Gleaner*, 29th January 1898). These sites were collected by F. C. Nicholas from New York and described by R. P. Whitfield, the curator at the American Museum of Natural History (Whitfield, 1897a, b). Work by Trechmann (1922, 1924) and Chubb (1955, 1956a, b, 1968, 1971) led to subsequent revisions of the rudist bivalves.

During the last 16 years, the Department of Geography and Geology at the University of the West Indies has undertaken extensive investigations of the Cretaceous rocks of Jamaica (**Figure 1**). This work has included geological mapping, the formal designation and revision of lithostratigraphic units, the logging of sections, and the collection of biostratigraphically important fossils (rudist bivalves, ammonites, inoceramids, crinoids, planktic foraminifers, etc.). The Upper Cretaceous succession of Jamaica is now very well constrained (**Figure 2**), and the revision of many of the rudists has either been completed (Mitchell and Gunter, 2002, 2004, 2006; Mitchell, 2003a, 2005, 2009, 2010a, b, c; Mitchell et al., 2007; Mitchell and Ramsook, 2009; Mitchell and Pons, 2010) or is in progress.

Cretaceous rocks are exposed in a series of inliers across central and western Jamaica (**Figure 1**); some inliers are small (a few square tens of metres), others are large (many hundreds of square kilometers), and many of them contain limestones with rudist bivalves. Four groups of inliers can be recognized: the Central Inlier (with minor assocated inliers), the St. James inliers (Sunderland, Carlton Hill, Maldon, Marchmont, etc.), the St. Ann's Great River Inlier, and the Hanover inliers (Lucea, Green Island, Grange, and Jerusalem Mountain).

The late Cretaceous succession can be divided into an older series of deposits (Coniacian to late Campanian) and a younger series of deposits (Maastrichtian) which are separated by an angular unconformity (Mitchell, 2003b, 2006). This angular unconformity was caused by the collision between the Caribbean and North American Plates (Mitchell, 2003b).

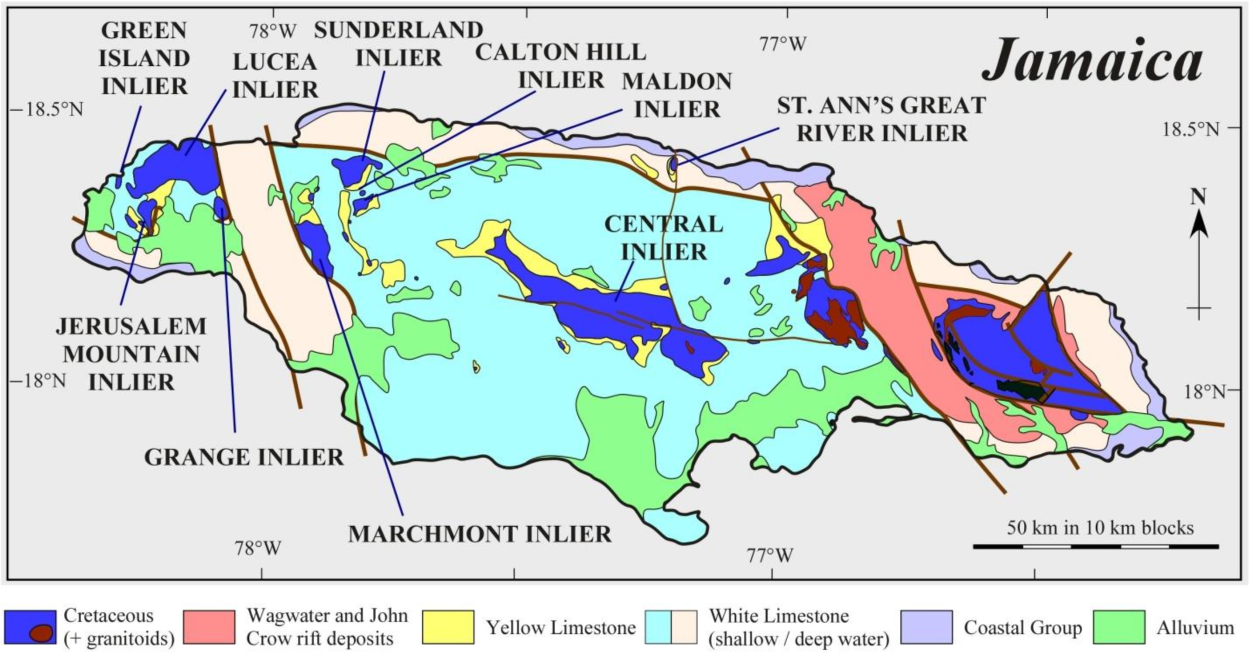

Figure 1. Locations of Cretaceous inliers in central and western Jamaica that are referred to in the text.

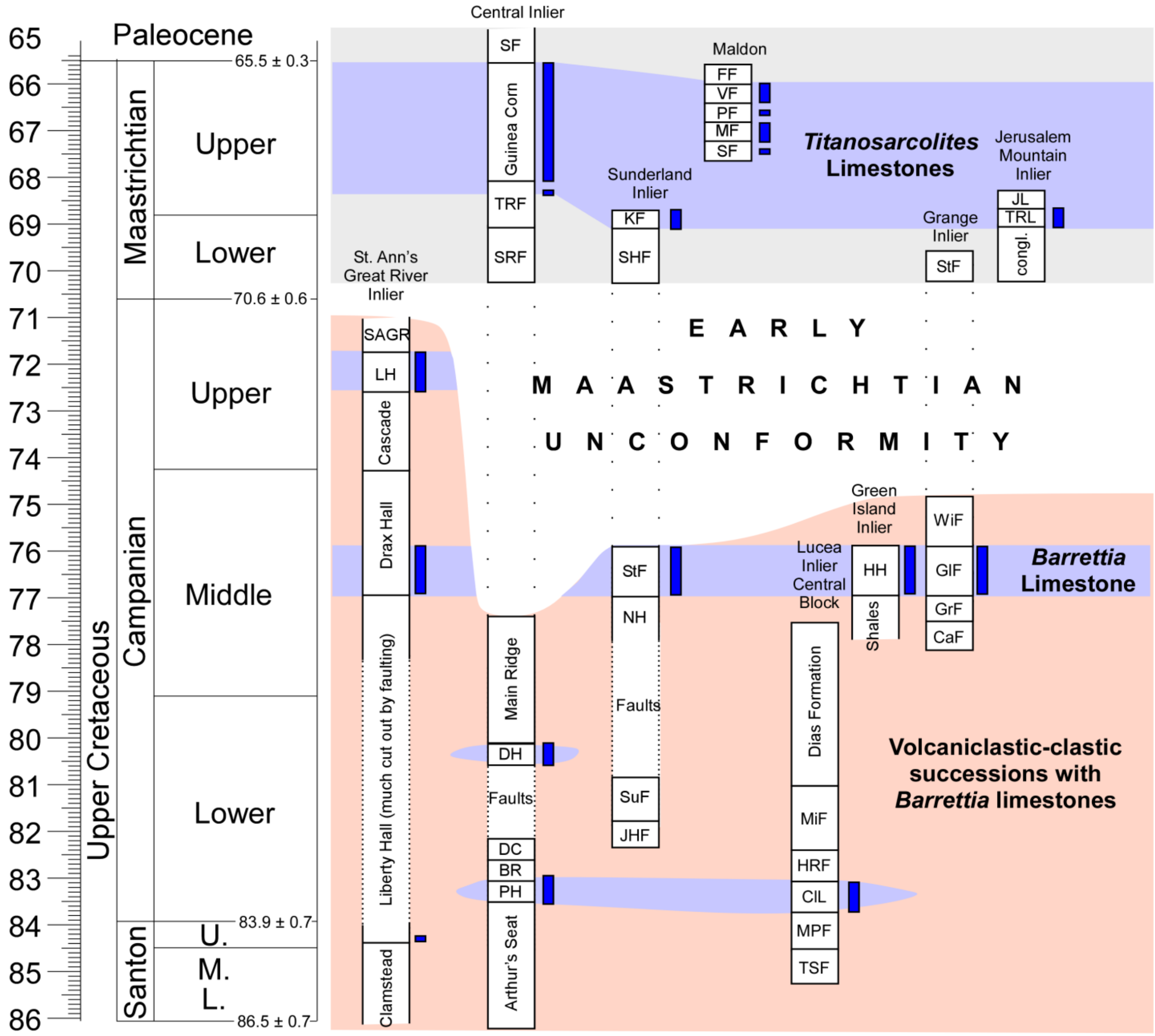

Figure 2. Summary stratigraphy of the St. Ann's Great River, Central. St. James and Hanover inliers. KEY: St. Ann's Great River Inlier: LH, Lime Hall Fm.; SAGR, St. Ann's Greta River Formation. Central Inlier: PH, Peters Hill Fm.; BR, Back River Fm.; DC, Dawburns Content Fm.; DH, Dry Hill Fm.; SRF, Slippery Rock Fm.; TR, Thomas River Fm.; SF, Summerfield Group. Sunderland Inlier: JHF, Johns Hall Fm.; SuF, Sunderland Shales; NH, Numans Hall Shales; StF, Stapleton Fm.; SHF, Sherpherds Hall Fm.; KF, Kennsington Lmst. Lucea Inlier: TSF, Tom Spring Fm.; MPF, Mount Peace Fm.; ClL, Clifton Lmst.; HRF, Harvey River Fm.; MiF, Middlesex Fm. Green Island Inlier: HH, Haughton Hall Fm. Grange Inlier: CaF, Cabartia Fm.; GrF, Grange Fm.; GlF, Glenbrook Fm.; WiF, Williamsfield Fm.; StF, Strawberry Fm. Jerusalem Mountain Inlier: TRF, Thicket River Lmst.; JL, Jerusalem Lmst.

Although Jamaica is a relatively small island (230 km from east to west and 80 km from north to south), its mountaineous terrane means that it is not easy to transverse quickly. In selecting field locations to visit for this conference, the authors of this field guide have had to weigh up what exposures we should see, and what exposure we can feasibly get to in the time available. Heavy rains in early June, 2011, have also left their mark on Jamaica's roadways! We have chosen to highlight outcrops in western Jamaica (in the parishes of Hanover and Westmoreland) with their assemblages of Mid Campanian and early Maastrichtian rudists, and central Jamaica (the Central Inlier of Clarendon) with its exposures of early Campanian and mid- to late-Maastrichtian rudists.

The Hanover Inliers

Lucea Inlier

The Lucea Inlier is the third largest area of Cretaceous rocks in Jamaica and exposes a mid Upper

Cretaceous sequence of predominantly deep-water clastic sedimentary rocks (Hanover Shale) and the shallow-water 'reefal' Clifton Limestone (Chubb in Zans et al., 1963). Grippi (1980) divided the inlier into three structural blocks (northern, central and southern) which were defined by the Fat Hog Quarter and Maryland fault zones. Separate lithostratigraphic schemes were developed for each block (Grippi, 1980). The succession in the Central Block (**Figure 3**) begins with the Pioneer Formation and is succeeded by the Tom Spring Formation (as modified by Schmidt, 1988) that has been interpreted as a deep-sea canyon-fill complex (Grippi and Burke, 1980). Grippi (1980) interpreted the complex to pass laterally into the lower part of the overlying Mount Peace Formation, whereas Schmidt (1988) thought that it was overlain unconformably by the Mount Peace Formation. The Mount Peace Formation consists of thinly bedded shales and has the Clifton Limestone in its upper part. The Clifton Limestone is up to 100 m thick and consists of biosparite containing rudist bivalves, molluscan shell debris, corals, echinoids, rhodoliths and fragments of red algae. Many of the rudists are articulated and show little sign of abrasion. The rudist fauna of the Clifton Limestone includes ***Barrettia ruseae*** **Chubb**, ***Vaccinites vermunti*** **Mac Gillavry**, ***Whitfieldiella*** **sp. nov.**, ***Plagioptychus*** **sp.** and ***Mitrocaprina*** **sp.** (Chubb, 1971; van Dommelen, 1971; Donovan et al., 2006). The rudist assemblage suggests an early Early Campanian age (by comparison with central Jamaica and Puerto Rico), and is consistent with other macrofossil (ammonite and inoceramid) and calcareous nannofossil (Grippi, 1980; Jiang and Robinson, 1987; Wiedmann and Schmidt, 1993) records.

Grange and Green Island Inliers

The Grange and Green Island inliers show similar successions. Both include rudist limestones (Haughton Hall Formation in the Green Island Inlier: Mitchell, 2010a; Glenbrook Formation in the Grange Inlier: Fisher and Mitchell, submitted) which are regarded as equivalents to the Stapleton Formation of the Sunderland Inlier (Meyerhoff and Kreig, 1977; Mitchell, 2010a, b). The limestones contain the larger foraminiferan *Pseudorbitoides trechmanni* Douvillé showing similar levels of development indicating that all three limestones are of a similar age (Krijnen, 1972; Krijnen et al., 1993). Jiang (1993) described the succession of calcareous nannofossils from the Sunderland Inlier and showed that the shale (Newman Hall Formation) below the Stapleton Limestone yielded nannofossils assignable to Sissingh zone CC20b, whereas those from above the limestone were assignable to zone CC20c. This indicates that this widespread limestone (Stapleton, Haughton Hall, Glenbrook) can be assigned to either the top of zone CC19b or the base of zone CC20c and is broadly equivalent to the middle Campanian of the three-part North American division of the Campanian Stage.

The rudist assemblage from the Haughton Hall Limestone includes: ***Barrettia multilirata*** **Whitfield**, ***Whitfieldiella gigas*** **(Chubb)**, ***Parastroma trechmanni*** **Chubb**, ***Torreites sanchezi*** **(Douvillé)**, ***Durania*** **sp.**, ***Durania krijneni*** **Mitchell & Ramsook**, ***Bournonia baileyi*** **Chubb**, ***Macgillavryia nicholasi*** **(Whitfield)**, ***Antillosarcolites macgillavryi*** **Chubb,** ***Parantillosarcolites lenticularis*** **Mitchell**, ***'Antillocaprina' willamsoni*** **Chubb**, ***Mitrocaprina bayani*** **(Douvillé)**, and ***Plagioptychus antillarum*** **(Douvillé)**; that from the Glenbrook Limestone contains: ***Whitfieldiella gigas***, ***Whitfieldiella*** **sp. nov.**, ***Parastroma trechmanni***, ***Macgillavryia nicholasi***, and ***Plagioptychus antillarum***.

Jerusalem Mountain Inlier

The Jerusalem Mountain Inlier exposes a succession of Cretaceous fossiliferous limestones and associated clastics. Two units of limestone are present in the inlier (Trechmann, 1924) an older 'Titanosarcolites Limestone' now called the Thicket River Limestone and a younger 'Oyster Limestone' or the Jerusalem Limestone separated by a succession of shales (Kozary, 1956; Jiang and Robinson, 1987). The Jerusalem Limestone in the Jerusalem Mountain Inlier was traditionally regarded as the youngest Cretaceous horizon in Jamaica showing the supposed mid-Maastrichtian extinction of the rudists (Trechmann, 1924; Johnson and Kauffman, 1996), but ages derived from strontium isotope ratios obtained from pristine rudist calcite demonstrate that these limestones are older than Maastrichtian limestones in the Central and Maldon inliers (Steuber et al., 2001).

The Jerusalem Limestone contains a rudist assemblage including: ***Titanosarcolites*** **sp. nov.**, ***Biradiolites rudissimus*** **Trechmann**, ***Thyrastylon chubbi*** **Alencáster**, ***Caribbea mullerriedi*** **Vermunt**, ***'Antillocaprina' stellata*** **Chubb**, ***Bournonia cancellata*** **(Whitfield)**, ***Plagioptychus*** **sp. (small)** and **P. cf.** ***jamaicensis*** **(Whifield)**.

Central Inlier

The Central Inlier of central Jamaica exposes a Cretaceous to Paleocene suite of sedimentary and volcaniclastic/pyroclastic rocks (Mitchell and Blissett, 2001). The Central Inlier is the key to unravelling Jamaica's Cretaceous geological history for two reasons: the succession exposed in the inlier extends from the early late Cretaceous to the Paleocene; and the succession contains many levels with abundant fossils allowing age determination. Details of the succession can be found in Trechmann (1924), Chubb (in Zans et al., 1963), Coates (1964, 1965, 1969), Robinson et al. (1972), Mitchell (1999, 2003b, 2006) and Mitchell and Blissett (2001).

The rock succession exposed in the Central Inlier can be divided into stratigraphic units defined by angular unconformities to which the term synthem (Chang, 1975; Salvador, 1994) is applied. The older volcanic successions are revised herein using unpublished Ar-Ar ages obtained by Alan Hastie during his Ph.D. work on the geochemistry of the igneous rocks.

Older Volcanic-Sedimentary Succession

The oldest rocks are the andesitic lavas and associated volcaniclastics of the Arthurs Seat Formation (Coates, 1969). These are overlain by the Peters Hill, Back River and Dawburns Content formations (Mitchell, 2003b, 2009).

The Peters Hill Formation rests unconformably on conglomerates, andesites and basalts of the Arthurs Seat Formation. It is up to 25 m thick, and consists of a basal conglomerate succeeded by shallow-water, rudist-bearing limestones. The rudist fauna consists of: ***Barrettia coatesi*** **(Chubb)**, ***Torreites chubbi*** **Grubić**, ***Durania lopeztrigoi*** **(Palmer)**, ***Biradiolites*** **sp.**, ***Bournonia*** **sp.**, ***Antillosarcolites*****? sp.** and ***Antillocaprina*** **sp.** The lower part of the Back River Formation consists of three units. The lowest is a sequence of about 4 m of mudstones and thin sandstones. Rare rudists are found in a sandstone at the top of this unit and include ***D. lopeztrigoi*** and ***Contraspira khanae*** **Mitchell**. The rudist assemblage suggests an early Early Campanian age (by comparison with Puerto Rico), and is consistent with other macrofossil (inoceramid) and calcareous nannofossil records (Kauffman, 1966; Jiang and Robinson, 1987).

A further limestone occurs in the eastern part of the Central Inlier at Dry Hill. This contains a different, younger (late Early Campanian) rudist fauna that has yet to be described. Access to the site is difficult and it is not possible to visit on this trip.

Kellits Synthem

The Kellits Synthem rests on a marked angular unconformity on the underlying Cretaceous succession and cosnists of a transgressive-regressive cycle of late Maastrichtian to Paleocene age (Mitchell and Blissett, 2001; Steuber et al., 2002).

The Kellits Synthem begins with a succession of poorly stratified, red, brown and grey pebble conglomerates of the Slippery Rock Formation (some 150 m thick) which were deposited in alluvial fans and fan deltas (Mitchell and Blissett, 2001).

The succeeding Thomas River Formation (up to 150 m thick) consists of red and grey mudstones and sandstones, with low-diversity mollusc assemblages, and was deposited in tidally influenced lagoons, channels and mudflats. The red mudstones are largely uniform and lack sedimentary structures, but may be cut by channel sandstones with bidirectional ripple-cross-lamination. The overlying grey mudstones are typically laminated, with laminae defined by plant debris. Channel sandstones cut some of the grey mudstones and show inclined heterolithics with bidirectional palaeocurrents indicative of tidal channels. Rudist assemblages are limited to a few silty limestones in more open marine environments and include ***Bournonia cancellata*** and ***Mitrocaprina bayani***.

The overlying Guinea Corn Formation is up to 200 m thick. In the western areas of the inlier it rests on the Thomas River Formation, but to the east it rests on the Slippery Rock Formation. The Guinea Corn Formation thins to the east and passes from platform limestones in the north-west to coastal mudstones and sandstones with thin inpure limestones in the east; eventually the limestones disappear and the conglomerates of the Slippery Rock Formation are overlain by the sandstones of the Green River Formation at the base of the Summerfield Group.

The Guinea Corn Formation is typically cyclic (Mitchell, 2002), with a lower unit of clastics (mudstones over sandstones, or mudstones) and an upper unit of limestones. The base of each cycle (base of the sandstone or mudstone) is sharp, but the transition from mudstones up into limestones is gradational with an increase in carbonate content. Where limestones dominate, the cycles are typically 3 to 5 m thick; but towards the south-east, the lower clastic portions of the cycles thick dramatically and some cycles may be up to 40 or 50 m thick. Individual cycles can be correlated from section to section based on macrofossil zones (rudists), the distinctive morphologies of the small solitary coral *Paracycloseris*, or by distinctive (sedimentological or palaeontological) event beds.

Rudist bivalves are abundant in the limestones, and very rich assemblages are present. The list of rudists present includes: ***Praebarrettia sparcilirata*** **(Whitfield)**, ***Caribbea muellerreidi***, ***C. maldonensis*** **(Chubb)**, ***Caribbea*** **sp. nov.**, ***Macgillavryia nicholasi***, ***Chiapasella radiolitiformis*** **(Trechmann)**, ***C. aguilae*** **(Adkins)** (=*C. trechmanni* Mitchell & Gunter), ***Bournonia cancellata***, ***B. barretti*** **Chubb**, ***B. thiadensi***, ***Biradiolites jamaicensis***

Trechmann, ***B. mooretownensis* Trechmann**, ***'B.' rudissimus* Trechmann**, ***Thyrastylon adhaerens* (Whitfield)**, ***'Radiolites' macroplicatus* (Whitfield)**, ***Titanosarcolites giganteus* (Whitfield)**, ***Titanosarcolites* sp.** (4 new species), ***Antillocaprina occidentalis* (Whitfield)**, ***A. suboccidentalis* Chubb**, ***A. quadrangularis* (Whitfield)**, ***A. stellata***, ***Parasarcolites baileyi* Mitchell & Gunter**, ***P. monotubularis* Mitchell & Gunter**, ***P. quadratus* Mitchell & Gunter*,* *P. greeni* Mitchell & Gunter*,* *P. atkinsoni* Mitchell & Gunter**, ***Plagioptychus zansi* Chubb**, ***P. trechmanni* Chubb**, ***P. jamaicensis***, ***Mitrocaprina bayani***, and ***M. tschoppi* (Palmer)**.

Above the Guinea Corn Formation is the Summerfield Group (Mitchell, 2000; Mitchell and Blissett, 2001). The Summerfield Group consists of a shallowing-upwards succession of marine to terrestrial volcaniclastic sedimentary rocks. The lower part consists of mudstones with normal graded sandstones (Green River Formation – 60 m thick) that pass up into massive sandstones (Peckham Formation – 150 m thick). The overlying Mahoe River Formation (210 m thick) consists of thickly-bedded, pebble and boulder conglomerates with rounded clasts. The Mahoe River Formation is succeeded by up to 75 m of ignimbrites (Waterworks Formation).

Field Stops

Day 1. Stop 1. Glenbrook Limestone at Glenbrook, Grange Inlier (GPS 18° 20.004; 078° 04.963)

The Glenbrook Limestone crops out along a minor road near Glenbrook in the Grange Inlier. The rudist assemblage is dominated by ***Parastroma trechmanni*** (**Figure 3A**), but a small undescribed species of ***Whitfieldiella*** (**Figure 3C**) and ***Macgillavryia nicholasi*** also occur. Recent foundation constructions for a house should allow the collection of specimens of ***Parastroma trechmanni*** (**Figure 3A**).

Day 1. Stop 2. Jerusalem Mountain - Road Section (GPS 18° 19.948; 078° 13.861)

The Thicket River Limestone is exposured beside the road leading from Grange Hill to Jeruslam Mountain. The rubbly hard limestones yield a moderately diverse rudist fauna, and large fragments of *Titanosarcolites* sp. (**Figure 3E**) can be collected. Other rudists from here include *'Birdaiolites' rudissimus*, *Parasarcolites* sp. and *Caribbea muellerreidi*.

Day 1. Stop 3. Jerusalem Mountain - Playing Field (GPS 18° 19.3672; 078° 13.999)

The Thicket River Limestone is exposured at the southern end of the football pitch at Jeruslam Mountain. Rubbly, hard limestones are exposed which yield a typical assemblage of small rudists. Loose examples can be collected from the talus, including ***Thyrastylon chubbi*** (**Figure 3F**), ***Bournonia cancellata***, ***Plagioptychus* sp.** and ***Caribbea muellerreidi***.

Day 1. Stop 4. Haughton Hall Limestone at Green Island (GPS 18° 23.266; 078° 16.762)

The classic locality at Haughton Hall has been collected for more than 100 years. Rudists can still be collected loose in the soil when vegetation conditions permit, but the large specimens of ***Barrettia multilirata*** (**Figure 3B**) and ***Whitfieldiella gigas*** (**Figure 3D**) in many museum collections are only rarely found these days due to previous extensive collecting. A limestone bed near the top of the succession forms a prominent ledge on some of the hills.

The drive to Montego Bay passes through road cuts in the deep-water successions of the Lucea Inlier. Turbiditic sandstones are well-displayed in some of the cuts.

Day 2. Stop 5. Thomas River Formation (GPS 18° 09.307; 077° 23.187)

This is a small exposure in the Rio Minho near Grantham that shows a unit of sandstones in the Thomas River Formation. The succession consists of stacked small cycles which show a progradation from flaser bedding through wavy bedded units to lenticular beds. Flaser bedding consists predominantly of ripple cross laminated sandstone with small mudstone flasers; wavy bedding is an equal mix of mudstone and ripple cross laminated sandstone; lenticular bedding consists of isolated sandstones lenses containing ripple cross-lamination within mudstone. Careful examination of the ripple cross lamination demonstrates that ripple migration was bi-directional. stacked flaser-wavy-lenticular bedding cycles with bi-directional palaeocurrents are typical of tidal flat sequences. Such sequences are often called 'pin-stripe facies'.

The base and top of the sandstone unit are represented by fossiliferous beds, which yield low diversity assemblages of oysters and a few small infaunal bivalves, gastropods and bryozoans. The

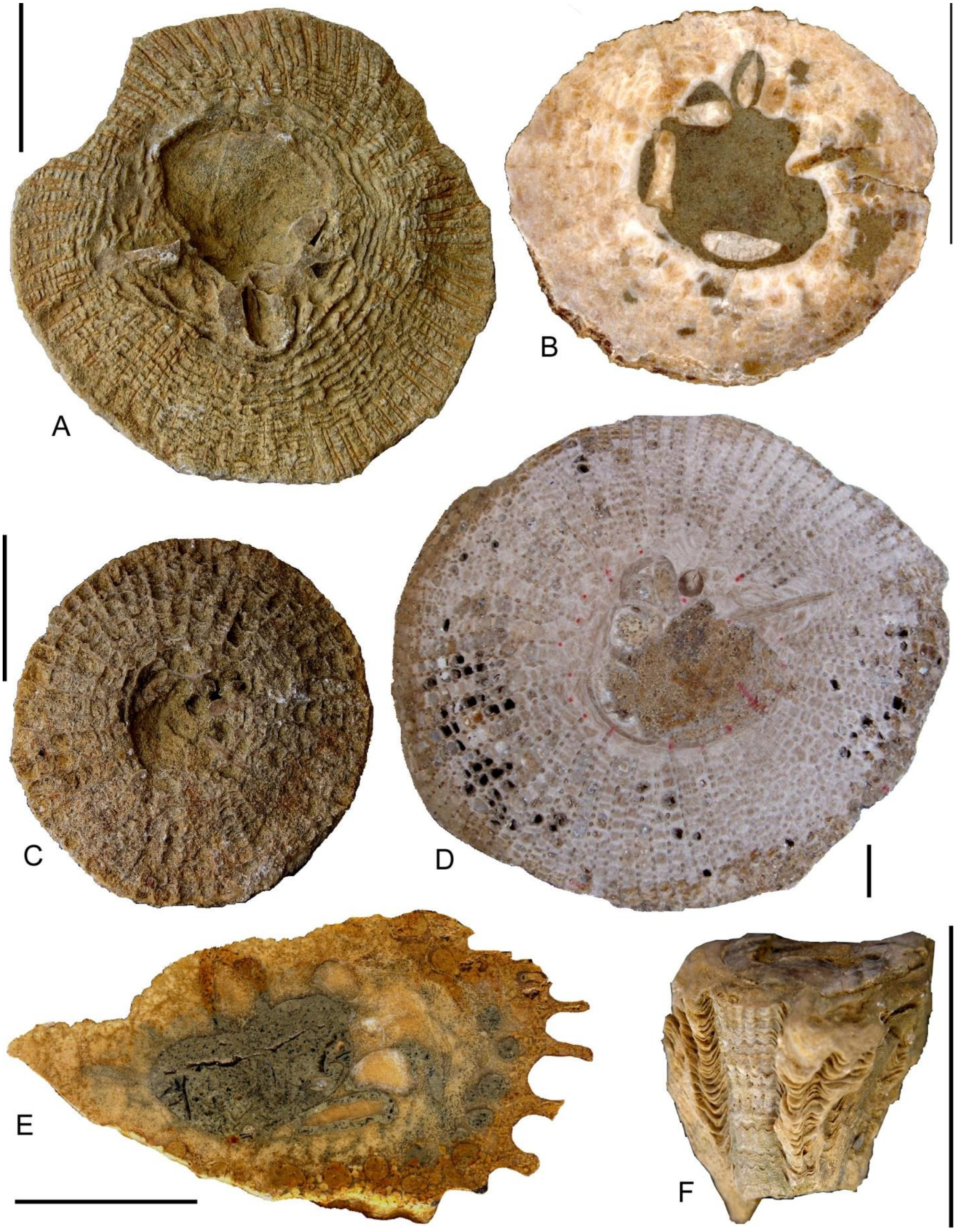

Figure 3. Campanian and Early Maastrichtian rudists from Western Jamaica. A, *Parastroma trechmanni* Chubb, Glenbrook Limestone; B, *Barrettia multilirata* Whitfield, Haughton Hall Limestone; C, *Whitfieldiella* sp. nov., Glenbrook Limestone; D, *Whitfieldiella gigas* (Chubb), Haughton Hall Limestone; E, *Titanosarcolites* sp. nov., Thicket River Limestone; F, *Thyrastylon chubbi* Alencáster, Thicket River Limestone. Scale bars are 50 mm.

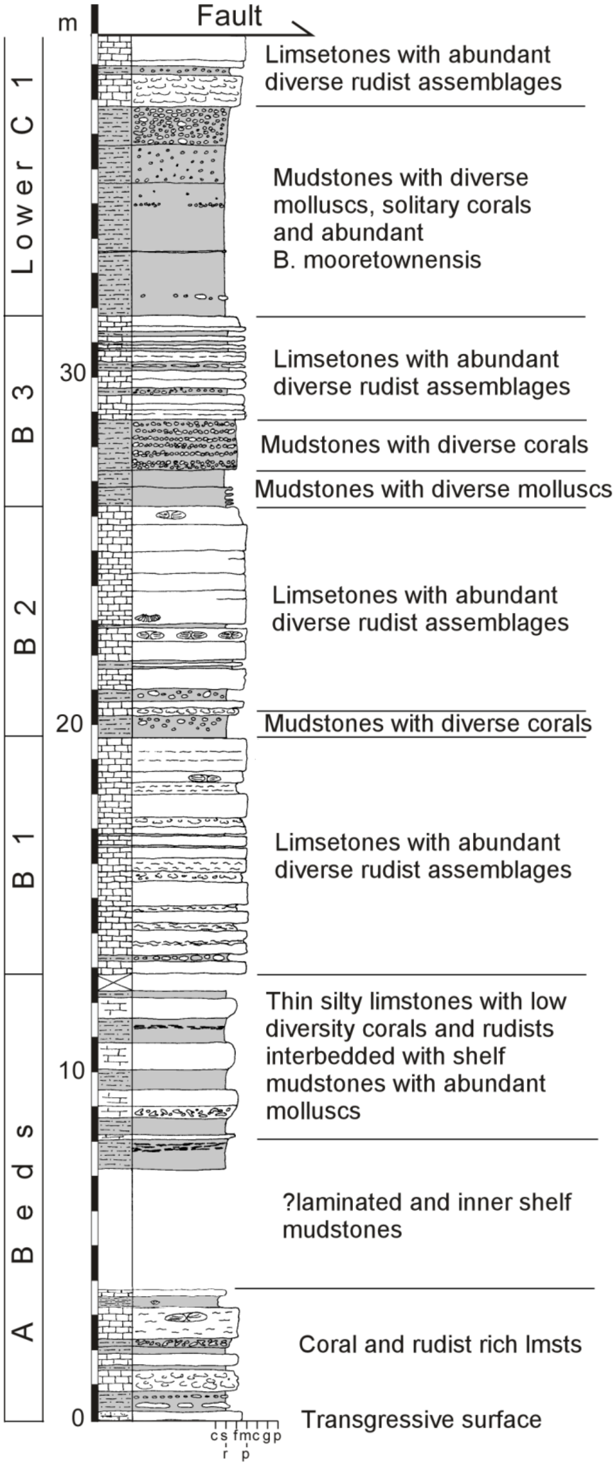

Figure 4. Logged succession through the A Beds, B Beds and lower C Beds at Grantham. This is the type section of the Guinea Corn Formation.

shell bed at the top has local concentrations of concretions. These concretions have been collonised by serpulids and bryozoans and bored by *Lithophaga* producing the trace fossil *Gastrochaenolites*.

The overlying and underlying mudstones contain rare gastropods and examples of gyrogonite charophytes which indicate fresh or brackish water conditions. Plant debris is abundant and the rock splits along surfaces due to its abundance.

The low diversity faunal assemblages, the abundant plant material, and the tidal flat sequences, suggest that the succession accumulated in an estuary.

Day 2. Stop 6. Guinea Corn Formation (Grantham, Type Section) (GPS 18° 09.398; 077° 23.058)

The succession immediately downstream from the confluence between the White Rock (or Rondons) River and the Rio Minho exposes the lower 40 m of the Guinea Corn Formation (**Figure 4**) and the junction with the underlying Thomas River Formation (Mitchell, 1999). The Guinea Corn Formation shows well developed cycles at this location (Mitchell, 2002). Here, each cycle consists of three distinct sedimentary units: (1) a lower siltstone unit rich in volcaniclastic grains and containing abundant gastropods (particularly actaeonellids) and solitary corals; (2) a siltstone or calcareous siltstone unit with abundant colonial corals (*Ovalastrea trechmanni* (Wells), *Actinacis* sp., *Vaughanoseris catadupensis* Wells, *Trochoseris catadupensis* (Vaughan), *Leptoria (Dictuophyllia) conferticostata* (Vaughan) and *Dichocoenia* sp.: Stemann et al., 2007) or scattered recumbent rudists including ***Antillocaprina stellata*** and ***Parasarcolites* spp.**; and (3) an upper bedded limestone with abundant elevator rudists, such as ***Bournonia***, ***Biradiolites***, ***Antillocaprina***, ***Thyrastylon*** and ***Chiapasella***. The siltstone of C1 is particularly rich in gastropods and infaunal bivalves, but also yields occasional examples of *Paracycloseris elizabethae* Wells and abundant small bouquets of the small rudist ***Biradiolites mooretownensis***. Selected rudists from the Guinea Corn Formation are shown in **Figures 5-7**.

Day 2. Stop 7. Guinea Corn Formation (Coffee Piece NE) (GPS 18° 09.418; 077° 22.966)

The section at Coffee Piece NE shows the lower part of the Middle C Beds, the top of the D Beds, and part of the F Beds; there are several bedding parallel faults here that are difficult to recognize.

Rudists are common and a typical Guinea Corn assemblage can be collected. The commoner forms at

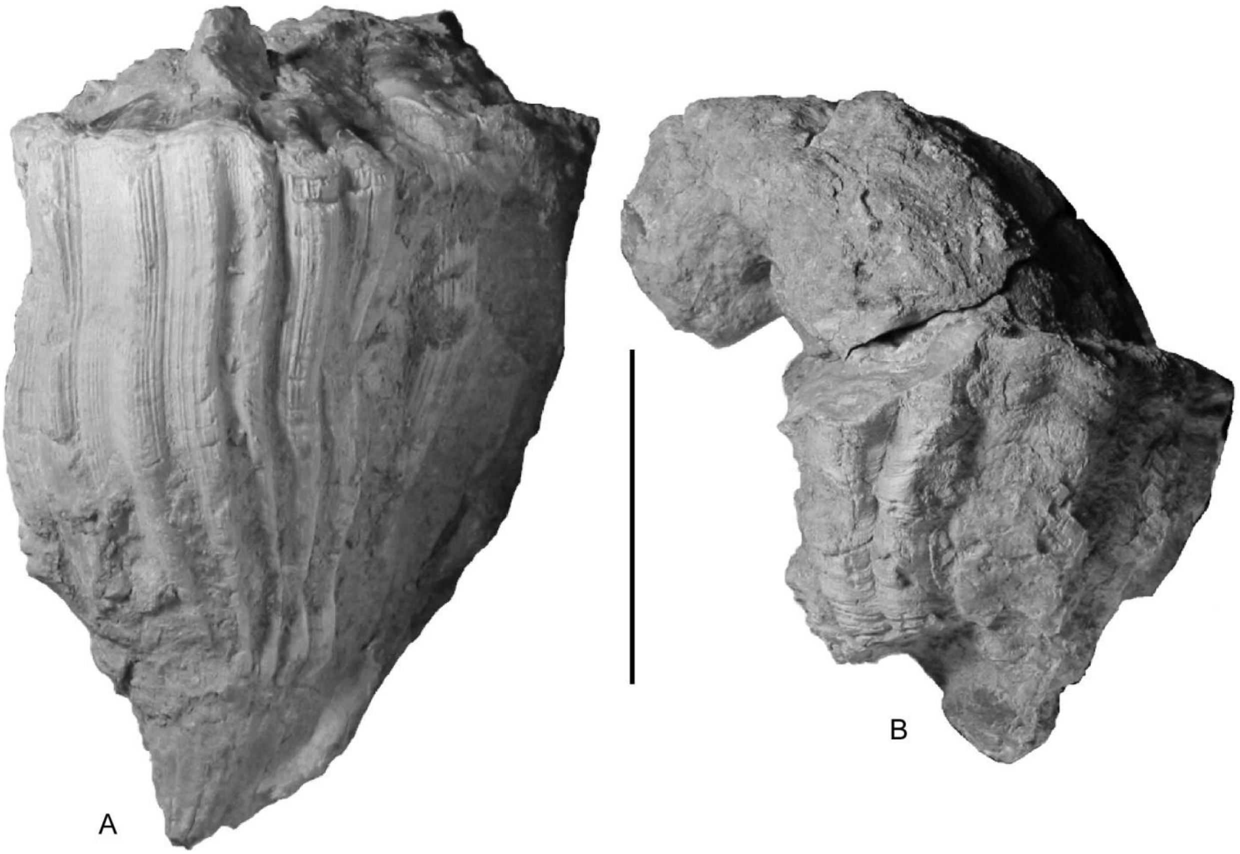

Figure 5. ***Chiapasella*** **from the Guinea Corn Formation. A,** ***Chiapasella aguilae*** **(Adkins), lower D Beds. B,** ***Chiapasella radiolitiformis*** **(Trechmann), C Beds. Scale bar is 50 mm.**

Figure 6. ***Titanosarcolites giganteus*** **(Whitfield) from the Middle C Beds of the Guinea Corn Formation, showing myocardinal arrangements. Scale bar = 50 mm.**

this locality include: ***Chiapasella radiolitiformis***, ***Bournonia barretti*** **Chubb**, ***Biradiolites jamaicensis***, ***B. rudissimus***, ***Thyrastylon adhaerens***, ***'Radiolites' macroplicatus***, ***Titanosarcolites giganteus***, ***Antillocaprina suboccidentalis***, ***A. stellata***, and ***Parasarcolites quadratus***.

Day 2. Stop 8. Guinea Corn Formation (Cabbage Hill) (GPS 18° 09.418; 077° 22.966)

The Guinea Corn section at Cabbage Hill (Mitchell, 1999) show the sequence from the upper part of the Upper C Beds to the top of the Guinea Corn Formation, although there is a small fault within the F Beds at this locality.

The Upper C Beds contain a range of small elevator rudists (mainly ***Bournonia*** and ***Thyrastylon*** with a few ***Antillocaprina*** **spp.**, ***Parasarcolites atkinsoni*** and ***Plagioptychus***), whereas the overlying D Beds contain abundant examples of ***Chiapasella aguilae***. Oncoids, up to 5 cm in diameter, are abundant in unit D5 each with a nucleus representing a reworked fragment of coral and mantled by red algae or crypt-algal laminae.

Beds D6 and F1 are characterized by the presence of large ***Macgillavryia nicholasi***, and these beds can be traced many kilometres to the northwest, and represent prominent marker beds in the upper part of the Guinea Corn Formation. Specimens of ***Macgillavryia*** are clerrly transported (although rare

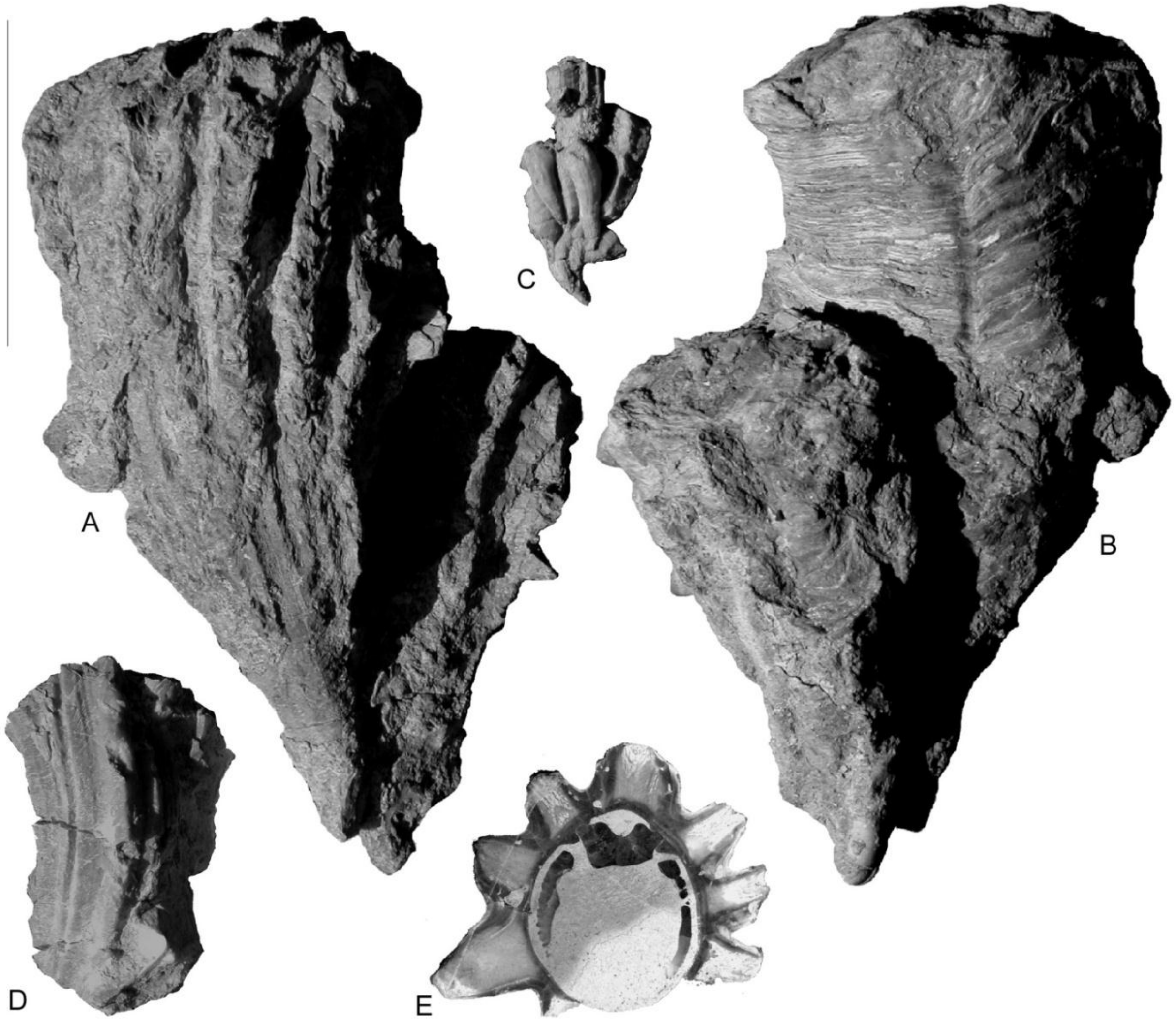

Figure 7. Radiolitids from the Guinea Corn Formation. A, C, *Bournonia cancellata* (Whitfield), B Beds. B, *Biradiolites mooretownensis* Trechmann, Lower C Beds. D, E, *Birdiolites jamaicensis* Trechmann, D Beds. Scale bar is 50 mm.

Figure 8. *Macgillavryia nicholasi* (Whitfield): specimen in growth position with LV (to right of hammer) overlain by limestones containing reworked specimens lacking their LVs. Bed D1, Cabbage Hill.

specimens in growth position (**Figure 8**) have been seen, lack their left valves, and often show *Gastrochaenolites* crypts. Specimens of *Plagioptychus jamaicensis* occur in Bed F1, and stromtium isotope ratios from these give a mean age of 65.78 Ma (relative to a K/T boundary age of 65.0 Ma) (Steuber et al., 2002).

The G Beds of the Guinea Corn Formation contain abundant specimens of the larger foraminiferan *Chubbina jamaicaenis* Robinson which give the rocks a speckled appearance when wet. Rudists are common, but the hard nature of the limestones often makes observation difficult. However, at the top of the G Beds cross-sections through numerous rudists can be seen showing that a highly diverse assemblage extends to the top of the Guinea Corn Formation.

Figure 9. *Barrettia coatesi* (Chubb) showing pallial canals and myocardinal-pillar arrangements. Peters Hill Limestone, Peters Hill. Scale bar is 10 mm.

Day 3. Stop 9. Guine Corn Formation – Union Section

The Union section shows the Middle C Beds of the Guinea Corn Formation. Various rudists typical of the Guinea Corn Formation can be collected from the weathered limestones at this locality.

Day 3. Stop 10. Guinea Corn Formation (Green River) (GPS 18° 08.532; 077° 21.047)

The section in the Rio Minho upstream of its confluence with the Green River shows the D Beds. There have been significant changes since Cabbage Hill. The poorly defined cycles visible at Cabbage Hill are now represented by obvious cycles. Three major limestones containing occassional ***Chiapasella aguilae*** are present and represent Cycles D1 to D3; these are separated by clastic deposits. These cycles consists of three units:

(1) a sharp-based, laminated sandstone division (shoreface);
(2) a mudstone division with fossils and/or concretions ('lagoon'), and
(3) a limestone (shelf)

The remainder of the D Beds consists of a deepening upwards succession, with D4 to D6 represented by thin sandy limestones in a thick mudstone succession.

Higher in the succession (further along the river), a limestone (Bed F4) contains abundant examples of ***Titanosarcolites*** in life position.

Day 3. Stop 11. Peters Hill Limestone (GPS 18° 07.595; 077° 14.464)

The area around Peters Hill shows the Peters Hill and Back River formations.

The Peters Hill Formation crops out on the road and on the hillsides below the road. It is represented by massive hard limestones and nodular limestones. Many of the nodules are specimens of the rudist ***Barrettia coatesi*** (**Figure 9**) which is abundant. Other rudists occur including: ***Torreites chubbi***, ***Durania lopeztrigoi***, ***Biradiolites* sp.**, ***Antillosarcolites*? sp.** and ***Antillocaprina* sp.** Locally at the base of the Peters Hill Limestone, a marly limestone is exposed that yields gastropods including the nerinacean *Simplotyxis*.

Above the Peters Hill limestone, the lower part of the Back River Formation is exposed. It consists of grey mudstones with occasional sandstones and a thin limestone full of ramose corals. The grey shales yield common molluscs including the inoceramids *Platyceramus* and *Cataceramus* from which it was formerly known as the 'Inoceramus Beds.' at Peters Hill has not been published previously. Rare rudists are found in a sandstone below the coral-bearing sandstones and include ***D. lopeztrigoi*** and ***Contraspira khanae***.

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