

## Biostratigraphy of Late Maastrichtian larger foraminifers in Jamaica and the importance of *Chubbina* as a Late Maastrichtian index fossil

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**ABSTRACT** – The succession of larger foraminifers from the White Rock River Bridge section of the Guinea Corn Formation (Late Maastrichtian) in Jamaica, West Indies, contains: *Sulcoperculina dickersoni* (Palmer), *Ayalaina ruteni* (Palmer), *Orbitoides* cf. *megaloformis* Papp & Küpper, *Vaughania cubensis* Palmer and *Chubbina cardenasensis* (Barker & Grimsdale). *A. ruteni* occurs in the lower beds and *C. cardenasensis* occurs in the upper beds. The orbitoid foraminifer *Or. cf. megaloformis* is restricted to the middle beds. The White Rock River Bridge Section can be correlated to the standard Guinea Corn successions using lithological/biostratigraphic markers and rudist marker beds, and linked ages derived from Sr-isotope values. This indicates that *Or. cf. megaloformis* occurs in the last 1.3 Ma of the Cretaceous in the Caribbean and that its evolution was retrograde compared to coeval populations in Europe. The first appearance of *Chubbina* represents a valuable datum since the genus occurs in various different biofacies (both with and without orbitoid foraminifers) and allows correlation in the Caribbean, Central America and Florida. *J. Micropalaeontol.* 24(2): 123–130, October 2005.

**KEYWORDS:** Foraminifera, biostratigraphy, Guinea Corn Formation, Upper Cretaceous, Jamaica

### INTRODUCTION

The most important section of rudist-bearing, shallow-water, platform-type limestones in Jamaica is exposed in the Central Inlier (Coates, 1965; Mitchell & Blissett, 2001; Mitchell, 2002). These limestones are known as the Guinea Corn Formation and contain rudist assemblages dominated by *Titanosarcolites* and *Chiapasella*. The most complete section is exposed in the Rio Minho between Grantham and Frankfield, and was described in detail by Mitchell (1999), who introduced a bed lettering system (beds labelled from A to G) for the limestones based on variations in lithology. Two *Chiapasella* zones were erected by Mitchell & Gunter (2002) and five strontium isotope ages, using well-preserved calcite from the outer shell layer of rudists, were given by Steuber *et al.* (2002).

Despite the large amount of data collected from these sections in the Rio Minho, an outstanding problem is the stratigraphic distribution of the larger foraminifers. Although *Kathina*, *Sulcoperculina* and *Chubbina* are common in certain beds (e.g. Robinson, 1968), larger foraminifers, such as *Orbitoides*, *Pseudorbitoides*, *Omphalocyclus* and *Vaughania* are not present, although they were reported to be abundant elsewhere in Jamaica (Jiang & Robinson, 1987; Krijnen *et al.*, 1993; Gunter *et al.*, 2002), but not from measured sections. Broadly coeval larger foraminifers are also distributed widely elsewhere in the Caribbean (Cuba: Palmer, 1934; Rutten, 1935; Brönnimann, 1954a, b, 1955a, b, 1956; Seiglie & Ayala-Castañares, 1963), Central America (Mexico: Ayala-Castañares, 1963; Rosales-Domínguez *et al.*, 1997; Caus *et al.*, 2002), South America (Venezuela: Renz, 1955) and Florida (Cole & Applin, 1970) and have been correlated with the European *Orbitoides* succession (Caus *et al.*, 1996).

In this paper, a section exposed in the White Rock River near the village of Tweedside is described (Fig. 1). This section contains lithological and faunal marker beds that allow a correlation with the standard Guinea Corn succession in the Rio Minho, and abundant larger foraminiferal assemblages. This

allows for the first time an independent dating of the supposed Late Campanian–Early Maastrichtian *Orbitoides* succession in the Caribbean and demonstrates that the *Orbitoides* evolutionary pattern in the Caribbean is retrograde when compared to Europe. Furthermore, *Chubbina* is restricted to the Late Maastrichtian and should prove a valuable index fossil in sections around the Caribbean Plate.

### METHODOLOGY

The section in White Rock River was logged and samples were collected for foraminifers at regular intervals throughout the section. Bulk samples of siltstones/mudstones were collected from the softer layers (WR and TM prefixes). These were dried in an oven and sieved through a 125 µm sieve. Foraminifers were picked using a binocular microscope. In the intervals lacking suitable soft lithologies, limestone samples were collected (Samples 1 to 9). Ten thin sections were prepared from each sample and the foraminifers identified under a binocular microscope.

For the specimens of *Orbitoides* in the soft layers, equatorial thin sections were prepared. Eight thin sections were prepared, but four of these were strongly recrystallized and did not show the embryonic apparatus. Additionally, equatorial thin sections from the studies of Jiang & Robinson (1987) and Gunter *et al.* (2002) were also examined. Measurements of the embryonic apparatus of *Orbitoides* follow Caus *et al.* (1996 and references therein). The maximum and minimum diameters of the outside ( $L_o$  and  $l_o$ , respectively), and inside ( $L_i$  and  $l_i$ , respectively) of the embryonic apparatus, together with the number of epi-auxiliary chambers ( $E$ ) were measured. These are compared graphically with plots of  $L_o+l_o$  versus  $E$  and  $L_o+l_o$  versus  $L_i+l_i$  for populations of *Orbitoides* from Europe (Caus *et al.*, 1996).

All samples are housed in the Geology Museum at the University of the West Indies (UWIGM numbers). Representative foraminifers in thin section are shown in Plate 1.

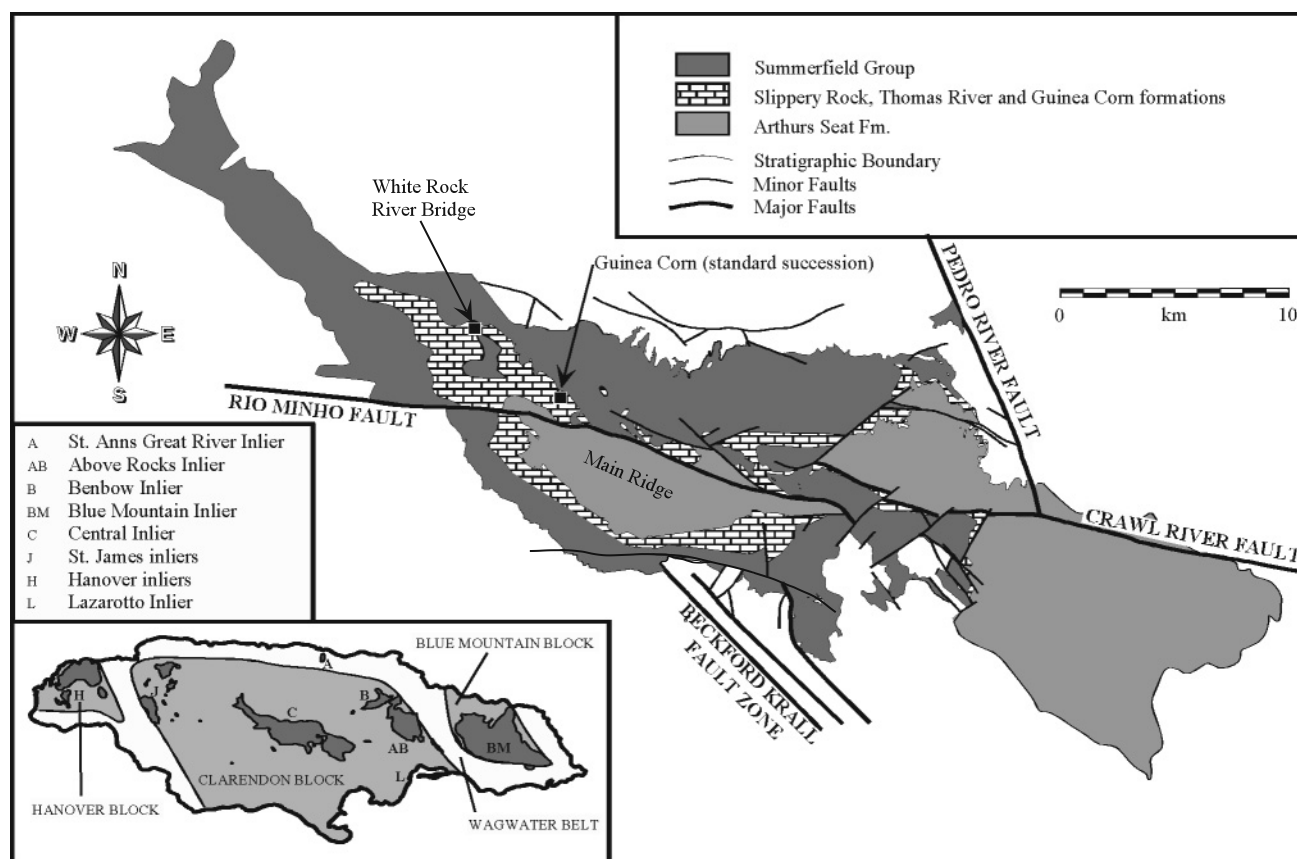


Fig. 1. Location of the White Rock River Bridge and standard (Guinea Corn) sections in the Central Inlier of Jamaica. Inset, distribution of Cretaceous inliers in Jamaica.

### WHITE ROCK RIVER BRIDGE SECTION

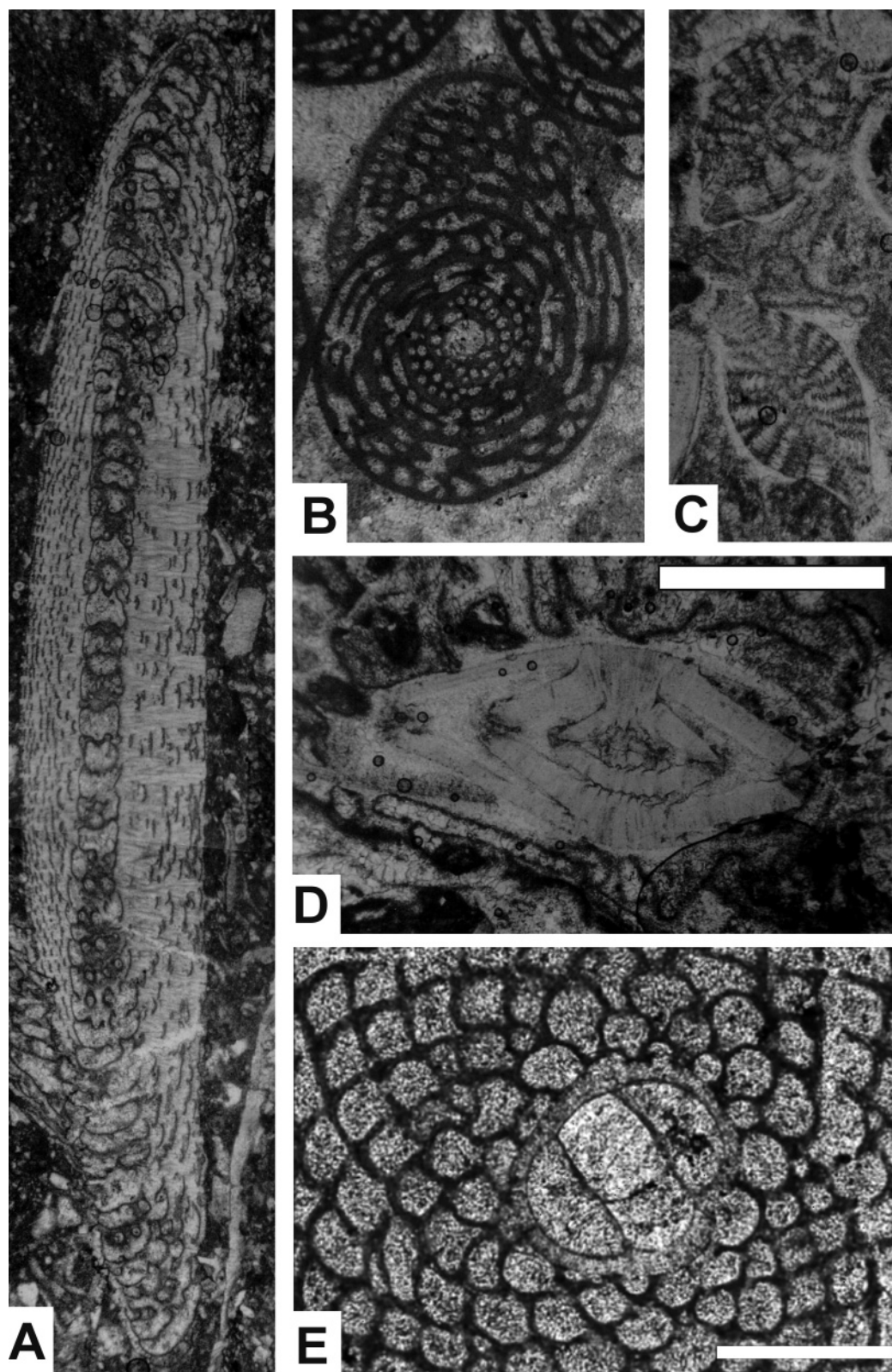
The White Rock River Bridge section exposes a near-continuous succession of limestones with subsidiary mudstones. A total of 86 m was logged (Fig. 2). The lower part of the section is exposed in the White Rock River in the 100 m upstream of the bridge. The base of the Guinea Corn Formation is not seen. The upper part of the section is exposed along the road on the southern side of the bridge, although the junction with the overlying Green River Formation, Summerfield Group, is concealed.

The lower 11 m of section consists of bioclastic limestones with scattered rudists including *Titanosarcollites* sp., *Bournonia thiadensi* Vermunt and *Biradiolites jamaicensis* Trechmann. Two important marker horizons are a rudist rudstone (*Mac* 1) containing abundant *Macgillavryia nicholasi* (Whitfield) with an impure, calcarenitic matrix, and a white micritic limestone (*Mac* 2) with scattered *M. nicholasi*. Sample WR 5 yielded only *Kathina jamaicensis* (Cushman & Jarvis). The two *Macgillavryia* beds correlate with similar beds in the standard Guinea Corn succession. *Mac* 1 correlates with the *Praebarrettia* Bed at the top of the D Beds of Mitchell (1999). The name *Praebarrettia* Bed is not retained here since *Praebarrettia* itself is not common even in the standard succession, whereas *Macgillavryia* is abundant. *Mac* 2 correlates with the *Macgillavryia* Bed of Mitchell (1999) in Bed F1 of the standard succession; in both sections *Mac* 2 is represented by a prominent white limestone.

Above *Mac* 2 there is a marked facies change from limestones to marls with nodules. The succeeding 7 m consists of nodular limestones and mudstones. At the top of this interval is a prominent bedset composed of thin platy limestones with mudstones between. Rudists are rare in these beds and limited to scattered examples of *Antillocaprina williamsi* Chubb. Other prominent macrofossils include *Neitheia* sp., *Hamulus* sp. and *Hemiaster* sp. The foraminiferal assemblage (samples WR 14 & 18) includes *Kathina jamaicensis* and *Sulcoperculina dickersoni* (Palmer). The succession can be correlated bed-for-bed, because of the similarities in lithologies, with F1 of the standard Rio Minho section (Fig. 2).

The following 5 m are composed of mudstones with a single limestone, whereas the overlying 5 m are represented by micritic limestones. The lower part of the latter limestone (WR 30) yields abundant specimens of *Orbitoides*. The succeeding 15 m, or so, of section consists of mudstones with several thin limestones. Rudists are absent, whereas branching corals and echinoids (*Hemiaster* sp. and tests and spines of *Phyllocanthas leoni* Papp & Küpper) are abundant. The foraminifers (samples WR34, 40, 44, 61 & 71) include *S. dickersoni*, *K. jamaicensis* and *Ayalaina ruteni* (Palmer).

There is then a major facies change from silty mudstones to thickly bedded limestones that continue up to the top of the formation (Fig. 2). Rudists are generally rare, although a few *Antillocaprina* and *Titanosarcollites* sp. are present. Three



**Explanation of Plate 1.**

Larger foraminifers from the Guinea Corn Formation at White Rock River Bridge. (A) *Orbitoides* cf. *megaloformis* Papp & Küpper, sample WW1; (B) *Chubbina cardenasensis* (Baeker & Grimsdale), G Beds, standard Guinea Corn section; (C) *Vaughania cubensis* Palmer, sample WW5; (D) *Sulcoperculina dickersoni* (Palmer), sample WW8; (E), *Or.* cf. *megaloformis*, embryonic apparatus, Sample WR29. Scale bar for (A)–(D) (shown on (D)) 1 mm; scale bar for (E) 100  $\mu$ m. All specimens preserved in UWIGM.



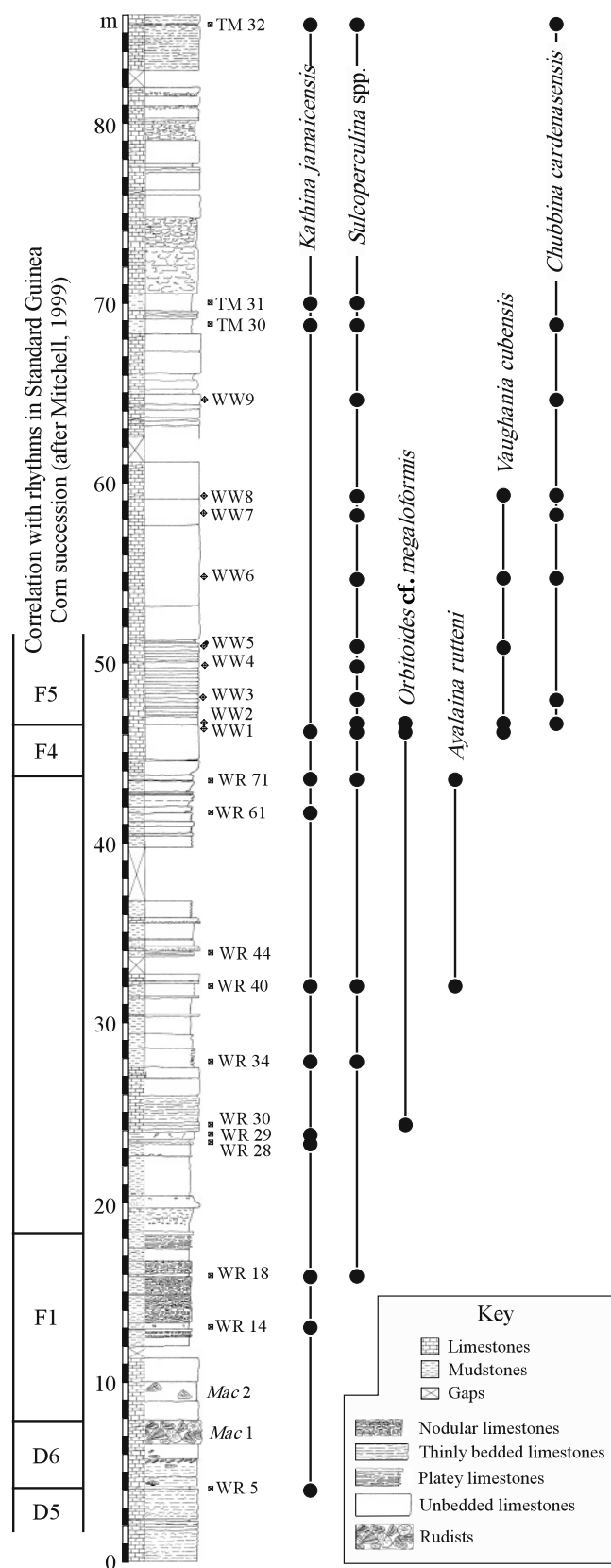


Fig. 2. Graphic log of the White Rock River Bridge section showing the distribution of foraminifers. Marker beds correlated from the standard Guinea Corn succession are also shown (after Mitchell, 1999).

important foraminifers are present. Samples WW1 and WW2 (Fig. 2) contain abundant *Orbitoides* and *Vaughania cubensis* Palmer. Sample WW2 also sees the first appearance of *Chubbina cardenasensis* (Barker & Grimsdale) (= *Chubbina jamaicensis* Robinson, 1968, = *Chubbina macgillavryi* Robinson, 1968). This species remains abundant throughout the remainder of the Guinea Corn Formation. *V. cubensis* occurs consistently up to sample WW8. The appearance of *Chubbina* in the standard Rio Minho section is between rhythms F4 and F5 of Mitchell (1999).

#### FORAMINIFER BIOSTRATIGRAPHY

*Orbitoides* has been used as an important zone fossil in the Upper Cretaceous of Europe (see summary in Caus *et al.*, 1996), where successive species show an increase in size of the embryonic apparatus and an increase in the number of epi-auxillary chambers. The critical measurements of Jamaican specimens are shown in Table 1. Plots of  $L_o + l_o$  versus  $E$  show that the Jamaican material falls between the ranges of *Or. megaliformis* and *Or. gruenbachensis* Papp (Fig. 3), although the range of both variables in the Jamaican population is larger than in either of these species. Plots of  $L_o + l_o$  versus  $L_i + l_i$  show that the Jamaican population has notably small values of  $L_i + l_i$  (comparable with *Orbitoides media* (d'Archiac)) than the European populations for the same range of  $L_o + l_o$  values (Fig. 3). The *Orbitoides* population from Jamaica is referred to here as *Or. cf. megaliformis*.

The age of the Guinea Corn Formation was determined by Steuber *et al.* (2002) from strontium isotope values in well-preserved calcite from the outer shell layer of the rudists *Chiapasella* and *Plagioptychus*. Five samples were analysed from the Central Inlier (Table 2). The four samples from the standard section of the Guinea Corn Formation are all below the equivalent of the *Orbitoides* level in the White Rock River Bridge section. The Logie Green sample is from immediately to the west of the *Orbitoides* exposure of Jiang & Robinson (1987) and contains the rudists *Chiapasella radiolitiformis* (Trechmann) and *Bournonia barretti* Trechmann, indicating a level in the Middle C Beds. Therefore, the ages derived from strontium isotope values indicate that the *Orbitoides* level in the Central Inlier is in the latest Late Maastrichtian. Figure 4 compares the distribution of *Orbitoides* species in Europe (Caus *et al.*, 1996) with the *Orbitoides* level from Jamaica. It is clear from this, that the Jamaican *Orbitoides* are phylogenetically retrograde when compared with coeval European *Orbitoides*. This has important implications for the use of *Orbitoides* as a biostratigraphic indicator outside of Europe.

*Ayalaina ruteni* has not previously been recorded from the Central Inlier. The level at which it occurs in the White Rock River Bridge section is probably broadly equivalent to its highest occurrence in the Popkin Formation of the Maldon Inlier (Gunter & Mitchell, 2005).

*Chubbina* enters at the top of the distribution of *Or. cf. megaliformis* in the White Rock River Bridge Section (Fig. 2). Its first appearance is an important datum in Jamaica (e.g. Mitchell, 1999) and around the Caribbean region (Fig. 5). This datum can be used in the field, since *Chubbina* can be recognized with a hand lens.

Specimens	$L_o$ ( $\mu\text{m}$ )	$l_o$ ( $\mu\text{m}$ )	$L_i$ ( $\mu\text{m}$ )	$l_i$ ( $\mu\text{m}$ )	$E$
Specimens from White Rock River Bridge section, Guinea Corn Formation	424	380	354	336	9
	443	403	383	307	9
	408	376	320	259	8
	413	371	336	283	9
Specimens illustrated by Krijnen <i>et al.</i> (1993), Guinea Corn Formation	375	345	310	220	6
	415	365	365	310	8
	500	395	415	315	9
	385	335	315	240	9
Specimens from Jiang & Robinson (1987), Guinea Corn Formation	364	310	288	236	10
	355	323	297	246	8
Specimens from Gunter <i>et al.</i> (2002), Maldon Formation.	359	291	262	227	8
	460	364	374	249	11
	454	380	345	268	9

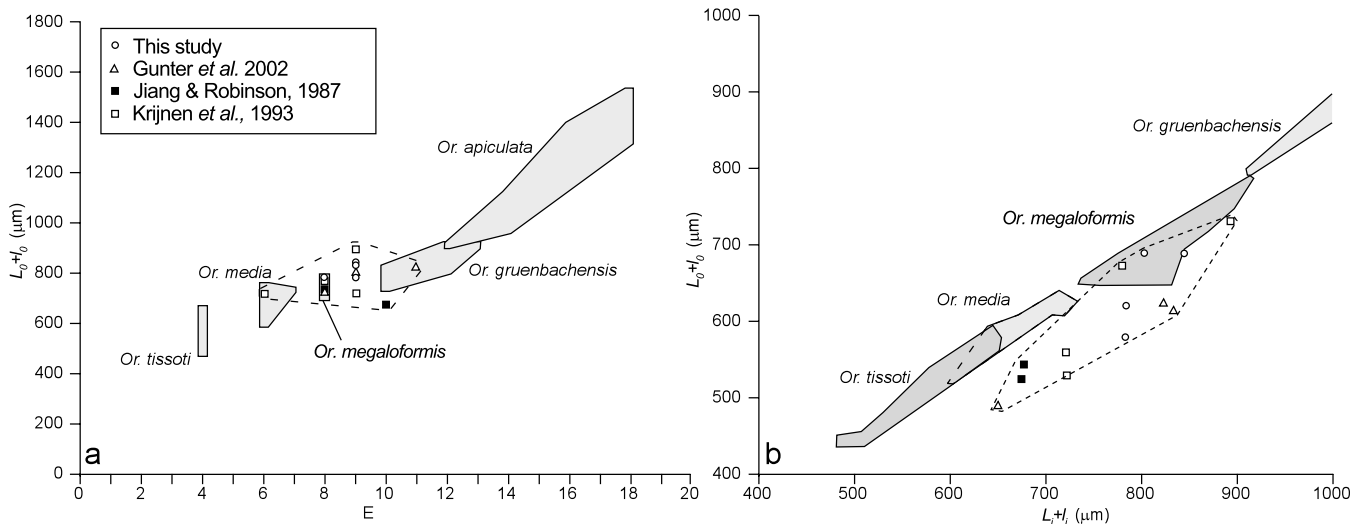
**Table 1.** Measurements of critical values for Jamaican specimens of *Orbitoides*.

## DISCUSSION

*Orbitoides* only occurs in the middle part of the White Rock River Bridge section. Krijnen *et al.* (1993, p. 39) suggested that further west in the Central Inlier, the orbitoid foraminifers had a 'more or less uniform vertical distribution'. Detailed geological mapping in this area indicates instead that all the traverses that Krijnen *et al.* (1993) undertook in the western part of the inlier are within the same *Orbitoides*-yielding horizon as in the White Rock River section.

In the Maldon Inlier of Jamaica, the Maldon Limestone has yielded *Omphalocyclus maldonensis* Gunter *et al.*, *Or. cf. megaliformis* and *Asterorbis cf. havanensis* Palmer (Gunter *et al.*, 2002; Gunter & Mitchell, 2005). The Maldon Limestone also yields the rudist *Chiapasella trechmanni* Mitchell & Gunter, which suggests a correlation with a level in the D Beds of the standard Guinea Corn succession (Fig. 5; Mitchell & Gunter, 2002).

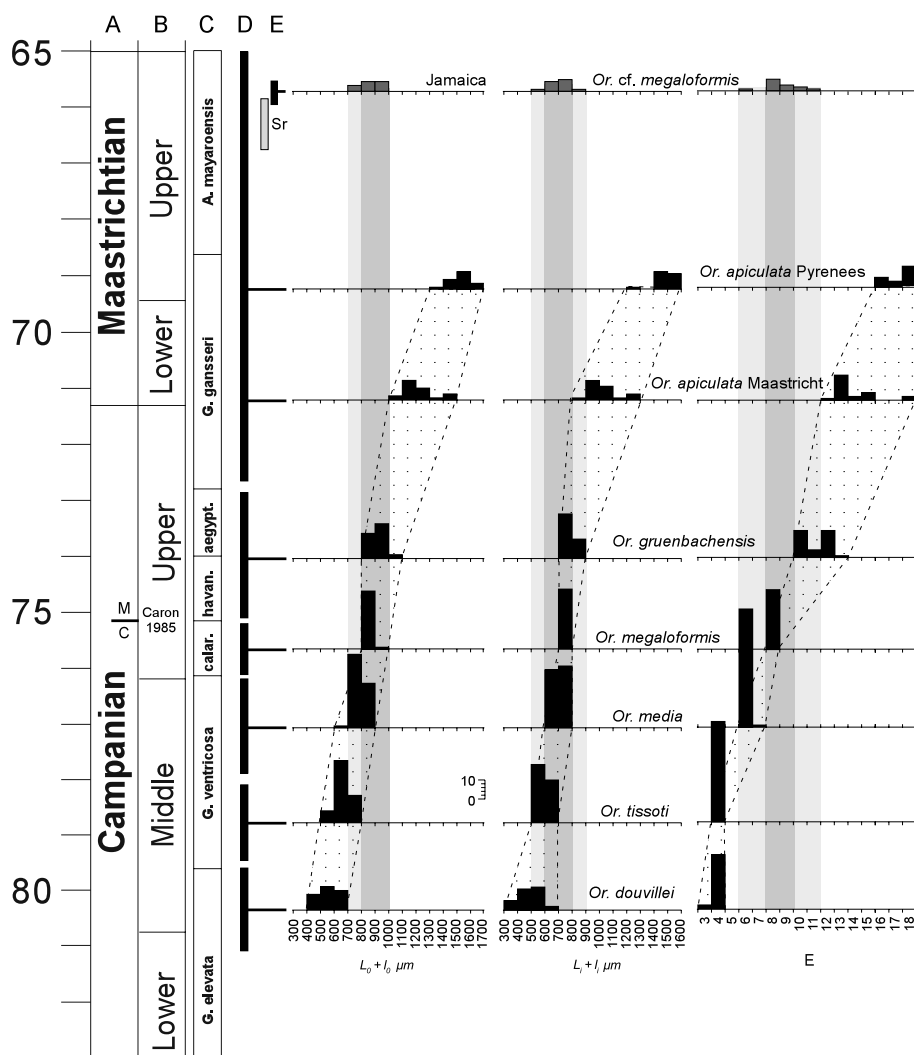
In Cuba, rich larger foraminiferal assemblages have been reported by Seiglie & Ayala-Castañares (1963). Three assem-



**Fig. 3.** Graphic plots for *Orbitoides*: (a) plot of  $L_o + l_o$  versus  $E$  for populations of *Orbitoides* from Europe (Caus *et al.*, 1996). Jamaican specimens fall between the plots of *Or. megaliformis* and *Or. gruenbachensis*; (b) plot of  $L_o + l_o$  versus  $L_i + l_i$  for populations of *Orbitoides* from Europe (Caus *et al.*, 1996). Jamaican specimens have smaller values of  $L_i + l_i$  (for the same  $L_o + l_o$ ) compared with the European populations. Data from Gunter *et al.* (2002), Jiang & Robinson (1987) and Krijnen *et al.* (1993).

Unit	Mean $^{87}\text{Sr}/^{86}\text{Sr}$ values ( $\pm 2$ S.E. $\times 10^{-6}$ )		Age (Ma)	
Lower C Beds	0.770 806 ( $\pm 8$ )	>66.21	66.68	<67.46
Middle C Beds (D25)	0.707 813 ( $\pm 7$ )	>65.95	66.39	<66.91
Bed D1	0.707 809 ( $\pm 7$ )	>66.13	66.55	<67.17
Bed F1	0.707 827 ( $\pm 8$ )	>65.0	65.78	<66.31
Logie Green	0.707 812 ( $\pm 8$ )	>65.95	66.43	67.03

**Table 2.** Ages derived from strontium isotope ratios of well-preserved skeletal calcite in rudist bivalves from the Central Inlier (from Steuber *et al.*, 2002).



**Fig. 4.** Evolution of *Orbitoides* (black histograms) in Europe based on data in Caus *et al.* (1996). Jamaican population (grey histograms) of *Or. cf. megaliformis* shows more primitive characters in each case. A, stages; B, substages; C, planktonic foraminiferal zones from Caron (1985); D, stratigraphic range of *Orbitoides* species in Europe (from Caus *et al.* (1996); E, range of *Or. cf. megaliformis* in Jamaica together with age range derived from Sr-values (Steuber *et al.*, 2002). Base of Maastrichtian adjusted based on Gradstein *et al.* (1995).

blage zones were recognized, an *Orbitoides tissoti*–*Sulcorbitoides pardo* Zone, an *Orbitoides media*–*Pseudorbitoides rutteni* Zone, and an *Orbitoides apiculata*–*Omphalocyclus* Zone. *Chubbina cardenasensis* was listed commonly from the *Orbitoides apiculata*–*Omphalocyclus* Zone and as a rare element in the *Orbitoides media*–*Pseudorbitoides rutteni* Zone.

In Sierra de Chiapas, southeastern Mexico, Late Campanian–Maastrichtian foraminiferal assemblages have been discussed by Ayala-Castañares (1963) and Rosales-Domínguez *et al.* (1997). Rosales-Domínguez *et al.* (1997) recognized three assemblages: wackestones with planktonic foraminifera considered to be of Late Campanian–Early Maastrichtian age; packstones with larger benthic foraminifera of Campanian–Maastrichtian age; and a packstone with *Chubbina* considered to be of Maastrichtian age. Ayala-Castañares (1963) recognized two assemblages of larger foraminifera: an Upper Campanian assemblage containing *Orbitoides tissoti* Schlumberger, *Lepidorbitoides minima* H. Douvillé, *Sulcoperculina* sp. and *Pseudorbitoides* sp.; and an

Upper Maastrichtian (probably partly Lower Maastrichtian) assemblage with *Orbitoides apiculata browni* (Ellis), *Smoutina bermudezi* (Cole), *Vaughania cubensis* and *Sulcoperculina* sp. Caus *et al.* (2002) and Aguilar *et al.* (2002) considered that the type section from which *L. minima* was described, and which contained a larger foraminiferal assemblage consisting of *L. minima*, *Sulcoperculina dickersoni*, *S. globosa* de Cizancourt, *Smoutina*? sp., *V. cf. cubensis* and fragments of *Ayalaina* and *Orbitoides*, was of upper Middle to lower Upper Campanian age.

In southern Florida, *Chubbina* has been reported from the upper Lawson Limestone, just below the top of the Cretaceous (Cole & Applin, 1970).

Gunter *et al.* (2002) pointed out that two orbitoid foraminiferal assemblages appear to be represented in the Maastrichtian of the Caribbean–Central American Tethys. An assemblage with *Orbitoides megaliformis*, *Omphalocyclus maldonensis*, *Vaughania cubensis* with *Asterorbis havanensis* and *Pseudorbitoides rutteni*

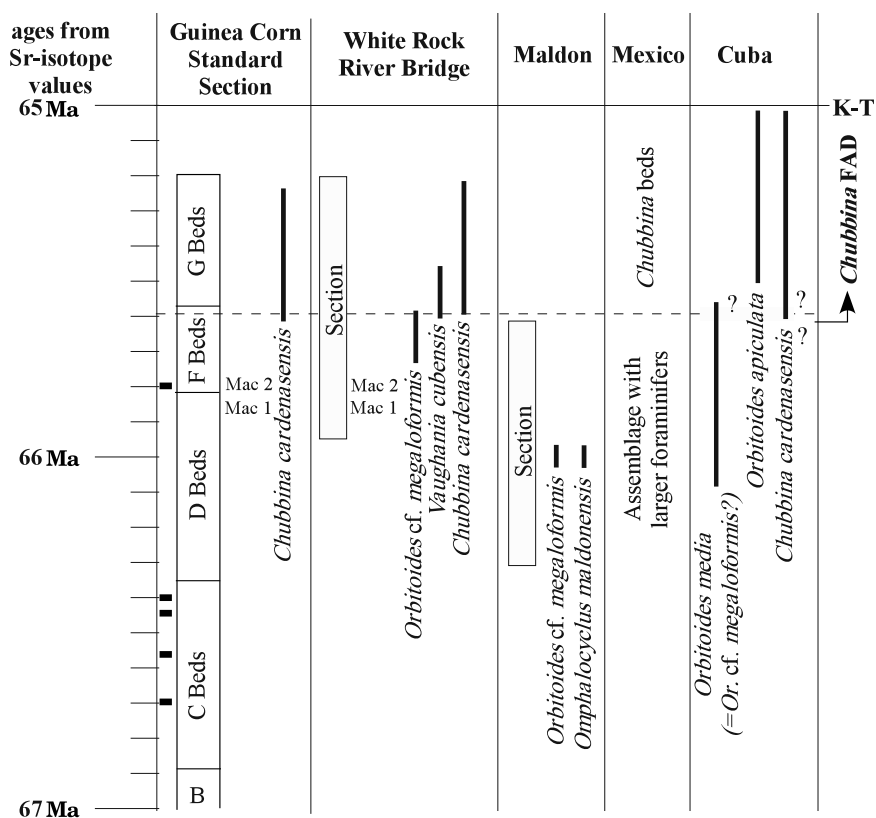


Fig. 5. Correlation of larger foraminifer successions in the Caribbean and Mexico using first appearance datum (FAD) of *Chubbina*. Chronostratigraphy based on ages derived from Sr-isotopic values (Steuber *et al.*, 2002), shown on right as black bars.

in Jamaica (Krijnen *et al.*, 1993; Gunter *et al.*, 2002). Elements of this assemblage are also seen in Cuba (Seiglie & Ayala-Castañares, 1963) and probably Venezuela (Renz, 1955; Gunter *et al.*, 2002). In the White Rock River Bridge section, *Chubbina* enters in the upper part of this assemblage zone.

A second assemblage with *Orbitoides apiculata*, *Omphalocyclus macroporus* (Lamarck), *Asterorbis cubensis* Palmer, *Vaughania cubensis* and *Chubbina cardenasensis* is present in Cuba (Seiglie & Ayala-Castañares, 1963), while some of the elements are represented in Mexico (*Orbitoides apiculata browni* and *Vaughania cubensis*: Ayala-Castañares, 1963) and ?Jamaica (beds with *Chubbina cardenasensis* above the *Or. cf. megaliformis* level).

The *Or. cf. megaliformis* assemblage can be dated precisely in Jamaica using the Sr-isotope stratigraphy given by Steuber *et al.* (2002). The *Or. cf. megaliformis* level in the Maldon Limestone (Gunter *et al.*, 2002) correlates with the D Beds, the base of which gave a Sr-isotopic age of 66.3 (+0.14/−0.15). The *Or. cf. megaliformis* beds in the White Rock River Bridge Section correlate with the middle and upper F Beds, F1 having given a Sr-isotopic age in the standard Rio Minho section of 65.81 (+0.2/−0.29). Thus, in Jamaica *Or. cf. megaliformis* ranges from 66.3 to <65.8 million years. This suggests that the succeeding *Or. apiculata* assemblage represents less than 800 000 years at the end of the Maastrichtian (Fig. 5).

*Chubbina* is a much more widely distributed genus than *Orbitoides* in the Caribbean and occurs in both low diversity, restricted platform settings and in more open-water assemblages

that contain diverse larger foraminifers. *Chubbina* appears in the upper part of the range of *Or. cf. megaliformis* and remains a prominent faunal member throughout the remainder of the Maastrichtian (Fig. 5). The first appearance of this genus is, therefore, a potentially important regional bioevent in the Late Maastrichtian of the Greater Caribbean Region (the Antilles, Florida, Central and northern South America).

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#### REFERENCES

- Aguilar, M., Caus, E. & Höttinger, L. 2002. *Lepidorbitoides minima* Douvillé from Mexico, a foraminiferal index fossil for the Campanian. *Journal Foraminiferal Research*, **32**: 126–134.
- Ayala-Castañares, A. 1963. Foraminíferos grandes del Cretácico Superior de la región central del Estado de Chiapas, México. Parte 1. El género *Orbitoides* D'Orbigny, 1847. *Paleontologica Mexicana*, **13**: 57–73.

- Brönnimann, P. 1954a. Upper Cretaceous orbitoidal Foraminifera from Cuba – Part 1. *Sulcorbitoides* n. gen.. *Contributions to the Cushman Foundation for Foraminifera Research*, **5**: 55–62.
- Brönnimann, P. 1954b. Upper Cretaceous orbitoidal Foraminifera from Cuba – Part 2. *Vaughanina* Palmer, 1934. *Contributions to the Cushman Foundation for Foraminifera Research*, **5**: 91–105.
- Brönnimann, P. 1955a. Upper Cretaceous orbitoidal Foraminifera from Cuba – Part 3. *Pseudorbitoides* H. Douvillé, 1922. *Contributions to the Cushman Foundation for Foraminifera Research*, **6**: 57–76.
- Brönnimann, P. 1955b. Upper Cretaceous orbitoidal Foraminifera from Cuba – Part 4. *Rhabdorbitoides*, n. gen. *Contributions to the Cushman Foundation for Foraminifera Research*, **6**: 97–104.
- Brönnimann, P. 1956. Upper Cretaceous orbitoidal Foraminifera from Cuba – Part 5. *Historbitoides*, n. gen. *Contributions to the Cushman Foundation for Foraminifera Research*, **7**: 60–66.
- Caron, M. 1985. Cretaceous planktic foraminifera. In: Bolli, H., Saunders, V. & Perch-Nielsen, K. (Eds), *Plankton Stratigraphy*. Cambridge University Press, Cambridge, 17–86.
- Caus, E., Bernaus, J.M. & Gomez-Garrido, A. 1996. Biostratigraphic utility of species of the genus *Orbitoides*. *Journal of Foraminiferal Research*, **26**: 124–136.
- Caus, E., Tambareau, Y., Colin, J.-P., Aguilar, M., Bernaus, J.-M., Gomez-Garrido, A. & Brusset, S. 2002. Upper Cretaceous microfauna of the Cárdenas Formation, San Luis Potosí, NE Mexico. Biostratigraphical, palaeoecological, and palaeogeographical significance. *Revista Mexicana de Ciencias Geológicas*, **19**: 137–144.
- Coates, A.G. 1965. A new section in the Maestrichtian Guinea Corn Formation near Crawle River, Clarendon. *Journal of the Geological Society of Jamaica (Geonotes)*, **7**: 28–33.
- Cole, W.S. & Applin, E.R. 1970. Analysis of some American Upper Cretaceous larger Foraminifera. *Bulletins of American Paleontology*, **58**: 41–80.
- Gradstein, F.M., Agterberg, F.P., Ogg, J.G., Hardenbol, J., van Veen, P., Thierry, J. & Huang, Z. 1995. A Triassic, Jurassic and Cretaceous timescale. In: Berggren, W.A., Kent, D.V., Aubry, M.-P. & Hardenbol, J. (Eds), *Geochronology, time scales and global stratigraphic correlation*. SEPM special publication, **54**: 95–126.
- Gunter, G.C. & Mitchell, S.F. 2005. The lithostratigraphy of the Maldon Inlier, northwestern Jamaica. *Caribbean Journal of Earth Science*, **38**: 1–10.
- Gunter, G.C., Robinson, E. & Mitchell, S.F. 2002. A new species of *Omphalocyclus* (Foraminiferida) from the Upper Cretaceous of Jamaica and its stratigraphical significance. *Journal of Micropalaeontology*, **21**: 149–153.
- Jiang, M.-J. & Robinson, E. 1987. Calcareous nannofossils and larger foraminifera in Jamaican rocks of Cretaceous to Early Eocene age. In: Ahmad, R. (Ed.), *Proceedings of a workshop on the status of Jamaican geology*. Special issue. Geological Society of Jamaica, 24–51.
- Krijnen, J.P., MacGillavry, H.J. & van Dommelen, H. 1993. Review of Upper Cretaceous orbitoid larger foraminifera from Jamaica, West Indies, and their connection with rudist assemblages. In: Wright, R.M. & Robinson, E. (Eds), *Biostratigraphy of Jamaica*. Geological Society of America, Memoir, **182**: 29–63.
- Mitchell, S.F. 1999. Stratigraphy of the Guinea Corn Formation (Upper Cretaceous) at its type locality between Guinea Corn and Grantham (northern Clarendon, Jamaica). *Journal of the Geological Society of Jamaica*, **33**: 1–12.
- Mitchell, S.F. 2002. Palaeoecology of corals and rudists in mixed volcanoclastic-carbonate small-scale rhythms (Upper Cretaceous, Jamaica). *Palaeogeography, Palaeoclimatology, Palaeoecology*, **186**: 237–259.
- Mitchell, S.F. & Blissett, D. 2001. Lithostratigraphy of the Late Cretaceous to ?Paleocene succession in the western part of the Central Inlier of Jamaica. *Caribbean Journal of Earth Science*, **35**: 19–31.
- Mitchell, S.F. & Gunter, G.C. 2002. Biostratigraphy and taxonomy of the rudist *Chiapasella* in the *Titanosarcolithes* Limestones (Maestrichtian) of Jamaica. *Cretaceous Research*, **23**: 473–487.
- Palmer, D.K. 1934. Some larger fossil Foraminifera from Cuba. *Memoir Society Cubana Natural History*, **8**: 235–264.
- Renz, H.H. 1955. Some Upper Cretaceous and lower Tertiary foraminifera from Aragua and Guarico Venezuela. *Micropaleontology*, **1**: 52–71.
- Robinson, E. 1968. *Chubbina*, a new Cretaceous alveolinid genus from Jamaica and Mexico. *Palaeontology*, **2**: 56–534.
- Rosales-Domínguez, M. del C., Bermúdez-Santana, J.C. & Aguilar-Piña, M. 1997. Mid and Upper Cretaceous foraminiferal assemblages from the Sierra der Chiapas, southeastern Mexico. *Cretaceous Research*, **18**: 697–712.
- Rutten, M.G. 1935. Larger foraminifera of northern Santa Clara Province, Cuba. *Journal of Paleontology*, **9**: 527–545.
- Seiglie, G.A. & Ayala-Castañares, A. 1963. Sistemática y bioestratigrafía de los Foraminíferos grandes del Cretácico superior (Campaniano y Maestrichtiano) de Cuba. *Paleontologica Mexicana*, **13**: 3–40.
- Steuber, T., Mitchell, S.F., Buhl, D., Gunter, G. & Kasper, H.U. 2002. Catastrophic extinction of Caribbean rudist bivalves at the Cretaceous–Tertiary boundary. *Geology*, **30**: 999–1002.