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Lithostratigraphy and palaeogeography of the White Limestone Group

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The White Limestone Group of Jamaica is divided into six formations. The Troy, Swanswick, Somerset and Moneague formations were deposited on a carbonate platform that developed on the stable Clarendon Block; the Montpelier and Pelleu Island formations were deposited in the deep-water troughs adjacent to this platform. The formations are characterised by the following lithologies: Troy - grey and pink, micritic limestones, dolomicrites and sucrose-dolostones; Swanswick - white, foraminiferal grainstones; Somerset - grey and pink, foraminiferal and algal packstones; Moneague - white grainstones, packstones and wackestones; Montpelier - chalks with chert bands; Pelleu Island - chalks lacking chert bands. The Ipswich Formation is transferred to the Yellow Limestone Group. In the late Middle Eocene, the Clarendon Block had a rim of foraminiferal grainstones surrounding a restricted, tidal-flat dominated platform. In the Late Eocene the platform was flooded to greater depth and packstones spread across the northern half. In the Oligocene, the platform margin was occupied by a grainy *Lepidocyclina*-dominated marginal facies that passed inward into a restricted marine interior with diverse assemblages of miliolid foraminifera. Similar facies patterns persisted into the Miocene, although any White Limestone of this age that was deposited has been eroded from the northern half of the platform. During the late Middle Eocene to Middle Miocene, in the deep-water troughs adjacent to the platform, chalks accumulated together with coarse-grained detritus (calcarenitic turbidites and calciruditic debris flows) derived from the shallow-water limestones of the Clarendon Block.

KEY WORDS: White Limestone Group, Jamaica, lithostratigraphy, palaeogeography.

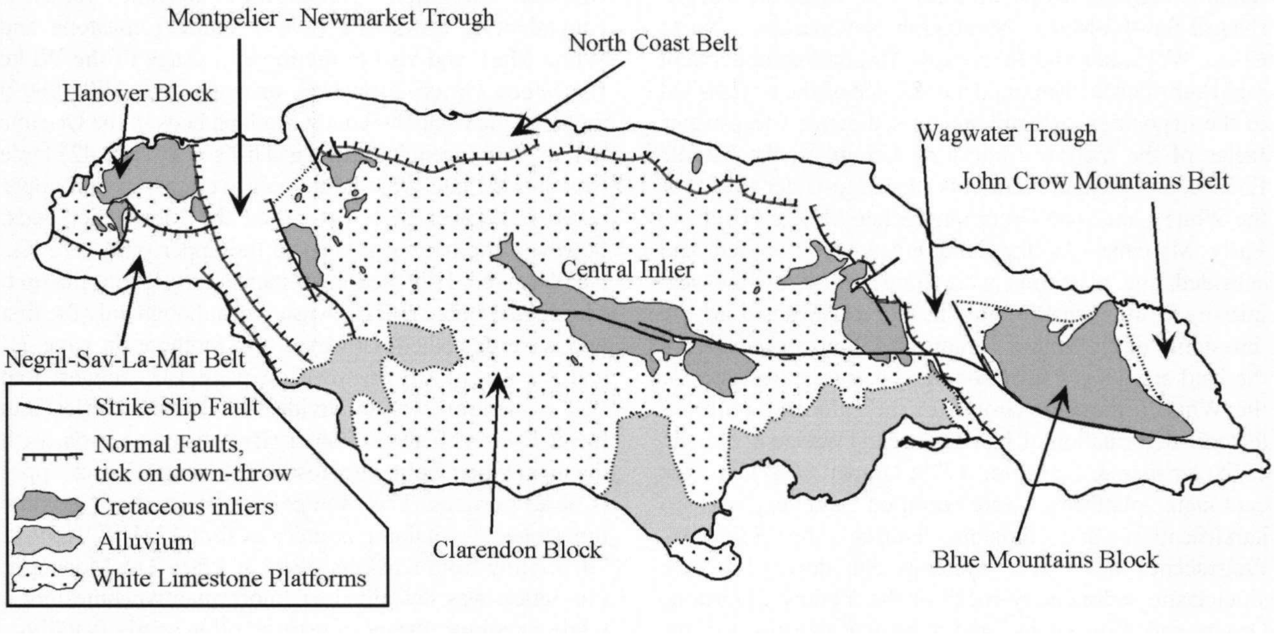

Figure 1. Simplified structural map of Jamaica, showing important normal faults that were active in Eocene to Miocene time, and distribution of the shallow-water carbonate platforms developed on the structural blocks.

Introduction

The White Limestone Group represents the most geographically widespread lithostratigraphic unit at outcrop in Jamaica, occupying some 60-65% of the island's surface (Porter *et al.*, 1982, p. 113) and giving rise to extensive karst topography (Sweeting, 1958; Versey, 1972; Fincham, 1998; Miller, 2004). Despite this, it has received less detailed geological study than might be expected. This is largely due to its intense lithification, its tendency to weather to rubble, and the presence of most originally aragonitic fossils now preserved only as moulds. The formation is particularly important for other reasons. It is extensively mined for the construction industry (Henry & Elliston, 1987; Geddes, 1987), all the economic bauxite deposits of Jamaica rest on its karstified surface (Hill, 1973; Comer, 1974) and it is the main freshwater aquifer on the island (White, 1979).

Deposition of the White Limestone Group occurred during a relatively tectonically quiescent phase in Jamaica's geological history (Draper, 1987). During the Late Cretaceous to earliest Paleocene, the volcanic island arc chain, of which Jamaica was a part, collided with the Yucatán Peninsula (Mitchell, in press). This produced an extensive mountainous region, now the Upper Nicaragua Rise. As left-lateral, strike-slip displacement began along the Caribbean-North American Plate boundary (Pindell, 1994), this land area underwent erosion and new fault systems propagated through the area. Two major fault systems developed: an east-west set and a northwest-southeast set (Mann *et al.*, 1985; Draper, 1987). These faults defined a set of blocks and troughs, the blocks (Blue Mountains, Clarendon and Hanover; see Figure 1) remained as isolated positive features, while the troughs (Negril-Sav-La-Mar, Montpelier-Newmarket, North Coast, Wagwater and John Crow Mountains) underwent rapid subsidence. The rapid subsidence of the troughs led to the deposition of hemipelagic sediments (deep-water facies of the Yellow Limestone Group) in the Middle Eocene, and pelagic sediments (the deep-water chalks of the White Limestone Group) in the late Middle Eocene to Early Miocene. As the land areas were eroded and subsided, the platforms were transgressed by the sea; initially forming shallow-marine siliciclastics and impure limestones of the Yellow Limestone Group and finally, as the land areas were fully submerged, pure carbonates of the White Limestone Group. In the Miocene, renewed tectonic deformation of Jamaica began (Wadge & Draper, 1978; Krijnen & Lee Chin, 1978; Draper, 1987), and the carbonate platforms were uplifted and exposed to karstification and erosion. During the Pliocene-Pleistocene, new river systems cut down into the siliciclastic sedimentary rocks of the Yellow Limestone Group and Cretaceous, and supplied detritus for the deposition of the mixed clastic-carbonate rocks of the Coastal Group (Robinson, 1994).

Because of their very pure lithologies, the strata of the White Limestone Group have always been difficult to subdivide. In this paper, the history of the subdivision of the White Limestone is reviewed. Only formal publications are considered, as theses are not considered formal publications under the guidelines of the International Stratigraphic Guide (Salvador, 1994) (Appendix 1). This is followed by descriptions of three areas of White Limestone Group rocks and a suggestion for the establishment of formal lithostratigraphic formations. Only the shallow-water limestones of the Clarendon Block, and deep-water limestones of the belts and troughs are considered here. The Blue Mountains and Hanover blocks have different sedimentary records (Robinson, 1997; Mitchell, unpublished data), and need separate lithostratigraphic schemes that are beyond the scope of this paper. Finally, the palaeogeography and depositional environments of the White Limestone Group are considered.

Historical review

De la Beche (1827, p. 169) referred to all the Tertiary limestones in Jamaica as the 'white limestone formation' (Appendix 1), while Sawkins (1869) divided De la Beche's unit into separate Yellow Limestone, White Limestone, White Marl and Coast Limestone.

Hill (1899, p. 65) divided the White Limestone in Jamaica into two series; the Oceanic Series, or 'Upland White Limestone,' and the Coastal Series. In his table (Hill, 1899, p. 42), he showed the Oceanic Series as containing three units, the Montpelier, the Moneague and the Cobre. The series is underlain by the Chapelton and Catadupa beds (= Yellow Limestone) and overlain by the Bowden Formation. Thus, Hill's Oceanic Series is equivalent to Sawkins's (1969) White Limestone and White Marl, and also to the modern usage of the White Limestone Group. However, on page 143, Hill (1899) included the Chapelton and Catadupa beds in the Oceanic Series! The Oceanic Series in Hill's (1899, p. 42) table was divided into what he thought were lower and upper parts. His lower part was called the Montpelier beds; however, the names applied to the upper part were less clearly given. Hill used three names throughout the text: Moneague, Cobre and Brownstown, although only the first two were described. However, the footnote on page 71, and the use of Brownstown on page 142, suggest that Hill's intention was to divide the Oceanic Series into lower (Montpelier) and upper (Brownstown) parts, with the upper part split into lower (Moneague) and upper (Cobre) portions. The Montpelier consisted of '... white limestone ... containing nodules of flint ...' (Hill, 1899, p. 70, quoting from Sawkins, 1869, p. 250). The Moneague Formation was described as 'more massive limestones, white in colour, firmer in texture, often semi-crystalline, sometimes containing casts of fossil mollusks and solitary corals', and the Cobre Formation as having an 'irregular lumpy texture' (Hill, 1899, p. 76).

Member	Description
TROY LIMESTONES pp. 34, 35.	“*Pink, white, yellow or brown limestones, well bedded, recrystallized tough and compact ... frequently magnesian and grade into pure dolomite ... recrystallized series passes upwards, by intercalation, into limestones with miliolids and rare* Dictyoconus”
SWANSWICK LIMESTONES pp. 34, 35.	“*calcarenite, or limestone-sandstone, made up largely of organic débris with a greater variety of foraminifera that any other series ... the limestones pass by intercalation upwards into standard limestones with occasional beds made up of organic débris*”
SOMERSET LIMESTONES p. 35	“*junction with the Troy is clearly definable, as* Fabularia *and* Dictyoconus cookei *appear suddenly and are frequent in these limestones*”
GIBRALTAR LIMESTONES p. 36	“*equivalent to the Somerset Limestones in the south. It is temporary given a separate name because it overlies the Swanswick member – not the Troy*”
BROWN’S TOWN LIMESTONES p. 36	“*complete incoherence and lack of structure of the limestones and also by the presence of a typical Antiguan fauna of* Lepidocyclina undosa, L. fabulosa, L. gigas *and* L. parvula”
MONTPELIER p. 36	“*hard chalks, with flints, that are devoid of the larger foraminifera*”
WALDERSTON LIMESTONES p. 37	“*limestone which is rich in small foraminifera, particularly miliolids and buliminids and often* Archaias, Peneroplis *and a* Spirolina. Amphisorus matleyi *does not occur*”
NEWPORT LIMESTONES p. 37	“*all those limestones which are usually poorly fossiliferous but contain* Amphisorus matleyi”

Table 1. Classification of the White Limestone Formation by Hose & Versey (1957). Quotes of the characteristics of the different members are given (page numbers refer to individual quotations).

The lithologies of the Brownstown were given on page 77 and include (my interpretation from the descriptions given): recrystallized limestones; micritic limestones; and fossiliferous limestones with algae, foraminifera and starfish ossicles. Hill also introduced the name May Pen Beds (Hill, 1899, p. 84) for nodular limestones that overlie the Oceanic Series. Trechmann (1922, table facing p. 423) suggested that the White Limestone be divided into the Moneague Beds and the Montpelier Beds.

Hose & Versey (1957) divided the White Limestone into eight members, which they called Troy, Swanswick, Somerset, Gibraltar, Brown’s Town, Montpelier, Walderston and Newport. These ‘members’ were largely characterised by their foraminiferal assemblages, and little detail on their respective lithologies was given (Table 1). This is particularly true of the Somerset Limestones, which were described thus (Hose & Versey, 1957, p. 35), ‘... includes the fossiliferous strata of the Upper Eocene. The junction with the Troy is clearly definable as *Fabularia* and *Dictyconus cookei* appear suddenly and are frequent in these limestones.’ This is clearly a palaeontological, and not a lithological, datum. Versey (1957a) described an additional member, the Ipswich Limestone, which occurred on the western margin of the Clarendon Block. Hose & Versey (1957, p. 37) considered that the May Pen Beds were part of the Newport Limestones.

The name ‘Spring Garden Formation’ was introduced in the Geological Survey Department Jamaica Report for the financial year 1958-1959 (Geological Survey Department, 1959, p. 4) with the following description “type section ... along the coast road between Spring Garden and Buff Bay. ... massive chalks soft at the top gradually becoming harder. The lower parts of the type section are hard chalky or earthy limestones with occasional bands of nodular light brown flint.”

The memoir accompanying the 1958 provisional geological map of Jamaica was published in 1963 (Zans *et al.*, 1963). It contains a description of the White Limestone by Versey. The same eight members of Hose & Versey (1957) were described together with the Ipswich and Claremont Limestones (Table 2). Robinson (*in* Zans *et al.*, 1963, p. 45) introduced the term Pelleu Island Formation for the chert-free chalky limestones at San San Bay between the Montpelier cherty limestones and San San Clay. Robinson (1967a, p. 569) introduced the term Bonny Gate Formation for the older cherty limestones, which he believed were separated from the Montpelier by a significant hiatus. He also introduced the term Lloyds Member (Robinson, 1967a, p. 570) for the lower part of the Bonny Gate Formation in the Yallahs area that contained calcirudites and non-carbonate conglomerate beds. Robinson (1967b, p. 35) applied the name Spring Garden Member for chalks similar to the Monpelier Formation, but lacking cherts, that were exposed along the main road between Buff Bay and Spring Garden in Portland. Robinson (1969a) considered that the Pelleu Island Formation was equivalent to the Spring Garden Member and dropped the former name.

Member	Description
TROY LIMESTONE p. 33	"*brown, yellow, pink or white, well-bedded limestones. It is completely recrystallized and extremely tough and compact. The limestones are devoid of organic remains, except for occasional, doubtful "ghosts" of* Dictyoconus"
SWANSWICK LIMESTONE p. 33	"*bioclastic careous sand derived from reef degradation and contains broken and worn tests of foraminifera*"
IPSWICH LIMESTONE p. 34	"*limestones are similar to those of the Yellow Limestone in that they are more clayey and feruginous that other parts of the White Limestone. They contain infrequent plant remains and abundant foraminifera*"
CLAREMONT LIMESTONE p. 34	"*soft limestone, for the most part poor in foraminifera except for upper Eocene* Dictyoconus *but with abundant molluscs ... fauna constitutes the* Phacoides *band of Hose and Versey (1956) ... North of Claremont, the molluscan fauna is absent or entirely untypical and the only distinguishing character of the member is the paucity of the foraminifera fauna*"
SOMERSET LIMESTONE p. 35	"*The typical facies is a limestone rich in* Fabularia verseyi *Cole. This species occurs also in the Claremont Limestone on the northern side of the island but is nowhere common; in the Somerset it is everywhere abundant*"
GIBRALTAR LIMESTONE p. 35	"*Hose and Versey (1956) included in this member* Fabularia *limestones, that have proven indistinguishable from the Somerset, the* Phacoides *limestones, here referred to the Claremont, and a group of other limestones to which the member is now restricted ... There is again no good facies characteristic to define this member.* Lepidocyclina *is common ... the most frequent species* L. chaperi"
WALDERSTON LIMESTONE p. 35	"*a compartively soft limestone, largely made up of miliolids, and containing small species of* Peneroplis *and* Archaias *... In Manchester, Clarendon and north-east St. Elizabeth, the limestones frequently include local beds of intraformational conglomerate*"
BROWN'S TOWN LIMESTONE p. 36	"*loose and nodular with a large amount of interstitial calcareous powder but otherwise lacking in sedimentary structures ... A more easily used criterion for recognition of the Brown's Town is the abundance of those large species of Lepidocyclina so typical of the Caribbean Oligocene,* L. undosa, L. favosa, *and* L. gigas"
NEWPORT LIMESTONE p. 36	"*moderately well-bedded and compact limestones, generally poor in fossils though containing beds with oysters and pectens, and others with* Amphisorus matleyi. *This foraminiferon is typical for the member and is often abundant*"
MONTPELIER p. 37	"*well-bedded chalk, generally with flint nodules. Occasional beds of marl, or crystalline foraminiferal limestone, occur interbedded with the chalk*"

Table 2. Classification of the White Limestone Formation as given by Versey (*in* Zans *et al.*, 1963). Quotes of the characteristics of the different members are given (page numbers refer to individual quotations). Note: Hose & Versey (1956) was, in fact, published in 1957.

The first 1:50,000 scale geological maps with the Hose & Versey (1957) names appeared in April 1974. These included the sheets for Balaclava, Alligator Pond, Mandeville, Discovery Bay, Spaldings and Falmouth (Bateson, 1974a-f). The White Limestone Group was split up into the following formations; Troy-Claremont Limestone Formation (Etc) (although only Troy Limestone Formation [Etc] is shown on maps for Spaldings and Mandeville; see Bateson, 1974e, f), Somerset Limestone Formation (Est), Swanswick Limestone Formation (Es), Gibraltar-Bonny Gate Limestone Formation (Egb), Walderston-Browns Town Limestone Formation (Owb), Montpelier Limestone Formation (Mm), and Newport Limestone Formation (Mn). Wright & Robinson (*in* Wright, 1974, pp. 47-51) treated the following as formations: Troy/Claremont Formation; Bonny Gate Formation; Somerset Formation; Swanswick Formation; Walderston/Browns Town Formation; Montpelier Formation and Newport Formation. Wright & Robinson (*in* Wright, 1974, p. 50) considered that the Walderston and Browns Town Limestones 'may be considered as distinct facies within the same formation.'

Steineck (1974) studied the foraminiferal assemblages of the Montpelier and Lower Coastal Groups. He suggested the introduction of the term Clarendon Group for the shallow-water limestones of the Clarendon Block, and included within them platform interior formations (Troy, Claremont, Walderston and Newport) and platform edge formations (Swanswick, Gibraltar and Brown's Town). The deep-water Montpelier Group was subdivided into the Lloyds Member, Bonny Gate Formation, Sign Beds and Spring Garden Formation, the name Sign Beds being introduced informally (Steineck, 1974, p. 224) for the lower chert-yielding part of the Montpelier Formation (*sensu* Robinson, 1969a, c).

AGE	ZONES (Berggren *et al.* 1995)	Robinson & Mitchell 1999	Robinson, 2004 (and pers. comm., 2002)		
			TYPICAL ASSEMBLAGES SHELF/PLATFORM	TYPICAL ASSEMBLAGES SHELF EDGE	Larger foraminiferal Zones [subzones]
Middle Miocene	N8 - N10		Archaiasinids, soritids	*Nummulites* cf. *tamanensis, Amphistegina* spp.	***Amphistegina***
Early Miocene	N5 - N7, N8?			Biserial *Miogypsina, Nummulites* cf. *tamanensis, Amphistegina* spp.	***Miogypsina*** *[Lepidocyclina]*
	N4 - N5			Uniserial *Miogypsina, Heterostegina antillea, Spiroclypeus bullbrooki, Lepidocyclina canellei, Eulepidina* spp. (rare), *Nummulites* cf. *panamensis*	***Miogypsina*** *[Heterostegina]*
Late Oligocene	P22		Archaiasinids, *Praerhapydionina*	*Miogypsinoides bermudezi, Lepidocyclina* spp., *Nephrolepidina* spp., *Eulepidina* spp.	***Eulepidina*** *[Heterostegina – Miogypsinoides]*
	P21			*Lepidocyclina* spp., *Nephrolepidina* spp., *Eulepidina* spp., *Heterostegina antillea, Neorotalia mexicana*	***Eulepidina*** *[Heterostegina – Neorotalia]*
Early Oligocene	P18 - P20	10-11	*Fallotella cookei,* peneroplids	*Nephrolepidina yurnagunensis, Eulepidina favosa, Halkyardia minima, Neorotalia mexicana*	***Eulepidina*** *[Nephrolepidina – Neorotalia]*
Late Eocene		8-9	*Fallotella cookei, Fabularia verseyi, Pseudochrysalidina floridana*	*Heterostegina ocalana, Asterocyclina minima, Eulepidina chaperi, Nummulites striatoreticulatus, Operculinoides* spp., *Nephrolepidina* cf. *caudri* sp.	***Asterocyclina*** *[Lepidocyclina – Heterostegina oculana]*
Middle Eocene		5-7	*Cushmania* spp., *Fabularia gunteri* gr., *Yaberinella jamaicensis, Pellatispirella matleyi*	*Lepidocyclina macdonaldi, Pliolepidina* cf. *panamensis*	***Asterocyclina*** *[Lepidocyclina – Yaberinella]*
	P12	4	*Cushmania* spp., *Fabularia gunteri* gr., *Yaberinella hottingeri, Y.* spp., *Pellatispirella matleyi*	*Eulinderina antillea, E. subplana, Polylepidina antillea, Nummulites* cf. *vanderstoki*	***Asterocyclina*** *[Eulinderina – Polylepidina]*
	P10-P11	3		*Helicostegina dimorpha, Nummulites guayabalensis*	***Asterocyclina*** *[Helicostegina – Nummulites]*

Table 3. Foraminiferal zonation of the White Limestone Group (from Robinson, 2004, and pers. comm., 2002).

The 1:250,000 geological map of McFarlane (1977) showed the White Limestone Group divided into Troy/Claremont-Somerset-Swanswick Formation (Ewl), Walderston-Brown's Town Formation (Owb), Gibraltar-Bonny Gate Formation (Egb), Newport Formation (Mn) and Montpelier Formation (Mm).

Robinson (1994, fig. 6.6) recognised a White Limestone Supergroup separated into Moneague and Montpelier Groups. The Moneague Group was divided into the Troy, Claremont, Somerset, Swanswick, Gibraltar, Browns Town, Walderston and Newport formations; the Montpelier Group into the Bonny Gate, Sign and Spring Garden formations. Mitchell (1996) recorded the presence of fenestrae in the Troy Formation, and suggested that the limestones were deposited on tidal flats with periodic emergence. Robinson & Mitchell (1999) recognised the problems with the division of the White Limestone Group, and used separate Moneague and Montpelier formations divided, with reservations, into the members suggested by Hose & Versey (1957) and Versey (*in* Zans *et al*., 1963).

The biostratigraphic division of the White Limestone Group using larger benthic foraminifera has developed over some seventy-five years (Matley, 1925, 1951; Hose & Versey, 1957; Versey, 1957a, b; Robinson, 1974, 1977, 1993, 1995, 1996a, b, 2004; Robinson & Wright, 1993; Robinson & Mitchell, 1999). The most recent biozonation scheme for larger foraminifera is shown in Table 3 (from Robinson, 2004).

Group or Supergroup?

Since the elevation of Hose & Versey's (1957) 'members' of the White Limestone to formations (Bateson, 1974f; Steineck, 1974; Wright, 1974), the lithostratigraphic rank of the White Limestone has varied among authors. Some authors assign the deep-water and shallow-water limestones to separate groups within the White Limestone, which was either assigned (Robinson, 1988, p. 62; 1994, p. 119), or inferred (Steineck, 1974) to have, the rank of supergroup. The deep-water limestones were assigned to the Montpelier Group (*e.g.*, Steineck, 1974, p. 223; Robinson, 1988, p. 63; 1994, p. 119) and the shallow-water limestones to either the Clarendon Group (*e.g.*, Steineck, 1974, p. 223) or the Moneague Group (*e.g.*, Robinson, 1988, p. 63; 1994, p. 119). Other schemes retained the White Limestone as a group separated into formations (Bateson, 1974f; Wright & Robinson *in* Wright, 1974; Eva, 1977; McFarlane, 1977; Eva & McFarlane, 1985; Robinson & Mitchell, 1999).

The International Stratigraphic Guide (Salvador, 1994; Murphy & Salvador, 1999) gives guidelines for the use of stratigraphic terms. A group is 'A succession of two or more contiguous or associated formations with significant and diagnostic lithologic properties in common. Formations need not be aggregated into groups unless doing so provides a useful means of simplifying stratigraphic classification ...' (Murphy & Salvador, 1999, p. 260). Equally, 'The component formations of a group are not necessarily everywhere the same' (Salvador, 1994, p. 35). The term supergroup is used for 'several associated groups or for associated formations and groups ... Supergroups should be established only where their recognition serves a clear purpose' (Salvador, 1994, p. 35). Because it is clear that there are mappable units in the White Limestone, these should be given the status of formation. Since these formations are all relatively pure limestones, and there is an interdigitation of deep-water and shallow-water facies (Versey *in* Zans *et al.*, 1963, table 3; Wright & Robinson *in* Wright, 1974, fig. 2), the White Limestone should be given the rank of group rather than supergroup. This practice is adopted here and recommended for future usage.

The White Limestone Group is composed of pure carbonates (limestones and dolostones). It overlies the siliciclastic and impure carbonate rocks of the Yellow Limestone Group.

Problems with the lithostratigraphy

The supposed lithostratigraphic scheme for the White Limestone Group derives largely from the publication of Hose & Versey (1957) as emended by Versey (1957a; *in* Zans *et al.*, 1963). The division of the White Limestone into members, was typically based on the appearance of particular species of foraminifera (*e.g.*, *Fabularia* sp. A [= *Fabularia verseyi* Cole] for the base of the Somerset Limestones), or a change in the foraminiferal biofacies (*e.g.*, the Brown's Town Limestones are dominated by *Lepidocyclina*, while the Walderston Limestones are dominated by miliolids) (Appendices 1, 2). These are largely palaeontological markers and should be used in biostratigraphic zonations or in broad foraminiferal biofacies. They are not appropriate for the erection of lithostratigraphic units.

The problems with the lithostratigraphy of the White Limestone Group are similar to those of the Chalk Group in England. Rowe (1902, 1903, 1904, 1905) divided the Chalk into zones based on the presence of particular macrofossils (largely ammonites, echinoderms and belemnites). This scheme lasted for some eighty years with the inherent problem that data could only be related to a particular zone. In the late 1970s and 1980s, lithostratigraphic schemes were published for the Chalk Group (*e.g.*, Wood & Smith, 1978; Mortimore, 1986; N.D. Robinson, 1986), although discussion still continues (*e.g.*, Bristow *et al.*, 1997; Gale & Hancock and Bristow *et al.*, 1999).

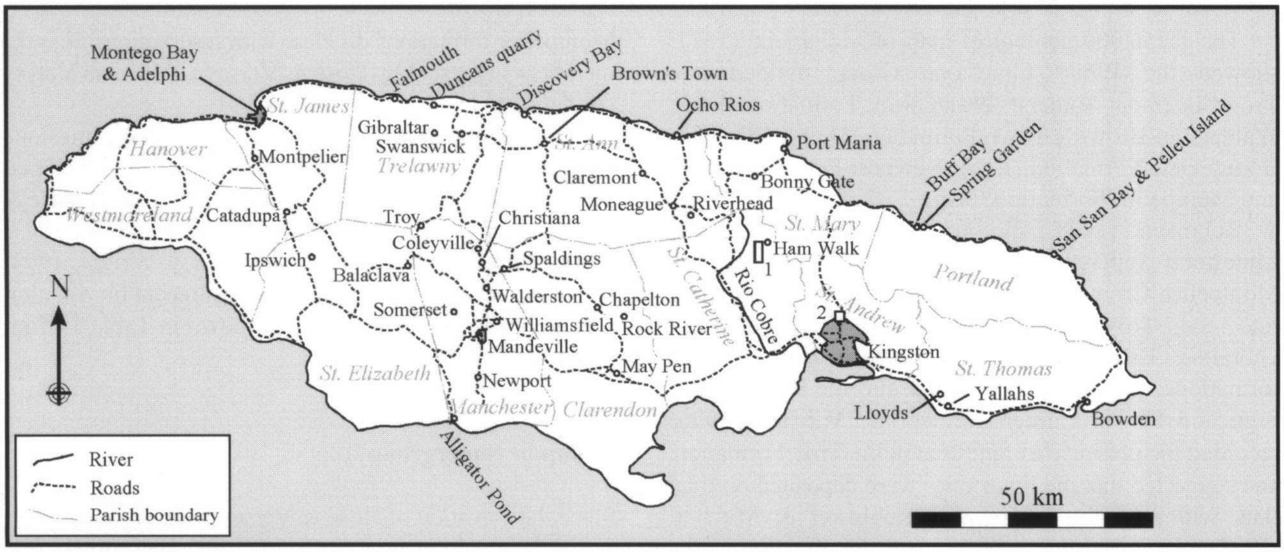

Figure 2. Distribution of sections mentioned in the text; (1) position of Riversdale map; (2) position of Stony Hill map.

Although Rowe's traditional zones are still used, they can now be related to separate lithostratigraphic schemes.

The situation with the White Limestone Group is clearly more problematic; not only is it divided into zones, but the zones have been given geographical names. In this paper, the White Limestone Group is divided into formations, which have lithostratigraphic integrity and can be defined solely on lithological criteria. As such, the existing names are used, as far as possible, to try and preserve some continuity in the nomenclature. The geology of the carbonate rocks in the Riversdale, Stony Hill and Duncans areas is here outlined as a preliminary to setting down the new lithostratigraphy of the White Limestone Group established in this paper. The locations of sections mentioned in the text are shown in Figure 2.

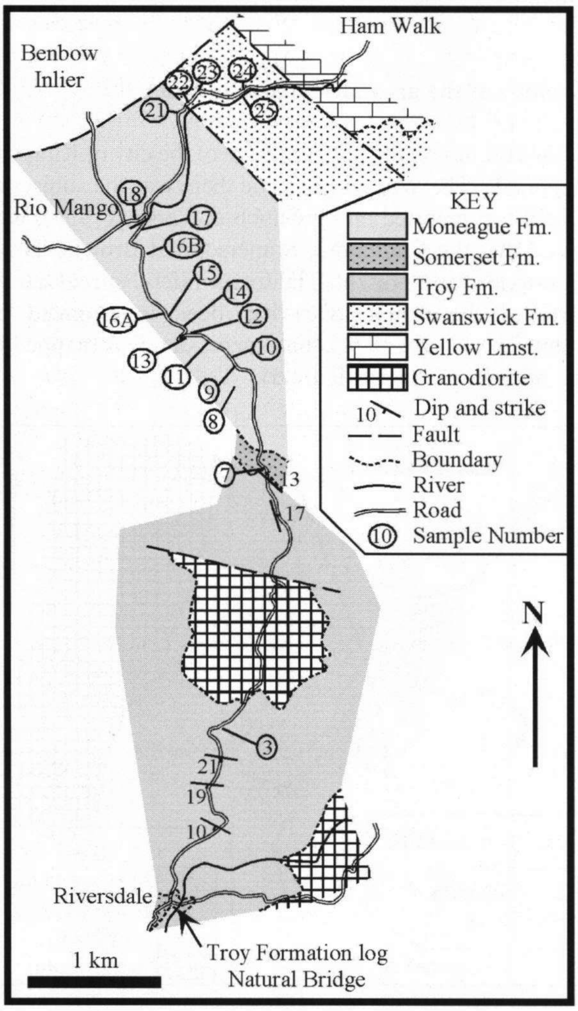

Figure 3. Geological map of the area around Riversdale.

Riversdale, in the parish of St Catherine (Fig. 2), has a mapped succession ranging from the Eocene into the Miocene on the 1:50,000 scale (Green, 1972) and 1:250,000 scale (McFarlane, 1977) geological maps of Jamaica. This area was, therefore, chosen as a good place to study the succession in the White Limestone Group. A geological map of this area is shown in Figure 3.

The White Limestone succession in this area can be divided into four lithostratigraphic units that can be mapped in the field and are therefore suitable for formational status (Figure 3). The first three units are well exposed along the roadside from Riversdale to Rio Mango, and the fourth is exposed between Rio Mango and Ham Walk.

The White Limestone Group in this area rests nonconformably on the Above Rocks Granodiorite or conformably on the Ham Walk Limestone of the Yellow Limestone Group (Burke *et al.*, 1968). The lowest unit (Troy Formation as defined herein) of the White Limestone Group consists of pale pink or pale grey, micritic limestones, with subordinate micritic dolostones and sucrose dolostones. Rarely the micritic limestones contain low-diversity, low-abundance faunas of tall-spired gastropods or small sand-dollars of the genus *Neolaganum* (Donovan, 1994, reported as from the Somerset Formation, but actually from the Troy Formation; see Donovan, 2004). A single thin bed of foraminiferal-peloidal grainstone was noted intercalated with the other lithologies (Figure 3, sample 3). The foraminifera in the grainstone include *Amphistegina parvula* (Cushman), *Fabiana* sp. and *Lepidocyclina peruviana*? Cushman, probably indicating the presence of the *Eulinderina-Polylepidina* Subzone (*Asterocyclina* Zone) (Robinson, 2004; = Assemblage 4 of Robinson & Mitchell, 1999). The micritic limestones are well exposed in the sides of the Natural Bridge (Figure 4), the geomorphology of which has been discussed by Miller & Donovan (1999). Individual micritic limestone beds range in thickness from 0.2 to 1.5 m and are composed of dense micrite. The upper parts of many beds contain abundant, well-developed irregular fenestrae. The top of one bed is characterised by a laminated appearance, due to the presence of laminoid fenestrae. Irregular fenestrae are irregular pores up to 5 mm in diameter formed by desiccation and shrinkage or air and gas bubble formation (Shinn, 1968; Tucker & Wright, 1990). Laminoid fenestrae are flattened parallel to lamination, up to 5 mm high and 20 mm long; they are especially associated with microbial mats and form due to parting of laminae and oxidation of the microbial layers (Logan, 1974; Tucker & Wright, 1990).

The micritic limestones are succeeded, relatively abruptly, by highly fossiliferous, pale pink or pale grey, packstones (Somerset Formation as defined herein). The packstones contain an abundant and diverse fauna that includes corals, calcareous algae and foraminifera. The foraminifera present include *Fabularia verseyi*, *Cushmania americana* (Cushman), *Spirolina* sp. and *Fallotella cookei* (Moberg), amongst others, indicative of the lower part of the *Lepidocyclina-Heterostegina ocalana* Subzone (*Asterocyclina* Zone) (Upper Eocene) (Robinson, 2004; = Assemblage 8 of Robinson & Mitchell, 1999).

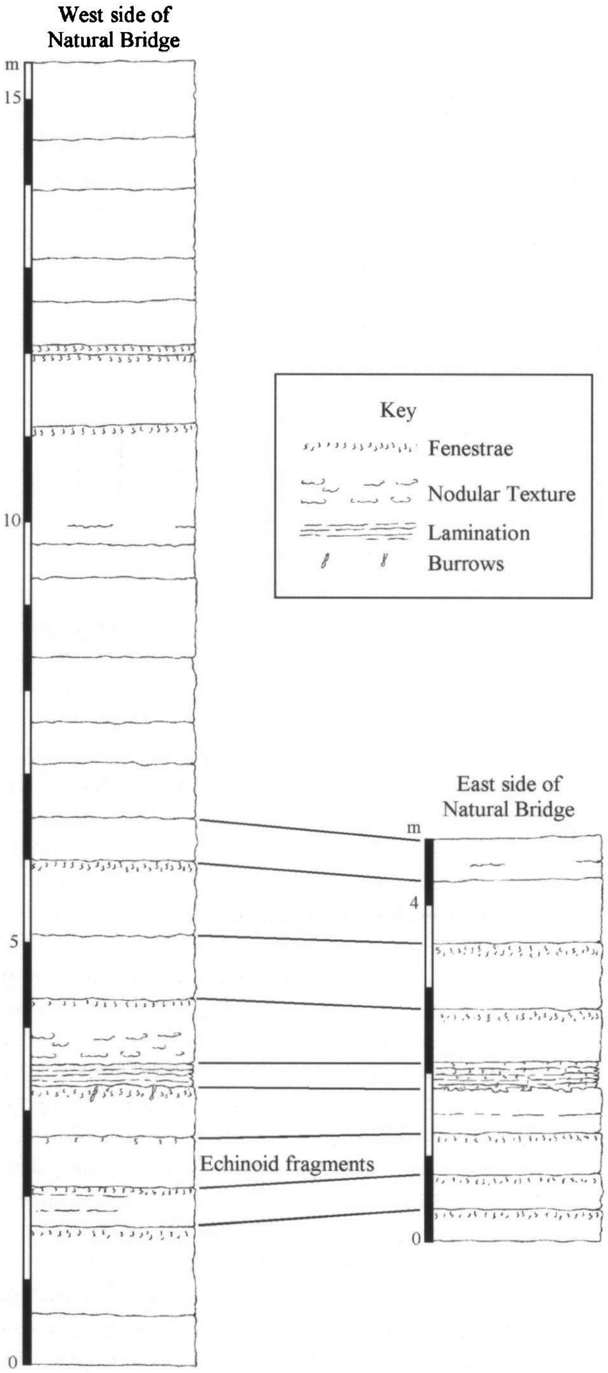

Figure 4. Graphic log of the succession through the Troy Formation at the Natural Bridge, Riversdale. Succession consists solely of micritic limestones; horizontal scale is a weathering profile.

The pink and grey packstones are succeeded by pure white fossiliferous limestones (Moneague Formation as defined herein). The limestones range in texture from packstones to carbonate mudstones. The abundant fauna includes ubiquitous foraminifera, together with large moulds of gastropods at some levels and locally corals and bivalves. The foraminiferal assemblage is diverse and changes significantly up-section. This succession of foraminifera (Table 4) is very similar to that reported by Robinson & Mitchell (1999) from the Riverhead area near Moneague.

To the northeast of a significant fault on the road from Rio Mango to Ham Walk (Figure 3), distinctive, very white, foraminiferal-peloidal grainstones are developed (Swanswick Formation as defined herein). The succession is massive and shows no obvious bedding. The allochems are set in a well-developed calcite cement. Locally, a few euhedral dolomite rhombs are present cross-cutting the grainstone fabric. The foraminiferal fauna includes *Fabiania cassis* (Oppenheim), *Eorupertia bermudezi* Anisgard, *Amphistegina parvula* and *Eulinderina guayaboleusis*? (Nutall), indicative of the mid Middle Eocene *Eulinderina-Polylepidina* Subzone (*Asterocyclina* Zone) (Robinson, 2004; = Assemblage 3 of Robinson & Mitchell, 1999).

Geology of the area around Stony Hill

Stony Hill lies on the northern edge of the city of Kingston (Figure 2). The White Limestone there was the subject of a field trip reported on by Chubb & Versey (1957), who stated that the Claremont, Somerset and Browns Town limestones were present. The foraminiferal succession in parts of these limestones has been investigated by Robinson (1969b, 1974). The succession was mapped in the summer of 2001 (Figure 5).

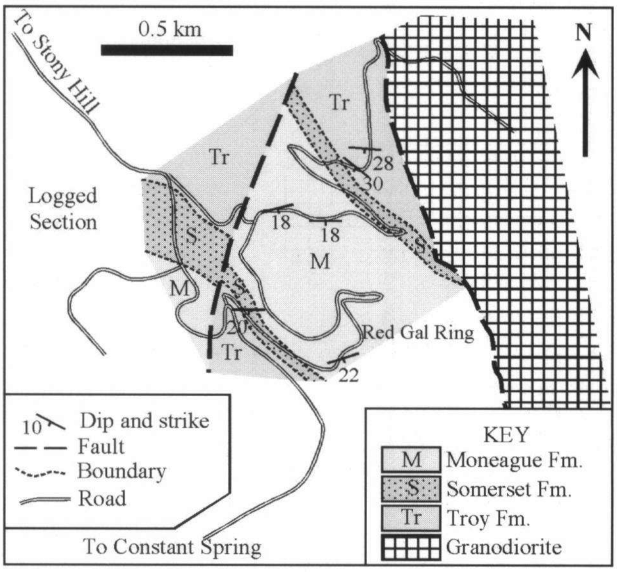

Figure 5. Geological map of the area around Stony Hill.

The lower part rests on igneous (Above Rocks Granodiorite) and metamorphic rocks belonging to the Above Rocks Inlier, and consists of poorly fossiliferous to unfossiliferous micritic limestones (the Troy Formation as defined herein).

Formation	Sample	Fauna	Age
Troy Formation	**WL 3**	*Amphistegina parvula, Fabiana* sp. and *Lepidocyclina ?peruviana.*	**Middle Eocene**
Somerset Formation	**WL 7**	*Cushmania americana; Fabularia verseyi; Spirolina; Fallotella cookei.*	**Late Eocene**
Moneague Formation	**WL 8**	*Lepidocyclina chaperi; L. macdonaldi; Fabiana* sp.	**Oligocene**
	WL 10	*Lepidocyclina chaperi; L. macdonaldi; Fabiana* sp.	
	WL 11	*Fallotella cookei*	
	WL 12	*Eulepidina undosa; ?Lepidocyclina* sp. *Pararotalia* sp.	
	WL 15	*Miogypsina* sp.	**Early Miocene**
	WL 16B	Archasinids; *?Miogypsina* sp. (?reworked); *Amphisoris* cf. *matleyi.*	
	WL 17	*Amphistegina* sp.; *Miogypsina* sp.; small *Spirogypsina* small sp.	

Table 4. Foraminiferal succession in the road from granodiorite inlier (between Riversdale and Rio Mango) and Rio Mango. See Figure 3 for locations of samples.

This is succeeded by a succession of off-white, light-grey and pale-pink limestones with common foraminifera (the Somerset Formation as defined herein). The succession (Figure 6) is well exposed along the Constant Spring to Stony Hill main road, although it is dangerous to study because of the heavy traffic. It consists of alternating sedimentary rhythmic units beginning with molluscan and foraminiferal packstones that pass upwards into wackestones and, finally, micritic mudstones. The wackestones and micritic mudstones contain low-diversity, low- to high-abundance faunas of tall-spired gastropods and foraminifera. In some rhythmic units, the uppermost micritic limestones contain small, irregular fenestrae. The foraminiferal assemblages in the nearby Red Gal Ring section were described by Robinson (1969b, 1974). The foraminifera exhibit an important change with the appearance of abundant *Fabularia verseyi* in the middle of the packstone sequence (Robinson, 1974). Hose & Versey (1957) used this appearance to define the base of their Somerset Formation. The fossiliferous limestones below the *F. veresyi* band, which contained the *Phacoides* band (Versey *in* Zans *et al.*, 1963), were placed in the Claremont Formation by Chubb & Versey (1957). Because similar lithologies are represented, the coloured packstones, wackestones and subordinate micritic limestones in this part of the sequence are herein also placed in the Somerset Formation.

The coloured foraminiferal limestones are succeeded by pure white limestones in the Red Gal Ring section (Figure 5). These limestones are highly fossiliferous and contain rich assemblages of molluscs, scleractinian corals and foraminifera. The foraminifera include successive assemblages characterised by *Lepidocyclina chaperi* Lemoine & R. Douvillé, *Eulepidina undosa* Cushman and *Lepidocyclina cancelli* Lemoine & R. Douvillé, indicating levels extending from the Oligocene up into the Lower Miocene (Robinson, 1969b).

Geological succession at Duncans

Deep-water White Limestone units are widely developed in the Wagwater, North Coast Belt and Wagwater and Montpelier-Newmarket troughs. The succession was examined in detail in the North Coast Belt at a small quarry, approximately 5 km west of Duncans (Figure 2). This quarry exposes a thick succession of limestones that contains cherts throughout and debris layers in the upper part (Figure 7). The succession is Miocene (Steineck, 1974; Donovan *et al.*, 1995, p. 17) and is attributed to the chert-bearing Montpelier Formation.

The section adjacent to the access road into the quarry was measured. Beds are identified by a numbering scheme for marlstones (prefixed by M) and chert layers (prefixed by C), and this is shown in Figure 7. The lower part of the succession consists of pure white micritic limestones that contain abundant planktic formaminifera. Layers of nodular, semitabular and cavernous chert up to 12 cm thick are a distinctive feature of this part of the succession. The cherts are parallel to bedding and contain abundant trace fossils on their surfaces (Blissett & Pickerill, 2004). Marlstone layers are also common in this part of the succession. They consist of up to 8 cm of clay-rich strata with a grey or brown colour. The marlstones recess giving a prominent weathering profile. Geochemical studies (Comer & Jackson, 2004) suggest that similar marlstones in the deep-water White Limestone Group successions are of volcanic ash origin.

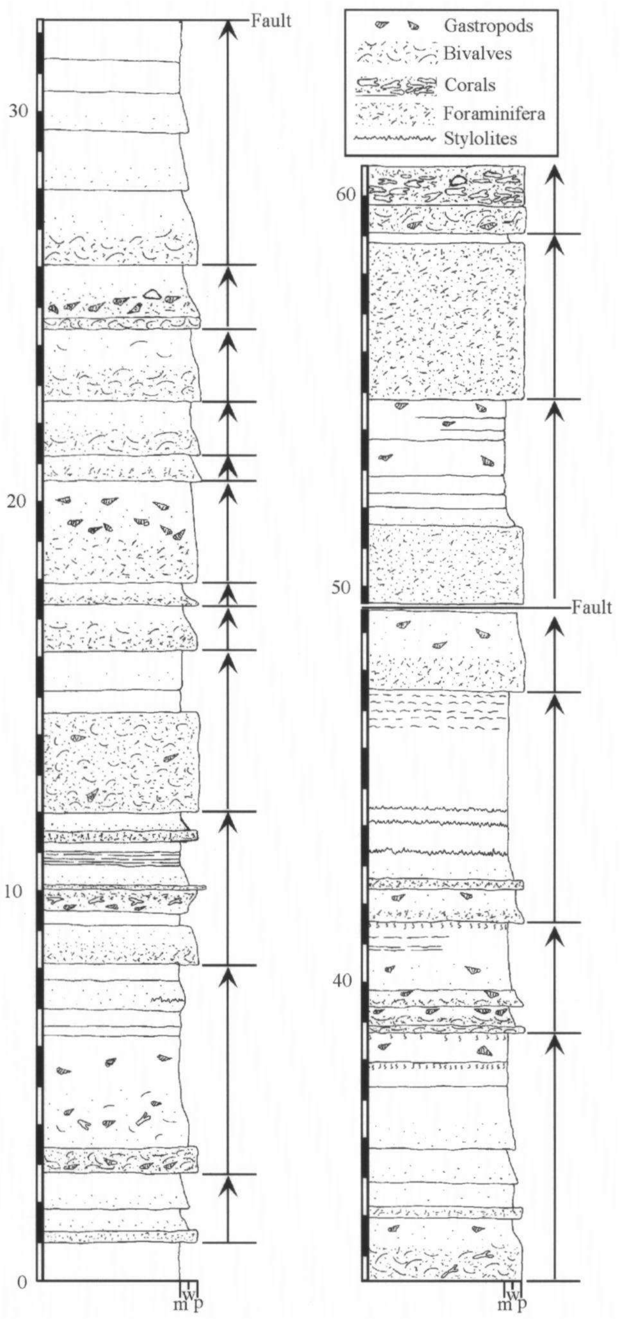

Figure 6. Graphic log through the Somerset Formation exposed on the main road between Constant Spring and Stony Hill. Arrows indicate suggested rhythmic units. Key: m, micrite; w, wackestone; p, packstone.

Thin marlstone bands in deep-water chalks elsewhere (*e.g.*, northeast England) are often attributed to volcanic sources (*e.g.*, Pacey, 1984).

The upper part of the succession shows an increased input of detrital carbonate. The succession consists of numerous beds that show normal grading from sand-sized to silt- or clay-sized sedimentary rock. The sand-sized grains are dominated by bioclasts including abundant foraminifera (*Miogypsina*) and other fossils. Some layers contain large blocks of shallow-water, coral-rich limestone, from which diverse Miocene faunas have been obtained (*e.g.*, Portell & Collins, 2004; Portell *et al.*, 2004). The debris layers thin dramatically laterally (from 5 m down to 20 cm, see Figure 7), suggesting they represent slump lobes. Silicification is present in the upper part of the Duncans succession, with preferential chertification of burrow fills and incipient/poorly defined nodular chert layers. Thin marlstones are also present.

Lithostratigraphy of the White Limestone Group

The detailed study of the White Limestone Group in the three areas described has made it possible to revise the stratigraphy of the group generally. For the first time, a comprehensive lithostratigraphic subdivision of the group is attempted. Six formations with definable lithostratigraphic characters developed in type sections are erected (Figure 8). Because of the inherent difficulty of studying the White Limestone Group at outcrop, it is anticipated that the divisions defined herein and their recognised distribution will require frequent revision.

White Limestone Group

Six formations are placed in the White Limestone Group; Troy, Swanswick, Somerset, Moneague, Montpelier and Pelleu Island formations. The Ipswich Formation, which is also described below because it has previously been placed in the White Limestone, is here transferred to the Yellow Limestone Group.

1 - Troy Formation

Diagnosis — The Troy Formation consists of unfossiliferous, pale pink or pale grey, poorly fossiliferous micritic limestones, dolomicrites and sucrose dolomites. Locally, thin packstones and grainstones form a minor part of this unit.

Type section — The type section was defined as 'the higher part of Cockpit Country of Trelawny, north of the District of Troy' by Hose & Versey (1957, p. 33). Many sections exist in the type region, however; none have yet been carefully logged or described in detail as of this writing.

Definition of base — In its type area, the Troy Formation rests on the Chapelton Formation of the Yellow Limestone Group. Mapping around the Central Inlier has demonstrated that there is an abrupt, although not necessarily synchronous, junction between the Chapelton and Troy formations.

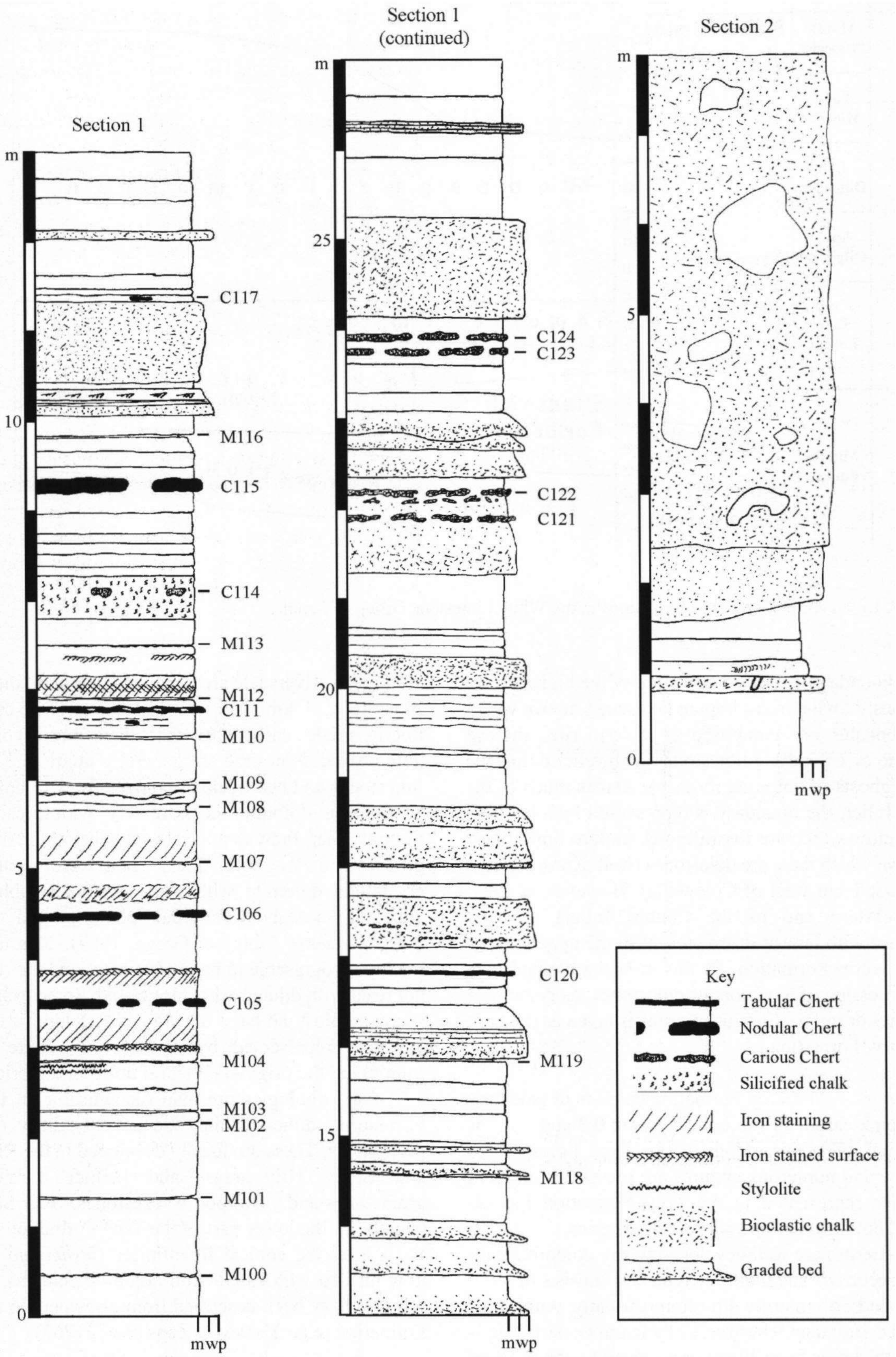

Figure 7. Graphic log through the Montpelier Formation exposed in Duncans Quarry. Section 1 represents the main section on the side of the access road into the quarry; Section 2 is on the south face of the quarry and probably correlates with the upper part of Section 1. Key: m, micrite; w, wackestone; p, packstone. Numbers preceded by M and C are marlstone bands and chert layers, respectively, that are used to describe the succession.

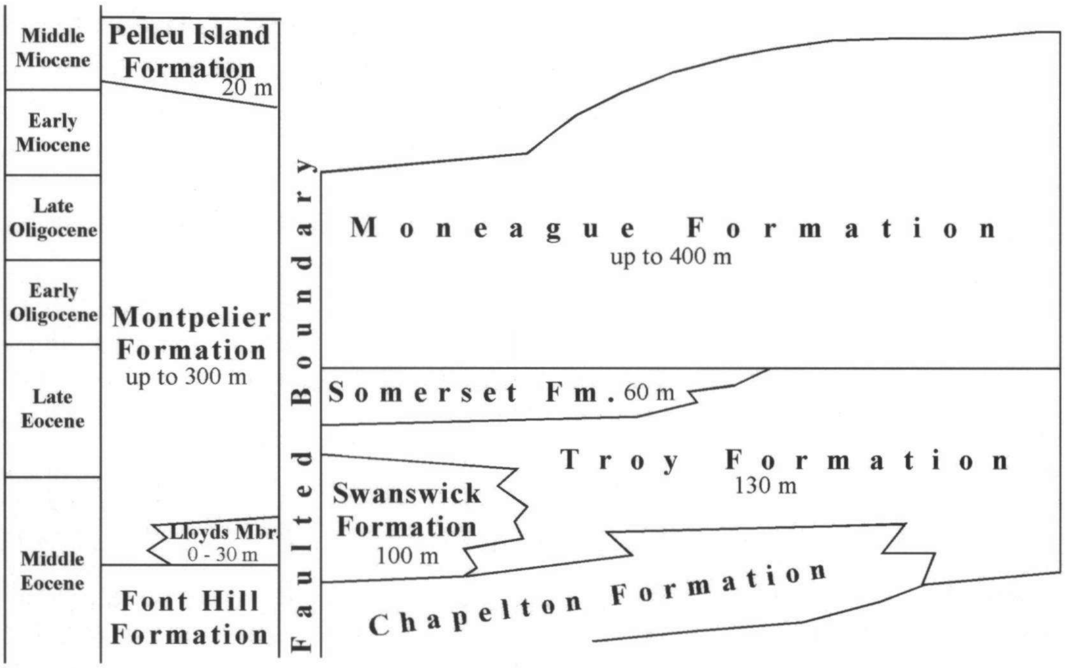

Figure 8. Broad correlation of the formations in the White Limestone Group of Jamaica.

The boundary is defined as the top of the highest level of obviously fossiliferous, impure limestones, above which the carbonates are composed of dolomicrite, sucrose dolostone or crystalline limestones with relict dolostone fabrics (ghosts of dolomite rhombs). Across much of the Central Inlier, the boundary is represented by a bedding plane, below which are fossiliferous, impure limestones, and above which there are dolostones (well exposed on the road about 1 km west of Coleyville). However, at Rock River (eastern end of the Central Inlier), micritic limestones with fenestrae are present in the upper part of the Chapelton Formation. In this area the change to a thick succession of monotonous dolostones, recrystallized limestones or unfossiliferous micrites is taken as the base of the Troy Formation.

Description — The Troy Formation consists of pale grey or pale pink carbonates in beds between 0.3 and 5 m, or more, thick. The mineralogy varies from limestone to dolostone and numerous textures are present. Prominent lithologies represented in the Troy Formation include micrites, dolomicrites and sucrose dolostones.

The micrites are well developed where dolomitization has not occurred. The lithology typically consists of well-defined beds of micritic limestone, usually with well-developed irregular fenestrae in their upper parts. Beds range in thickness from 20 cm up to several metres. These limestones are commonly developed in the Riversdale area (Figure 4), although many similar limestones are found in the Troy Formation all around the Central Inlier.

Dolomicrites are relatively rarely developed. They are seen in the Riversdale area and locally around the Central Inlier (e.g., 1 km west of Christiana). They consist of micrite-grade carbonates that have been completely dolomitized. Fenestrae are generally ubiquitous in these limestones and bed thickness ranges from 10 cm to 2 m.

Sucrose dolomite is extremely widespread in the Central Inlier. Individual layers are generally in the region of 2 to 5 m, or more, thick. Their texture consists of crystalline dolomite with well-developed subhedral to euhedral crystals (unimodal planar-s and planar-e dolomite, *sensu* Sibley & Gregg, 1987). This texture is readily recognisable in hand specimen, and the rock does not react with dilute hydrochloric acid. Some examples of sucrose dolostone have undergone dedolomitization and are now represented by mosaics of calcite crystals mimicking the original euhedral dolostone fabric.

Other lithologies are also recognisable in the Troy Formation, although they occur only in very small proportions. These are locally developed in the Riversdale and Stony Hill areas, and include foraminiferal grainstones and gastropod wackestones. Near Spaldings (Figure 2), the lower part of the Troy Formation contains voids after the conical foraminifer *Cushmania* that are now infilled with calcite and dolomite cements. Similar 'ghosts' have been described from elsewhere in the Troy Formation (e.g., Versey *in* Zans *et al.*, 1963).

Distribution — The Troy Formation is widely distributed in the central part of the Clarendon Block. It is present wherever the base of the White Limestone in the shallow-water facies is exposed. Notable occurrences are around the Central Inlier, at Riversdale and at Stony Hill.

Thickness — The thickness of the Troy Formation has been estimated at 130 m (Versey *in* Zans *et al.*, 1963).

Age — The Troy Formation rarely yields diagnostic faunas. The underlying Chapelton Formation is lower Middle to middle Middle Eocene, while the overlying Somerset Formation is upper Middle to lower Upper Eocene (Robinson & Mitchell, 1999). The grainstones in the Troy Formation near Riversdale are middle Middle Eocene.

Discussion — The Troy Formation, as defined here, includes all those limestones that either lack fossils, have very few fossils or have rare beds containing diverse fossils. It, therefore, corresponds to the Troy Limestones of Hose & Versey (1957), and the Troy and part of the Claremont limestones of Versey (*in* Zans *et al.*, 1963). Ever since its introduction by Versey (*in* Zans *et al.*, 1963), the Claremont Limestones have been hard to recognise. In almost all publications (e.g., Bateson, 1974a-d; Wright & Robinson *in* Wright, 1974) the Troy and Claremont formations have been grouped together. The logical course of action is therefore to suppress the name Claremont Member, and select a lithological boundary to define the boundary between the Troy and Somerset formations. This action is taken here.

2 - Swanswick Formation

Diagnosis — The Swanswick Formation consists of foraminiferal-peloidal grainstones. This lithology is very distinct and easily mappable.

Type section — The type section of the Swanswick Formation was defined as 'in the hills south of Swanswick in Trelawny' (Hose & Versey, 1957, p. 34). Versey (*in* Zans *et al.*, 1963, p. 33) defined the type section as 'in the hill on which Swanswick House stands, one mile east of Clark's Town, Trelawny.'

Definition of base — The base of the formation is defined at the appearance of extensive grainstones.

Description — The Swanswick Formation consists of white grainstones composed of the broken and worn tests of foraminifera and algal fragments. Peloids may also be present. Bedding is generally poorly defined, and sedimentary structures are absent. McFarlane (1974, p. 65) recorded rhodoliths in the Swanswick Formation.

Distribution — The Swanswick Formation is widely distributed around the northern and north-eastern margin of the Clarendon Block.

Thickness — The thickness was stated to be about 100 m by Hose & Versey (1957, p. 35).

Age — The lower part of the Swanswick Formation at its type locality yields the foraminifera *Eulinderina* and *Linderina* of middle Middle Eocene age, while the upper part yields species of the groups of *Lepidocyclina macdonaldi* Cushman and *L. pustulosa* H. Douvillé, of late Middle Eocene age (Hose & Versey, 1957; Robinson & Mitchell, 1999). Near Ham Walk, the Swanswick Formation yields *F. cassis*, *E. bermudezi*, *A. parva* and *E. guayabalensis* of middle Middle Eocene age. The formation therefore has a similar age to the Troy Formation.

Discussion — The Swanswick Formation is an easily mappable unit on the surface in Jamaica. It is a lateral equivalent of, and is also locally overlain by, the Troy Formation (Versey *in* Zans *et al.*, 1963) (Figure 8).

3 - Somerset Formation

Diagnosis — The Somerset Formation can be mapped as a fossiliferous packstone with subordinate foraminiferal and gastropod-bearing wackestones, and carbonate mudstones.

Type section — In the original description of the Somerset Member (Hose & Versey, 1957), no type section was listed. Hose & Versey (1957, p. 35) stated that, 'the member shows its greatest development between Somerset and Marshall's Pen, west of Mandeville and south of Spaldings, both areas being in Manchester.' Versey (*in* Zans *et al.*, 1963) stated, 'The type section is in the district of Somerset to the west of Mandeville in the parish of Manchester.'

Definition of base — The base of the formation is here defined as the change from predominantly carbonate mudstone-dominated lithologies to predominantly foraminiferal packstone-dominated lithologies. This is a boundary that can be mapped in the field and is not dependent of the appearance of a particular benthic foraminifer (*Fabularia verseyi*), which is a palaeontological datum. Around the Central Inlier and near Riversdale, the base of the formation is abrupt with packstones of the Somerset Formation resting on micritic limestones, dolomicrites or sucrose-dolostones of the Troy Formation. Further east, the boundary is less clearly defined. Packstones become progressively more important up-section in the Stony Hill area, and an arbitrary boundary must be chosen. It is suggested that the base of the Somerset Formation be defined as where packstones represent more than 25% of the succession.

Description — The formation consists predominantly of foraminiferal and molluscan packstones with subordinate wackestones and carbonate mudstones. The packstones are dominated by foraminifera (including *Cushmania* spp. and *Fabularia verseyi*, amongst others), but also include scleractinian corals, calcareous algae and benthic molluscs. Large molluscs are locally present, including the fauna described by Cox (1941) and related to the *Phacoides megameris* band by Hose & Versey (1957). The wackestones are characterised by low-diversity, low-abundance assemblages of foraminifera and gastropods, while the carbonate mudstones yield the same species, and sporadically also contain irregular fenestrae. Bedding ranges from 30 cm up to 5 m. The limestones are characterised by light grey or pale pink tones.

Distribution — The Somerset Formation is widely distributed around the northern half of the Clarendon Block, but is absent from the south of the block (Hose & Versey, 1957; Versey *in* Zans *et al.*, 1963).

Thickness — The formation is typically thin across much of the Clarendon Block, ranging from 10 to 20 m. On the main road between Constant Spring and Stony Hill, 60 m are assigned to the Somerset Formation (Figure 6).

Age — The Somerset Formation yields a typical fauna of *Fabularia verseyi* of early Late Eocene age. In the lower part of the Somerset Formation on the Stony Hill main road, *F. verseyi* is absent, and the lower part is probably of latest Middle Eocene age.

Discussion — The Somerset Formation, as redefined here, includes elements of the Somerset and Gibraltar Limestones of Hose & Versey (1957) and the Somerset and Claremont limestones of Versey (*in* Zans *et al.*, 1963). The name Claremont Limestone was introduced by Versey (*in* Zans *et al.*, 1963) for the *Phacoides* band of Hose & Versey (1957). The assumption, although unproven at the time, was that the characteristic molluscan assemblage occurred at the same horizon throughout Jamaica. At Red Gal Ring, near Stony Hill, the molluscan assemblage of Cox (1941) occurs in the limestones beneath the *Fabularia verseyi* band (= *Fabularia* band of Hose & Versey, 1957). Robinson & Mitchell (1999, p. 33) recognised that in the area around Riverhead, the molluscan band of Cox (1941) occurred overlying the *Fabularia* band. Consequently, the presence of large molluscs at a site is not a mappable level and should not be used as a criterion for defining a lithostratigraphic unit. The term Claremont Formation has previously been used for any lithology below the Somerset Member that contains fossils (whether they be large molluscs or scattered foraminifera; see Versey *in* Zans *et al.*, 1963). As such, the member has not been mappable, and the combined Troy and Claremont formations have been described as the "Troy-Claremont" or "Troy/Claremont" Member/Formation. Herein, the name Claremont Member/Formation is suppressed, and the boundary between the Troy and Somerset formations defined at the lithological change from predominately carbonate mudstones to predominately foraminiferal packstones.

The Gibraltar Limestones as originally defined (Hose & Versey, 1957, p. 36) included limestones that are 'equivalent to the Somerset Limestones in the south' and 'temporarily given a separate name because it overlies [they overlie] the Swanswick member - not the Troy.' This reasoning is unacceptable, because a formation (or member) should be given the same name throughout its geographical range. Regardless of subsequent amendments (e.g., Versey *in* Zans *et al.*, 1963), the name must be interpreted according to its original definition; consequently, it is recommended here that the names Gibraltar Limestones/Member/Formation should be suppressed.

4 - Moneague Formation

Diagnosis — The Moneague Formation makes up the intensely white limestones in the upper part of the White Limestone Group. The formation consists of foraminiferal and molluscan grainstones and wackestones, with less frequent carbonate mudstones. Molluscan wackestones become more dominant up-section, although the exact distribution of carbonate lithologies is not known.

Type section — No type section was stated by Hill (1899), although a number of named localities were given. Robinson & Mitchell (1999, p. 10) suggested that a section along the main highway between Moneague and Claremont might be used as a type section. This section is equivalent to the Brown's Town Limestone as defined by Hose & Versey (1957).

Definition of base — The base of the formation is defined at the change from coloured (pale pink or light grey) limestones below to white limestones above. In the areas studied the boundary is easily mappable.

Description — The formation consists of very pure carbonates without intercalations of impure limestone. As such, the formation is brilliant white, and is clearly differentiable from the underlying coloured limestones of the Somerset and Troy formations.

Textures are variable. The lower part of the formation is characterised by foraminiferal packstones and wackestones, with subordinate grainstones and carbonate mudstones. Abundant molluscan faunas occur at some levels (e.g., at Riverhead; see Robinson & Mitchell, 1999, p. 33). There is a progressive change in the foraminiferal assemblages in the lower part of the unit from north to south. In the north, assemblages are dominated by *Lepidocyclina*, while to the south, miliolids become commoner and dominate the assemblages.

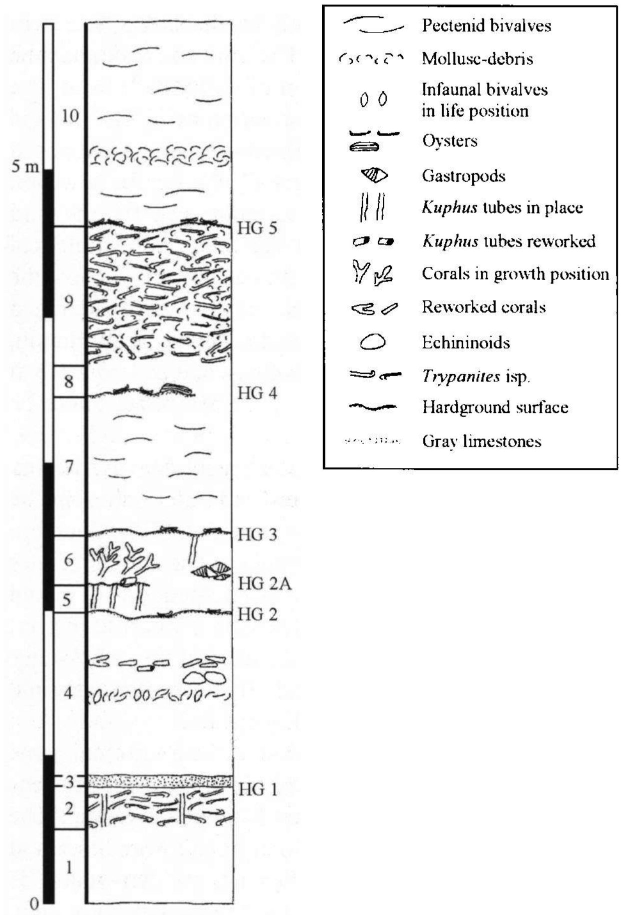

Figure 9. Graphic log through the Moneague Formation (*Amphisorus matleyi*-yielding beds) near Williamsfield. The succession consist of micritic limestones.

Up-section, there is also a change in the fossil assemblages, from foraminifer-dominated to molluscan-dominated, although large molluscs occur locally at the base of the Moneague Formation (Robinson & Mitchell, 1999).

A detailed log of the upper part of the Moneague Formation near Williamsfield (Figure 2) is given in Figure 9. The section contains rich molluscan and echinoid assemblages, and has five hardgrounds. The hardgrounds are cemented by oysters and barnacles, and bored by the trace fossil *Trypanites* (Blissett & Pickerill, 2004).

Distribution — The Moneague Formation is widely distributed on the Clarendon Block, forming much of the Manchester Plateau. It is also well developed near Brown's Town, Riversdale and Stony Hill.

Thickness — The thickness of the formation has not be determined with certainty, but Hose & Versey (1957) suggested a probable thickness of up to 400 m.

Age — The formation yields various foraminiferal assemblages ranging from the *Eulepidina-Neorotalia* Subzone (*Eulepidina* Zone) to the *Nummulites* Subzone of the *Amphistegina* Zone of Robinson (2004). This suggests an Early Oligocene to Middle Miocene age.

Discussion — The term Moneague Formation is applied to a great thickness of carbonates. There is no limit on the thickness of a formation (Salvador, 1994, p. 34).

The name Brown's Town Limestones was introduced for the *Lepidocyclina*-rich limestones in the lower part of the Moneague Formation (as interpreted here), while the name Walderston Limestones was introduced for the miliolid-dominated limestones (Hose & Versey, 1957). The name Brown's Town Limestones is preoccupied by Brownstown Formation of Hill (1899), and is therefore unavailable. Wright & Robinson (*in* Wright, 1974) suggested that the *Lepidocyclina*-rich limestones and the miliolid-rich limestones were facies of a single formation. In the western area of the Moneague Formation (i.e., around Riversdale), *Lepidocyclina* is relatively rare, and distinct *Lepidocyclina*-dominated and miliolid-dominated limestones cannot be recognised. Consequently, it is considered inadvisable to recognise separate Brown's Town and Walderston limestones, because their definition is based solely on the presence or absence of *Lepidocylina* (a foraminiferal biofacies indicator, rather than a lithostratigraphic boundary).

The name Newport Limestones was introduced by Hose & Versey (1957, p. 37) for poorly fossiliferous limestones that contained *Amphisorites matleyi*. This is a palaeontological datum, not a lithostratigraphic one. Herein, the Brown's Town, Walderston and Newport limestones of Hose & Versey (1957) are all placed in the Moneague Formation.

Versey (*in* Zans *et al*., 1963) suggested that the name Gibraltar Limestone should be restricted to the limestones that contain the *Lepidocyclina chaperi* fauna. He stated (Versey *in* Zans *et al*., 1963, p. 35) that, 'there is no good facies characteristic to define this member.' Thus, Versey suggested restricting the name Gibraltar Limestone to the *L. chaperi* Biozone. Because the lithology of this biozone is identical to that of the Moneague Formation as described here, the name Gibraltar Limestone (*sensu* Versey *in* Zans *et al*., 1963) is not retained.

5 - Montpelier Formation

Diagnosis — The name Montpelier Formation is applied to the deep-water carbonates (coccolith and planktic foraminiferal limestones and chalks) of the White Limestone Group that contain cherts. The formation consists of micritic limestones with marlstone bands, and layers of nodular and semitabular chert. At various levels, beds containing coarse-grained detritus (sand grade, but up to block size) are also present.

Type section — The type section is situated in the valley of Montpelier in the parish of St James (Versey *in* Zans *et al.*, 1963, p. 37).

Definition of base — The base is defined by the change from the impure limestones of the Font Hill Formation (Yellow Limestone Group) to the pure carbonates of the Montpelier Formation.

Description — The Montpelier Formation consists of alternating successions characterised by micritic deep-water limestones and bioclastic-rich beds derived from shallow water. The deep-water sedimentary rocks consist of micrite-grade carbonates. They are dominated by coccolith debris and also contain abundant planktic foraminifera. These micritic limestones have common bands of chert. The cherts range from nodular to semitabular to carious and are up to 20 cm thick. The cherts form well-defined bands parallel to bedding and can be used to establish a series of marker beds (Figure 7). These coccolith limestones also contain common marlstone bands up to 8 cm thick.

Bioclastic-rich layers are intercalated with the micritic limestones. These layers are characterised by thin beds up to 30 cm thick that show normal grading. Some show sedimentary structures, including horizontal lamination followed by ripple cross-lamination, and can be interpreted as carbonate turbidites. In addition to the normally graded beds, there are thick beds (up to 5 m thick) that consist of sand grade carbonate sediment and include blocks of shallow-water carbonates (e.g., coral-rich limestones and foraminiferal grainstones) up to several metres across. These coarse-grained beds record the transportation of shallow-water (platform-edge) carbonates into deep-water chalks as debris avalanches or debris flows.

Distribution — The Montpelier Formation is extensively developed in the troughs and belts among the shallow-water blocks, notably in the North Coast Belt and the Montpelier-Newmarket Trough.

Thickness — In northern St James, Versey (*in* Zans *et al.*, 1963) suggested that more than 300 m of Montpelier Formation was present.

Age — Steineck (1974, p. 226) indicated the age range for the deep-water chert-bearing limestones as Eocene to Early Miocene. Robinson & Mitchell (1999, p. 17) indicated that the base of the Montpelier Formation (their Bonnygate [*sic*] Member) was of late Middle Eocene age (*Truncorotaloides rohri* Zone).

Discussion — Robinson (1967a, p. 569) introduced the name Bonny Gate Formation for 'evenly bedded pure white chalk with a few graded bioclastic units containing algal fragments and larger foraminifera. In addition there are thin (2-10 cm) platy layers of dark brown chert, and in a few localities there are regularly bedded layers, 1 to 2 cm thick, of greenish gray clay.' The unit was distinguished from the Montpelier Formation of Hill (1899) by an age difference, the Bonny Gate Formation being Eocene and the Montpelier Formation, Miocene, with a supposed hiatus between the two. Steineck (1974, fig. 5), however, showed that there was only a minor gap (if any?) in sections between Montego Bay and Adelphi. Regardless of whether there is a hiatus in the succession or not, the Montpelier and Bonny Gate chalks have identical lithologies, and should be placed in the same formation. The name Montpelier has precedence and consequently it is recommended here that the name Bonny Gate should be suppressed.

Robinson (1967a) introduced the name Lloyds Member for siliciclastics, conglomerates and calcirudites in the lower part of the Bonny Gate Formation of the southern Wagwater Belt (area around Yallahs). The conglomerates consist of fine-grained limestones alternating with mixed carbonate-clastic conglomerates with a micritic matrix. They were regarded as a local facies in the deep-water chalks. The name Lloyds Member is accepted here and transferred to the Montpelier Formation.

Steineck (1974, p. 224) introduced the informal name Sign Beds for the uppermost Oligocene to Lower Miocene chert-bearing limestones in his Montpelier Group. The Sign Beds came above the Bonny Gate Formation and below the Spring Garden Formation. The name is equivalent to the upper part of the Montpelier Formation, as defined here, and is superfluous.

6 - Pelleu Island Formation

Diagnosis — The name Pelleu Island Formation is used for the deep-water carbonates (coccolith and planktic foraminiferal limestones and chalks) of the White Limestone Group that lack cherts.

Type section — The type section is situated on Pelleu Island in San San Bay (Robinson *in* Zans *et al.*, 1963, p. 45).

Definition of base — The base is defined as the change from limestones with chert to limestones lacking chert. The last chert layer represents the top of the Montpelier Formation. The top is defined by the incoming of impure brown marlstones at the base of the Buff Bay Formation (Robinson *in* Zans *et al.*, 1963, p. 45; Robinson, 1969a, pp. 3, 7).

Description — The Pelleu Island Formation consists of massive, evenly bedded soft white chalks without chert layers. The rocks contain abundant sponge spicules (Robinson, 1969a, p. 3). In San San Bay, the formation contains calcareous sandstones or sandy detritus towards the base (Robinson *in* Zans *et al.*, 1963, p. 45).

Distribution — The Pelleu Island Formation occurs above the Montpelier Formation at Buff Bay and San San Bay in eastern Portland (Robinson *in* Zans *et al.*, 1963; Robinson, 1967b, 1969a) and also along the North Coast (Robinson, 1967b, p. 35; Steineck, 1974).

Thickness — Robinson (*in* Zans *et al.*, 1963, p. 45) quoted a thickness of around 20 m for the Pelleu Island Formation at San San Bay.

Age — The age of the Pelleu Island Formation is late Early Miocene to Middle Miocene (zones N8 to N14: Steineck, 1974, p. 226).

Discussion — The name Spring Garden Formation was introduced in the Geological Survey Report for 1959 (Geological Survey Department, 1959) for all the limestones below the Costal Coastal Group. Robinson (*in* Zans *et al.*, 1963, p. 45) introduced the name Pelleu Island Formation for the chert-less chalks below the San San Clay, while Robinson (1967b, p. 35) revised the name Spring Garden Member to exclude the chert-bearing limestones. Robinson (1969, p. 7) suggested that the Spring Garden Member should be used in preference to the Pelleu Island Formation. However, since the first properly defined name for this unit is the Pelleu Island Formation (Spring Garden Formation specifically includes the cherts), this name has preference, and is used for the chert-less chalks at the top of the deep-water White Limestone Group succession.

Yellow Limestone Group

1 - Ipswich Formation

Diagnosis — A succession of impure limestones. The lower part consists of 60 m of well-bedded limestones with *Yaberinella* and dictyoconids. This grades upwards (through 10 m) into 105 m of blue-hearted, cross-bedded limestones with abundant *Lepidocyclina.*

Type section — The type section extends along the road through Ipswich to a point 45 m beyond the road leading to Ipswich House (Versey, 1957a, b; Robinson & Mitchell, 1999).

Distribution — The Ipswich Formation is only found on the western margin of the Clarendon Block.

Thickness — The formation has a thickness of 160 m (Robinson & Mitchell, 1999).

Age — The lower part of the Ipswich Formation yields the *Eulinderina-Polylepidina* fauna of the middle Middle Eocene, while the upper part contains the *Lepidocyclina macdonaldi* fauna of the late Middle Eocene (Robinson & Mitchell, 1999).

Discussion — Although Versey (1957b; *in* Zans *et al.*, 1963) placed the Ipswich Limestones in the White Limestone Group, lithologically they are closer to the Yellow Limestone Group, because they consist of impure and blue-hearted limestones. The Ipswich Formation is here transferred to the Yellow Limestone Group herein. The Ipswich Formation is succeeded by the Troy Formation (Versey, 1957a).

Palaeogeography

The palaeogeography of the White Limestone has previously been considered by Versey (*in* Zans *et al.*, 1963, pp. 40, 41), Wright & Robinson (*in* Wright, 1974, p. 47) and Eva & McFarlane (1985). Versey (*in* Zans *et al.*, 1963) suggested facies distributions and palaeogeographical reconstructions for the upper Middle Eocene and the Oligocene. In the upper Middle Eocene of the Clarendon Block, he recognised a northern belt of biocalcarenites (miliolid and orbitoid facies), a central belt of recrystallized limestones, and a southern belt of dolomites and magnesian limestones. In the Oligocene of the Clarendon Block, he recognised a platform margin orbitoid facies, a miliolid belt and a peneroplid facies passing in towards the platform interior. Wright & Robinson (*in* Wright, 1974), recognised an open shelf facies in the northern part of the Clarendon Block, and a lagoonal facies in the south. Eva & McFarlane (1985) suggested more elaborate palaeogeographic models in the upper Middle Eocene to Lower Miocene. On the Clarendon Block, they recognised shelf-edge facies in the upper Middle Eocene and Upper Oligocene represented by 'agitated waters with reefs, cays and beaches', and 'shallow water facies with '*Thalassia*' fields and molluscs' over much the interior of the block. In the Upper Eocene-Lower Oligocene, the whole Clarendon Block consisted of the 'shallow water facies with '*Thalassia*' fields and molluscs'. In the Lower Miocene, they showed extensive barrier reefs around the margins of the Clarendon Block, and patch reefs surrounded by 'shallow sea with lagoonal interreefal '*Thalassia*' fields' across the majority of the block. All the palaeogeographic reconstructions agree with the belts and troughs being represented by pelagic deposition.

There is little doubt that deposition during White Limestone Group time was largely influenced by active tectonics. The tectonic regime at the time was represented by northeast-southwest directed extension, related to the opening of the Cayman Trough (Mann & Burke, 1990; Mitchell, in press). Important sets of east-west and northwest-southeast faults were active at this time, and these border the western, northern and eastern margins of the Clarendon Block. Subsidence was rapid within the troughs, but more gradual on the blocks.

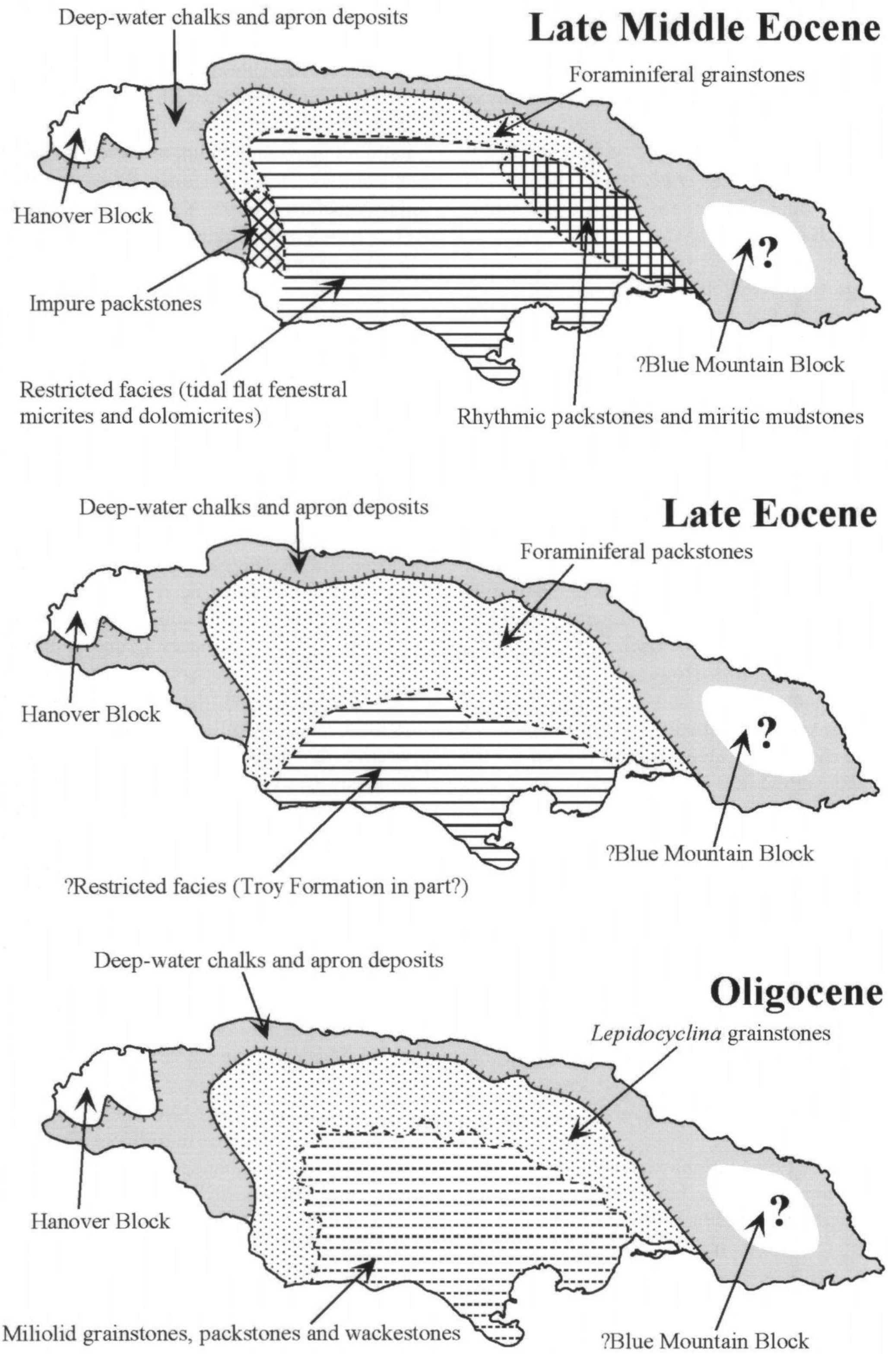

Figure 10. Generalised palaeogeography of the White Limestone Group.

Deep-water chalks accumulated in the troughs and belts, together with large quantities of detritus (grains and blocks) derived from the nearby shallow-water blocks. These include clastics, derived from the Cretaceous-

Paleocene basement succession of the Clarendon Block (e.g., as preserved in the Lloyds Member, see Robinson, 1967a), and carbonates, derived from the shallow-water marginal deposits of the Clarendon Block (e.g., corals and bioclastic debris in Duncans quarry, blocks of Swanswick limestone in the Montpelier Formation of the northeastern Wagwater Belt; see Robinson & Mitchell, 1999, p. 17). This material occurs either in graded turbidites, or in thicker beds of debris avalanche or debris flow origin. The presence of these debris units is due either to eustatic sea-level falls (e.g., Sarg, 1988), active tectonics or a combination of both. These deep-water sedimentary rocks also include marlstone bands indicating the distant eruptions of volcanoes, possibly in Central America (Comer & Jackson, 2004). The rapid subsidence of the North Coast Belt is indicated by the fish fauna present in these deep-water strata. This fauna (Underwood & Mitchell, 2004) suggests minimum depths of greater than 200 m, and probable depths in the range of 1,000-2,000 m. In the present paper, palaeogeographic reconstructions for the White Limestone Group are presented for three time slices, *viz.* late Middle Eocene (Troy-Swanswick-Montpelier time), Late Eocene (Somerset-Montpelier time) and Late Oligocene (Moneague-Montpelier time) (Figure 10).

Late Middle Eocene (Troy-Swanswick-Montpelier) time (Figure 10)

By late Middle Eocene time, most of the land areas that had been the source for clastics during the deposition of the Yellow Limestone Group had been submerged and clastic influx only continued on the south-western part of the Clarendon Block (deposition of the Ipswich Formation, with the clastics derived from an unknown land area). Over the remainder of the Clarendon Block, pure carbonates of the White Limestone Group were deposited. The northern and eastern margins of the Clarendon Block were sites where the accumulation of extensive grainstones of the Swanswick Formation took place. These grainstones consist of the worn tests of foraminifera, peloids and algal fragments, that were deposited in a relatively high-energy environment. The grainstones accumulated in large banks, and locally contain corals and rhodoliths (McFarlane, 1974). The grainstones lack primary sedimentary structures, probably because of extensive bioturbation. Evidence for subaerial exposure (e.g., vadose zone cementation, aeolian sedimentary structures, karstic surfaces, etc.) has not been recognised, suggesting that the grainstones represented submarine sand banks. The carbonate sand banks of the northern and northeastern margin pass towards the platform interior into the dense fenestral micrites and dolomicrites of the Troy Formation. Fenestrae indicate subaerial exposure, while the fine-grained nature of the sedimentary rocks indicates a low-energy depositional environment. Rarer laminar fenestrae indicate the former presence of algal mats. The sedimentary rocks of the Troy Formation therefore suggest deposition in protected environments where shallow-water carbonate mudflats prograded across restricted tidally influenced inlets. Rare beds with tall-spired gastropods in the Troy Formation in the Riversdale area indicate less restricted environments, while thin grainstones indicate interior-directed transportation of platform-edge sands, probably by major storms or hurricanes. Around the eastern, northern and western margins of the Clarendon Block, deep-water carbonates accumulated. Robinson & Mitchell (1999) indicated blocks of Swanswick-type lithology resedimented into mass-flow deposits in the Montpelier Formation in the northeastern part of the Wagwater Belt. Such deposits were presumably derived from the platform margin during periods of instability (perhaps earthquakes related to fault movement or falls in relative sea level leading to the development of low-stand talus aprons; compare Sarg, 1988).

Late Eocene (Somerset-Montpelier) time (Figure 10)

Significant changes in the shallow-water carbonate platform of the Clarendon Block occurred in the Late Eocene. The packstones of the Somerset Formation, with their abundant molluscan-algal-coral fauna, were deposited across the northern half of the Clarendon Block. This facies suggests a more open marine environment than that of the restricted facies of the underlying Troy Formation. On the southern part of the Clarendon Block, the Somerset Formation is absent. The Somerset Formation therefore represents a significant change in the development of the carbonate platform of the Clarendon Block. During the late Middle Eocene, carbonate production kept pace with subsidence, a keep-up carbonate system (Kendall & Schlager, 1981). In the Late Eocene, the system changed to a catch-up system (Kendall & Schlager, 1981) and the platform was flooded. In the deep-water areas around the platform, chalks and shallow-water-derived carbonate talus deposits accumulated.

Late Oligocene (Moneague-Montpelier) time (Figure 10)

Previous interpretations of the Oligocene foraminiferal biofacies (e.g., Versey *in* Zans *et al.*, 1963; Eva & McFarlane, 1985) have suggested a transition from a platform-margin facies dominated by *Lepidocyclina*-rich foraminiferal assemblages to a platform interior facies dominated by miliolids and peneroplids. In Figure 10, the platform edge is shown as characterised by thick banks of *Lepidocyclina* sands and gravels. Sedimentary structures, such as cross-bedding, however, are not preserved, suggesting extensive bioturbation. Associated with these carbonate sand banks were diverse stands of coral thickets, many now preserved as pillarstones and rudstones (Stemann, 2004). These corals are dominated by stick-morphologies, suggesting deposition in protected areas behind the carbonate platform's margin. Towards the platform interior, there was a change in foraminiferal assemblages from the *Lepidocyclina*-dominated assemblages of the platform edge to miliolid- and peneroplid-dominated assemblages. Miliolid-dominated assemblages are characteristic of restricted marine environments (Brasier, 1980), indicating some restriction in the platform interior. Evidence of tidal flats and fenestral fabrics is unknown. The carbonate platforms of the Oligocene were, therefore, still part of a catch-up system. Around the margin of the Clarendon Block, deep-water chalks and talus aprons developed.

Early and Middle Miocene sedimentary rocks have only been preserved on the southern half of the Clarendon Block. They were clearly deposited on the northern part of the block - detritus derived from the shallow-water lithologies is present in the deep-water strata of the North Coast Belt - but have been subsequently removed by erosion. The Early and Middle Miocene limestones of the southern Clarendon Block include molluscan wackestones and packstones, locally with hardgrounds. Fenestral fabrics and tidal-flat facies are again absent, suggesting that the Miocene palaeogeography was similar to that of the Oligocene.

Conclusions

This study has attempted to produce a workable lithostratigraphic scheme for the White Limestone Group. The White Limestone has been divided into six formations, four on the shallow-water Clarendon Block and two in the deep-water troughs and belts. The shallow-water formations are distinguished on lithological criteria, including their dominant lithology, either grainstones, packstones or carbonate mudstones, and their colour. Four units, the Troy, Swanswick, Somerset and Moneague formations, are mappable across the Clarendon Block. The deep-water limestones consist of chalks, and interbedded carbonate turbidites and debris flows/avalanches. The two remaining formations are distinguished on the presence (Montpelier) or absence (Pelleu Island) of chert bands. As with all lithostratigraphic schemes, its worth will only become apparent with more extensive mapping. The palaeogeography of the White Limestone Group of the Clarendon Block shows a change from restricted, tidal flat platform interior facies and margin carbonate sands in the late Middle Eocene, to open marine platform interior facies and marginal carbonate sands in the Oligocene.

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Appendix 1. White Limestone Lexicon

Authorship and rank changes of units in the White Limestone Group (n.b., only formally published papers, not theses, are regarded as valid publication of names; see Salvador, 1994). Valid names shown in bold with rank accepted herein; other names shown in italics with originally cited rank.

Bonny Gate Formation — Introduced as 'Bonny Gate Formation' by Robinson (1967a, p. 569). Incorporated into the Montpelier Formation herein.

Bonnygate Member — Typographical error in Robinson & Mitchell (1999, p. 17) for Bonny Gate Member.

Brownstown Formation — Introduced by Hill (1899, p. 71) in a footnote, for what he thought was the upper half of his Oceanic Series (apparently his Moneague and Cobre formations). The name has not been subsequently used in the sense of Hill (1899). Regarded as obsolete here.

Brown's Town Limestones — Introduced as a member 'Brown's Town Limestones' of the White Limestone Formation by Hose & Versey (1957, p. 36). Elevated to rank of formation in the combination 'Brown's Town-Walderston Formation' by Bateson (1974a-f), and 'Brown's Town Formation' by Steineck (1974, p. 223). Invalid, since the name Brownstown as used by Hill (1899) has priority.

Claremont Limestone — Introduced as a member 'Claremont Limestone' of the White Limestone Formation by Versey (*in* Zans *et al.*, 1963, p. 34). Elevated to a formation in the combination 'Troy/Claremont Formation' by Bateson (1974a-d). Not regarded as mappable herein and regarded as obsolete.

Clarendon Group — Introduced as 'Clarendon Group' for shallow-water limestones of the White Limestone by Steineck (1974, p. 221). Not subsequently used and generally regarded as obsolete (e.g., Robinson, 1988; Robinson & Mitchell, 1999).

Cobre Formation — Introduced as a formation in the Oceanic Series by Hill (1899, p. 78). This subdivision has not been accepted and the name is considered obsolete.

Gibraltar Limestones — Introduced as a member 'Gibraltar Limestones' of the White Limestone Formation by Hose & Versey (1957, p. 35). Versey (*in* Zans *et al.*, 1963, p. 35) restricted the name Gibraltar Limestone to the limestones containing the *Lepidocyclina chaperi* fauna. Raised to rank of formation in the combination 'Gibraltar-Bonny Gate Formation' by Bateson (1974a). Original definition is poor and includes parts of the Troy, Somerset and Moneague formations as used here (Versey *in* Zans *et al.*, 1963). Gibraltar Limestone of Versey (*in* Zans *et al.*, 1963) is equivalent to the *L. chaperi* Biozone and part of the Moneague Formation as used here. The name 'Gibraltar Limestones' is therefore of little lithostratigraphic use and should be suppressed.

Ipswich Formation — Introduced as a member 'Ipswich Limestone' of the White Limestone Formation by Versey (1957b). Name retained here as a formation, but transferred to the Yellow Limestone Group.

Lloyds Member — Introduced as a member of the Bonny Gate Formation by Robinson (1967a, p. 570). Retained as a local member and placed in the Montpelier Formation herein.

May Pen Beds — Introduced by Hill (1899, p. 84) for 'loosely consolidated mixture of yellow colored limestone lumps and clay marl, and contains many casts of Mollusca.' Hill was of the opinion that this was equivalent to the Bowden Formation. Hose & Versey (1957, p. 37) included the May Pen Beds in their Newport Limestones. The name has not been used in mapping. The type locality needs to be studied to determine if the name has any validity.

Moneague Formation — Introduced as a formation of the Oceanic Series by Hill (1899, p. 76). Raised to group status by Robinson (1988, p. 63) for the shallow-water facies of the White Limestone Supergroup. The name is here used for the higher part of the shallow-water facies limestones on the Clarendon Block.

Montpelier Formation — Introduced as 'Montpelier Beds' by Hill (1899, p. 70) for the deep-water, chert-bearing limestones of the Oceanic Series. Accepted as a formation herein.

Newport Limestones — Introduced as a member 'Newport Limestones' of the White Limestone Formation by Hose & Versey (1957, p. 37). Raised to formation rank by Bateson (1974b, c, e, f). Considered part of the Moneague Formation here, as original definition was based on foraminiferal assemblages.

Oceanic Series — Name introduced by Hill (1899, p. 69) as an equivalent to the current usage of the White Limestone Group. The name has not subsequently been used and is now obsolete.

Pelleu Island Formation — Introduced by Robinson (*in* Zans *et al.*, 1963, p. 45) for the limestones without cherts stratigraphically above the Montpelier Formation and below the San San Clay at San San Bay. Retained here as a formation.

Sign Beds — Introduced informally for the lower part of the cherty Montpelier Formation by Steineck (1974, p. 224). Incorporated into the Montpelier Formation herein.

Somerset Limestones — Introduced as a member 'Somerset Limestones' of the White Limestone Formation by Hose & Versey (1957, p. 35). Raised to formation rank by Bateson (1974a, b, d-f). Retained here, in a modified sense, for a formation.

Spring Garden Member — Introduced by Geological Survey (Geological Survey Department, 1959, p. 4) for chert-bearing and chert-free limestones below the Coastal Group. Revised by Robinson (1967b, p. 35) to contain only the chert-free limestones above the Montpelier Formation and below the Buff Bay Formation. The name Pelleu Island Formation was formally defined for the chert-free limestones by Robinson (*in* Zans *et al.*, 1963, p. 45) before this revision, and, therefore, has preference.

Swanswick Limestones — Introduced as a member 'Swanswick Limestones' of the White Limestone Formation by Hose & Versey (1957, p. 34). Raised to rank of formation by Bateson (1974a, d). Retained as a formation here.

Troy Limestones — Introduced as a member 'Troy Limestones' of the White Limestone Formation by Hose & Versey (1957, p. 33). Raised to the rank of formation in the combination 'Troy-Claremont Formation' by Bateson (1974a-d) and 'Troy Formation' by Bateson (1974e, f). Retained herein as a formation.

Walderston Limestones — Introduced as a member 'Walderston Limestones' of the White Limestone Formation by Hose & Versey (1957, p. 37). Raised to rank of formation in the combination 'Brown's Town-Walderston Formation' by Bateson (1974a-f), and 'Walderston Formation' by Steineck (1974, p. 223). Included in the Moneague Formation herein.

White Limestone Group — First named as 'white limestone formation' by De la Beche (1827, p. 169); raised to group status by Wright and Robinson (*in* Wright, 1974, p. 46); inferred supergroup rank by Steineck (1974); formally called a supergroup by Robinson (1988, p. 62).

Appendix 2. Suggested terminology

The following is a suggested terminology for some previously used lithostratigraphic names that are not recognised in this revision.

Bonny Gate Formation — Lower part of the Montpelier Formation.

Brown's Town Limestones (*sensu* Hose & Versey, 1957) — *Lepidocyclina*-dominated biofacies of the Moneague Formation.

Gibraltar Limestone (*sensu* Versey *in* Zans *et al.*, 1963) — *Lepidocyclina chaperi*-yielding limestones of the Moneague Formation.

Newport Limestones — *Amphisorites matleyi*-yielding limestones of the Moneague Formation.

Sign Beds — Upper part of the Montpelier Formation.

Walderston Limestones — Miliolid-dominated biofacies of the Moneague Formation.