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The first Paleogene transgression onto the Clarendon Block (Jamaica)

SIMON F. MITCHELL

Department of Geography and Geology, the University of the West Indies, Mona, Kingston Jamaica. Email: simon.mitchell@uwimona.edu.jm

ABSTRACT. This paper presents a new geological map for the area around Bottom Leinster (including the newly identified Bottom Leinster Inlier) on the north-eastern margin of the Clarendon Block and shows part of the northern Wag Water Belt (parish of St Mary, Jamaica). This allows a study of the flooding of the Clarendon Block during the early Paleogene. The northern part of the area shows rocks belonging to the succession deposited in the Wag Water Belt that includes the Wag Water and Richmond formations. The southern part of the map shows the northern part of the Above Rocks and the Bottom Leinster inliers, together with mid Paleogene rocks that overlie the rocks exposed in the inliers. Around the Bottom Leinster Inlier (composed of granodiorite), the late Paleogene rocks consists of the thin Bottom Leinster Limestone (new name) and rocks attributed to the Wag Water Formation. The Bottom Leinster Limestone consists of grey micritic limestone which is locally bioclastic. The fauna of Larger Benthic Foraminifers consists of *Tremastegina* cf. *lopeztrigoi*, *Helicostegina gyralis* and *Eoconuloides wellsi*, which indicate a late Ypresian age. This represents the first identified marine transgression onto the Clarendon Block. The Wag Water Formation consists of immature, conglomerates with angular clasts on the edge of the Wag Water Belt (interpreted as talus deposits) and sandstones with pebble conglomerates with rounded clasts on the Clarendon Block (interpreted as fluviatile deposits). The Bottom Leinster Limestone is also found as a thin unit within the conglomerates of Wag Water Formation of the Wag Water Belt. An assessment of the ages of the Wag Water and Richmond formations, using the Bottom Leinster Limestone as a datum indicates a diachronous relationship, with the conglomerates of the Wag Water Formation deposited on the edge of the Wag Water Trough, and shales and sandstones of the Richmond Formation deposited within the main part of the trough itself. These results also demonstrate transgressions onto the northern edge of the Clarendon Block during the late Ypresian (Bottom Leinster Limestone) and early Lutetian (Stettin Limestone).

Keywords: Eocene, Jamaica, limestone, Wag Water Belt, Clarendon Block.

1. INTRODUCTION

In the late Cretaceous to earliest Paleogene, the Jamaican-Siuna Arc collided with the Chortis and Maya blocks resulting in central and western Jamaica and the Nicaragua Rise (between Jamaica and Honduras) becoming a subaerial landmass (**Mitchell, 2003, 2006, 2020**). Evidence for the existence of this land mass is preserved in central Jamaica and includes silicified angiosperm and palm (*Palmoxylon*) trunks preserved in the base of the Eocene succession (**Porter, 1998**), mangrove pollen (**Graham, 1977, 1993**) and the remains of terrestrial animals, the rhinoceratoid ungulate *Hyrachyus* and a squamate lizard, preserved in deltaic sediments of the Litchfield Formation (**Domning et al., 1997**; **Pregill, 1999**; **Portell et al., 2001**).

The first evidence for a break up of this land area comes from the North Coast Belt of Jamaica where marine sedimentation began in the mid early Eocene (**Mitchell, 2016**) with the rapid formation of deep-water shales (Richmond Formation) and marlstones (the Palmetto Grove and Preston Hill formations: (**Burke et al., 1969**; **Wise and Constans, 1976**; **Jiang and Robinson, 1987**). In central Jamaica (Trelawny, Manchester and Clarendon) the first transgression onto the central to northern parts of the Clarendon Block is recorded by the Stettin (Limestone) Formation (**Porter and Robinson, 1974**; **Robinson, 1996**; **Robinson and Mitchell, 1999**; **Mitchell, 2013a**), a series of molluscan and foraminiferal wackestones, which can be dated as early Lutetian (**Robinson and Mitchell, 1999**).

This paper represents a study of the north-eastern part of the Clarendon Block (**Figure 1**). It defines the northern margin of the Clarendon Block which lines up with the Northern Platform Boundary Fault (NPBF) of **Mitchell (2013b)**. The rocks found in the supposed embayment of the Wag Water Belt/Trough (**McFarlane, 1977**; **Mann and Burke, 1990**) should now be interpreted as fluvial deposits deposited on the Clarendon Block and not as part of the Wag Water Belt (as demonstrated below). In addition, a thin limestone (dated as early Eocene = Ypresian) has been mapped that rests

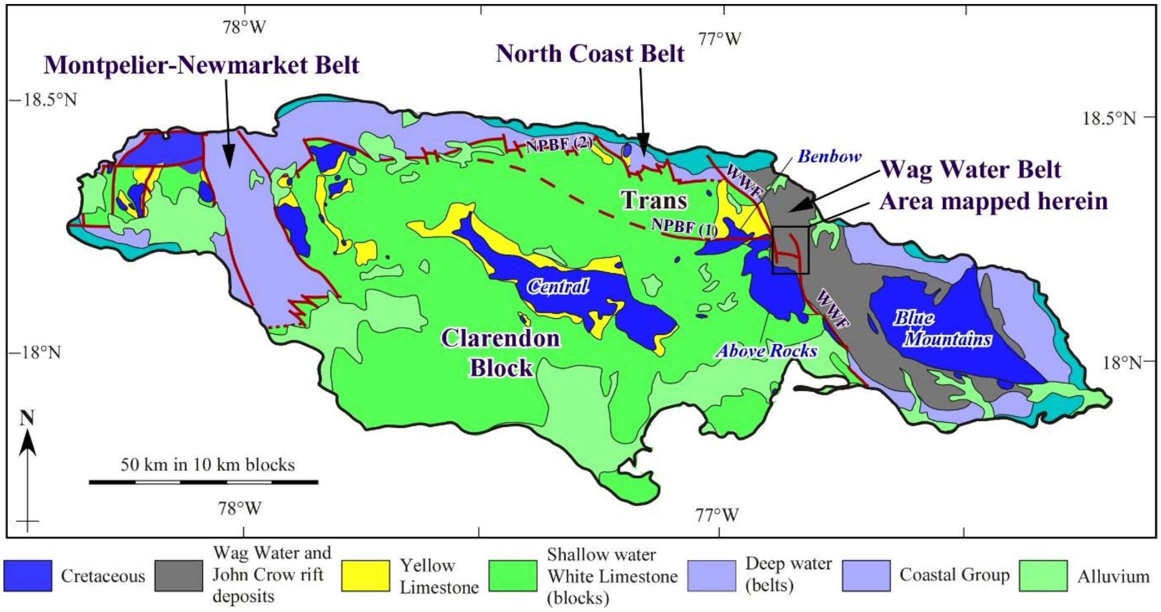

Figure 1. Distribution of blocks and belts in Jamaica; updated and revised from Versey (in Zans et al., 1963), Eva and McFarlane (1985), Robinson and Mitchell (1999) and Mitchell (2004, 2013b). Trans – This is an area which is part of the North Coast Belt in the Ypresian to Lutetian, but becomes part of the Clarendon Block in the Late Eocene (= Priabonian) (Mitchell, 2016). NPBF (1), NPBF (2), Northern Platform Boundary Fault in the early-middle Eocene (1) and Late Eocene to early Miocene (2) separating the 'Trans' zone. WWF. Wag Water Fault.

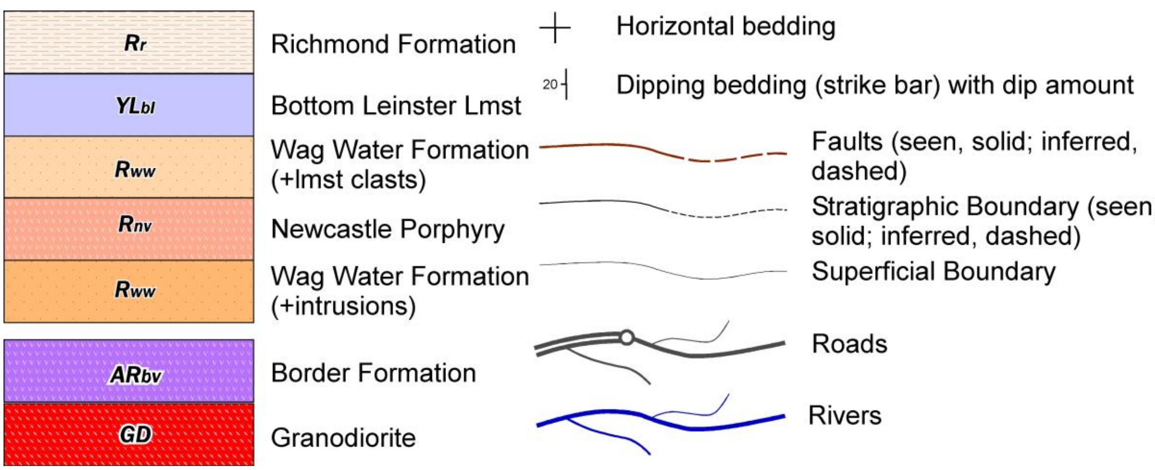

Figure 2. Key for lithologies and symbols used on the geological map in Figure 3.

directly on the Cretaceous to Paleocene rocks (equivalent to those of the Above Rocks Inlier) around the small Bottom Leinster Inlier. This paper describes the revised geology and gives details of the revised sedimentary succession of the area.

2. METHODOLOGY

The geology of the north-eastern part of the Clarendon Block, the southern North Coast Belt and the western margin of the Wag Water Belt (**Figure 1**) were mapped as part of this research. Mapping of the Cretaceous inliers was largely undertaken using field sheets with the Jamaican Survey 1:12,500 scale topographic maps as base. Mapping of intervening areas was undertaken using a handheld Garmin GPS unit with data being recorded in a field notebook and subsequently plotted to produce a geological map. Field data collected included geographic features (e.g., road and path courses, junctions, river bridges, etc.) and geological data (rock lithologies, bedding orientations, fossils, etc.). Rock samples were collected for further analysis in the laboratory and have field numbers preceded by the letters WL. Rock samples were cut with a slab saw and polished

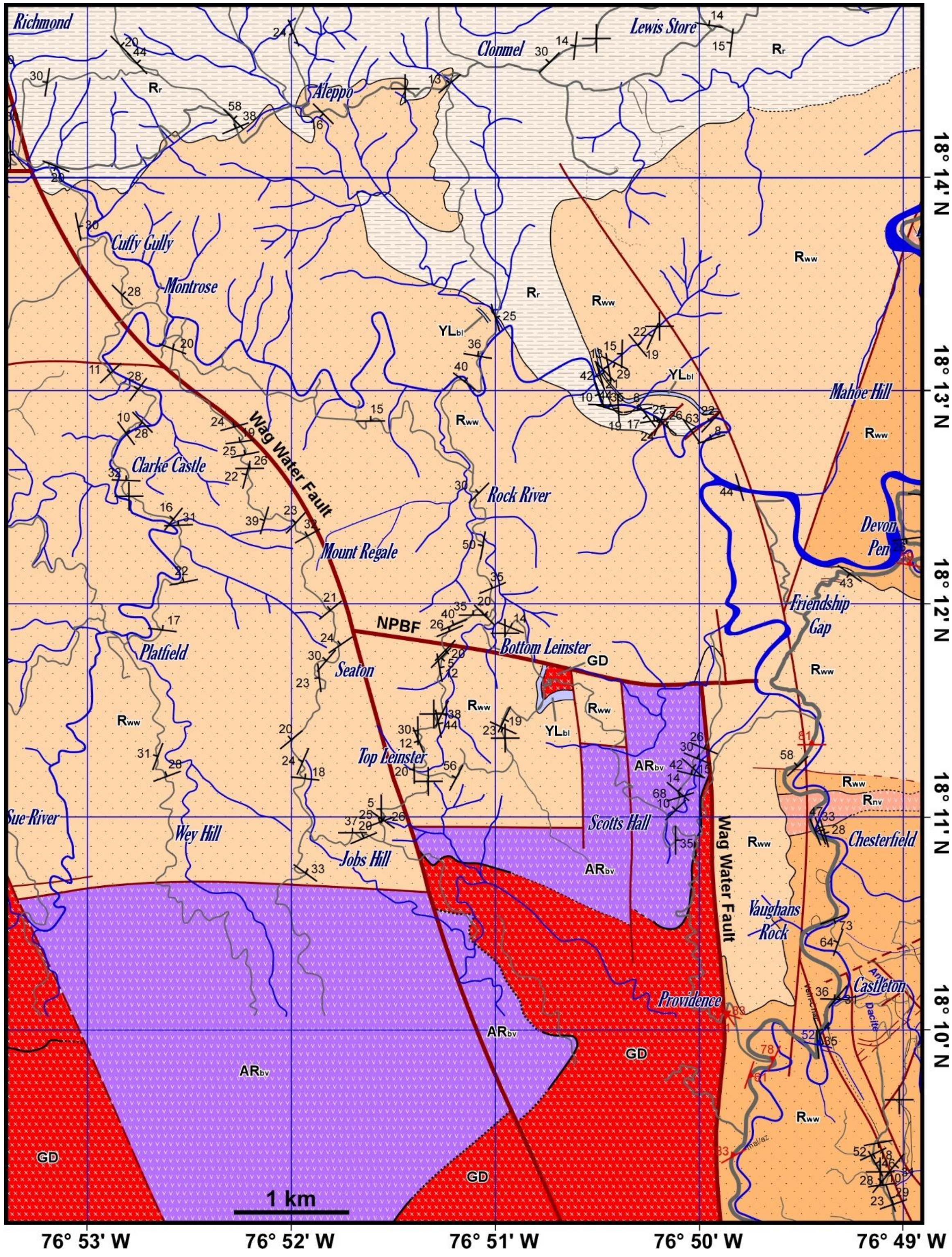

Figure 3. Geological map of the area around Bottom Leinster derived from geological mapping. The small Bottom Leinster Inlier is situated just to the north of the Above Rocks Inlier (SW corner of map). See Figure 2 for key. Richmond is shown in the NW corner, Devon Pen in the middle of the eastern side of the map, and Castleton toward the SE corner. NPBF, Northern Platform Boundary Fault. GPS grid established through geological mapping with a hand-held GPS.

to show sedimentary and igneous textures. Selected samples were then cut into thin sections (30 µm thick) for petrographic and biostratigraphic analysis. Photomicrographs were produced using a digital camera mounted on a trinocular Prior Petrographic Microscope. The terms 'block' and 'belt' are used for current tectonic features (e.g., Clarendon Block and Wag Water Belt) and the terms 'platform' and 'trough' are used for original deposition systems (e.g., Clarendon Platform and Wag Water Trough).

3. RESULTS

A geological map and key for the study area are presented in **Figures 2-3**. The map shows the different lithologies present as well as the boundary (Northern Platform Boundary (NPBF) and Wag Water faults) between the Clarendon Block and the Wag Water Belt. The various physiographic and lithostratigraphic units are described below and age relationships are shown in **Figure 4**.

3.1. Above Rocks Inlier

The Above Rocks Inlier is a large inlier on the eastern margin of the Clarendon Block and has previously been described by **Matley** (**1951**), **Chubb** (in **Zans et al., 1963**), **Reed** (**1966**) and **Mitchell** (**2015, 2020**). The inlier consists of a series of lava flows associated with volcaniclastic sediments (sandstones and conglomerates) and cut by a series of dykes to which the names Border Volcanics and Mount Charles Formation have been given (**Green, 1972**; **Henry and McFarlane, 1978**). These 'volcanic' rocks are not differentiated on **Figure 3** where they are mapped as the Border Formation. The Border Formation has been intruded by granodiorite stocks which have been dated to the Campanian and earliest Paleocene (**Chubb and Burke, 1963**; **Harland et al., 1964**; **Hastie, 2007**; **Mitchell, 2020**).

3.2. Bottom Leinster Inlier

This very small inlier is poorly exposed in the vicinity of Bottom Leinster (**Figure 3**). There are a few outcrops of granodiorite below the Eocene rocks. The Bottom Leinster Inlier represents an extension of the rocks found in the Above Rocks Inlier, and is interpreted to be part of the northern margin of the Clarendon Block which is separated from the Wag Water Belt by the Northern Platform Boundary Fault (NPBF) (**Figure 3**).

3.3. Wag Water Formation

The name 'Wagwater Group' was introduced by **Matley** (**1940**, p. 100) for what had previously been designated "the Purple Conglomerate Group" (**Matley, 1929**). The name was corrected to Wag Water Formation by **Matley** (**1951**) to conform to the accepted geographical names for the hill, community and district as shown on topographic maps, and this correction is used here. **Matley** (**1951**, p. 31) stated that the group was 1,500 ft. (= 460 m) thick and consisted of "coarse conglomerates, sandstones and red marls."

Mann and Burke (**1990**) divided the Wag Water Formation into a series of members, which in the northern part of the Wag Water Belt included the Ginger River (conglomerates), Pencar River (sandstones and shales) and Dry River (conglomerates) members. Thin limestones within the Ginger River Member have yielded the LBF *Ranikothalia catenula* from the road west of Wiltshire (below Irish Town) from the southern part of the Wag Water Belt, which would indicate a late Paleocene age (**Ramsook and Robinson, 2009**). Limestones in the Ginger River Member further to the north have not, as of yet, yielded LBFs. No biostratigraphically significant samples have been collected from the Pencar River member in the northern part of the Wag Water Belt. However, around Catherine's Peak in the southern part of the Wag Water Belt shales attributed to the Pencar River Member have yielded a latest Paleocene to earliest Eocene calcareous nannoflora (**Jiang and Robinson, 1987**). The Pencar River Member, however, is not necessarily a unit that can be mapped across the Wag Water Belt. I have mapped repeated units of shale and sandstone alternating with conglomerates, and it would appear that these units of shales and sandstones inter-finger with the conglomerates. It may, therefore, be that mapping distinct Ginger River, Pencar River and Dry River members is less useful that mapping different lithological units. Many of the shale-sandstone units contain thin beds of limestone, but the faunas of these, if useful, have yet to be studied. The conglomerates (Wag Water Formation) are widely developed in the northern part of the Wag Water Belt (**Figure 3**). At Devon's Pen a loose block (E. Robinson, pers. comm.) of calcareous conglomerate yielded a LBF association with *Tremastegina*, but lacking *Eoconuloides*/*Helicostegina* (**Jiang and Robinson, 1987**), which would indicate a mid Ypresian age. This is directly equivalent to LBF assemblages from the Richmond Formation (Roadside Member of **Mann and Burke, 1990**, see below) in the northern part of the Wag Water Belt

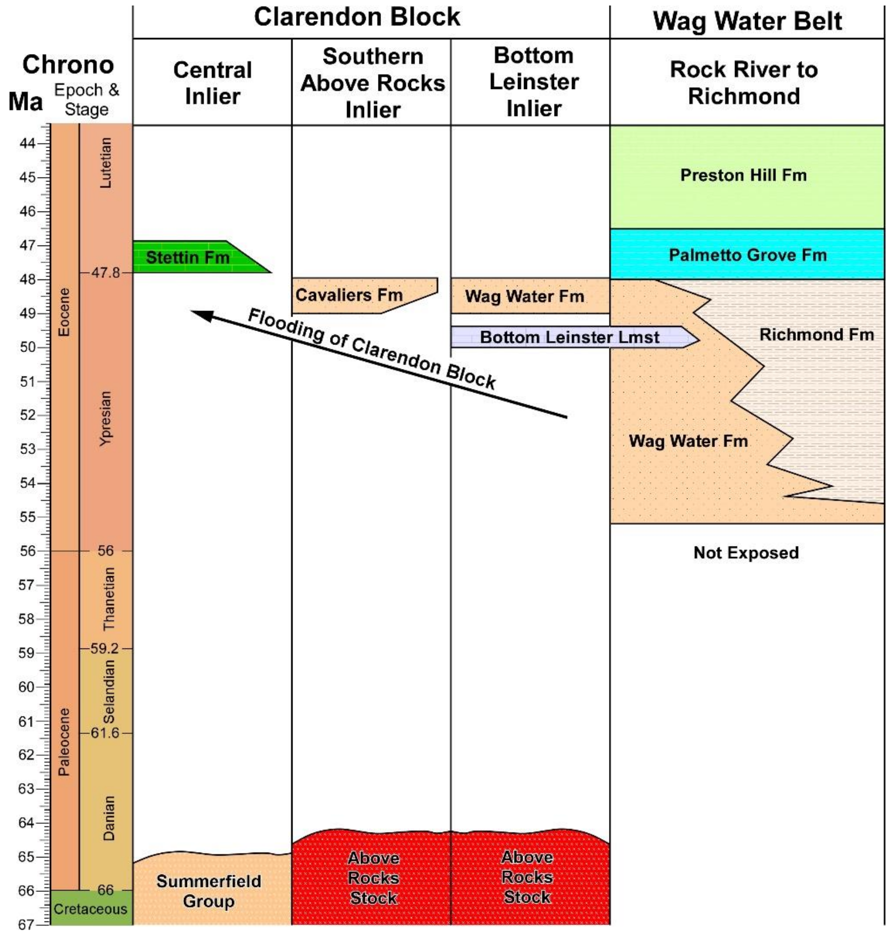

Figure 4. Correlation of rocks discussed in this paper from the Clarendon Block and Wag Water Belt.

that have also yielded at NP12 calcareous nannoflora (**Jiang and Robinson, 1987**). In fact, in the Flint River below the community of Rock River the conglomerates of the Wag Water Formation can be seen to interfinger with shales of the Richmond Formation. It therefore seems likely that the conglomerates of the 'Dry River Member' in this area are a lateral facies variation of the shales and sandstones of the 'Roadside Member' of the Richmond Formation. At the present time it seems appropriate to map conglomerate-dominated facies as Wag Water Formation, with local inter-beds of limestone and shale/sandstone, and shale/sandstone-dominated facies as Richmond Formation (**Figure 3**).

The rocks included in the Wag Water Formation here include a series of predominately conglomerates with minor sandstones that were deposited in the Wag Water Trough and also on the margin of the Clarendon Platform (**Figure 4**). The various facies will be described briefly here.

In the area around Castleton and in the beds and banks of the Wag Water River, the Wag Water Formation consists of a series of indurated, bedded, pebble to cobble conglomerates that lack limestone clasts. These conglomerates have been intruded by a series of small stocks and dykes. This represents the older part of the Wag Water Formation, but is not separated formally as a distinct unit at the present time (although it is shown in a different colour on **Figure 3**).

To the north, these conglomerates are overlain? by a series of pebble and cobble conglomerates that contain frequent pebbles and cobbles of Cretaceous (both grey and recrystallized) limestone that renders them distinctive when compared with the indurated conglomerates at Castleton. However, in places where limestone clasts are rare, it is difficult to separate these conglomerates from the underlying conglomerates, particularly in areas where stocks and dykes are not present. It may, however, in the future be possible to separate these as distinct units (for the present time they are shown in different colours on the map in **Figure 3** where they can be

Figure 5. Rocks of the Wag Water Formation. 5A, steeply dipping conglomerate beds of the talus facies, road east of Rock River (GPS: 18° 12.4' N, 076° 51.7' W). 5B, detail showing poorly sorted very angular clasts, Flint River north of Rock River (GPS: 18° 13.1' N, 076° 51.2' W). 5C, inter-fingering of Richmond Formation and Wag Water Formation, Flint River, north of Rock River (GPS: 18° 13.4' N, 076° 51.0' W), hammer (arrowed) is on boundary between conglomerate bed and shale bed. 5D, fluviatile sandstones and minor conglomerates, west of Bottom Leinster (GPS: 18° 11.6' N, 076° 51.3' W).

distinguished). To the north of the Northern Platform Boundary Fault (of **Mitchell 2013b**), these conglomerates are immature containing angular and sub-angular pebbles, cobbles and boulders, and the beds dip at relatively steep angles to the north (**Figure 5A-B**). These are interpreted as submarine debris fans associated with the steep slopes on the margin of the Wag Water Trough. These are particularly well developed in road cuts around Rock River and also in the roadway/trail that extends from Rock River down to the Flint River (**Figure 5C**). Clast types are dominated by Cretaceous igneous rocks (basaltic andesites and andesites) with a small component of limestone and very rare clasts of granodiorite.

To the south of the Northern Platform Boundary Fault (NPBF), the Wag Water Formation is again characterised by extensive conglomerates and locally by sandstones with pebble stringers (**Figure 5D**). The clasts are sub-rounded to well-rounded indicating significant transport in a fluvial system and contrasting with the more angular clasts in the debris fans to the north of the NPBF. A further distinction is that south of the NPBF the beds have low dips (rarely above 10 degrees) compared with the steeper dips to the north. These conglomerates are probably genetically related to the conglomerates of the Cavaliers Formation in the southern part of the Above Rocks Inlier (Cavaliers Conglomerate of **Green, 1972**). Lithologically, the conglomerates in the Wag Water Belt, within the North Coast Belt and on the eastern margin of the Clarendon Block are difficult to separate lithologically. They are all referred to the Wag Water Formation in this paper. The conclusions to be drawn are that the various conglomerates in the Wag Water Formation were deposited in different depositional environments. North of the NPBF the conglomerates consists of marine talus beds that were formed on a steep slope separating the Wag Water Trough from the Clarendon Platform. Rapid mass wasting resulted in the deposition of immature

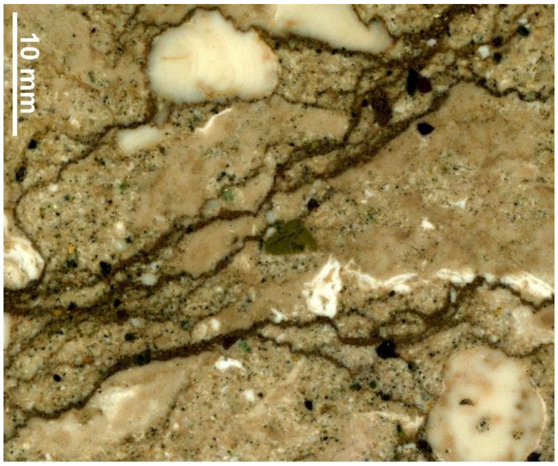

Figure 6. Scanned image showing the texture of the Bottom Leinster Limestone. Bioclastic limestone with calcite masses and red algae (Sample WL4091, GPS: 18° 11.7' N, 076° 50.7' W).

conglomerates in talus fans. In contrast, to the south of the NPBF conglomerates deposited in fluvial environments are preserved and either overlie the Bottom Leinster Limestone or Cretaceous/Paleocene rocks.

3.4. Bottom Leinster Limestone (new name)

Introduction. The name Bottom Leinster Limestone is introduced for a thin unit of grey limestone that is found overlying the Cretaceous/Paleocene rocks around the Bottom Leinster Inlier (around GPS: 18° 11.7' N, 076° 50.7' W). The same limestone can also be mapped in the Wag Water Belt to the north of the NPBF (**Figure 3**), where it is intercalated within the conglomerates of the Wag Water Formation (e.g., at GPS: 18° 13.4' N, 076° 51.1' W and GPS: 18° 12.9' N, 076° 51.3' W). The limestone therefore provides a time datum within the Wag Water Formation at these localities.

Description. The limestone consists of thickly bedded to unbedded grey limestone which may be micritic or contain clastic grains and bioclastic debris (**Figure 6**). Much of it is micritic, and bioclastic debris is found in only a few places. Stylolites are well-developed suggesting either relatively deep burial or pressure solution due to tectonic forces. In the bioclastic intervals small pebbles and sand grains are frequent. The bioclasts include red algae and LBFs. The LBF assemblage (**Figure 7**) contains *Tremastegina* cf. *lopeztrigoi* (Palmer), *Helicostegina gyralis* Barker and Grimsdale and *Eoconuloides wellsi* Cole and Bermüdez. This assemblages indicates a late Ypresian (Early Eocene) age (**Jiang and Robinson, 1987**).

Type Area. The type area for the formation is in and around the community of Bottom Leinster (around GPS: 18° 11.7' N, 076° 50.7' W). Occasional exposures show the limestone in situ, whereas loose blocks are common along roadways in this area.

Distribution. The limestone is found in a small area surrounding the community of Bottom Leinster where it overlies granodiorite and in turn is overlain by fluviatile conglomerates of the Wag Water Formation. Limestones are also found to the north of the NPBF where they are intercalated within the Wag Water Formation (at GPS: 18° 13.4' N, 076° 51.1' W and GPS: 18° 12.9' N, 076° 51.3' W). These limestones also contain a similar assemblage of LBFs and are also attributed to the Bottom Leinster Limestone here.

Remarks. The Bottom Leinster Limestone is the first unit that overlies the Cretaceous/Paleocene succession on the north-eastern margin of the Clarendon Block (**Figures 3-4**). The fact that the limestone can be traced as a tongue into the Wag Water Formation to the north of the NPBF (**Figure 3**) suggests that it formed at a time of low sediment supply, possibly due to the fact that the Clarendon Platform had been flooded by marine waters at this time.

3.5. Richmond Formation

The name Richmond Formation was introduced by **Hill** (**1899**) for the sandstone-shale sequences developed in the northern part of the Wag Water Belt. **Matley** (**1929**, p. 451) introduced the name Mount Hybla Group for similar rocks in the southern part of the Wag Water Belt that **Matley** (**1951**, p. 32) described as "… brown-weathering argillaceous shales, flags, beds of sandstone and some seams of conglomerate in which granodiorite and schist pebbles have been found." However, the name Richmond Formation has date priority and is used here.

The Richmond Formation consists of a series of clastic mudstones and shales which locally contain intervals of bedded sandstones (**Figure 8**) and minor conglomerates. **Mann and Burke** (**1990**) divided the Richmond Formation in the northern part of the Wag Water Belt into a series of members. Unpublished biostratigraphic studies, however, suggest that these members are not time equivalents and in this paper all the shale sequences in the northern part of the Wag Water Belt are referred to the Richmond Formation.

Limited biostratigraphic data indicate that conglomerates of the Wag Water Formation which

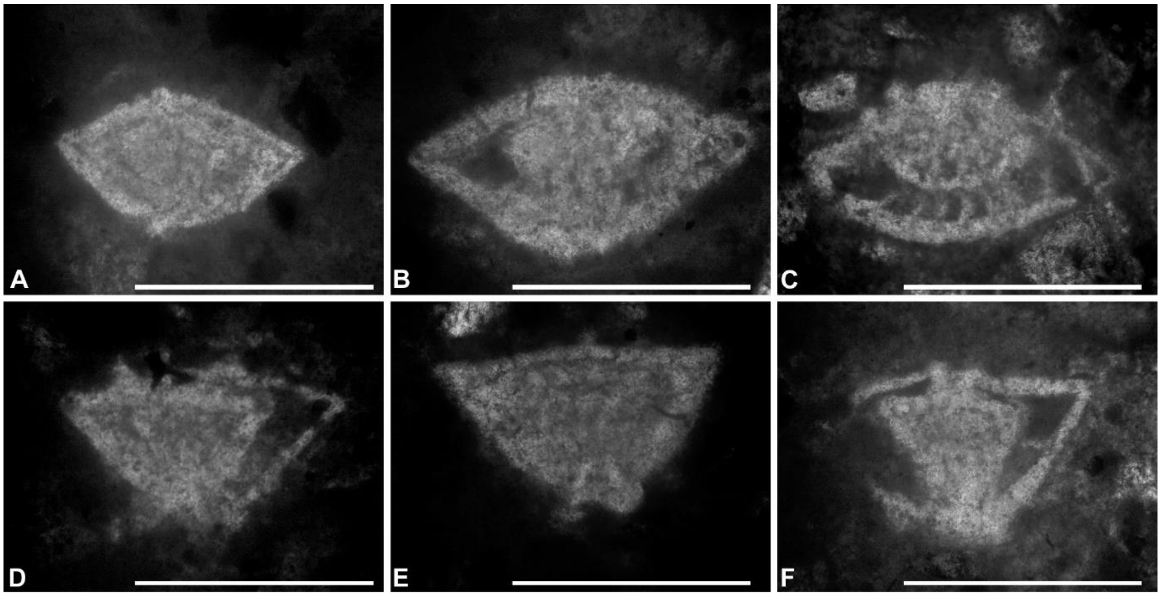

Figure 7. Off-centred axial sections of poorly preserved Larger Benthic Foraminifers (partly recrystallized) from the Bottom Leinster Limestone at Bottom Leinster. The specimens occur in a lime mudstone matrix. 7A-B, *Tremastegina* cf. *lopeztrigoi*. 7C, *Helicostegina gyralis*. 7D-F, *Eoconuloides wellsi*. All specimens from sample WL4090-1. Scale bar = 0.5 mm. GPS: 18° 11.7' N, 076° 50.7' W.

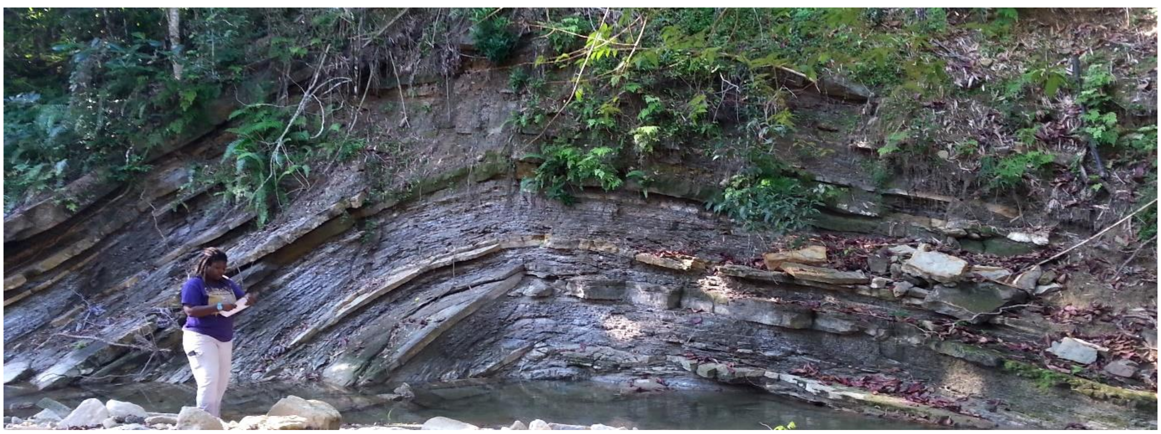

Figure 8. Typical exposure of the Richmond Formation showing shales interbedded with thin sandstones in the Orange River, north of Richmond (GPS: 18° 20.116' N; 076° 59.907' W). The sandstones contain a LBF assemblage including *Tremastegina lopeztrigoi* and *Eoconuloides wellsi* indicating they are equivalent to the Wag Water Formation/Bottom Leinster Limestone to the south.

contain limestone clasts (shown on **Figure 3**) are broadly age equivalent to the shales and sandstones of the Richmond Formation. Thus lower levels yield only *Tremastegina lopeztrigoi* (e.g., conglomerates at Devon's Pen (**Jiang and Robinson, 1987**) in the Wag Water Formation and sandstones in the lower Richmond Formation), whereas higher levels (Bottom Leinster Limestone and shales in the upper part of the Richmond Formation) yield *T. lopeztrigoi* in association with *Eoconuloides wellsi*. This suggests diachronous facies changes from basinal shales and sandstones to marginal conglomerates (talus fans) at this time (**Figure 4**).

4. Discussion

The Bottom Leinster Limestone is a useful datum locally and allows the dating of successions and records the first marine transgression onto the Clarendon Platform. In the Wag Water Belt, the Bottom Leinster Limestone is intercalated with rocks of the talus-fan facies of the Wag Water Formation, and these are the lateral equivalents of the Richmond Formation further to the north. The relationships can be seen to the north of Rock River, where conglomerates of the Wag Water Formation inter-finger with, and pass into, the rocks of the Richmond Formation (**Figures 3** and **5C**). On the eastern margin of the Clarendon Block, the Bottom Leinster Limestone represents the first transgression onto the granodiorite of the Bottom Leinster Inlier. It is subsequently overlain by fluviatile conglomerates of the Wag Water Formation that may be equivalent to the Cavaliers Formation in the southern part of the Above Rocks Inlier (**Figure 4**). The transgression that produced the Bottom Leinster Limestone either did not extend that far south, or the Bottom Leinster Limestone has been removed by erosion prior to the deposition of the Stettin Formation. The Stettin Formation (early middle Eocene) represents the first transgression onto the Clarendon Block around the northern parts of the Central Inlier (**Robinson, 1996**; **Mitchell, 2013a**; **Figure 4**). It is notable that the Cavaliers Formation and the fluviatile conglomerates north of the Above Rocks Inlier both are overlain by outliers of Troy Formation dolostones. This indicates that erosion, prior to the deposition of the Troy Formation, had removed any rocks of the Yellow Limestone that had been deposited on the Wag Water Formation (**Mitchell, 2013b, 2016**).

5. CONCLUSION

This paper has demonstrated the difficulties of mapping rocks across the different structural areas of Jamaica, because of: (1) similarities in rock lithologies; (2) the diachronous distribution of facies; and (3) difficulties in dating the sedimentary successions. It has been argued (**Mitchell, 2020**) that during the Cretaceous, Jamaica was the site of a significant transform fault that allowed the Caribbean Plate (including the Cuban arc and the eastern Jamaican terranes) to be translated to the north-east while the western Jamaican terranes remained as a part of Central America. Fault-releasing basins were generated in the Paleocene which led to the formation of the Wag Water Trough. It was only with the collision of Cuba with the North American Plate, most likely beginning in the mid early Eocene (judging from successions in Jamaica), that plate reorganisation led to a change in plate movement directions, and the accretion of western Jamaica and the Chortis Block onto the Caribbean Plate. The new tectonic regime resulted in a releasing bend that resulted in the formation of the Cayman Trough and the subsidence of Jamaica's North Coast Trough. Transgressions onto the Western-Jamaican Landmass began in the east with the deposition of the Bottom Leinster Limestone in the late Ypresian, and subsequently further west with the deposition of the Stettin Formation in the early Lutetian. This new data provides a better understanding of the changes that occurred in Jamaica during the Paleocene and early Eocene related to plate tectonic reconfigurations due to interactions between the Caribbean and North American plates.

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Author contributions. SFM: conceptualization, data collection, analysis, methodology, writing original draft, writing, review and editing.

Data availability statement. The samples collected during this study are stored in the UWI Geology Museum and access can be sought through the Museum's website (https://www.mona.uwi.edu/geoggeol/GeolMuseum/index.htm).

REFERENCES

Burke, K., Coates, A. G. and Robinson, E. 1969. Geology of the Benbow Inlier and surrounding areas, Jamaica. In **J. B. Saunders** (Ed.), *Transactions of the Fourth Caribbean Geological Conference 28th March – 12th April 1965 Port-of-Spain, Trinidad and Tobago*, 299-307, Caribbean Printers, Arima.

Chubb, L. J. and Burke, K. 1963. Age of the Jamaican granodiorite. *Geological Magazine*, **100**, 524-532.

Domning, D. P., Emry, R. J., Portell, R. W., Donovan, S. K. and Schindler, K. S. 1997. Oldest West Indian land mammal: rhinocerotoid ungulate from the Eocene of Jamaica. *Journal of Vertebrate Paleontology*, **17**, 638-641.

Eva, A. and McFarlane, N. 1985. Tertiary to early Quaternary carbonate facies relationships in Jamaica. *Transactions of the Fourth Latin American Geological Congress Trinidad and Tobago 7th – 15th July, 1979*, 210-219.

Graham, A. 1977. New Records of *Pelliceria* (Theaceae/Pelliceriaceae) in the Tertiary of the Caribbean. *Biotropica*, **9**, 48-52.

Graham, A. 1993. Contribution toward a Tertiary palynostratigraphy for Jamaica: the status of Tertiary paleobotanical studies in northern Latin America and preliminary analysis of Guys Hill Member (Chapelton Formation, middle Eocene) of Jamaica. In **R. Wright and E. Robinson** (eds.), *Biostratigraphy of Jamaica, GSA Memoir* **182**, 443-461, Boulder, Colarado.

Green, G. W. (Compiler) 1972. *Geological Sheet 22. Above Rocks. 1:50,000 Jamaica*. Geological Survey Division, Kingston, Jamaica.

Harland, W. B., Smith, A. G. and Wilcock, A. (eds.). 1964. *The Phanerozoic Time-scale*. *Geological Society Special Publication* **1**, vii + 458 pp.

Hastie, A. R. 2007. *The tectonomagmatic evolution of the Caribbean plate: insights from igneous rocks of*

Jamaica. PhD. Thesis, University of Cardiff, pp. i-xx, 1-358, A1-A204.

Henry, L. A. and McFarlane, N. (Compiler) 1978. *Geological Sheet 21. Port Maria. 1:50,000* Jamaica. Geological Survey Division, Kingston, Jamaica.

Hill, R. T. 1899. The geology and physical geography of Jamaica: a study of a type of Antillean development. *Bulletin of the Museum of Comparative Zoology at Harvard College in Cambridge*, **34**, 256 pp.

Jiang, M.-J. and Robinson, E. 1987. Calcareous nannofossils and larger foraminifera in Jamaican rocks of Cretaceous to early Eocene age. In **R. Ahmad** (Ed.), *Proceedings of a workshop on the status of Jamaican geology,* 24-51, Geological Society of Jamaica, Signart Printing House, Kingston, Jamaica.

Mann, P. and Burke, K. 1990. Transverse intra-arc rifting: Palaeogene Wagwater Belt, Jamaica. *Marine and Petroleum Geology*, **7**, 410-427.

Matley, C. A. 1929. Short sketch of the geology of Jamaica. In: *Jamaica in 1928*, pp. 167-169.

Matley, C. A. 1940. The geology of the Kingston district, Jamaica. *Abstracts of the Proceedings of the Geological Society of London*, No. **1373**, 99-106.

Matley, C. A. 1951. *Geology and physiography of the Kingston district, Jamaica.* Crown Agents of the Colonies, London, 139 pp.

McFarlane, N. (Compiler). 1977. *1:250,000 Jamaica. Geology.* Mines and Geology Division, Ministry of Mining and Natural Resources, Jamaica.

Mitchell, S. F. 2003. Sedimentology and tectonic evolution of the Cretaceous rocks of central Jamaica: relationships to the plate tectonic evolution of the Caribbean. In: **C. Bartolini, R. T. Buffler and J. F. Blickwede** (Eds.), *The Circum-Gulf of Mexico and the Caribbean: hydrocarbon habitats, basin formation, and plate tectonics. American Association of Petroleum Geologists Memoir*, **79**, 605-623, Tulsa, Arizona, USA.

Mitchell, S. F. 2004. Lithostratigraphy and palaeogeography of the White Limestone Group. In: **S. K. Donovan** (Ed.), *The mid-Cainozoic White Limestone Group of Jamaica. Cainozoic Research*, **3**, 5-29.

Mitchell, S. F. 2006. Timing and implications of Late Cretaceous tectonic and sedimentary events in Jamaica. *Geologica Acta*, **4**, 171-178.

Mitchell, S. F. 2013a. Lithostratigraphy of the Central Inlier, Jamaica. *Caribbean Journal of Earth Science*, **46**, 31-42.

Mitchell, S. F. 2013b. Stratigraphy of the White Limestone of Jamaica. *Bulletin de la Société Géologique de France*, **184**(1-2), 111-118.

Mitchell, S. F. 2015. *Geology of the parish of St Catherine (1:50,000 scale). Geological Map.* Department of Geography and Geology, The University of the West Indies, Mona, Kingston 7, Jamaica.

Mitchell, S. F. 2016. Geology of the western margin of the Benbow Inlier - implications for the relationship between the Yellow Limestone and White Limestone groups (with the description of the Litchfield Formation, new name). *Caribbean Journal of Earth Science*, **48**, 19-25.

Mitchell, S. F. 2020. Cretaceous geology and tectonic assembly of Jamaica. In **I. Davison, J.N.F. Hull and J. Pindell** (Eds.), *Geological Society of London, SP504 The basins, orogens and evolution of the southern Gulf of Mexico and northern Caribbean*, https://doi.org/10.1144/SP504-2019-210

Portell, R. W., Donovan, S. K. and Domning, D. P. 2001. Early Tertiary vertebrate fossils from Seven Rivers, parish of St James, and their biogeographical implications. In **C. A. Woods and F. E. Sergile** (Eds.), *Biogeography of the West Indies patterns and perspectives*, second edition, 191-200, CRC Press, Roca Baton/London/New York/Washington D. C.

Porter, A. R. D. 1998. Fossil wood in Jamaica. *Jamaican Journal*, **26**(3), 13-17.

Porter, A. R. D. and Robinson, E. 1974. Excursion 4. Kingston – Above Rocks – Rock River – Frankfield – Spaldings. In **R. M. Wright** (Ed.), *Field guide to selected Jamaican geological localities*, *Mines and Geology Division, Special Publication* No. **1**, 38-45, Kingston, Jamaica.

Pregill, G. K. 1999. Eocene lizard from Jamaica. *Herpetologica*, **55**, 157-161.

Ramsook, R. and Robinson, E. 2009. A new record of the Paleocene larger foraminifer *Ranikothalia catenula* in the Wagwater Formation of eastern *Jamaica. Caribbean Journal of Earth Science*, **40**, 21-23.

Reed, A. J. 1966. *Geology of the Bog Walk Quadrangle, Jamaica. Geological Survey of Jamaica, Bulletin*, no. **6**, 1-54. Kingston, Jamaica.

Robinson, E. 1996. Freemans Hall Beds and Stettin Member, Chapelton Formation, Jamaica: a revision of Geological Sheets 8, 9 and 12. *The Journal of the Geological Society of Jamaica*, **31**, 23-32.

Robinson, E. and Mitchell, S. F. 1999. Middle Eocene to Oligocene stratigraphy and palaeogeography in Jamaica: a window on the Nicaragua Rise. Prepared for the Fourth Annual Meeting of IGCP 393, 12-18 July, 1999. *Contributions to Geology UWI Mona*, **#4**, 1-47.

Wise, S. W. and Constans, R. E. 1976. Mid Eocene planktonic correlations: northern Italy–Jamaica, W. I. *Transactions of the Gulf Coast Association of Geological Societies 26th Annual Meeting Shreveport Louisiana October 13, 14, 15, 1978*, **26**, 144-155.

Zans, V. A., Chubb, L. J., Versey, H. R., Williams, J. B., Robinson, E. and Cooke, D. L. 1963. *Synopsis of the geology of Jamaica an explanation of the 1958 provisional geological map of Jamaica. Bulletin*, No. **4**, Geological Survey Department, Jamaica, 1-72, Government Printer, Duke Street, Kingston. [Dated on front cover and title page 1962, Printers imprint at bottom of front page is 1963.]

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