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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)

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ABSTRACT. A revised geological map for the western margin of the Benbow Inlier, Clarendon Block, Jamaica, centred on Middlesex is presented. This demonstrates that the Troy Formation (White Limestone Group) rests on an angular unconformity that progressively cuts out units in the Yellow Limestone Group (upper Yellow Limestone, Guys Hill Formation) and then cuts down into the Cretaceous succession exposed in the Benbow Inlier. This explains conflicting ages for the Yellow Limestone around Guys Hill (Early Eocene) and Yellow Limestone around the Central Inlier (middle Eocene). This also demonstrates that the units referred to as Guys Hill Formation in the Central Inlier and Guys Hill Formation in the Guys Hill area are not the same formation. The name Litchfield Formation is adopted for what has previously been called Guys Hill Formation in the Central Inlier. The Yellow Limestone and White Limestone groups of Jamaica have been interpreted to have formed during a time of tectonic quiescence, but this has to be questioned because of the presence of unconformities at the base of the Troy and Somerset formations, when active tectonism faulting, and emergence can be demonstrated. Cretaceous inliers in Jamaica (e.g., the Above Rocks and Green Bay inliers) might be interpreted as uplifted areas having lost their Yellow Limestone cover rather than as areas that were not transgressed by the Yellow Limestone sea. This work has implications for understanding the Eocene successions across the Nicaragua Rise which is currently being explored for hydrocarbons.

Keywords: Yellow Limestone Group, White Limestone Group, Jamaica, Eocene, Litchfield Formation.

1. INTRODUCTION

The Yellow Limestone and White Limestone were first separated by **Sawkins** (**1869**) when describing the succession in the parish of St Elizabeth (p. 212): *"Next in descending order comes a remarkably well characterized group of limestones, shales and marls* {i.e., the Yellow Limestone} *which underlie the white limestone and are evidently unconformable to it."* Elsewhere in the work the relationship between the units is only mentioned. Although much criticised (e.g., **Hill, 1899**; **Chubb, 1964**), Sawkins himself expressed his disappointment with his published memoir, stating (**Sawkins, 1870**): *"I am much displeased and disgusted at the manner in which my report on the island of Jamaica has been sent out by the Lord Com.s – they have rendered the text of the least value by omitting the sections and diagrams referred to. ... I could not superintend its publication and be here* [in British Guiana] *on duty at the same time. Consequently* [I] *do not hold myself responsible for the various errors I notice in it."*

Hill (**1899**, p. 9) recognised that the Bowden beds, which he attributed to the Miocene, had been confused with the Yellow Limestone of Eocene age. **Hill** (**1899**, p. 60) reported his Monteplier beds (Montpelier Formation) resting unconformably upon his Cambridge beds (Yellow Limestone) but on p. 65 states that the Cambridge beds grade up into the White Limestone. Other workers (e.g., **Hose and Versey, 1957**; **Robinson and Mitchell, 1999**) have considered that there was a gradation, or dolomitization front, that separated the Yellow Limestone and White Limestone, and that during the Eocene there was a progressive onlap of the Cretaceous land area, such that, in some places the Yellow Limestone rested on the Cretaceous whereas over higher land areas the Yellow Limestone was overstepped and the White Limestone lay on the Cretaceous.

Recent geological mapping has clearly identified an unconformable relationship between the Yellow Limestone and White Limestone groups in the area around Ipswich and Aberdeen in the parish of St Elizabeth. This brought to mind the problems with explaining the geology of the western margin of the Benbow Inlier when it was mapped in the early 2000s (**Brown and Mitchell, 2010**), where the

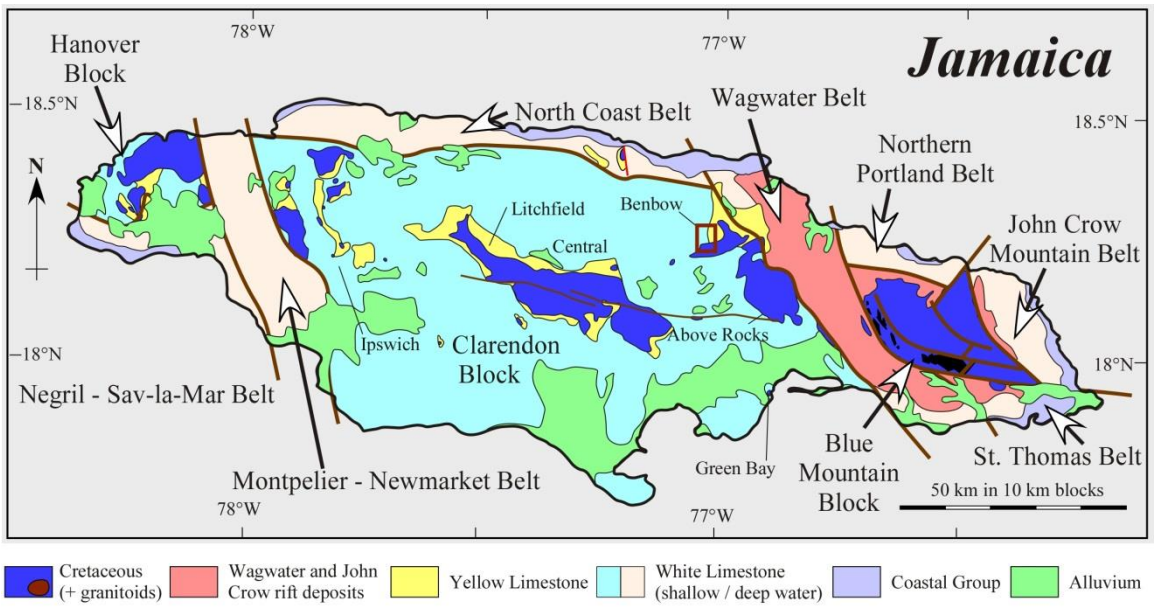

Figure 1. Simplified geology of Jamaica showing the locations of inliers mentioned in the text and the Ipswich area.

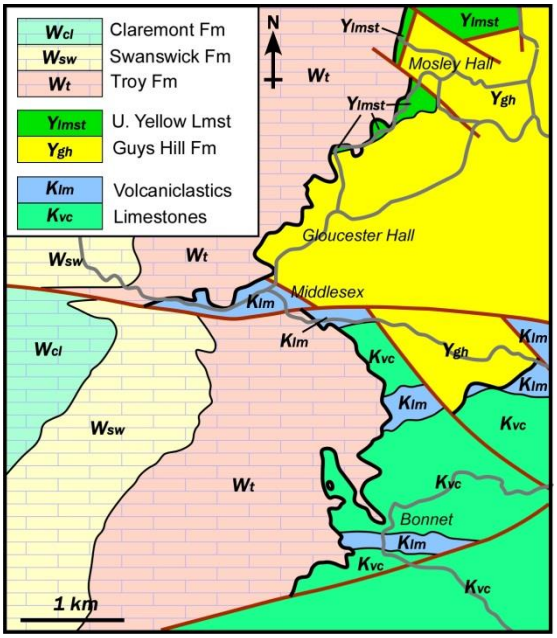

Figure 2. Geological map of area to the west of Benbow. Faults in red, stratigraphic boundaries as thin black lines, unconformity as a thick black line. Note that the unconformity at the base of the Troy Formation progressively cuts out section towards the south, resting on the upper Yellow Limestone at Mosley Hill, the Guys Hill Formation at Gloucester Hall and on the Cretaceous from Middlesex to Bonnet.

relationship is even more pronounced. This paper describes the results of five days spent remapping the western boundary of the Benbow Inlier and its implications for understanding the geological history of Jamaica during the Eocene.

2. LITHOSTRATIGRAPHY

The Benbow Inlier is situated on the eastern margin of the Clarendon Block (**Figure 1**). The geology of the area (**Figure 2**) includes formations within the Benbow Inlier (**Brown and Mitchell, 2010**; **Mitchell and Green, 2011**), the Yellow Limestone Group and the White Limestone Group (**Burke et al., 1969**). These units, as they relate to this paper, are briefly described herein.

2.1. Devils Racecourse Group

The Lower Cretaceous Devils Racecourse Group (**Burke et al., 1969**) was divided up into formations by **Brown and Mitchell** (**2010**). The group consists of alternating rudist-bearing limestones, volcaniclastic sediments and lava flows and ranges in age from Valanginian or Hauterivian to late Barremian or Aptian (**Hastie et al., 2009**; **Brown and Mitchell, 2010**; **Mitchell, 2015**). **Brown and Mitchell** (**2010**) named three limestone-dominated lithostratigraphic units within the group, the Jubilee (which included the Copper, Bonnet and Phillipsburg limestone members of **Chubb, 1971**, and **Burke et al., 1969**), Benbow and Burtons formations. The new map presented here suggests the presence of three limestone formations, with the upper equated to the Benbow Formation. This would suggest that **Brown and Mitchell**'s (**2010**) interpretation of the number of limestones within the Devils Racecourse Group may need

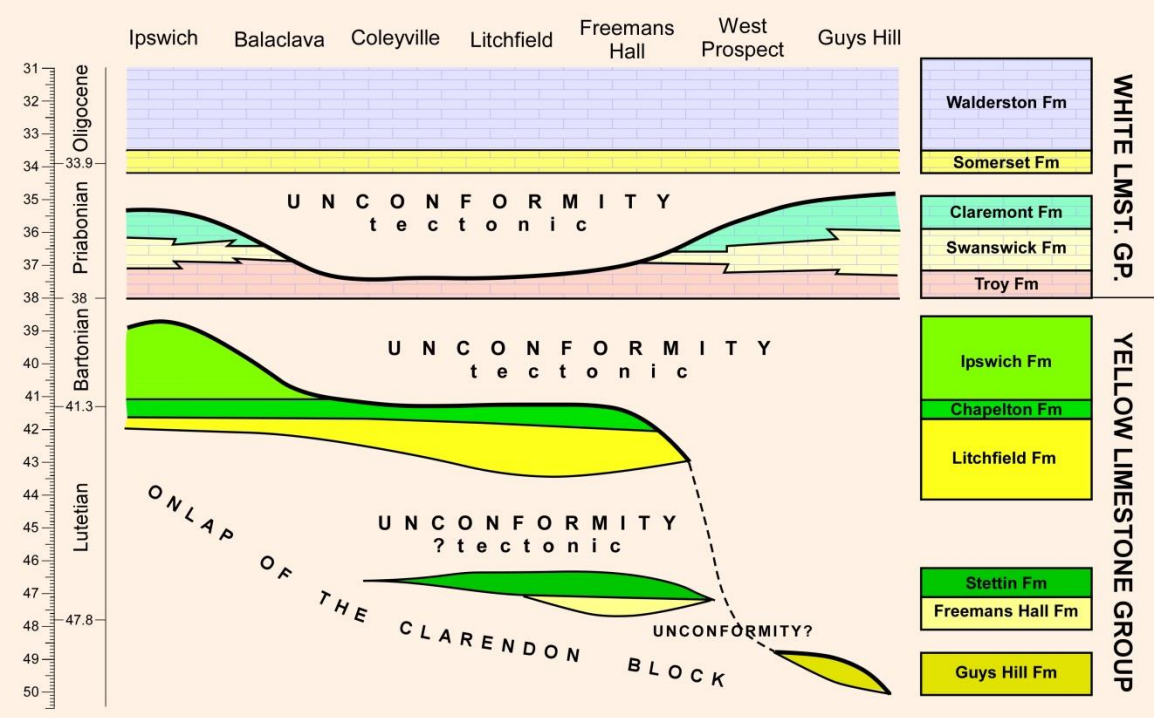

Figure 3. Relationships between formations of the Yellow Limestone and lower White Limestone groups across the Clarendon Block from SW (left) to NE (right).

modification. A resolution (stratigraphy or faulting) of this will only be possible once a detailed understanding of the palaeontology of each limestone has been undertaken. For the present I tentatively call the limestones, in ascending order: Bonnet Formation, Jubilee Formation and Benbow Formation. The limestones are separated by deeply weathered volcaniclastics, and only occasionally can primary sedimentary or igneous textures be recognised. The number of limestones within the Devils Racecourse Group is not important to the main point of this paper.

2.2. Yellow Limestone Group

The name 'Yellow Limestone' was introduced by **Sawkins** (**1869**) and has been equated (since the corrections to **Sawkins' 1869** memoir by **Hill, 1899**) with the Eocene impure limestones and clastics (claystones, siltstones, shales and sandstones) that underlie the White Limestone Group. The geology of the Yellow Limestone Group is probably best understood from the successions exposed around the margin of the Central Inlier (**Robinson and Mitchell, 1999**; **Maharaj and Mitchell, 2000**; **Mitchell, 2015**). In this area, a four-fold division is present (**Figure 3**), with the Freemans Hall Formation, Stettin Formation and Chapelton Formation named after localities around the Central Inlier (**Hill, 1899**; **Coates, 1969**; **Porter and Robinson, 1974**, **Robinson 1994, 1996**), and the Guys Hill Formation named from a locality at Guys Hill on the edge of the Benbow Inlier (**Burke et al., 1969**; **Coates, 1969**). The Stettin Formation yields a larger foraminiferal assemblage indicative of the earliest middle Eocene, whereas the 'Guys Hill' Formation of the Central Inlier and Chapelton Formation yield larger foraminiferal assemblages of the mid middle Eocene (**Figure 3**).

The Yellow Limestone succession to the north of the Benbow Inlier (Guys Hill area) consists of the Guys Hill Formation containing various limestone units (collectively called the Ham Walk Limestone Member) (**Burke et al., 1969**). At least some of these limestones, especially the ones within the Guys Hill Formation, contain the larger foraminiferan *Eoconuloides wellsi* Cole & Bermudez (**Burke et al., 1969**; **Jiang and Robinson, 1987**; **Robinson and Wright, 1993**; **Robinson and Mitchell, 1999**) that is a marker for late Early Eocene (**Robinson and Mitchell, 1999**; **Blanco-Bustamente et al., 1999**). Therefore the Guys Hill Formation of the type area (Guys Hill area around the Benbow Inlier) is of a different age from the clastics attributed to the Guys Hill Formation that crop out around the Central Inlier (**Figure 3**). This could be due to diachronous distribution or to the two units representing separate lithological units. The notable recurrence of Guys

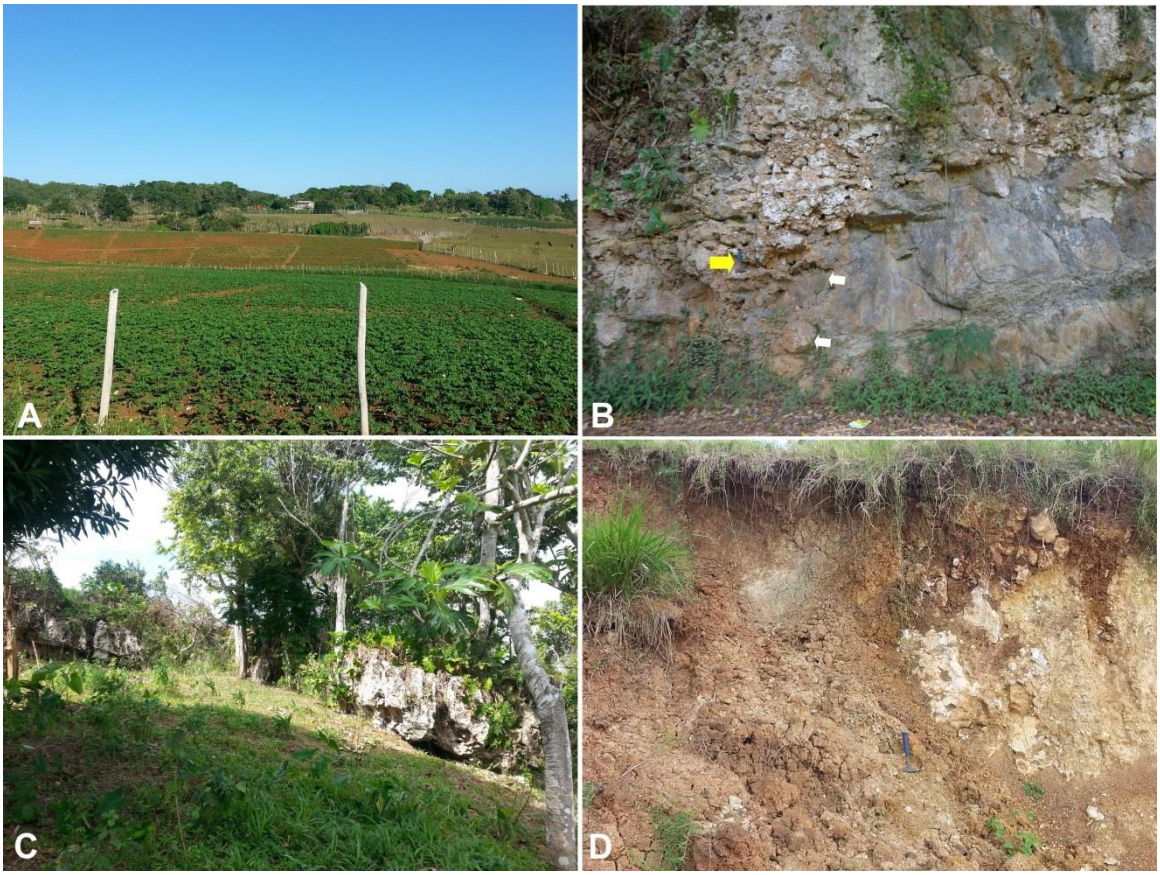

Figure 4. Field relationships on the western margin of the Benbow Inlier. A, Agriculture on the Guys Hill Formation (foreground) with the Troy Formation forming the forested karstic hills in the distance, north-west of Gloucester Hall. B, Unconformity showing the Troy Formation resting on the Benbow Formation, the base of the Troy Formation shows extensive dissolution and a palaeokarstic feature (small white arrows) is filled by Troy Formation indicating subaerial emergence prior to the deposition of the White Limestone (hammer [large yellow arrow] for scale), road section west of Middlesex. C, Troy Formation resting unconformably on volcaniclastics of the Devils Racecourse Group north of Bonnet. D, Fault between Guys Hill Formation (left) and Benbow Formation (right) exposed in a cut for a new house, Middlesex.

Hill type facies in the upper part of the Freemans Hall Formation (**Maharaj and Mitchell, 2000**), indicates that Guys Hill type facies do represent transgressive deposits of different ages across the Clarendon Block. Given the different succession around the Benbow and Central Inliers, it is clearly useful at the present time to distinguish between these units. As such, sedimentary rocks previously attributed to the Guys Hill Formation in the Central Inlier are herein renamed the Litchfield Formation (**Appendix 1**).

2.3. White Limestone Group

For some time it has worried me that the White Limestone Group rested on middle Eocene Yellow Limestone (containing early *Lepidocyclina*) around the margins of the Central Inlier, but rested on early Eocene Yellow Limestone (containing *E. wellsi*) on the northern margin of the Benbow Inlier. Previously I felt this might be explained by a diachronous change of facies or a dolomitization front. However, the new mapping demonstrates that an angular unconfromity is present at the base of the White Limestone Group.

The lithostratigraphy of the White Limestone Group has recently been described and illustrated by **Mitchell** (**2004**, **2013**, **2015**). In the area to the west of Benbow a full White Limestone sequence is present, including the Troy, Swanswick, Claremont, Somerset and Walderston formations. For details of these formations, readers are referred to **Mitchell** (**2013**) where full descriptions are provided.

The age of the base of the White Limestone Group has generally been attributed to the mid middle Eocene (e.g., **Robinson and Mitchell, 1999**). **Robinson and Wright** (**1993**) recorded *Eulepidina chaperi* (Lemoine and R. Douville) from the Swanswick Formation, and this is a marker for

the late Eocene (e.g., **Robinson, 2004**). Edward Robinson (pers. commun. 2015) has confirmed the presence of *E. chaperi* and *Heterstegina ocalana* Cushman in the Swanswick Formation at its type locality at Swanswick House in northern Trelawny. Older, pre-White Limestone units include the lower part of the Swanswick Formation (see **Robinson and Mitchell, 1999**), the Ipswich Limestone (**Versey, 1957**), and the Healthy Hill Formation (**Mitchell, 2013**). These all yield middle Eocene foraminifers and demonstrably lie below the Troy Formation. These three units, together with the Guys Hill, Freemans Hall, Stettin, Lorrimers and Chapelton formations, are placed within the Yellow Limestone Group here as they onlap the deformed Cretaceous rocks of the Clarendon Block (**Mitchell, 2003**, **2006**) and underlie the lowest unit (Troy Formation) of the White Limestone Group.

3. GEOLOGICAL INTERPRETATION OF THE WESTERN MARGIN OF THE BENBOW INLIER

The Cretaceous rocks have a generally east-west strike, and dip at a moderate to steep angle towards the north (**Figure 2**). To the north, the Cretaceous succession is offset by a left-lateral east-west fault, and further to the north the Cretaceous outcrop is terminated by a WNW-ESE trending fault. To the north of this fault, the Guys Hill Formation crops out and forms low undulating pastoral lands, with scattered dolines, that are farmed for Irish potatoes. The dolines are not associated with limestone outcrops, and are probably collapse dolines related to a thin limestone that is not seen at outcrop due to faulting.

To the north-west, a more persistent limestone (a rubbly yellow-brown nodular limestone) appears above the Guys Hill Formation. Despite the collection of numerous samples, this limestone has yet to yield diagnostic foraminfers other than *Fallotella*, and is referred to here as 'upper limestone' (U. Yellow Lmst in **Figure 2**). It could be equivalent to the Stettin Formation, but it is quite distinct lithological.

The White Limestone forms a marked change in topography and land use. The weathered volcanicalstics of the Cretaceous and the clastics of the Yellow Limestone (and to some extent the upper Yellow Limestone) are used for extensive agriculture, but this stops at, or close to, the boundary with the White Limestone Group where extensive forest begins (**Figure 4A**). This boundary maps out as an angular unconformity, resting on the Cretaceous in the south and the middle Eocene in the north (**Figure 4A-C**). Where the unconformity rests on Cretaceous limestones (**Figure 4B**), palaeokarstic hollows are filled with dolostones of the Troy Formation indicating subaerial emergence prior to the deposition of the Troy Formation. The boundary between the Cretaceous (Benbow Formation) and the Yellow Limestone Formation (Guys Hill Formation) is represented by a fault (**Figure 4D**) that truncated by the unconformity at the base of the White Limestone. The unconformity itself is offset by two younger faults, one close to the southern area of the map and one that forms the deep valley to the west from Middlesex.

4. DISCUSSION AND IMPLICATIONS

In the simple geological model proposed for Jamaica by **Draper** (**1987**, **1998**), a four-fold history was suggested: (1) island arc phase (Cretaceous); (2) extensional phase (Paleocene to early Eocene); (3) quiescent phase (mid Eocene to mid Miocene); (4) Uplift phase (mid Miocene to present). The interval dealt with for our purposes is stage 3, the quiescent phase where Jamaica transforms from an active rift system into a series of carbonate platforms.

The geological mapping in the Benbow area indicates that the quiescent phase is not without tectonic deformation. If we compare the Yellow Limestone successions across Jamaica (Benbow-Guys Hill area, around the margins of the Central Inlier, and in the Ipswich area), we find that an angular unconformity progressive erodes the Yellow Limestone succession to eventually rest on the Cretaceous. At Middlesex the Yellow Limestone (Guys Hill Formation) and Cretaceous are separated by a fault that is unconformably overlain by the Troy Formation. This indicates tectonic activity between the deposition of the Yellow Limestone and White Limestone groups. Taken together with an unconformity at the base of the Somerset Formation (**Hose and Versey, 1957**; **Mitchell, 2004**, **2013**, **2015**), this indicates two intervals of tectonic activity during the mid-late Eocene in Jamaica.

In some areas of Jamaica (e.g., the Green Bay Inlier and the Above Rocks Inlier), the White Limestone rests directly upon the Cretaceous-Paleocene (arc rocks, metamorphics and granodiorites) (e.g., **Mitchell, 2015**) and has been interpreted to be due to onlap of the Troy Formation landward of the Yellow Limestone. Instead, now we could interpret these as areas of uplift where the Yellow Limestone succession has been removed prior to the deposition of the White Limestone. This situation may not just relate to Jamaica, but may extend to carbonate platforms across the Nicaraguan

Rise; and, if so, has significant implications for ongoing hydrocarbon exploration within the region.

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APPENDIX 1. DESCRIPTION OF LITCHFIELD FORMATION (YELLOW LIMESTONE GROUP), NEW NAME

LITCHFIELD FORMATION (NEW NAME)

History. Previously referred to as the Guys Hill Member (**Coates, 1969**) or Guys Hill Formation (**Robinson and Mitchell, 1999**), but of a different age. The unpublished name name Lorrimers Formation was used in an unpublished oil company report by **Kozary** (**1956**), but the community of Lorrimers does not lie on the outcrop of the Litchfield Formation and the name 'Lorrimers' is therefore inappropriate.

Description. The Litchfield Formation is the clastic middle division of the Yellow Limestone Group in the Central Inlier and consists predominantly of sandstones, heterolithics and mudstones, but fine-grained conglomerates and thin limestones are also present. The formation has a thickness of some 350 m in the north-western part of the Central Inlier, but thins towards the southeast.

Age. The Stettin Formation below yields an early middle Eocene foraminiferan assemblage. Limestones within the unit (Dump Member) yield an early middle Eocene foraminferan assemblage. The limestones above (Chapelton Formation) yield a mid middle Eocene foraminferan assemblage.

Distribution. Extensively developed around the margins of the Central Inlier, into western Inliers (Elderslie, Nottingham and Sunderland) and extending into the Newmarket-Montpelier Belt (Content Well #1).

Remarks. A detailed discussion of the Lorrimers Formation (as Guys Hill Formation) was given by **Maharaj and Mitchell** (**2000**) and should be consulted for further details. The Lorrimers Formation contains a single named member, the Dump Member (**Robinson, 1969**). The formation also contains black organic rich shales which are a potential source rock for hydrocarbons in the Walton Basin to the south of Jamaica (**Matchette-Downes and Mitchell, 2005**).

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