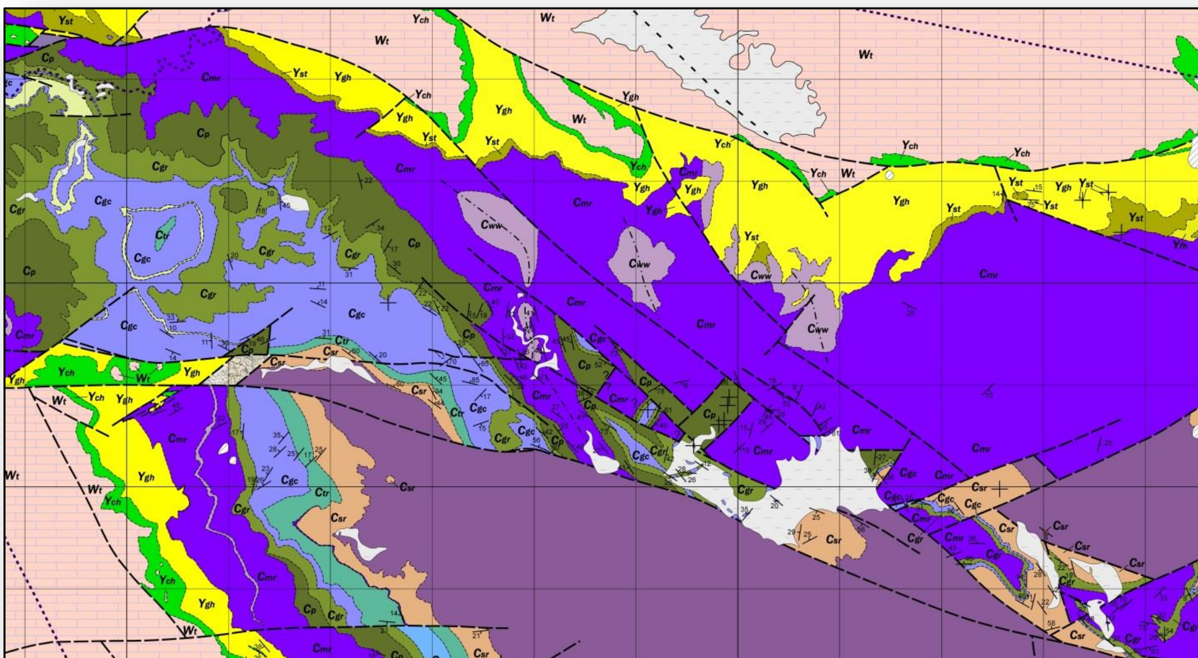
Geological Society of Jamaica
60th Anniversary Conference
Abstracts and Field Guides
23rd-28th November, 2015

Edited by Simon F. Mitchell and Sherene A. James-Williamson



United Nations Educational, Scientific and Cultural Organization

International Hydrological Programme

CAFE BLUE

Contributions to Geology UWI Mona #7 **ISSN 0799-0162**

Cite as: **Mitchell, S. F. and James-Williamson, S. A. 2015.** *Geological Society of Jamaica, 60th Anniversary Conference, Abstracts and Field Guides 23rd-28th November, 2015. UWI Contributions to Geology* **#7**, 1-30.

Cover. Portion of geological map: Geology of the Parish of Clarendon (1:50,000 Scale), UWI Geological Map Series (reproduced at 46% of original size).

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P01. Geology of the Green Bay Schist, Port Henderson Hill, St. Catherine Parish, Jamaica

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Apart from Westphalia Schist and Mt. Hibernia Schist in the Blue Mountain Inlier in eastern Jamaica, the only other occurrence of medium- to high-grade metamorphic rocks in Jamaica is in the small Green Bay Inlier, southwest of Kingston, ~30 km west of the Blue Mountain inlier. New geochemical data and thermodynamic calculations show that the hitherto poorly-studied Green Bay Schist relates very closely to Westphalia Schist. Trace element patterns are nearly the same for both rocks. The protoliths for both were basaltic, related to a subducted ocean-ridge. The geochemistry identifies both as C-MORB. Retrograde metamorphic conditions in the Green Bay Schist are ~7 kbars and ~500 °C, for equilibrium involving Hbl+Chl+Ksp+Pl+Qz+Cc+(CO_2-H_2O). While the protolith for blueschist/greenschist facies Mt. Hibernia Schist is also basaltic, the tectonic environment was very different. The original Mt. Hibernia basalt was extruded onto the mantle plume-related Caribbean platform (CLIP). Trace elements are consistent with P-MORB. Whereas the inferred pre-Cenozoic P-T histories for Green Bay Schist and Westphalia Schist are presumed to be similar, the Cenozoic P-T histories differ markedly. The difference reflects the location of each rock type with respect to the NW-trending, NE-dipping Wagwater fault. Westphalia Schist resides in the hanging wall; Green Bay Schist resides in the footwall. From Early Paleocene (~65 Ma) to Middle Eocene (~50 Ma) normal movement on the fault was in response to NE-SW extension. Deposition of redbeds of the Wagwater Group on the subsided hanging wall was accompanied by upper zeolite facies burial metamorphism (~250 °C). The redbeds are nonconformably overlain by Eocene (~50 Ma) to Miocene (~10 Ma) platform limestone. The Wagwater fault was inactive during this interval of limestone deposition (50-10 Ma). At Green Bay, the Wagwater Group is missing, such that platform limestone lies nonconformably, directly on Green Bay Schist. New $^{40}Ar/^{39}Ar$ age determinations for the Green Bay Schist imply that the hornblende cooled through ~500 °C at ~60 Ma and that the K-spar cooled through ~250 °C at ~58 Ma. Whole-rock $^{40}Ar/^{39}Ar$ ages are ~58 Ma, the same as the age for the K-spar. The data indicate a P-T-t path involving very rapid cooling in the Late Paleocene from a temperature exceeding ~500 °C. The Paleocene/Early Eocene P-T-t paths for Green Bay Schist and Westphalia Schist are complementary, but the maximum temperature in the Green Bay Schist (>500 °C) was greater than the maximum temperature in the Westphalia Schist (~250 °C). Both paths imply rapid heating in the Earliest Paleocene (65-61 Ma), during the initial stages of the deposition of the Wagwater Group, followed by rapid cooling in the Green Bay Schist and relatively slow cooling in the Westphalia Schist. Later, in the Middle Miocene (~10 Ma), the Wagwater fault was reactivated with reverse motion in response to NE-SW compression. Differential, ongoing regional uplift has exposed Green Bay Schist and Westphalia Schist at the present level of erosion.

P02. Beachrock facilitating erosion: Observations at the Palisadoes, Kingston, Jamaica

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Beachrocks have been reported at the Palisadoes since the 1940s, and have been recognized as a pervasive feature on the windward coast of the spit, but the effects on wave morphodynamics and coastal erosion have not been assessed. Spatial analysis of aerial photographs of 1941 and 1991were used to characterize dominant net coastal processes. These were then correlated to the presence of beachrock. Observation of wave morphodynamics and the relationship with sediment behaviour was evaluated to create a model for the effect of beachrock on the coastal zone in particular with respect to erosion following ideas proposed by Jackson and Cooper (2009). More beachrocks, with a total length of 6.8 km, were associated with sections of the coastline experiencing dominant net erosion. Considerably less beachrocks, at total length of 0.87 km, were associated with sections of the coastline experiencing buildout. And an even smaller amount, less than 0.5 km are associated with sections of the coastline identified as stable. Beachrock reduces infiltration and increases backwash when buried in the foreshore, and when exposed, in addition to reducing infiltration and increasing backwash effects, it facilitates across-shore sediment transport behind beachrock and seaward sediment transport through shore-perpendicular channels. Beachrocks also lock up beach sediment resulting in a loss to the longshore drift sediment budget. Overtime these result in increased net erosion and dramatically modified beach profiles that can prevent or delay the ability of beaches to re-equilibrate.

P03. Utilization of Remote Sensing and GIS in a multistorey building seismic vulnerability assessment for the Liguanea Plain, Kingston and St. Andrew.

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Jamaica is located in a tectonically active belt within the Greater Antilles, West Indies. As such buildings and other infrastructure are vulnerable to earthquake effects. Multistorey building seismic vulnerability assessment can be used as a tool for earthquake hazard mitigation. This type of assessment takes into account the site characteristics and building information. GIS and remote sensing can also be used as a tool to identify building period characteristics which is then used to classify buildings. This study demonstrates the utilization of a remote sensing technique known as Object Based Image Analysis (OBIA). This technique is used to extract building information such as shape, shadow and location from very high resolution (0.3 m) satellite imagery. This is obtained in vector format which allows for easy integration of data set with GIS. An analysis of the buildings shadow was used to obtain the building height which is inputted in GIS and building five stories or taller were extracted for further analysis. Various building parameter such as building height/deformation, adjacency and building shape characteristics as outlined by several major

seismic assessment methods were examined and ranked (ordinal) in GIS. These building parameters were then used along with the site conditions to develop a building seismic vulnerability model for the Liguanea Plain. The model indicated that several mulitstorey buildings are highly vulnerable to seismic effects. These buildings are located near the Kingston Waterfront and New Kingston areas. This data can be used in conjunction with detailed structural assessment and seismic microzonation techniques for a more comprehensive assessment.

P04. Rock fall protection screens and its application for Jamaica's roadways

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The incidence of rock falls and rock slides on cliff faces and steep slopes on Jamaica's roads has been a major concern for the motoring public and other users of the road, particularly through main thoroughfares crossing the hinterland of Jamaica's countryside. Currently, no special provision has been made to provide security on these roadways due to rock fall hazards. Under the Carib Risk Cluster Project, a partnership agreement has been forged between the General Council of Martinique and the Jamaican Government to establish technical co-operation between both countries through the transfer of technology. Under this agreement, a feasibility study was conducted on two vulnerable sites; the Bog Walk Gorge, St Catherine and Gordon Town, St Andrew to determine the type of rock fall protection techniques that would be required to mitigate the effects of rock falls and slides and to prepare a financial budget for implementation of the project. The main aim of the project is to transfer the rock fall protection technology using the experience in Martinique to provide training to public technical agencies in Jamaica as well as to develop private/private partnership between technical experts from the Martinique Company CAN and interested Jamaican companies. The Office of Disaster Preparedness and Emergency Management acted as the focal point on behalf of the Jamaican Government and supported by the Mines and Geology Division, which provided technical support. The feasibility study at the Bog walk Gorge and Gordon Town included site surveys, monitoring, defining priorities and risks as part of the rock fall protection methodology. The pilot study has established the basis for a technical and organizational response to prevent and treat rock falls on selected sites in Jamaica.

P05. Development of an engineering geology map for Jacks Hill and surrounding areas – St Andrew

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The Jacks' Hill area is a sensitive and complex geological environment susceptible to geological and geotechnical hazards. These hazards are caused by the combined effects of geological faults, weak rocks, steep slopes, landslides and numerous incised gullies. In recent past, high-value residential structures have been damaged or destroyed by slope/ground failures, debris flows, debris floods and excessive erosion, while damage to road infrastructure and public utilities have incurred additional cost from the National Budget to rehabilitate roads in the area. The construction of high density developments has posed serious challenges for the area, as zoning is currently the main requirement for controlling development in Jacks Hill and surrounding localities. Planners, developers and engineers do not have the required geotechnical/geo-hazard information that will aid in the planning and design of development and this has created geo-hazard and environmental problems. The main purpose is to develop a zoning map that characterizes the study area into geotechnical groups, which will assist planners in making informed decisions in the approval of developments as well as informing engineers and their clients on the geotechnical issues that are unique or characteristic of their development sites. The methodology used is based on current conventional techniques for developing engineering geology maps worldwide. It consists of four main themes; a slope map, landslide susceptibility map, geotechnical unit map and erosion map. The map provides very useful information for the planning and design of engineering and construction projects in the study area.

P06. Geoconservation in Jamaica: a proposal towards the protection and designation of geological sites.

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Preservation and designation of sites or localities of geological significance in Jamaica are important for meeting the needs of the Jamaican population as it relates to sustainable development and sustainable use of resources, educational, scientific, cultural, aesthetic and economic needs. This intersects with the basic tenets of the Jamaica Vision 2030 (PIOJ, 2009) as well as the UN Millennium Development Goals. The concept of natural sites is provided for in both the Natural Resource Conservation Authority (NRCA Act 1991) and Jamaica National Heritage Trust (JNHT Act 1985). The NRCA Act (1991) provides for the protection and designation of sites of scientific interest. NEPA along with the JNHT can designate sites that are scientifically significant, this is addressed specifically in section 5 of the NRCA Act (1991). The JNHT has direct responsibility through the JNHT Act (1985) to declare and protect sites which are deemed as important or significant for national heritage. There are such sites that have geological significance which are suited by the criteria; however, none have been so designated by the JNHT or NEPA. Geological sites and by extension sites of special scientific interest, termed "natural heritage" by UNESCO are provided for under the UNESCO Convention Concerning the Protection of the World Cultural and Natural Heritage. The definition of the cultural and natural heritage is given in Article 2 of the convention. Jamaica is signatory to this convention and as such is bound by it and should seek to ratify these particular sections under the JNHT. There has never been a designation or declaration based on any geoscientific criteria despite the rich geoscientific heritage, relevant Acts and regulations within the Jamaican law and international conventions. This is largely due to the absence of criteria for such designations in Jamaica. This paper represents the first formal proposal for the classification for defining such sites and how they should be categorized for designation. To this end this paper seeks to define a set of criteria for designation of localities with geoscientific significance using the concept of SSSIs and RIGS as a basis for declaration and preservation and eventual use for geoheritage, geoconservation and geodiversity.

P07. Geoarchaeology of Colbeck Castle, St. Catherine, Jamaica

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Colbeck Castle is a three-storey bungalow constructed in the 1680s in Palladio style architecture. It is constructed of limestone and red brick held together by lime mortar. Colbeck Castle lends itself to geoarchaeological study simply because after 300 years, other than ordinary wear and tear and anthropogenic impacts the structure and its surrounding buildings remain standing with all its walls intact. This is thought to be quite remarkable with Jamaica being located in an earthquake zone and has been affected by 4 major earthquakes.

The Castle itself offers some intrigue in that for an old building there are still many unanswered questions and not much research being done. Investigations at Colbeck includes a study of the mortar and building stone of the bungalow and the four other buildings on the property, an aerial survey using an unmanned aerial vehicle (UAV) and subsurface study using ground penetration radar (GPR).

This paper provides modern techniques for the study of a historic structure as a basis for conservation, disaster mitigation and historic restoration.

P08. Ridge Karst and Tower Karst in Southern St. Elizabeth, Jamaica: Form, Process and Geological Controls

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This paper examines an area of tower karst and ridge karst in southern St. Elizabeth between Bull Savanna and Duff House. Elongate towers occur on the slopes to the west and north of Alligator Pond and around Bull Savannah, with an east-west asymmetry, where the west-facing slopes of the towers are steeper than the slopes on the eastern side. These tower-like hills were described by Pfeffer (1967) as being only about 10 m-12 m high, with striking east-west asymmetry, where the west facing slope (60°) is about 25° steeper. Pfeffer suggested aspect related moisture changes as an explanation for the asymmetry, where rainfall evaporates more quickly on the east-facing slope and with it corrosive action is impeded. Pfeffer also noted that the west-facing slopes have a conspicuously thicker case-hardened caprock. The tower karst is examined with respect to its structural characteristics and hardness values, obtained from an N-type Schmidt Hammer, The author considers that the asymmetry is related to geological controls and not the product of differential dissolution and case-hardening with aspect as proposed by Pfeffer.

P09. Controls on facies patterns and stratal geometries in the Yellow Limestone and White Limestone of Jamaica – tectonic quiescence or carbonate productivity?

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Jamaica has been situated close to the North American – Caribbean plate boundary for the last 140 million years and records a series of tectonic events in the Cretaceous and Neogene with a proposed tectonic quiescence in the Paleogene during which the Yellow Limestone and White Limestone groups accumulated. Shallow-water deposits accumulated on the blocks (platforms) and deep-water marlstones and chalks accumulated in the intervening troughs. Geological mapping, lithostratigraphic revision, biostratigraphic dating and microfacies studies across central Jamaica over the last twenty years have now established the patterns of sedimentation in these two units. Rather than a thick layer-cake style platform succession, these carbonates are represented by sedimentary packages separated by major angular unconformities indicating that continued episodes of tectonic deformation affected the northern part of the Caribbean Plate throughout the Paleogene. Each tectonic sequence is represented by a transgressive-regressive package that rests on a truncated erosion surface (angular unconformity) with some 100-500 m of section removed by erosion. The transgressive interval shows progressive onlap onto the trough-slope-block topography with a progressive landward movement of marine facies followed by a regressive interval when platform interior facies prograded seawards over more open marine facies. Locally, a global sea-level signature can be identified through less significant changes in facies patterns. In the Yellow Limestone, tectonic sequences typically show a progression from: fluvial clastics to marine clastics to restricted carbonates to open marine carbonates and then more restricted carbonates. In the White Limestone, tectonics sequences show a progression from restricted carbonates to open marine carbonates to restricted carbonates (often with dolomitization or recrystallization affecting the restricted carbonates). This demonstrates that tectonic quiescence can no longer be seen as the driving force for the development of these platforms. Regional studies indicate the widespread development of carbonate platforms during the Eocene and these flourished until the carbonate crash in the mid Miocene. The development of the carbonate platforms of the Yellow Limestone and White Limestone of Jamaica is therefore better attributed to changes in ocean chemistry favouring high carbonate productivity. This not only explains the geological successions on the platforms, but also the occurrence of shallow-water carbonates at several levels in the 'deep-water' troughs. The new results are important for understanding the evolution of the Caribbean Plate, the facies patterns developed on carbonate platforms and the search for hydrocarbon reservoirs in the northern Caribbean.

P10. Late Cretaceous to early Paleogene geological evolution of Jamaica

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The relationship between the rocks of Jamaica and the evolution of the Caribbean has always been difficult to explain. We have analysed and dated: stratigraphic sequences and unconformities across Jamaica and the geochemistry and age of volcanic and metamorphic rocks. Two main terranes are recognized: a Western Jamaica Terrane (WJT) and an Eastern Jamaica Terrane (EJT). The WJT consists of an arc and basin succession with basaltic, andesitic and rhyolitic volcanics with IAT/CA affinity extruded from the Lower Cretaceous through to the Campanian. Arc volcanics are intercalated with thick units of volcaniclastics, rudist bearing limestones, and subsidiary deep-water shales, and indicate at least 60 Myr of island arc volcanism. Basinal successions include shales, sandstones and conglomerates. In the thicker and best preserved basinal successions, a regressive sequence extends from at least the Coniacian to the early late Campanian. Following a major unconformity, the transgressive-regressive Kellits Synthem represents the mid Maastrichtian-Paleocene with CA volcanism (ignimbrites). A further unconformity brings in the clastics and carbonates of the Yellow Limestone Group. The EJT of the Blue Mountains has a basement formed of CLIP basalts of late Turonian to Coniacian age overlain by deep-water limestones and an arc-derived sandstone-shale sequence of presumed Santonian age. Overlying are thick piles of Campanian volcanics (derived from a depleted plateau source) and volcaniclastics with rudist limestone intercalations in the mid (Back Rio Grand Limestone) and upper (Rio Grande Limestone) Campanian, and the early Maastrichtian. Two rift basin successions are developed in eastern Jamaica: the late Maastrichtian-Paleocene John Crow Mountain Rift (JCMR) and the mid Paleocene to early Eocene Wagwater Rift (WR). Volcanics in the WR can be generated by partial melting of subducted CLIP rocks during rifting. Blueschists, with a CLIP geochemistry, amphibolites, with arc geochemistry, and a serpentinite melange record the presence of a Campanian subduction zone that subducted CLIP rocks (EJT protolith), which were returned to the surface before the mid Paleocene. The geology of Jamaica is most easily explained by north-easterly directed subduction of the Farallon Plate beneath WJT (and Cuba) as insufficient oceanic crust was present in the Proto-Caribbean to drive Jamaican island arc volcanism for 60 Myr. Following the eruption of the CLIP, the CLIP collided with the WJT and began subducting with the development of an unconformity and subsequent change in volcanism to CLIP derived source regions. The WJT was thrust onto the North American Plate and a strike-slip fault systems and two tears in the subduction slabs initiated allowing Cuba (and the EJT) to move to the NE and eventually collide with the Bahamas Platform in the Eocene. Subduction zone rocks were uplifted along the strike-slip fault systems and transtensional basins (JCMR followed by WR) developed progressively in the latest Maastrichtian to Paleocene. Decompressional melting resulted in the partial melting of the CLIP and the formation of Jamaican-type adakites that were erupted into the WG. The model explains the geology of Jamaica well, but still leaves the geological evolution of Jamaica disparate from other parts of the Caribbean.

P11. Micropaleontology of the White Limestone and Coastal Group near Innes Bay, Portland, Jamaica

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New exposures in eastern Jamaica near Innes Bay in the parish of Portland have allowed for an updated geological map of the area as well as an initiation of micropalaeontologic studies of important Neogene through Quaternary units in the area. The lowermost units of the stratigraphic succession within this area consist of the upper beds of the Montpelier Formation of the Paleogene-Neogene White Limestone Group which are overlain first by the ?Miocene-Pliocene aged marls of the Layton Formation and then by the early Pleistocene reef associated limestones of the Manchioneal Formation. The Manchioneal Formation is in turn overlaid by the 'raised reef terraces' characteristic of the late Pleistocene Falmouth Formation. Much of this local succession is exposed along the coast at Innes Bay and along new tracks running westward from Innes Bay through Williamsfield.

In the district of Williamsfield, a thick section of the Montpelier Formation is exposed. Much of this material is too lithified to provide micropaleontological samples however thin section analysis revealed it to be a foraminiferal biomicrite dominated by planktic foraminfers, chiefly globerigeriniids. Further up-section are isolated less-indurated horizons in the Montpelier that have yielded abundant foraminifera, notably *Globorotalia* spp.; allowing for biostratigraphic and paleoenvironmental comparisons with the rich micropalaeontological samples collected from marly sediments in the younger units in the succession.

Preliminary results based on the occurrence of foraminifers in the *Globorotalia fohsi* lineage suggest a middle Miocene Serravallian age for the Montpelier Formation in this area. Planktic to benthic ratios suggest the unit was deposited in upper bathyal depths of approximately 800 m-1000 m. Comparisons with younger units in the area indicate a dramatic shallowing up-section with samples from the Layton Formation pointing to deposition at slightly shallower bathyal depths (800 m-600 m) in the lower portions of the unit to depths of 400 m-200 m at its boundary with the overlying Manchioneal Formation.

P12. Relationship between Rare Earth Elements and the origins of Bauxite in Jamaica

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The origin of Jamaican bauxite has been attributed to various hypotheses over the years; the residual hypothesis, the detrital hypothesis and the volcanic hypothesis being examples. Recent studies have used Rare Earth Elements (REE) and other trace elements to propose that Jamaican Bauxite originated from Miocene volcanic ash from Central America and Terra Rosa deposits from Mississippi Loess and wind-blown dust from West Africa. REE are an important commodity for industrial processes and have found prominence in the development of alternative energy solutions. The demand for REE has led to extraction processes being done on Jamaican red mud waste where exploitable quantities have been determined. To this end, a study was designed to investigate the concentrations of REE in bulk samples of bauxite as well as to test for the presence of such concentrations within the underlying limestone. An investigation into the mineralogy, and possible phase (clay or heavy mineral) that contain the REEs was also carried out. This paper provides insight into methodology that incorporated underlying geology with overlying bauxite in a bid to add value to the theories on the origin of bauxite as well as determine possible extractable quantities of REEs in raw bauxite and underlying limestone.

P13. Biostratigraphy of the White Limestone, Jamaica: data from strontium isotope studies

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Fifteen samples from localities covering the main formations of the White Limestone Group of Jamaica were analysed for their $^{87}Sr/^{86}Sr$ isotopic ratios. The Sr isotope ratio has varied in the ocean over time in a known way, and over the past 40 million years can be used to date marine sedimentary rocks, particularly limestones, to a high degree of accuracy. The larger foraminiferal assemblages from these samples have also been examined, the results providing a preliminary framework for dating both the foraminiferal assemblages and the lithostratigraphic units from which the samples were obtained. Sr isotopic ages range from 35.6 Ma (Claremont Formation, early late Eocene) to 21.5 Ma (Newport Formation, early Miocene). The results include indication that much, perhaps all of the Somerset Formation is of early Oligocene, rather than late Eocene age (as extensively quoted in literature); and confirm that the Browns Town and Walderston Formations are coeval stratigraphic units of Oligocene age, at least in their type areas, as suggested by Hose and Versey in the 1950s.

P14. Foraminiferal succession and lithofacies within the White Limestone Group during the Late Eocene to Early Oligocene

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The Eocene-Oligocene boundary is represented in the White Limestone Group in Jamaica and is traditionally placed at the extinction of *Fabularia verseyi* at the top of the Somerset Formation. In this paper, the succession through the top of the Claremont Formation through the Somerset Formation into the lower part of the Walderston Formation is investigated. Three sections are investigated: the Claremont-Somerset transition as exposed at Riversdale (Natural Bridge), the Claremont Formation-Somerset Formation on Stoney Hill Road, and the Somerset-Walderston transition in Bog Walk Gorge. The Claremont Formation consists of white or cream micritic limestones, the Somerset Formation of cream packstones, and the Walderston Formation by grey or cream grainstones. The succession of foraminifers through these intervals shows a succession of marker horizons, the last appearance datum (LAD) of *Cushmania americana*, the LAD of *F. verseyi*, and the LAD of *Fallotella*.

P15. Reef development in coarse clastic dominated facies in the Miocene through Pleistocene of south east Jamaica.

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In the late Neogene through the earliest Pleistocene, Caribbean reef coral communities underwent a major episode of taxonomic turnover. Coral species richness rose to a peak in the Plio-Pleistocene but dropped by >50% by the latest Pleistocene. Reef growth and structure changed dramatically with Neogene reefs dominated by massive forms and the locally extinct branching coral, *Stylophora*, and late Quaternary through recent reefs dominated by rapidly growing branched *Acropora* species. Jamaica has an excellent record of coral reefs of Miocene, Pliocene and Pleistocene age that clearly reflect this coral turnover event. As one would expect, most of these fossil reefs are in typical shallow water carbonate facies. Recent work on the south coast of Jamaica, however, has uncovered a succession of Miocene-Pleistocene age reefal deposits developed in environments dominated by coarse clastics. These well-exposed reef systems provide an excellent opportunity to examine how coral communities in these marginal habitats were affected by the major changes on Caribbean reefs from the Neogene through the Recent.

Much of the Neogene-Quaternary Coastal Group is exposed along a few kilometres of coast from Lyssons to East Prospect in the parish of St. Thomas, Jamaica. Within the shallow-water parts of the succession, patch reefs and small fringing reef tracts are found in the Mio-?Pliocene August Town Formation and the Old Pera Formation. There is also a possible small coral build-up in the Late Pleistocene Port Morant Formation. These coral build-ups generally originate by colonizing siliclastic cobbles and boulders and are found in growth position within a coarse conglomeratic matrix.

Coral sampling and transect point counting of exposures with coral growth fabric from multiple sites were used to describe the palaeoecology of these build-ups. In each formation, transects were placed across approximate bedding plane exposures roughly parallel to strike as well as through vertical sections. Coral species relative abundances and size distributions were used to examine the structure of reefs within units and to compare patterns between formations.

Coral species richness sampled here is generally low for each unit and does not follow the patterns of diversity change known for the Neogene-Recent Caribbean as a whole. Thus, it appears that coral species richness in these clastic-stressed environments is not governed by the size of the overall Caribbean species pool but by the paleoecology of the individual species present. Considerable turnover of species occurs between each of the units, although there is considerable stability in corals at the generic level. Some important species, such as *Stylophora monticulosa*, range through and dominate more than one unit. *Acropora* species first become abundant in the early Pleistocene but only as transported coral rubble, they do not appear as in situ components in these marginal reef habitats.

P16. Stratigraphy, Structure and Petrophysical Characteristics of Eocene-Miocene Successions of North-Central, Jamaica: Geotectonic Evolution of the North Coast Belt.

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Unravelling the geotectonic evolution of the North Coast Belt is imperative to understanding the sequence stratigraphy and structural configuration of Eocene-Miocene successions as well as the tectonic controls of northern Jamaica and Upper Nicaraguan Rise. A combination of geological mapping and sedimentological/stratigraphic analysis has allowed for interpretations on the depositional environments, hydrocarbon reservoir/seal potential and correlative biostratigraphy of Eocene-Miocene carbonates within the field area. Structural interpretations, fault kinematic solutions, seismicity data and geophysical techniques are also incorporated in interpretations. New geological mapping has identified Pliocene Coastal Limestones and elevated reefs, Eocene-Middle Miocene White Limestone Group, Eocene Yellow Limestone as well as Upper Cretaceous conglomerates/undifferentiated volcaniclastics of the fault bounded Sunderland Inlier. Focus has been placed on Eocene-Miocene successions as these carbonate facies exhibit distinct lithological and sedimentary character changes moving from the central Clarendon Block across the North Coast Belt. Eight formations within the White Limestone Group have been identified with 5 different facies being recognised: grainstones (Gst), packstones (Pst), wackestones (Wst), chalky marls/biomicirites (ChM) and chalks with chert (Chct). Interpretations for the depositional environments reflect a transition from platform carbonates, shelf edge, open-shelf to lower-shelf. The presence of lepidocyclid assemblages and several milliolid species define an Eocene-Miocene age and a *Eulepidinia undosa* rich assemblage within the grainstones of the shallow water formations indicate an Oligocene age. Petrophysical analysis of the grainstones and packstones display good secondary porosity (~15-35%) in the platform carbonates with thick marls and the Coastal Group providing excellent tight seals. Focal mechanism solutions have been derived for recorded earthquakes within the field area; these solutions allow for a new understanding of fault interaction, fault plane orientation and fault activity. Structural interpretations identifies signatures of a Late Miocene transpressional regime, strike-slip faulted-folded successions, NW-SE and N-S striking normal faults and reverse faults as well as a series of E-W and NE-SW striking normal faults. Fault kinematics solutions yield a compressional E-W stress direction and an extensional regime propagated along NW-SE and N-S faults. The relative structures in surface geology do not display significant E-W offsets along the previously interpreted left-lateral strike-slip Duanvale Fault Zone. This research emphasizes that structural signatures of the Late Miocene transpressional event of the Northern Caribbean Plate Boundary are expressed onshore (North Coast Belt) within the White Limestone Group as a series of sheared anticlines and synclines. This project is applicable to ongoing offshore hydrocarbon exploration initiatives and the mining sector in Jamaica as well as to advances in understanding northern Caribbean tectonics and seismic research.

P17. An examination on radioactive leakage within bauxite deposits and the health effects related to bauxite pit reclamation in Perth, Manchester, Jamaica

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Bauxitic soils in Jamaica are said to be characteristically enriched with Rare Earth Elements (REEs) and other heavy minerals/elements by up to two orders of magnitude relative to bedrock. Geochemical evidence supports the origin of Jamaican bauxite as volcanic ash fall out from Central America and windblown dust from West Africa. The Jamaican bauxite by virtue of its possible igneous origins, is then suspected to be a source of the radioactivity. The radioactive species commonly found in bauxite are Zircons and Lanthanides. Zircons and Lanthanides may be the source of the parent elements from which Radon is derived.

Radon, emits alpha particles and is a daughter product derived from Thorium and/or Uranium which are commonly associated with Zircons and Lanthanides. Radon can linger in the air for a little more than half a week. Residents in the immediate vicinity can then be exposed to cumulative doses of radon gas emissions which over several years, may cause radiation dose build-up and associated ailments. Due to the inherent mobility and radioactivity of radon, coupled with potential concentrations due to bauxite red mud waste, a study was conducted in Perth, Manchester to investigate whether the surrounding population is at risk from cumulative dosages of radioactivity. This investigation may inform occupational and environmental health and safety standards to be considered for pit reclamation, red mud disposal and rare earth element extraction policies.

P18. Benthonic foraminiferal paleoecology and community structures

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Foraminiferal community structure, revealed by SHE analysis, has been little used in palaeoenvironmental work. Two aspects of SHE analysis are presented here. SHE analysis for biozone identification (SHEBI) assigns samples to abundance biozones (ABs). The community structure in each AB is analysed using SHE analysis for community structure identification (SHECSI). Both proceed by accumulating samples and recalculating species richness S, the information function H [$= -\sum p_i \cdot \ln(p_i)$, p_i being the proportional abundance of the *i*th species] and the equitability index E ($= e^H/S$) as samples are added. SHECSI designates communities as Type 0, indicating stability, where H remains constant during sample accumulation. Where H increases, the community is assigned to Type 1, denoting growth or expansion. Where it decreases, the community is assigned to Type −1, indicative of instability or stress. SHEBI and SHECSI are here illustrated using the Lower to Middle Miocene Brasso Formation of Trinidad. It is hoped they will be applied to problems in Jamaican micropalaeontology, such as deciphering the impact of the global, deep-sea benthic foraminiferal turnover that occurred in the Early to Middle Miocene (Zones N8 to N11). This is apparently reflected in a biofacial change within the Montpelier Formation (Spring Garden Member).

The Lower and Middle Miocene geology of Trinidad documents the arrival of the Caribbean tectonic plate off NE South America, when the Northern Range allochthon was thrust on to the continental margin. The Northern Range eroded to form the monotonous clays of the Brasso Formation, in which carbonate bioherms mark occasional interludes of sediment starvation.

Twenty two samples were taken from four clay outcrops below the Mayo Limestone Member of western Central Trinidad. Ten came from Mayo Pond and four from each of Mayo Southside, Brasso Diapir and Little Mayo Quarry. These were compared with twenty samples recovered from limestone-marl couplets within the limestone. Mayo Pond and Mayo Southside yielded abundant *Cibicidoides crebbsi* and *Anomalinoides mecatepecensis*, indicating deposition at middle bathyal depths. Brasso Diapir, Little Mayo Quarry and the limestone-marl couplets were deposited at middle neritic depths. Dominant *Hanzawaia americana* shows the Brasso Diapir was deposited in a carbonate-prone environment. *Amphistegina martybuzasi* and *Elphidium poeyanum* show clearer and possibly shallower water conditions during the deposition of the clays underlying the Mayo Limestone Member at Little Mayo Quarry and the limestone-marl couplets within the Mayo Limestone. Nevertheless, there was an increase in the flux of organic matter through the Mayo Limestone Member.

Samples were assigned to ten ABs using SHEBI and the community structure examined in each using SHECSI. One AB of one sample only was not amenable to further analysis. Six ABs showed a stable Type 0 community structure. One AB at Mayo Pond had a stressed Type –1 structure. The uppermost two ABs in the Mayo Limestone were drawn from communities with Type 1 structures. Thus, the Brasso Formation was not always equally favourable for benthic foraminifera. Work on Jamaica would show if the same was true of the Spring Garden Member.

Field Trip 1: Geology of the White Limestone between Middlesex and Riverhead, Parish of St. Ann, Jamaica

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The White Limestone covers some two-thirds of the surface area of Jamaica and has importance for the economic extraction of pure limestone, and as the main aquifer for water supply in Jamaica, it also hosts Jamaica's bauxite deposits. The first attempt at subdivision was by Howard Versey in the 1950s (Versey, 1957; Hose and Versey, 1957) who recognised a series of members based on microfacies analysis and larger foraminifer assemblages. This scheme has proved difficult to apply across the island and several members were amalgamated for use in the 1:50,000 scale geological maps produced by the Geological Survey Department/Mines and Geology Division.

From 2004 to present, a renewed campaign has been undertaken to try and understand the stratigraphy of the White Limestone. The unit has been formally given "Group" status and has been divided up into a series of formations that can be mapped across the Clarendon Block (Mitchell, 2004, 2013). Formations are defined on lithological criteria – that is mainly a combination of limestone textures using the extended Dunham classification (carbonate mudstone, wackestone, packed wackestone, packstone, grainstone, crystalline) coupled with colour. Similar lithofacies do occur in different formations, but can be distinguished using age-diagnostic assemblages of foraminifers. The current scheme being used on the Clarendon Block is shown in **Figure 1**.

The geology between Middlesex and Riverhead is relatively simple (**Figure 2**). The area lies within a fault-bounded block with the White Limestone resting unconformably upon rocks of the Yellow Limestone (Guys Hill Formation) and Cretaceous (Benbow Limestone). The road transect shows rocks of the White Limestone Group exposed in stratigraphic succession beginning with the Troy Formation and ending with the Walderston Formation.

Details of the White Limestone succession can be found in Hose and Versey (1957), Robinson and Mitchell (1999) and Mitchell (2004, 2013). Descriptions of foraminifers and the foraminifer assemblages can be found in Robinson and Wright (1993) and Robinson (2013). The approximate locations of Stops on this field trip are shown on **Figure 2**. Participants will be able to collect samples representing the typical lithologies of each formation.

STOP 1: Benbow Formation at Middlesex. The Benbow Formation (Limestone) is the thickest limestone unit exposed within the Lower Cretaceous Benbow Inlier. It is represented by grey micrites and locally contains fossils including rudists (*Amphitriscoelus*) and gastropods that indicate a Barremian age. The Benbow Formation dips at a relatively steep angle towards the north.

STOP 2: Unconformity between the Troy Formation and the Benbow Limestone. The angular unconformity between the Troy Formation and the Benbow Formation is exposed on the road to the west of Middlesex (**Figure 3**). The unconformity itself is difficult to pick up since one limestone rests on another; however, the lithologies allow easy distinction – the Benbow Limestone is dark grey and micritic, the Troy Formation is recrystallized or dolomitized.

WHITE LMST. GROUP	Newport Fm	White carbonate mudstones in platform interior, locally with wackestones and some packstones closer to the platform margin. Distinguisged from the Walderston Fm by its predominant texture and colour.
	Walderston Fm	Cream packstones and grainstones dominanted by miliolids in the platform interior and by lepidocyclinids towards the platform edge. Layers with lepidocyclinids extend into the platform interior.
	Somerset Fm	Cream packstones, grainstones and wackestones with abundant miliolids and common to abundant examples of *Fabularia verseyi*. The white spotted texture is distinctive.
	Claremont Fm	Pale cream carbonate mudstones and wackestones with thin units of foraminiferal and molluscan packstones near the platform margin. Dolomitized in the southern part of the platform.
	Swanswick Fm	White (and occasionally cream) packstones and grainstones with miliolids and dictyoconids in the platform interior and lepidocyclinids on the platform margin. The white colour is distinctive.
	Troy Fm	Recrystallized limestones and dolostones with vugs after dictyoconids and fennestrae. Locally where not dolomitized it consists of wackestones with miliolids and dictyoconids.

Figure 1. Lithofacies classification of the shallow-water White Limestone Group on the Clarendon Block, Jamaica.

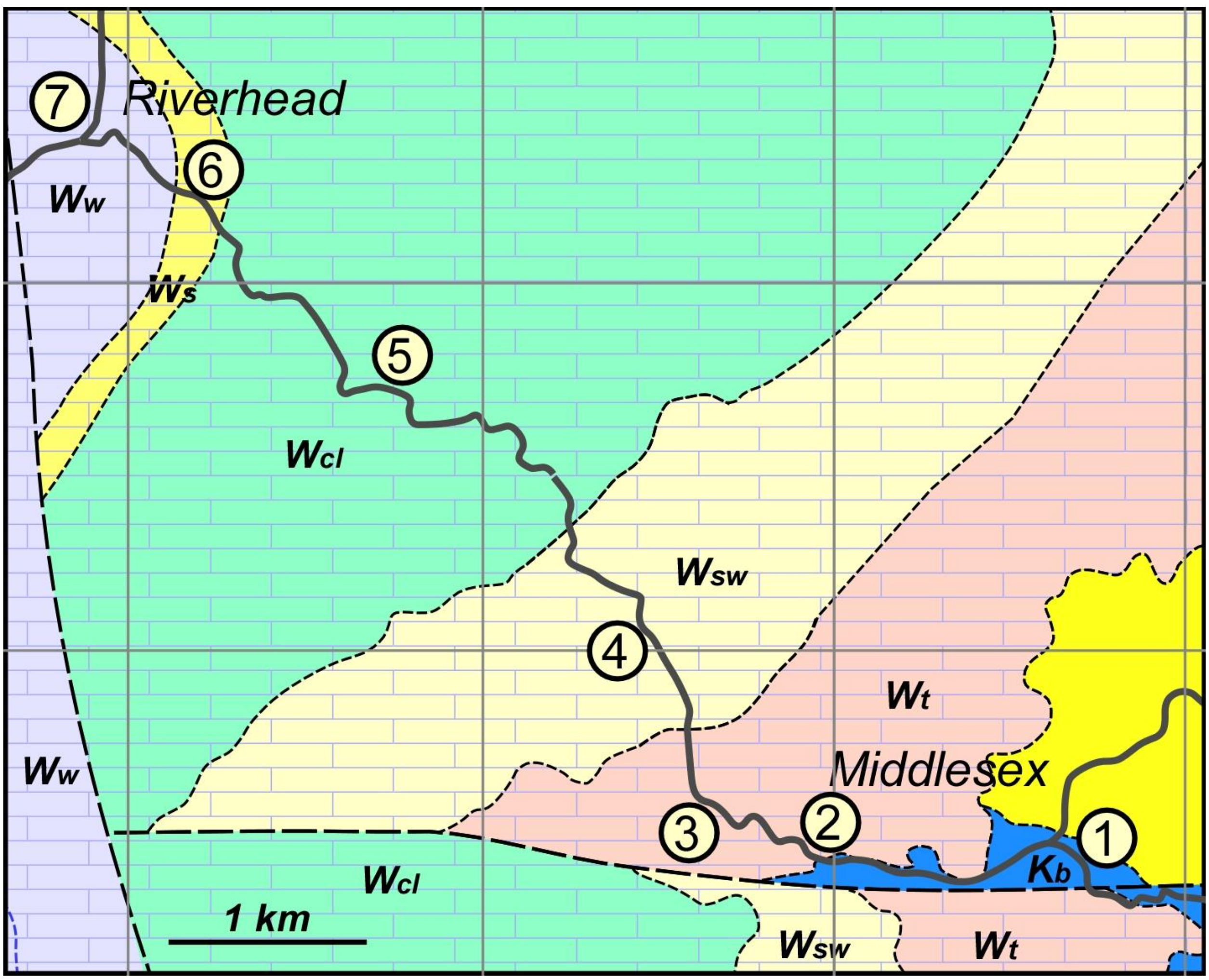

Figure 2. Geology and Stop locations of the area between Middlesex and Riverhead in the Parish of St Ann. Guys Hill Formation (Yellow Limestone Group) shown in yellow; Benbow Limestone (Cretaceous) indicated by *Kb*. For details of the formations in the White Limestone Group see Figure 1. Stops 1 to 7 indicated. Boundaries shown in thin dashed lines; faults by thick black lines. Roads in dark grey.

Figure 3. Unconformity between the Troy Formation and the Benbow Limestone at Stop 2. Hammer (mid left) is resting on the unconformity. The Benbow Limestone dips more steeply away from the road that the overlying Troy Formation.

STOP 3: Troy Formation. The lower part of the Troy Formation is composed of brownish crystalline limestones and dolostones often with conical vugs after dictyoconids. These crystalline limestones pass upwards into white and pale finely crystalline limestones. Other than for the vugs after the dictyoconids, no primary sedimentary fabrics are preserved. Studies elsewhere (Ipswich area of St Elizabeth), indicate that the Troy Formation was originally composed of micrites with scattered miliolids and dictyoconids. This fine-grained limestone allowed for the nucleation of dolomite crystals which grew and obliterated the primary sedimentary fabrics.

STOP 4. Swanswick Formation. The Swanswick Formation comes in rather suddenly above the Troy Formation, and the lower part shows partial irregular dolomitization. Dolomitization seems to have been controlled by lithology, with micrites becoming dolomitized, but packstones and grainstones resisting dolomitization. The Swanswick Formation consists of white grainstones with subsidiary packstones. The foraminiferal assemblage includes miliolids (quinquelocline forms and planispiral forms) *Fabiania cassis*, *Lepidocyclina pustulosa*, *L. macdonaldi*, *Cushmania americana* and *Fallotella* spp. Locally *Eulepidina chaperi* is present and indicates a late Eocene age. The brilliant white colour of these grainstones contrasts with the cream colour of younger Walderston Formation (although locally, the base of the Walderston Formation may also be white). The diverse foraminiferal assemblage with lepidocyclinids suggests an open marine platform environment.

STOP 5. Claremont Formation. The grainstones of the Swanswick Formation are succeeded by a very thick succession of pale carbonate mudstones and wackestones. Foraminifers include miliolids, dictyoconids (*Cushmania americana* and *Fallotella* spp.) and possible *Fabularia* sp. Laminoid and irregular fennestrae are locally present. The low diversity foraminiferal assemblage suggests deposition on a restricted inner platform, and the fennestrae indicate deposition within the intertidal zone. The Troy-Swanswick-Claremont succession therefore can be interpreted as a transgressive regressive cycle and records the first flooding of the Clarendon Block during White Limestone time. The unconformities beneath the Troy and Somerset formations indicates that this was a tectonically controlled/influenced cycle.

STOP 6. Somerset Formation. The Somerset Formation is relatively poorly exposed. The limestones of this formation contrast with those of the underlying Claremont Formation. They are composed of cream packstones and grainstones which carry a foraminiferal assemblage including miliolids, lepidocyclinids and the distinctive species *Fabularia verseyi*. *F. verseyi* is very distinctive; its test is composed of white microcrystalline calcium carbonate and contains an outer margin row of chamberlets and numerous worm-like inner chamberlets. The white spots formed by this species make the Somerset Formation easily identifiable, although other species of *Fabularia* at some levels in the Swanswick and Claremont formations are similar. The top of the Somerset Formation is defined where these distinctive white foraminifers disappear. The extinction of *F. verseyi* has been taken to mark the top of the Eocene in Jamaica, but it most likely represents a level low in the Oligocene (Edward Robinson, pers. commun.) and the top of the Eocene lies either within the lower part pf the Somerset Formation or within the time represented by the unconformity between the Claremont and Somerset formations.

STOP 7: Walderston Formation. The Somerset Formation is succeeded by a very thick succession of cream grainstones and packstones. In the lower part of the succession miliolids dominate together with dictyoconids (*Fallotella* spp.) and occasional specimens of *Eulepidina chaperi*. Higher in the sequence, specimens of *Eulepidina undosa* appear and sometimes occur in rock-forming quantities. Such fabrics have been referred to the Browns Town Formation, but they occur as layers within cream grainstones of typical Walderston lithology across much of the Clarendon Block and the Walderston and Browns Town formations cannot be mapped separately.

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Field Trip 2: Selected geological sites in the parishes of western St Andrew and St Thomas

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The understanding of the geology of Jamaica has significantly advanced in recent years with revisions of the stratigraphy (e.g., Mitchell, 2003, 2006, 2013a, 2013b; Mitchell et al., 2001; James-Williamson and Mitchell, 2012), the igneous rocks (Hastie et al., 2008, 2010) and metamorphic rocks (e.g., Abbott et al., 2013; West et al., 2014). Although many details remain to be published, an outline of the geological history of Jamaica is presented in **Figure 1** and described below based on these references and will be published in detail elsewhere.

Different parts of Jamaica evolved in different parts of the Caribbean plate-arc system. The eastern Blue Mountains (Bath area and Rio Grande Valley) are represented by plateau basalts that were produced by a mantle plume over the Galapagos Islands hotspot during the late Turonian-early Coniacian (88-91 Ma). The sequence consists of a basement of plateau basalts (Bath Volcanics) overlain by a sedimentary (Cross Pass Shales; Back Rio Grande Limestone, Rio Grande Limestone, Providence Shales) and a series of back-arc lavas (Bellevue Volcanics). Rudists from the limestones (Mitchell and Ramsook, 2009) share more in common with faunas from Costa Rica, than with those from the rest of Jamaica and other areas of the Greater Antilles. The Cretaceous rocks from the rest of Jamaica were formed in an island arc setting and consist of volcanic rocks (basalts, andesites and dacites) and a suite of clastic and carbonate sedimentary rocks. The volcanics were initially formed from the subduction of typical oceanic crust, and subsequently by the subduction of the CLIP. Metamorphic rocks in the western Blue Mountains were formed in a subduction zone setting; they include amphibolites (Westphalia Schists, Green Bay Schists) with arc derived protoliths and Greenschists/Blueshists (Mt. Hibernia Schists) with CLIP protoliths.

The two contrasting areas of Cretaceous rocks that would form ProtoJamaica were brought together by strike-slip faulting along NE-SW orientated faults initiated during the collision of the northeastwardly moving Caribbean Plate with the Yucatan Block at the end of the Campanian (producing an unconformity at the base of the Kellits Synthem). Uplift related to these faults saw the rapid return of the metamorphic rocks to the surface and releasing bends resulted in the development of rift basins (John Crow Mountains Rift, Wagwater Rift). The rifts were filled with thick sedimentary successions and volcanics (Halberstadt Volcanics, Newcastle Volcanics) derived from the CLIP as it was thrust under Jamaica.

Following the collision of the Caribbean Plate (Cuba) with the Bahamas Block in the late Early Eocene, ProtoJamaica was established, the Caribbean Plate took on an eastwardly motion relative to the North American Plate, and an unconformity was formed beneath the rocks of the Yellow Limestone Group. With a change in plate motions, new stress regimes resulted in extension along the Nicaraguan Rise with the formation of a block and trough topography. Shallow water platform carbonates (Yellow Limestone and White Limestone groups) developed over the blocks and deep-water chalks were deposited in the troughs from the mid Eocene to the mid Miocene). Tectonic episodes affected Jamaica throughout the deposition of the limestones, with notable unconformities at the base of the Troy and Somerset formations, as well as within the Oligocene.

With the collision of the leading edge of the Caribbean Plate (Dominica Republic) with the Bahamas in the Eocene, thrust stacks developed progressively across Hispaniola during the Oligocene-early Miocene and renewed tectonic deformation was transferred to Jamaica during the mid Miocene. This deformation was associated with a restraining bend (Plantain Garden-Blue Mountain Fault) and saw the progressive development of flower structures in the Blue Mountains (James-Williamson et al., 2014). As uplift took place, the Coastal Group was deposited around the margin of Jamaica. The Coastal Group is represented by mixed clastics (derived from the uplift of the Blue Mountains and Wagwater Belt) and carbonates (formed from marine organisms, such as, corals, foraminifers, molluscs and algae) and is particularly well developed in the coastal areas of Portland and St. Thomas. These mixed clastic and carbonate deposits formed in a range of environments and provide a window into the geologic development of this portion of Jamaica. The area also can boast of some world class fossil sites that document the major changes in Caribbean marine biota during the Late Neogene through Recent.

The stratigraphy of the Coastal Group of St Thomas includes four formations (August Town, Layton, Old Pera and Port Morant formations), each composed of mixed clastic and carbonate sediments. The Mio-Pliocene Layton Formation was deposited in deeper marine upper bathyal conditions and is made up chiefly of marlstones with some sandstones, conglomerates and occasional shell beds. The other units, the August Town Formation (late Miocene), the Old Pera Formation (early Pleistocene) and the Port Morant Formation (late Pleistocene), all contain sandstones and conglomerates along with localized fringing reefs and coral patches exposed along the coast from Port Morant westward to Morant Bay. In St. Andrew, the Coastal Group is represented by the August Town Formation overlain by the Harbour View Formation.

This Field Guide indicates some of the features of the evolution of the geology of eastern Jamaica. Stops are identified using GPS locations.

Stop 1. Harbour View Formation, Palms Apartments (GPS: N 17° 56.892', W 076° 41.940')

This locality is located just off the south coast road between Harbour View and Bull Bay and is situated about 500 m to the west of the bridge over the Cave River. Access is by a narrow road (GPS: N 17° 56.833', W 076° 41.951') immediately on the west of the Palms Apartments. The hillside has been excavated for the foundations of a house, but the house was never constructed. The section shows well-stratified, granule-pebble conglomerates and associated minor coarse-grained sandstones of the Harbour View Formation dipping at about 60° to the south. The conglomerates display imbrication indicating bidirectional currents (waves), and marine trace fossils (*Taenidium* isp.). On the western side of the exposure there are two successive erosively-based beach units which are deposited against ancient cliff lines cut into the Harbour View Formation). The older (lower) beach unit dips at about 10° to the south and shows landward-directed imbrication of boulders (**Figure 4**). The younger (upper) beach unit is subhorizontal and largely inaccessible. On the far southwestern extremity of the exposure, the lower beach bed is displaced by a small southerly dipping reverse fault (back-thrust). This locality shows synsedimentary deformation causing progressive southward tilting (development of footwall synclines) of the units and cutting of erosional marine terraces and deposition of cobble/boulder beaches as the Harbour View Formation were uplifted by thrust faults propagating to the south of the Wagwater Fault.

Figure 4. Unconformity showing boulder conglomerates (beach) overlying steeply dipping marine pebble conglomerates. Book for scale.

Stop 2. Bath Volcanics, Bridge at Bath (GPS N 17° 56.850', W 076° 21.624')

This location is located on the road from Port Morant to Bath and is situated immediately to the north of the new bridge over the Plantain Garden River just by the sign for Bath. Here, the Plantain Garden River runs along the course of the Plantain Garden Fault. This is an east-west, left lateral (sinistral), strike-slip fault with a lateral displacement of maybe 10 km. To the south of the fault there is a small Cretaceous inlier, the Sunning Hill Inlier, surround by an Eocene-Miocene clastic (Richmond Formation) and carbonate (Yellow Limestone and White Limestone groups) succession. To the north of the river are the Bath Formation (lavas with subsidiary cherts and mudstones) and the Cross Pass Shales (a deep-water turbiditic succession of probable Coniacian-Santonian age.

The Bath Formation is largely comprised of basaltic lavas, sometimes showing pillow structures, with minor chert and thin units of clastic mudstone. The lavas have typical immobile and trace element compositions that indicate that they were formed as a part of the Caribbean Large Igneous Complex (CLIP). The CLIP was produced over the Galapagos Island hotspot when the head of a mantle plume reached the ocean crust. It is this large volume of basaltic lavas that have caused the abnormally thick (c. 14 km) oceanic crust under the Caribbean Plate. The Bath lavas exposed at the bridge over the Plantain Garden River appear to show pillows; however, these are not pillows, but the cores of joint-defined blocks that have suffered extensive weathering. Fluids have broken down the basalt progressively from joint in thin layers forming a typical example of onion skin weathering

(**Figure 5**). A close look at the basalts reveals a complete lack of vesicles indicating extrusion of the lavas at great water depths where the high pressure kept the gasses dissolved in the magma.

Along the old road to the west, on the northern side of the Plantain Garden River are exposed a series of clastic mudstones that are most easily studied in a series of fallen blocks. The rocks consist of red or brown fine-grained clastic mudstones with no apparent structure. Nearby, these rocks have yielded late Turonian and early Coniacian radiolarians. The basalts and particularly the mudstones contain numerous thin calcite veins.

Figure 5. Bath Volcanics at Stop 2 showing onion-skin weathering.

Stop 3. Thornton Volcanics, Sunning Hill (GPS: N 17° 57.267', W 076° 24.584')

This locality lies within the Sunning Hill Inlier on the road from Sunning Hill to Whitehall. The best way to locate the exposure is using the GPS location as there are few markers along this road. The Sunning Hill Inlier contains a deepening-upwards succession that consists of, in ascending order: the Thornton Volcanics, red-bed conglomerates and sandstones, a thin limestone (Bon Hill Limestone) and a thick sequence of shales and sandstones. Fossils in the Cretaceous sequence (ammonites, inoceramid bivalves, rudist bivalves and nereinid gastropods) indicate an early Campanian age, and the Thornton Volcanics are therefore either of latest Santonian or, more likely, early Campanian age.

This locality shows a road cutting in very hard basaltic andesites that show well developed pillow structures (**Figure 6**). Individual pillows are separated by thin layers of sediments suggesting eruption into the uppermost part of a marine sedimentary pile. Basalts (not seen on this trip) higher in the sequence do not show pillows suggesting that the eruption was initially underwater, but built up to be subaerial. Immobile and trace element analyses indicate that these basaltic andesites are typical island arc volcanics, and therefore contrast markedly with the Bath Volcanics only 3-4 km to the east. Even allowing for movement along the Plantain Garden Fault, the Bath and Thornton volcanics could not have formed in such close proximity. The Bath Volcanics were formed within the central part of the Caribbean Plate, whereas the Thornton Volcanics formed in an island arc on the edge of the Caribbean Plate, with maybe 1,000-1,500 km separating the original sites of formation. Subsequently the two sets of volcanics have been juxtapositioned by tectonic processes as the Caribbean Plate collided with the North American Plate.

Figure 6. Pillow lavas in the Thornton Formation at Stop 3. Hammer (lower centre) for scale.

Stop 4. Mt Hibernia Schists, East Arm of the Morant River (GPS: N 17° 58.304', W 076° 28.861')

This locality is situated where the East Arm of the Morant River exits from the Blue Mountains Inlier to the north of the trace of the Plantain Garden Fault. The section extends from the alluvium upstream along the river to the old hydroelectric dam know as Reggae Falls. Formerly, the alluvium on the west bank of the river immediately to the south of the first bedrock outcrop showed fault movements within the alluvium similar to the fault seen cutting the lower beach bed in the Harbour View Formation at Locality 1.

To the north of the alluvium, the first rocks that are encountered are a series of weathered basaltic lavas. These rocks occur on both sides of the river and contain abundant vesicles. The presence of vesicles indicates extrusion into shallow water and indicates that they are island arc rocks potentially similar to the Thornton Volcanics.

The basalts are in faulted contact (the fault is represented by a gully on the western side of the river) with the greenschists of the Mt. Hibernia Schists which extend from this fault up to and beyond the dam forming Reggae Falls. The greenschists contain a mineral assemblage including: epidote and actinolite, together with chlorite, quartz, albite and clinopyroxene. A foliation is developed dipping gently towards the S/SW. The hill to the northwest on the western side of the East Arm of Morant River is called Union Hill, and contains the outcrops of the blueschists in the Mt. Hibernia schists. Immobile and trace element data from the blueschists indicates that they are derived from a protolith of the Bath Volcanics. This demonstrates that the CLIP was subducted towards the end of the Cretaceous beneath Jamaica.

Stop 5. Bowden Shell Bed (GPS: N17° 53' 23.76" W76° 18' 52.62")

This locality along the road from Port Morant to Bowden Marina just before the turn up the hill to Old Pera is one of the most famous fossil sites in the entire Caribbean. Having first come to light in the mid 19th century, it has been the focus of considerable work ever since (see Donovan 1998 for a review). Although the main shell bed itself is found in an exposure not more 8-10 m long and 2-3 m thick, it contains hundreds of species of molluscs, corals, and other marine invertebrates. The fauna represent a mixture of shallow marine and terrestrial forms transported down slope into a deeper marine setting.

A thick section of the outcrop was trenched and described by Pickerill et al. (1998). More recent work has re-cleared a broad section of the outcrop (**Figure 7**) allowing access to the main body of the shell bed close to road level as well as further uphill through much of the Pickerill et al. (1998) section.

Stop 6. East end of Fisherman's Bay, St. Thomas, Port Morant Formation (GPS: N17° 51' 37.72", W76° 20' 58.96")

Turning off the main south coast road (A4) at Prospect heading toward the coast on Crescent Rd. the track ends in an exposure of a low reef terrace in the Late Pleistocene Port Morant Formation. This represents the most westerly exposure of extensive pure carbonate reef facies in this unit. Here one can walk among excellent exposures of coral in growth position.

Figure 7. Bowden Shell Bed, late Pliocene, Bowden Member, Layton Formation. This image was taken in June 2009 after it had been cleared with a backhoe. A large channel fill is exposed to the right of the geologist and bedded units are exposed to the left.

At this site (**Figure 8**), there is a mixed coral fauna with considerable growth of more fragile thin branched species suggesting this developed in a more protected area behind a wave exposed reef crest. Common massive corals seen here include *Orbicella* and *Pseudodiploria* growing among abundant branched *Acropora* and *Porites*. These are all essentially identical to key species that inhabit the modern Caribbean. It should be noted, however, that this Late Pleistocene reef is more extensive and shows denser coral cover than any modern near shore reefs in this area.

Figure 8. Reef terrace in the late Pleistocene Port Morant Formation at Stop 2. Thin branched *Porites furcata* shown in centre of photo; thick branched *Acropora palmata* seen at lower left

Stop 7. Oxford Road Coastline, Old Pera Formation (GPS: N17° 52' 7.70" W76° 21' 44.02")

At the intersection of Oxford Road with the A4, a path leads to impressive coastal exposures of the early Pleistocene, Old Pera Formation consisting chiefly of coarse conglomerates and sandstones dipping slightly to the south. At various intervals, corals colonized the substrate and are seen in place growing up through cobble rich sediment to form small coral mounds and thickets, some with colonies over a metre across. At the eastern end of the outcrop just visible at sea level, large in place massive species form a coral rich limestone.

Given the rather strenuous environment represented at this site, coral diversity here is understandably low. However, like all early Pleistocene coral faunas of the Caribbean, this site shows a mixture of extant and extinct species. Plio-Pleistocene coral communities in the Caribbean were ~50% more diverse than at present and a major extinction event hit reefs sometime after the deposition of the Old Pera Formation. At this stop extant species of *Pseudodiploria*, *Porites* encrust cobbles as well as transported fragments of extant *Acropora*. The dominant in place branching coral (**Figure 9**), however, is *Stylophora monticulosa*, an extinct species whose closest relative is living today in the Pacific.

Figure 9. Coral in growth position within coarse conglomerates of the early Pleistocene Old Pera Formation, Stop 3. Branching coral at centre top is *Stylophora monticulosa*, a species extinct in the Caribbean.

Stop 8. Lyssons, Golden Shore Hotel, August Town Formation (GPS: N17° 52' 27.61" W76° 22' 42.24")

Turning off the A4 down Winward Road toward the Golden Shore Hotel, brings one to a coastal outcrop of the late Miocene August Town Formation. At this site, a fringing reef system developed with a base of small corals colonizing coarse conglomerates and grading upward into densely packed coral growth fabric 2-3 metres thick and exposed across more than 60 m of coastline. Until recently the impressive outcrop, (**Figure 10**) showed a clear transition from the more clastic rich back reef grading into purer carbonate and coral dominated reef core. Unfortunately, the epidemic of sea wall building that has affected much of this stretch of coastline destroyed some of this outcrop.

Still, some of the succession from conglomerate to reef is accessible and the main body of the reef tract is well exposed. Coral diversity here is low but almost completely distinct from that of the Old Pera Formation. Only 2 minor species in this reef are extant, most of the others go extinct during a period of significant taxonomic turnover in the Caribbean Plio-Pleistocene. The principal branching species is again *Stylophora monticulosa*. This reflects the dominance of *Stylophora* before the origination of the key elkhorn and staghorn species of *Acropora* that structure modern reefs in the Caribbean region.

Figure 10. Reef developed on coarse clastics in the late Miocene August Town Formation at Lyssons.

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