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GEOLOGY OF THE NORTHERN, CENTRAL AND SOUTH-EASTERN BLUE MOUNTAINS, JAMAICA, WITH A PROVISIONAL COMPILATION MAP OF THE ENTIRE INLIER

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ABSTRACT

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An interpretation of successive geological events is proposed, based on lithological and palaeontological evidence encountered in the northern, central and south-eastern Blue Mountains, Jamaica. A provisional geological map of the entire inlier is given. An interpretation of a number of structural features includes some remarks regarding a plate tectonic model of the northern Caribbean plate margin.

INTRODUCTION

As a preliminary result of mapping the central, northern and southeastern Blue Mountain area, the following division in main lithologic units, from base to top, can be given (see also Figs. 1, 2):

(1) The Back Rio Grande Formation. With only the top part of the formation exposed, the sequence consists of a submarine succession of volcaniclastic conglomerates, and a concluding 8-10 m thick limestone unit of Campanian age.

(2) The Bellevue Formation, a 600-?1500 m thick, mainly submarine volcanic island arc succession, volcaniclastic conglomerates and a concluding ?20-80 m thick limestone unit of Campanian-Maastrichtian age.

(3) Granodiorite-tonalite-adamellite stocks, consistently associated with the volcanic series of the Bellevue Formation, and supposedly of Maastrichtian-Early Tertiary age.

(4) The Blue Mountain Formation, a 1500-?2500 m thick succession of mudstones, siltstones, sandstones, coarse slump conglomerates, tuffaceous volcaniclastic conglomerates and lavas of Maastrichtian-Early Tertiary age.

(5) The Chepstow Limestone, an approximately 35 m thick impure, near the top bioclastic limestone unit of ?Palaeocene-Early Eocene age.

(6) The Richmond Formation, a 500-1500 m thick succession of conglomerates, siltstones and shales of Early Eocene age. The top of the Richmond Formation is in conformable contact with the White Limestone Formation which borders the Blue Mountain inlier on the northern, eastern and southern side.

STRATIGRAPHY

The Back Rio Grande Formation

Only the toppart of the formation is exposed along the banks of the Back Rio Grande, about a quarter of a mile downstream of the Catalina River confluence, and half a mile downstream from the Stony River confluence, to the west of Bellevue, as well as in the SE part of the Blue Mountain inlier, in the Bath area.

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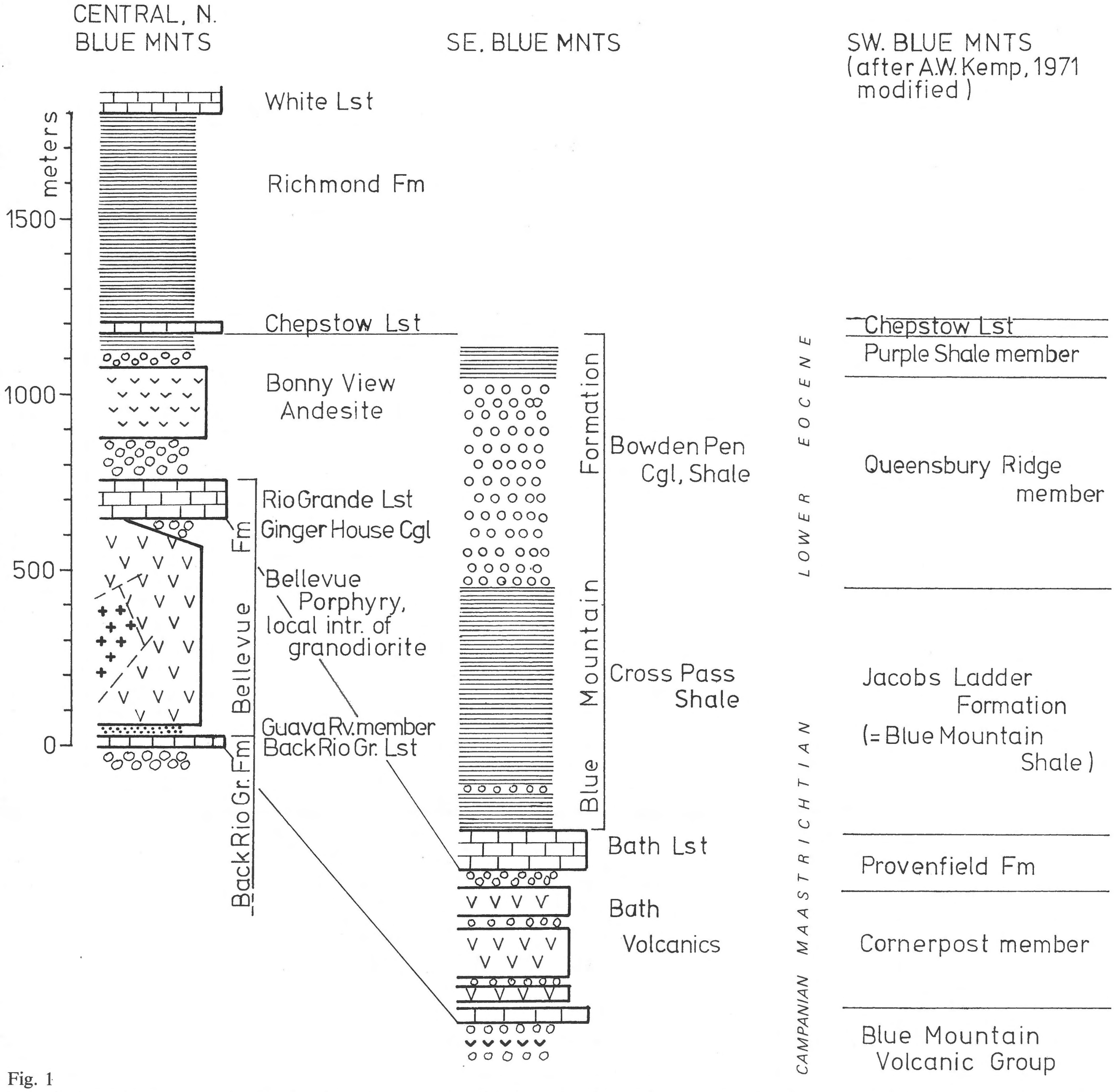

Fig. 1
Compiled stratigraphical columns showing the successive lithological units of the central, northern and southeástern Blue Mountains, with a tentative correlation with the lithostratigraphy as proposed by Kemp, 1971 (modified).

The sequence comprises two members, an unnamed volcaniclastic conglomerate member with andesitic? porphyritic components in a sandy to shaly matrix, conformably overlain by the Back Rio Grande Limestone Member. From the northern to the southeastern localities the lithology of this limestone changes from rubbly, biostromal and calcarenitic deposits to entirely bioclastic calcarenites, the calcarenites with abundant volcanic rock fragments.

Characteristic fossils in the rubbly limestones in the Back Rio Grande and the basal part of the calcarenites west of Bellevue are single individuals and clusters of *Barrettia monilifera*. The biostromal parts of the section consist almost entirely of radiolitid frameworks, whereas the calcarenitic parts contain abundant specimens of *Pseudorbitoides trechmanni trechmanni* and *Sulcoperculina*. The member obviously represents a break in a generally slowly sinking trend of the seafloor during Campanian times, terminating a cycle of volcaniclastic sedimentation in an island arc development.

Provisional geological map of the Blue Mountain inlier, Jamaica. Compiled by J.P.Krijnen and A.C.Lee Chin, 1977.

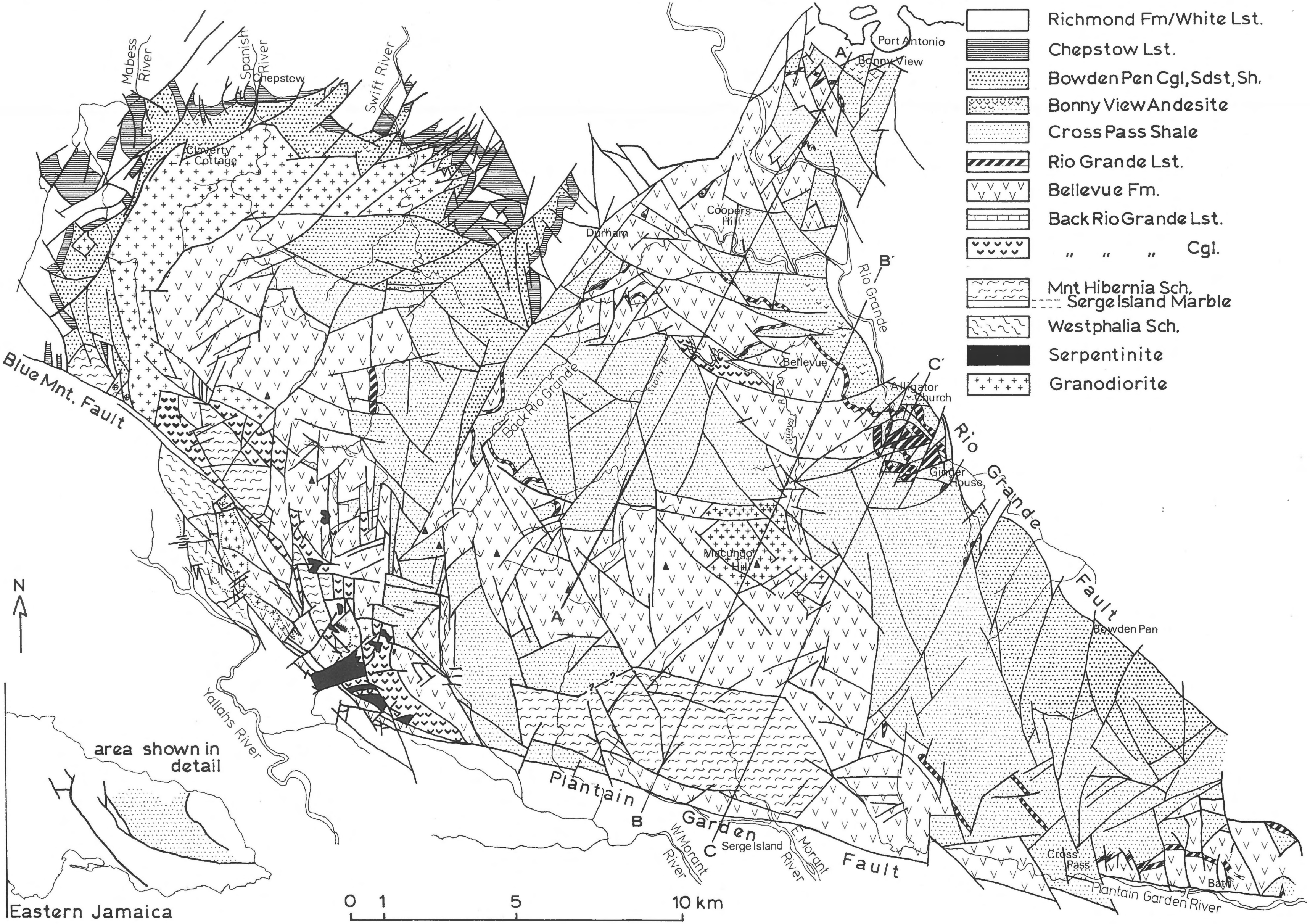

Fig. 2
Provisional geological map of the Blue Mountain inlier.

The Bellevue Formation

This formation covers a large area in the Blue Mountain inlier, and represents a second cycle of typical island arc deposits with a supposed lateral change from a generally deep to shallow evolving environment of deposition in the northern/central part to continuous deep water conditions in the southeastern part of the inlier.

In the northern/central part, the formation comprises a number of lithological units which have been grouped into four members with type localities in the Bellevue area between the Guava River and the Rio Grande. The basal unit, the Guava River Member, consists of 50-100 m thick well bedded grey calcareous mud- and siltstones which conformably overly the Back Rio Grande Limestone Member. The entire sequence shows a regular lamination with layers which are up to 15 cm in thickness. They may show turbidite affinities, and, accordingly, a sudden deepening of environment of deposition has been assumed. No fossils have been found in these beds, except some specimens of *Pseudorbitoides* sp. from some more sandy layers in a unit south of the type area, in the Guava River valley.

The member is in faulted contact with porphyries of the overlying Bellevue Porphyry Member which consists of an approximately 600 m thick succession of submarine volcanic extrusives (and intrusions?). The whole unit is intensely sheared and faulted with most of the predominant faults following a NW-SE pattern. In most of the outcrops in the Bellevue area the rock has been deeply weathered. From loose pebbles, cobbles and boulders in small streams, it is inferred that the texture ranges from finely grained to coarse porphyritic, the latter with phenocrysts of plagioclase, and ranging from andesitic to probably dacitic in composition. Usually the rock is hydrothermally altered. Along veins and in pockets quartz, jasper and occasionally a weak-purple-tinted amethyst, kaolinite and baryte have been deposited as secondary minerals. Pyrite occurs in characteristically leached patches as small disseminated crystals and along cracks and joints goethite is the predominant mineral. Boulders with less distinct porphyritic texture and small vesicles filled with chalcedony, and more basaltic in composition, have also been found, but thus far from only one locality.

The major phase of submarine extrusion has been accompanied by the deposition of pyroclastic agglomerates and or volcaniclastic conglomerates, but it has not been possible to ascertain to what extent due to extensive weathering, heavy vegetation and thick top soils.

Also incorporated in the Bellevue Formation are the Ginger House Member and the Rio Grande Limestone Member which are exposed as two successive units in a number of fault blocks in the Rio Grande valley between Ginger House and Alligator Church. Due to the consistent structural pattern of N-NE dips immediately northwest of Alligator Church, it is conceived that the succession overlies the Bellevue Porphyry Member.

With the base not exposed, the Ginger House Member consists of purple to grey polymict conglomerates with a sandy tuffaceous matrix and components of andesitic porphyry and bright green chloritized pelitic rock. The succession grades into an approximately 5 m thick conglomeratic to rubbly unit with many *Titanosarcolites* fragments, *Plagioptychus* sp. and coral fragments, embedded in a strongly tuffaceous sandy matrix, the base of the Rio Grande Limestone Member.

Along the banks of the Rio Grande, the total thickness of the limestone member ranges in the order of 70-80 m, and can be subdivided into the following units exposed on top of the basal rubbly conglomerates (from bottom to top):

(1) An approximately 8 m thick, grey compact bioclastic limestone with colonial corals, bryozoa, algae and fragments of *Titanosarcolites*. In a fracture zone, small faulted blocks with *Chiapasella* may represent a slightly younger level.

(2) A 19 m thick, grey sandy limestone, thick to average bedded, with horizons containing radiolitids, *Titanosarcolites, Sulcoperculina, Pseudorbitoides ?rutteni rutteni, Orbitoides* cf. *O. media* and occasionally gastropods.

(3) A 2 m thick sandy limestone with slumps of a thin sandstone layer, locally (in loose blocks) with abundant *Acteonella*.

(4) A 24 m thick unit of grey nodular to rubbly limestone layers, interrupted by a 2.5 m thick interval of tuffaceous sandstone with limestone nodules. The limestone is very fossiliferous, containing *Titanosarcolites, Antillocaprina?, Acteonella, Nerinea,* corals, *Sulcoperculina, Pseudorbitoides ?rutteni rutteni,* and *Orbitoides* cf. *O. Media.* Near the top of this unit, layers almost entirely made up of frameworks of *Distefanella mooretownensis* were used as a marker by which the entire limestone succession has been compiled from various fault blocks.

(5) A 12 m thick unit (of which 8 m are exposed) of bioclastic calcarenites, sandy, conglomeratic, with corals, rudist fragments, *P. ?rutteni rutteni, Sulcoperculina, O.* cf. *media* and possibly *Vaughanina* sp.

The limestone member is overlain by a greenish tuffaceous sandstone, the base of the Blue Mountain Formation.

The Rio Grande Limestone Member forms a well defined market unit which can be found in the periphery as well as in the high interior of the Blue Mountains. It is distinguished from any other limestone by its characteristic foraminiferal assemblage consisting of the genera *Orbitoides, Pseudorbitoides* and *Vaughanina* (in some instances exclusively *Orbitoides* and *Vaughanina:* in pockets within the limestone unit exposed in the Pumpkin Hill area, and in exposures in the Swift River).

In the southeastern part of the inlier, in the Bath area, the Bellevue Formation is represented by a volcanic phase characterized by the extrusion of spilitic basalts, occasionally with assumed pillow structures, interbedded with

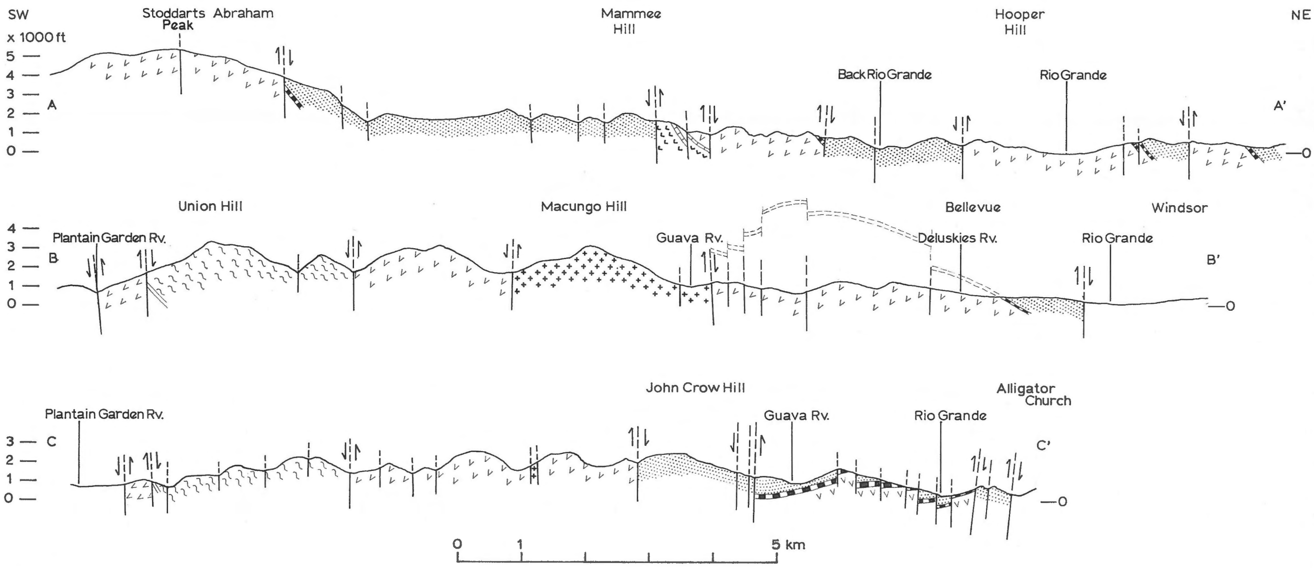

Fig. 3
Cross-sections along the lines A-A', B-B', C-C' of figure 2.

volcaniclastic layers (see BATESON, 1974).

The association of these volcanics with intervening chert bands may suggest a deeper-water environment of deposition; however, according to Bateson, the interbedded sediments show little sign of transportation which may point to more shallow conditions, and possibly to some differentiation in the vertical crustal movements. Locally within the succession and close to the top of the volcanic unit, finer grained, often calcareous sediments occur, concluded by the banded Bath Limestone with radiolaria and possibly reworked larger foraminifera. The generally pelitic texture of the limestone may point to more or less stable and deeper sedimentary conditions. Due to the predominant N-NE dip directions, the generally S-SE dips of the Rio Grande Limestone near Ginger House, and the stratigraphical position of the Bath Limestone Member well above a *P. trechmanni trechmanni* bearing lateral equivalent of the Back Rio Grande Limestone near Bath, the Bath Limestone can be considered as a deeper water equivalent of the Rio Grande Limestone.

The granodiorite-tonalite-adamellite stocks

In all the cases of recorded occurrences, the plutonic rocks were seen in faulted contact with either porphyries of the Bellevue Porphyry Member or volcaniclastic-pyroclastic beds associated with the porphyries. The major localities include the following occurrences:

(1) The largest granodiorite body in the region is situated around the Swift and Spanish Rivers, with deeply weathered outcrops south of Claverty Cottage and along the western bank of the Swift River immediately south of Chelsea. Most of the northern contacts are faulted against andesite porphyries and tuffaceous conglomerates. The rock shows the common granitoid texture. The colour variations are due to the weathering along fault and shear zones, and range from greenish to brown. The composition of the rock varies a little but plagioclase felspars make up approximately 50-60% of the rock. Quartz, biotite, K-felspar and hornblende are the major minerals present. In some cases apatite and hematite occur as secondary minerals, and alteration produced chlorite and epidote. Around the Chelsea area mineralization of chalcopyrite and malachite occurs mainly along a NW-SE strip.

(2) In the Johnsons River/Macungo Hill area, the plutonic rock is found intruding into andesites (considered to belong to the Bellevue Porphyry Member), and most of the contacts with the latter are faulted (see CRAIG, 1968). The composition ranges from granodiorite/tonalite to adamellite. The quartz content is fairly high, ranging between 25-30%. The range of the K-felspars is between 10-20%. Plagioclase felspars and biotite altering into chlorite are the main components.

(3) In the Durham-Coopers Hill area, the granodiorite is found as small stocks intruding the surrounding andesites and andesite breccias of the Bellevue Formation. The composition varies from north to south, where the granitoid texture is partially destroyed due to alterations. Mineralization is found associated with fault zones, and traces of malachite, azurite, bornite and pyrite have been recognized at some localities east of Durham, but never in economic quantities.

It is conceived that the intrusions of the granodiorite/tonalite/adamellite stocks in the region accompanied the uplift movements which have led to the emersion of the Proto-Blue Mountains. Accordingly, the age of the intrusions may be plotted with the Maastrichtian-Early Tertiary range.

The Blue Mountain Formation

This formation, clearly defined by the underlying Rio Grande Limestone (= Bath Limestone) and the overlying Chepstow Limestone, comprises a number of lithological units which may have been deposited on an emerging central/northern area, whereas sedimentation in the southeast shows a consistent deeper water environment of deposition.

In the central/northern part, the succession starts with argillaceous, silty to sandy layers, the basal part often conglomeratic with many fairly rounded fragments of Rio Grande Limestone (granules and pebbles). The series suggests a deeper-water environment or at least more off-shore conditions. More shallow conditions, however, may have prevailed during deposition of the succeeding volcaniclastic conglomerates, breccias and boulder beds which represent a major portion of the Blue Mountain Formation in the high interior and the northern slopes.

Intercalated lavas with pillow structures have been reported from the Port Antonio area, but a very conspicuous volcanic phase is represented by a unit of compact basaltic-andesitic porphyries along the road to the Bonny View Hotel in Port Antonio, the Bonny View Andesite. Possible equivalents of this porphyry have also been found in the Johns Hall and Bellevue area, and they may indicate a nearby submarine volcanic eruption centre.

Overlying volcanic debris deposits grade rapidly into finer-grained tuffaceous sandstones which underly the Chepstow Limestone, and conclude the Blue Mountain Formation in the north.

In the southern section, in the Bowden Pen-Bath area, the supposedly deeper-water Bath Limestone is succeeded by a mainly argillaceous sequence of the Cross Pass Shale Member which suggests that deeper-water conditions may have persisted. Certain slump conglomeratic levels within the succession with fragments of porphyries, metasediments, Rio Grande Limestone and radiolaria chert and in the matrix reworked *P. ?rutteni rutteni* and *Globotruncana* sp. may imply that some minor uplift movements or tremors occurred as a prelude to the major uplift phase which caused the thick unit of slump conglomerates of the Bowden Pen Member, ill-sorted conglomerates with sub-rounded to rounded fragments of andesitic porphyries, quartz, Rio Grande Limestone (with *Orbitoides* and *Pseudorbitoides*) and Back Rio Grande Limestone (with exclusively *P. trechmanni trechmanni).*

It has been suggested that in the Early Eocene (age based on the presence of nummulitids in the matrix of the Bowden Pen conglomerate), quite an important area must have emerged, rising above sea level up to a high mountain range referred to as the Proto-Blue Mountains. However, the magnitude of the uplift movements should be carefully considered. The presence of conglomerates like the Bowden Pen conglomerate may not show such large scale uplifts. It seems that a major part of the Richmond Formation originally covered the entire Blue Mountain area, so that uplift movements causing emergence must have been followed by rapid downward movements.

The shallow conditions which may have persisted in the northern part of the inlier throughout the Campanian-Maastrichtian-Early Eocene, changed to extremely shallow conditions in the Early Eocene (?Palaeocene) during the deposition of the Chepstow Limestone. This limestone is very fossiliferous with miliolids, algae, gastropods, bivalves, layers with echinoids near the base, larger foraminifera of the family Nummulitidae (*?Ranicothalia*) in pockets, and fragments of coral colonies embedded in compact hard bioclastic layers near the top.

The succeeding argillaceous Richmond Formation appears to be transgressive over the Chepstow Limestone, with a basal conglomerate as seen along the road from Chepstow to Claverty Cottage, and with conglomeratic intervals in the lower part of the succession exposed along the road from Port Antonio to Alligator Church. The majority of the succession, however, consists of fine-grained shales and siltstones with occasional layers with gastropods and bivalves. Along bedding planes carbonized plant remains are frequently visible and at certain localities, in the Mabess River valley and east of Alligator Church along the banks of the Negro River fragments of carbonized and silicified tree trunks have been collected.

Considering the major part of the Richmond Formation as well as the succeeding White Limestone Formation as holomarine deposits, a continuous downward movement of the crust has to be assumed during Eocene, Oligocene and Early Miocene times.

The most important uplift causing the present configuration of Jamaica has been dated as Miocene, with an estimated throw of 5-10 km along the Blue Mountain Garden Fault.

STRUCTURAL GEOLOGY AND GEOTECTONIC IMPLICATIONS

A striking structural feature in the Blue Mountain massif is the occurrence of a complex fault pattern, in almost all cases with vertical to nearvertical fault dips, along which mainly vertical movements must have taken place.

Major faults include the Blue Mountain-Plantain Garden Fault, the Rio Grande Fault and the Back Rio Grande Fault, the latter is a conspicuous fault running immediately west of the Back Rio Grande, in NNE-SSW direction. Most of the smaller faults are step-faults with the downthrown unit north or north-east of the faults which show throws ranging from a

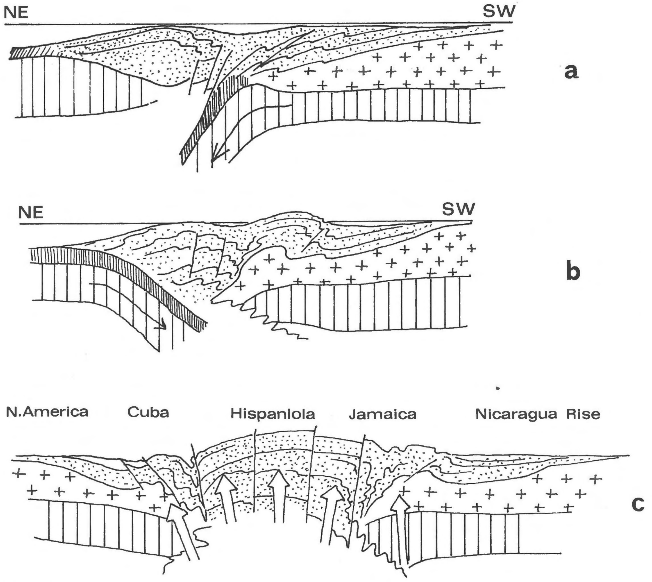

Fig. 4
Proposed stages in the development of the northern Caribbean Plate.
a: during Cretaceous times.
b: at the end of the Cretaceous or in the Early Tertiary.
c: in Late Cenozoic times.

couple to several hundred meters or more.

As can be seen from the provisional geological map of the inlier (Figs. 2, 3) there are numerous smaller and larger fault-blocks, some elevated into horst-structures, others down-faulted into grabens. The Macungo Hill area displays a good example of a horst-structure, which, consisting mainly of andesites (considered to be the lateral equivalent of the Bellevue Porphyry Member) and granodiorite/tonalite of the Johnson's River/Macungo Hill stock, is fault-bounded to the SW, N and E against younger shales and conglomerates (of the Blue Mountain Formation).

The general dips of the beds within each fault-block are to the north or north-east, but the Rio Grande Limestone out-crops near Alligator Church show SW to S dips, revealing the presence of a faulted anticline. The horst and graben pattern may be initiated by a compressional phase which caused a general structural pattern of wide anticlines and synclines.

In the SW rim zone of the Blue Mountain massif, the structural interpretation is far less obvious due to the presence of several narrow fault-bounded zones of the low-grade metamorphic Mount Hibernia Schists (containing the blue amphibole crossite, and stilpnomelane), the higher-grade metamorphic Westphalia Schists (epidote-amphi-bolite), granodiorite, relatively unmetamorphosed basaltic and andesitic porphyries and sediments, and lenses of serpentinized ultramafic rocks (see KEMP, 1971; DRAPER ET AL., 1976). Mainly based on the occurrence of crossite and stilpnomelane in the Mount Hibernia Schists, which are supposed to have been metamorphozed under high pressure (P) and low temperature (T), DRAPER ET AL. (1976) suggested that a SW dipping Cretaceous subduction existed along the Blue Mountain-Plantain Garden Fault zone, with contemporaneous blueschist metamorphism having affected a pre-Campanian rock sequence. Alternatively, a possible correlation of the Serge Island Marble (interbedded in the Mount Hibernia Schists) with the Maastrichtian Rio Grande and Bath Limestones: a remarkable similarity between Serge Island Marble and Bath Limestone, and the possible occurrence of orbitoid foraminifera in strongly recrystallized limestone equivalents of the Serge Island Marble, may support the hypothesis of an original Maastrichtian age of the Mount Hibernia Schist complex (cf. DRAPER, 1977). A detailed study of the schist complex and the Serge Island Marble still needs to be carried out in order to obtain conclusive evidence. If this hypothesis is verified, a Maas-trichtian to Early Eocene age for the blueschist meta-morphism is possible, and would fit the stratigraphical deduc-tions which point to an uplift movement at the end of the Cretaceous or during Early Eocene times (as concluded from the Bowden Pen Conglomerates).

It has to be stressed that the tectonic model presented below is still provisional and not yet complete. The tectonic model is based on field evidence encountered in Jamaica. From the geological map of the Blue Mountain inlier, the following geological events can be deduced:

(1) Period of sedimentation on an unstable, generally slowly sinking seafloor during Campanian to Late Maastrichtian or Early Tertiary times.

(2) Period of compression, concluded after the occurrence of wide anticlines and synclines. Estimated age: Late Maas-trichtian or Early Tertiary. The Bowden Pen Conglomerates are considered to be the result of this tectonic phase which must have included uplift movements.

(3) Period of tension, with block-faulting and resuming sedimentation on a generally sinking seafloor, during Late Maastrichtian or Early Tertiary to Late Cenozoic (Miocene) times.

(4) Period of general uplift of the whole region, with block-faulting, during Late Cenozoic times (Alpine orogeny).

The succession of geotectonic events suggested below is based on ideas proposed by MATTSON (1977) regarding the evolution of crustal movements at the northern margin of the Caribbean Plate. However, field evidence from Jamaica may point to a less complicated geotectonic history and to a younger age of various events than suggested by Mattson. Based on the conclusions (1) - (4), the following stages in the development of the northern Caribbean Plate may be taken into consideration:

(1) Development of an island arc succession of sediments and andesitic volcanics, caused by the NE dipping subduction of the Caribbean Plate under the Atlantic Plate during

Cretaceous times, with an approaching continent from the south (Fig. 4a). (The Jamaican Cornwall-Middlesex Block is considered to be part of the approaching continent, later separated from it by transform movements.)

(2) Collision of the continental margin (Cornwall-Middlesex Block) against the island arc and choking of the NE subduction, immediately followed by isostatic uplift, in Late Maastrichtian-Early Tertiary. Emersion of the Proto-Greater Antillean belt (in Jamaica: the Proto-Blue Mountains). Intrusion of plutons.

(3) Generation of SW dipping subduction of the Atlantic Plate under the Caribbean Plate, with resuming downward movement of the crust and renewed sedimentation, during Early Tertiary to Late Cenozoic times. North American continental crust approaching the region from the north. See Fig. 4b.

(4) Collision of the North American continent against the Proto-Greater Antillean belt, or disarrangement of SW dipping subduction mechanism, termination of subduction movement and immediate isostatic uplift into the Greater Antillean belt; age: Late Cenozoic (Miocene). See Fig. 4c.

(5) Breaking up of the Greater Antillean belt by block-faulting and transform-movements from Late Cenozoic onwards, with subsequent fanning out of the various tectonic units (now the islands of the Greater Antilles) into their present position.

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