Chapter 2

SYNOPSIS OF THE GEOLOGY OF JAMAICA

Location

Jamaica is located in the northwestern Caribbean Sea and is centered on latitude 18° 15' N and longitude 77° 20' W. It is the third largest of the Greater Antillean islands and lies along a WNW-ESE alignment within the 200 km-wide, seismically active plate boundary between the North American and Caribbean plates (McCann and Pennington, 1990; Mann et al., 1990; Fig. 2.1). The island is approximately 130 km long and 80 km wide, with a total area of 10,991 km^2 (Town Planning, Jamaica, 1971). This area includes 9,600 km^2 of offshore banks and shoals. Jamaica is an emergent part of the eastern extremity of the Nicaraguan Rise (Wadge et al., 1984), and is separated from the North American Plate by the Cayman Trough (Lewis and Draper 1990).

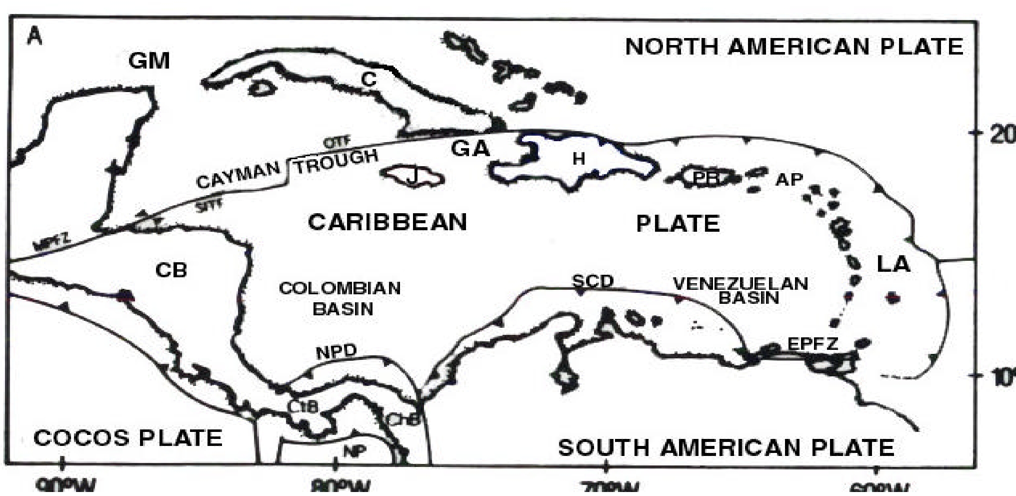

Figure 2.1. Location of Jamaica (J); Cuba (C); Haiti (H); Puerto Rico (PR); Anegada Passage (AP), Chortis Block (CB), Choco Block (ChB), Chorotega Block (CtB), El Pilar Fault Zone (EPFZ), Greater Antilles Orogenic Belt (GA), Gulf of Mexico (GM), Lesser Antilles (LA), Motagua-Polochic Fault Zone (MPFZ), Nazca Plate (NP), North Panama Deformed Belt (NPDB), South Caribbean Deformed Belt (SCD), (after Mann, 1990).

Geologic History of Jamaica

Jamaica has a complex geologic history during which morphotectonic processes of faulting and volcanism controlled sedimentation. Sedimentation was predominant from the late Cretaceous to the Tertiary seaward progression of a carbonate platform. The island evolved as a Cretaceous island-arc located at the convergent boundary between the North American and Caribbean plates. Horsefield and Roobol (1974) proposed a tectonic model for the geologic evolution of Jamaica and identified the following stages of development (Figure 2.2):

a. A Mesozoic island-arc trench,
b. A Maastrichtian subaerial arc and basin,
c. An Eocene mountain range with flysch and a keratophhyre-filled (alkali-rich igneous rocks with a volcanic texture) trough,
d. A Mid-Cenozoic submerged platform,
e. A Late Cenozoic uplifted, fault block.

The Cretaceous basement is divisible into three regions that have been interpreted as representing: 1) a complexly faulted subduction zone and a back-arc basin; 2) a central volcanic arc; and 3) an eastern fore-arc basin. Divergence along the volcanic arc led to the creation of an inter-arc basin, the Wagwater Belt (Jackson and Smith, 1979). Active submarine and subaerial volcanism occurred in a central volcanic arc, the Wagwater Belt, which separates the Blue Mountain and Clarendon blocks (Figure 2.3). The Clarendon

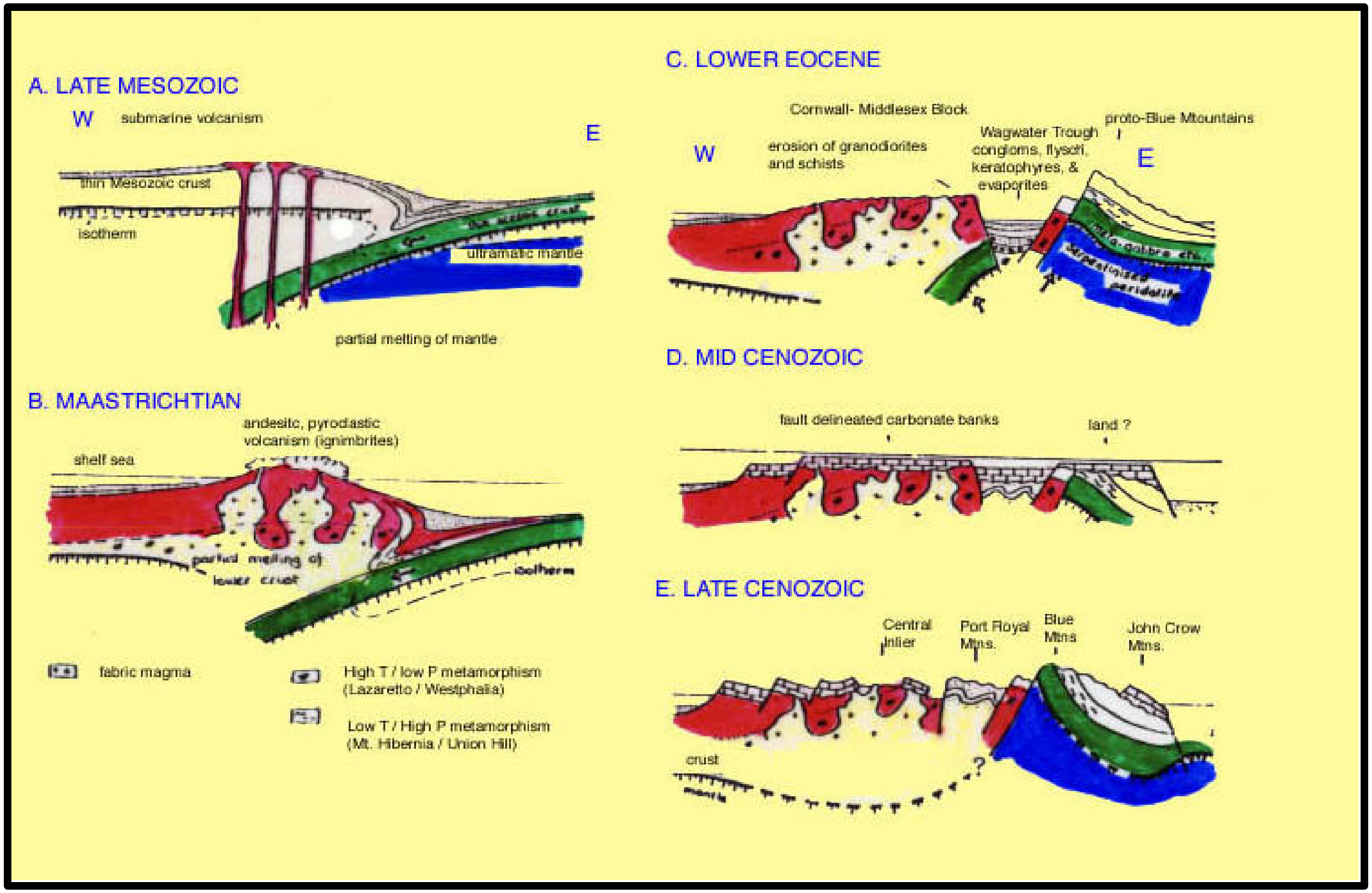

Figure 2.2 Sketched sections through Jamaica at various stages of the island's evolution (from Horsefield and Roobol, 1974).

and the Blue Mountain blocks represent the back-arc and the fore-arc basins (Donovan and Jackson, 1994).

Versey (1957) described the division of morphotectonic units by introducing the concept of "Blocks" and "Belts." These structures were superimposed on the island by extensional tectonics (Donovan, 1993). Jamaica's structure is divided into six morphotectonic units composed of three main structural blocks, separated by two northwest-trending graben structures (belts), and a third belt bordering the eastern side of the Blue Mountains (Fig 2.3). From west to east, these features are referred to as he Hanover Block, the Montpelier-New Market Belt, the Clarendon Block, the Wagwater Belt, the Blue Mountain Block, and the John Crow Mountains Belt (Fig 2.3). The blocks consist mainly of Cretaceous volcanic, and volcanically-derived clastic sedimentary rocks with some minor limestones and granitoid intrusive rocks capped by Tertiary limestones. Larger faults define the boundaries of morphotectonic units.

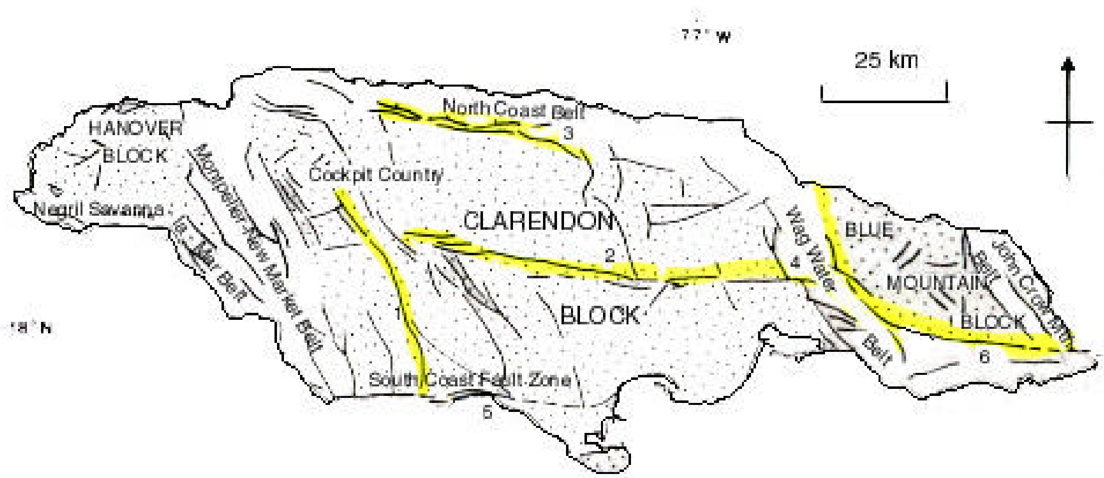

Figure 2.3 Simplified structural map of fault traces of Jamaica (modified after Draper, 1987). *Stippled areas* are blocks, *unornamented areas* are belts. Numbered fault systems are:1=Spur Tree; 2.=Crawle River; 3=Duanvale; 4=Wagwater; 5= South Coast; and 6=Plantain Garden.

Island-Arc Volcanism

In the early Cretaceous the western third of the island was a back-arc basin, the central section was a volcanic arc, and the eastern third was undergoing subduction-related sedimentation and metamorphism. Volcanic centers were concentrated on the southern and eastern parts of the Clarendon Block where volcanism continued until the Campanian (85my). In the late Cretaceous, the volcanic arc moved 30 km further east.

The Blue Mountain and Clarendon blocks represented the new back-arc and the fore-arc basins separated by a central volcanic arc, the Wagwater Belt. Jackson and Smith (1979) analyzed the thoeliitic composition of the basaltic rocks (plateau-type) and confirmed that the Wagwater Belt represented the central arc of the volcanic system. They suggested that the basalts were erupted from a chain of volcanoes forming the rear edge the fore-arc basin. Jackson and Smith (1979) further analyzed the basaltic compositon using the model of thesis (1970) to determine the stage of inter-arc basin development reached by the Wagwater Belt. They concluded that Jamaica's island-arc system (plateau-type thoeliite) may not have attained the stage of development seen in present day inter-arc basins of the western Pacific (oceanic thoeliites). Donelly and Rodgers (1973) interpreted the petrogenesis in order to understand the tectonic history of the Caribbean during the Jurassic and early Cretaceous. They classified the volcanic rocks of Jamaica as a primitive island-arc igneous rock series (PIA). These volcanic rocks differ from the calc-alkaline (CA) island-arc igneous suites located around the Pacific margin. Volcanism in Jamaica ceased by the early Eocene time and was succeeded by carbonate deposition.

STRATIGRAPHY

The oldest rocks in Jamaica outcrop in the eastern Clarendon Block, the fore-arc basin, and consist of volcanic lava and mudflows that erupted in a subaerial to shallow nearshore environment. The rock types of the Clarendon Block include andesite volcanic suites, granite plutons suites, derivative graywacke and arkose sedimentary suites, and alpino-type gabbro suites. This igneous/sedimentary combination of rocks is characteristic of mobile belts where repeated crustal deformation and metamorphism have occurred (e.g. the circum Pacific region [Dickenson, 1970]). Cenozoic carbonate rocks overly this late Cretaceous (Albian to Maastrichtian) basement of volcanic, volcanoclastic, and plutonic rocks. These igneous rocks are capped by three cycles of sedimentary rocks 1) Paleocene clastic rocks, 2) Tertiary carbonate rocks, and 3) Late Tertiary to Quaternary partial carbonates intercalated with clastic sequences (Woodley and Robinson, 1977). Carbonate sedimentation (Table 3) includes: 1) shallow island-shelf facies of the Brown's Town Formation, 2) pelagic chalky facies of the island slope (Montpelier Formation), and 3) tectonically unstable island-arc deposits mixed with carbonates in the Guinea Corn Formation. Alluvium is confined to interior valleys, river floodplains, and the coastal margins.

Clarendon Block

Extensive upland areas with rugged karst terrain and numerous faults characterize the Clarendon Block. Pre-Barremian to Maastrichtian rocks is exposed in the two Cretaceous inliers on this block namely: 1) the Benbow Inlier and 2) the Central Inlier

Table 3. The formations of the White Limestone Group present in the Rio Cobre and Rio Minho-Milk basins (adapted from Liddell, 1984).

GROUP	SHALLOW WATER FACIES	DEEP WATER FACIES	AGE
	Newport Formation	Montpelier Formation	LOWER MIDDLE MIOCENE
WHITE LIMESTONE	Brown’s Town / Walderston Formations	Bonny Gate Formation	UPPER OLIGOCENE
	Somerset Formation Swanswick Formation Troy/Claremont Formations		UPPER EOCENE

as well as areas outside it. The Benbow Inlier contains the oldest paleontologically-dated rocks on the island which are composed of sequences of volcanic flows, volcanogenic conglomerate, sandstone, shale, and rudist limestone that extend from the Lower (pre-Barremian) to Upper Cretaceous (Turonian) (Donovan and Jackson, 1993). The Cretaceous rocks of the Central Inlier form a west-east trending anticlinal structure cut by sinistral wrench faults (e.g. Crawle River fault system). These exposed sequences range from Santonian or older, to Paleocene and are unconformably overlain by Tertiary age transitional to shallow marine clastic and carbonate sequences. The youngest rocks are formed from unconsolidated sediments of Holocene age. The Rio Cobre and Rio Minho-Milk river basins are situated on the Clarendon Block. The following is a discussion of the igneous and sedimentary depositional patterns of the Clarendon Block The geological history is complex, and described in detail by Donovan and Jackson (1994), Donovan (1993) and Chubb et al. (1962).

A Late Cretaceous marine transgression developed extensive carbonate platforms and patch reefs on the shelves surrounding the volcanic islands of the island-arc situated within the Clarendon Block. Diverse species of rudist bivalves were the major contributors of these reefs (Coates, 1977; Heckel, 1974).

Tertiary deposition in the Wagwater Belt consists of a Paleogene to Middle hornblende-andesite, pyroclastic flows, basalts, dacites greywackes, red conglomerates, and arkosic sediments of the Wagwater Formation with intercalated pyroclastic flows, hornblend andesite and basaltic flows. The turbidites of the Richmond Formation conformably overlie the Wagwater Formation. Minor amounts of evaporite and limestone also occur in this area. The emergence of the Clarendon Block triggered the erosion of andesite flows and granites, and the subsequent depositon of volcanogenic sediments, conglomerate, and arkosic detritus in the Wagwater Belt.

A Lower Eocene transgression generated by random 10,000 year high-frequency, climatically driven cycles resulted in the exclusively calcareous deposits of several parasequences of the Yellow Limestone Group over a broad shelf on the Clarendon Block. These parasequences were intercalated with layers of medium to fine-grained quartz sandstone with minor evaporite and lignitic horizons (Guy's Hill Formation) and grade upwards into increased carbonate-rich units with intraparticulate silt and clay of the Chapleton Formation (Figure 2.4).

The Eocene-Mid-Miocene White Limestone Group succeeded the Yellow Limestone Group when sea-level rise increased accommodation on the shelf allowing the progressive onlap of a series of late highstand systems on the Clarendon Block. These systems formed a complex bank (formed below wave base) of purely carbonate depositional sequences. Tectonically-enhanced White Limestone deposition thickened to the south across the Clarendon Block as a result of: 1) southward rotational tilting of the block, 2) faulting, and 3) the emergence of the northern margin. The growth and development of back reefs over the central Clarendon Block promoted the formation of shallow lagoon facies of predominantly micritic deposition surrounded by a western,

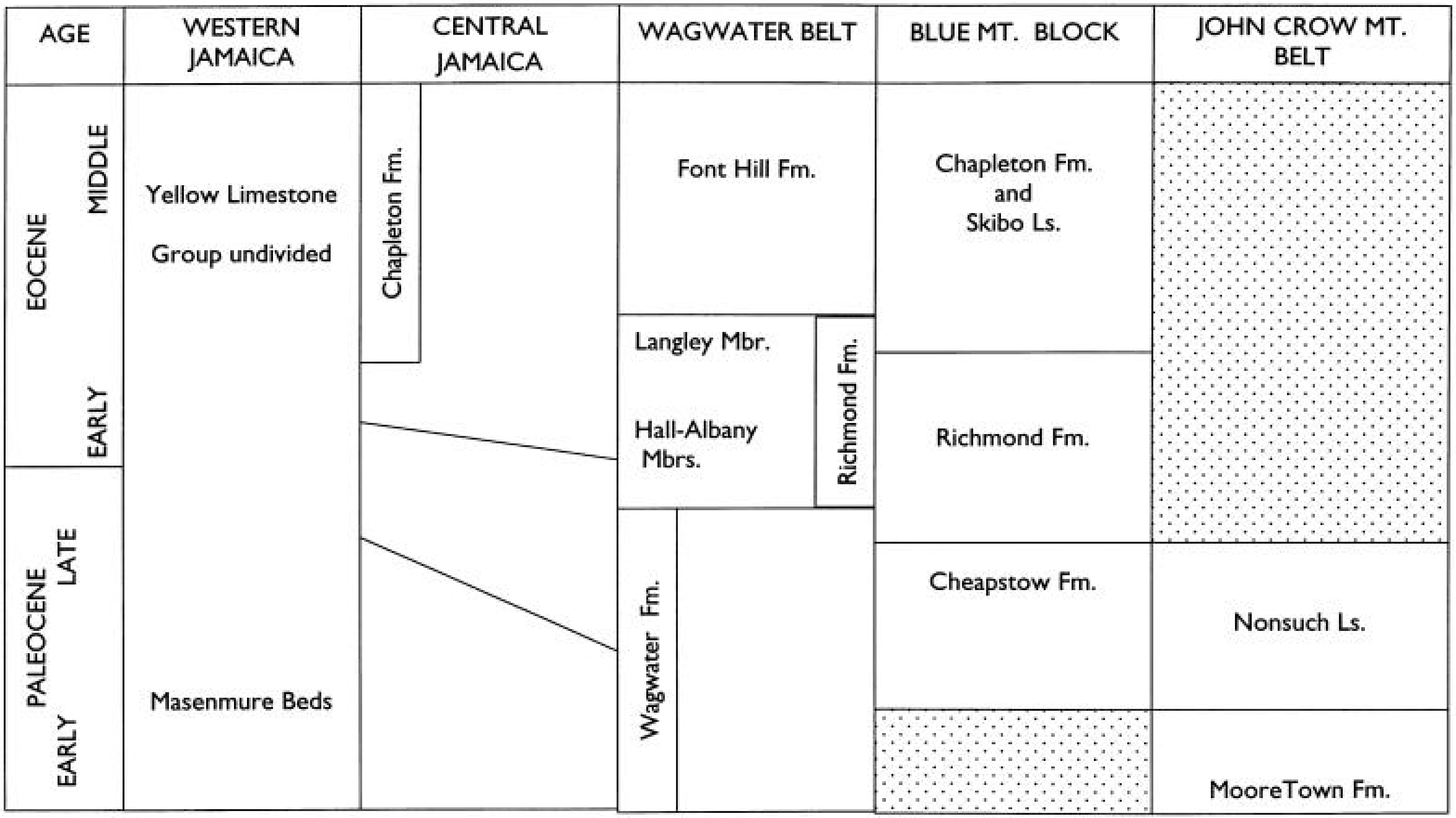

Figure 2.4 Correlation of lower Tertiary lithostratigraphic units in Jamaica (Adapted from Donovan and Jackson, 1994).

northern, and eastern periphery of high-energy calcarenites and patch reefs (Liddell, 1980). The pelagic, chalky facies were concentrated on this eastern periphery (figure 2.5). Small, isolated patch reefs grew locally in the back reef lagoons of isolated reef complexes. Shallow restricted marine deposition persisted along the coastal areas of the island from the Miocene to Pleistocene.

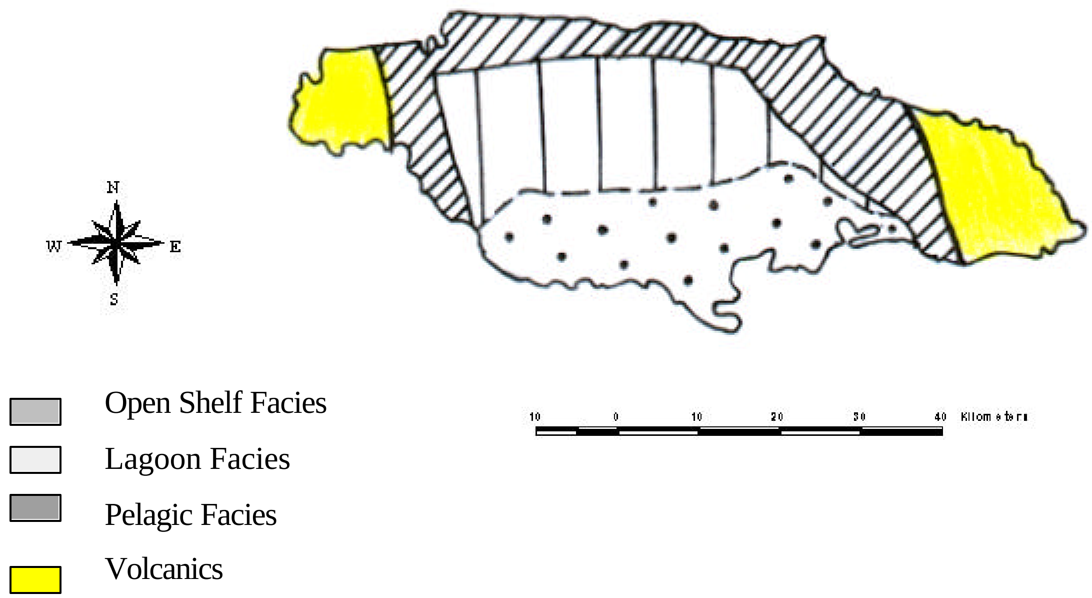

Figure 2.5 Map of carbonate facies deposition during the Tertiary of Jamaica (Adapted from Liddell, 1980).

Jamaica's hydro-isostatic response to episodes of sea level rise during Pleistocene deglaciation impacted the evolution of carbonate deposition (MacIntyre and Neuman, 1985). Pre-Pleistocene carbonate platforms (build-ups) were succeeded by the proliferation of modern fringing reefs and reef terraces (Cant, 1973).

During the Holocene transgression, reef development on the Clarendon Block consisted of scattered patch reefs on the broad shelf, with isolated fringing reefs in some areas (Woodley and Robinson, 1977). Extensive alluvium deposits of Recent age are located on the southern margin of the island.

STRUCTURE

Faults

Since the mid-Miocene, Jamaica has been affected by transcurrent deformation related to sinistral shear on the North Caribbean Plate boundary, and the formation of a restraining bend through the eastern side of the island. This has impacted the geometry of fault trends on the island. Two main sets of onshore faults define the morphotectonic features of Jamaica: 1) an east-west set from which sinistral strike-slip offsets have been measured or inferred, and 2) an intersecting NNW-SSE trending set that is evident over the karst highlands of central Jamaica. The structure of Jamaica is characterized by numerous faults that have undergone displacement since deposition of the Mid-Tertiary White Limestone (Figure 2.6). The rose diagram in Figure 2.7 illustrates the two major strikes; the dominant set is about 155°, while the subordinate set is oriented about 95°. Few faults strike in a NE-SW direction.

Faults and joints control the orientations of karst features and drainage patterns in the Rio Cobre and Rio Minho-Milk river basins. Faults dissecting the Rio Cobre and Rio Minho-Milk river basins are also oriented NNW-SSE and E-W. The three major faults of the Rio Cobre and Rio Minho-Milk river basins are the Crawle River-Rio Minho fault, the South Coast fault, and the Spur Tree fault (Fig 2.8). The South Coast and Crawle River-Rio Minho faults are transcurrent faults, whereas Spur Tree fault is a reverse fault.

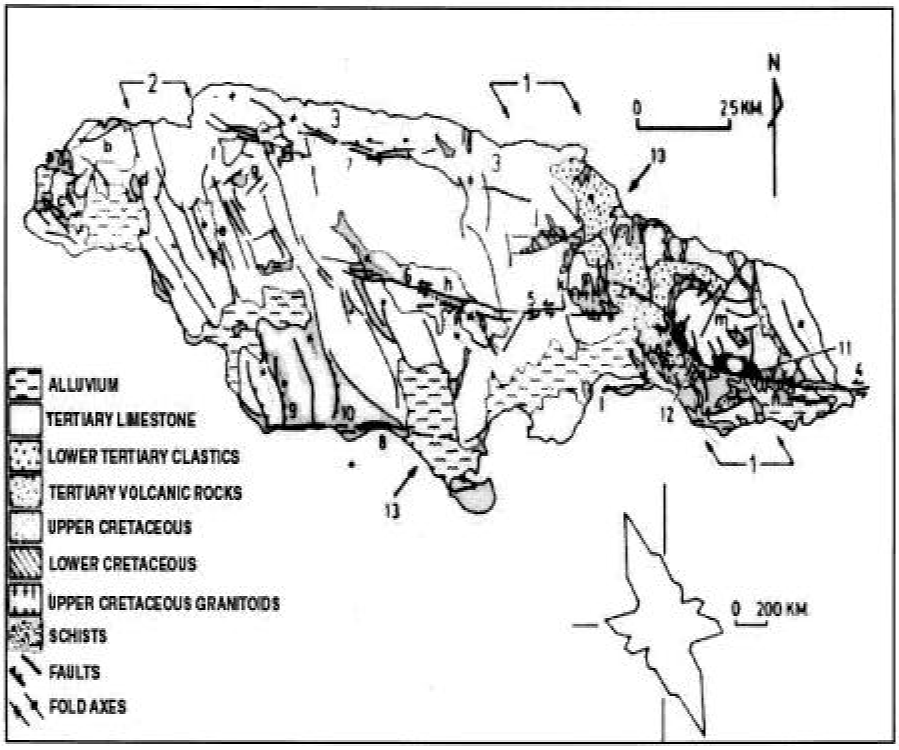

Figure 2.6 Simplified tectonic map of Jamaica showing the major structural features and tectonically important units (after Draper, 1987). Insert shows the rose diagram of fault traces in the map of MacFarlane (1977). Specific features indicated are: 1. Wag Water belt, 2. Newmarket-Montpelier zone, 3. North Coast belt, 4. Plantain Garden fault, 5. Cavalier's fault, 6. Crawle River - Rio Minho fault, 7. Duanvale fault zone, 8. South Coast fault zone, 9. Santa Cruz fault, 10. Spur Tree fault, 11. Bath - Dunrobin ophiolite, 12. Artnully serpentine, 13. Annotto vere Lineament (Wadge and Dixon, 1984). The major Cretaceous inliers are : (a) green island, (b) Lucea (Hanover), (c) Jerusalem Mt., (d) Grange, (e) Marchmont, , (f) Sunderland (g) Maldon and Carlton Hill, (h) Central, (I) St. Ann, (j) Benbow, (k) Above Rocks, (l) Lazaretto - Green Bay, (m) Blue Mountain, and (n) Sunning Hill.

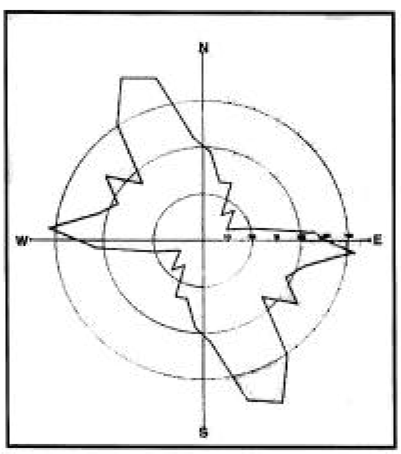

Figure 2.7 Rose diagram of orientation of faults in Jamaica, plotted from Geological Survey Map, 1958

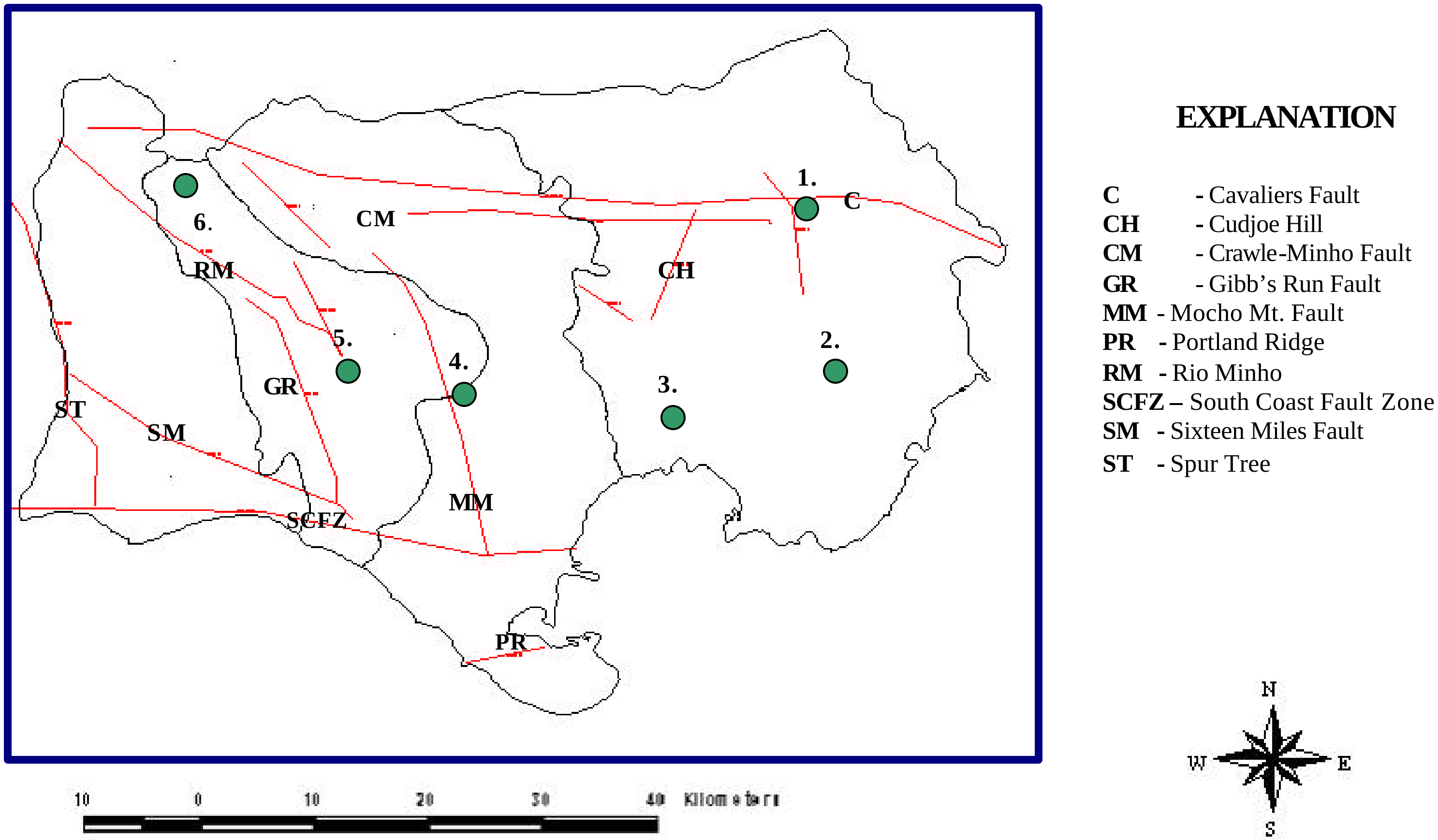

Figure 2.8 Map of faults located in the Rio Cobre and Rio Minho-Milk river basins. 1- Bog Walk, 2 – Spanish Town, 3 – Old Harbor, 4 – May Pen, 5 – Mandeville, and 6 – Christiana-Spauldings.

Other smaller reverse faults include the Cavaliers fault in the Rio Cobre basin. During the late Pliocene, old faults became active again as a result of east-west trending left lateral shear occurring in a 200-km-wide zone on the northern Caribbean and E-W trending strike-slip faults developed along the south coast. East-west trending strike-slip faults postdate the Miocene NNW-SSE set. These fault systems have been active since the early Tertiary and probably had their genesis during the second phase of the Laramide Orogeny at the end of early Eocene times (Zans, 1962). Bouguer gravity gradients decrease rapidly along the southern section of the island, particularly across the South Coast fault (SCF), indicate a substantial thickening of the basement caused by structural downthrow along the fault (Horsefield, 1974).

Intrusive and Metamorphic Rocks

Igneous and metamorphic structures on the Clarendon Block are highly complex. Granitoid igneous activity (Kesler 1978; Fenton 1987) was responsible for emplacement of several plutons in the eastern half of Jamaica. The age of these plutons is estimated at between 60 - 65 $\pm$ 5 Ma (Chubb and Burke, 1963; Ahmad et al., 1987; Lennox, 1984; Lewis et al., 1973). Outcrops of Maastrichtian to middle Eocene age granodiorite occur in the Rio Cobre basin at Above Rocks and Ginger Ridge (Fig. 2.9a). The Yellow Limestone Group: 1) is exposed in the northeastern part of the Rio Cobre basin, 2) overlies partially metamorphosed rocks of the Mount Charles Formation, and 3) forms an impermeable barrier to ground-water flow (Fig. 2.10). The ignimbrite horizon of the Summerfield formation is located 500 m south of Johns Hall (18° 10.3’N, 77° 22.7’W) in

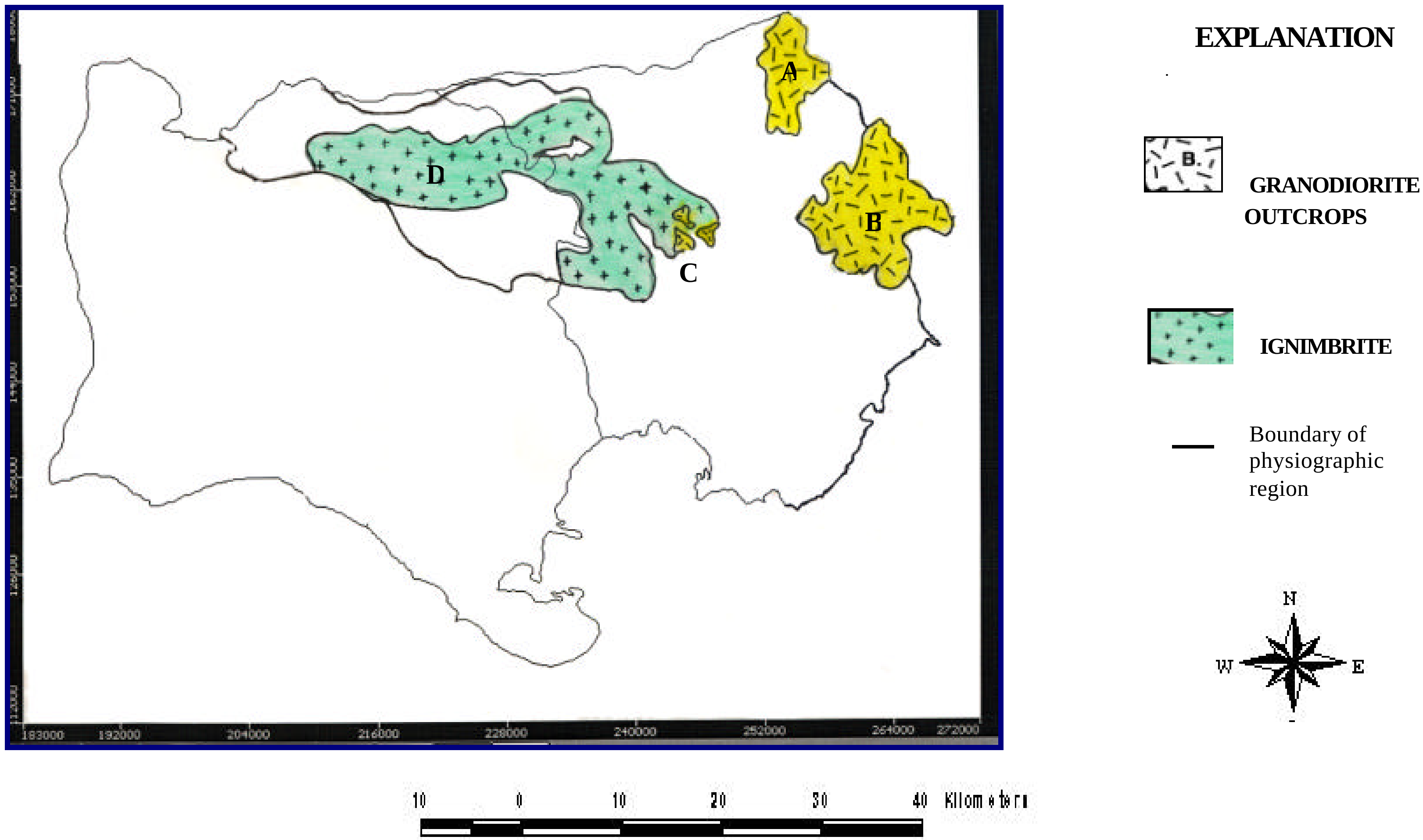

Figure 2.9a Granodiorite intrusions in Jamaica modified from Geological Survey 1:250,000 map.
(A – Flint River (Troja), B - Above Rocks (Zion Hill Bridge and Hall Green); C - Ginger Ridge (after Chubb and Burke, 1963); D – Summerfiield Formation (ahmad and Sharma, 1987).

the upper Rio Minho-Milk River basin (Ahmad and Sharma, 1987). This unit rests unconformably on the Guinea Corn Limestone (Figures 2.9b – 2.10). Fission track dating of the apatites from ignimbrite have yielded an age of 55.3±2.8 Ma (Ahmad and Sharma, 1987; Ypresian sensu Palmer, 1983).

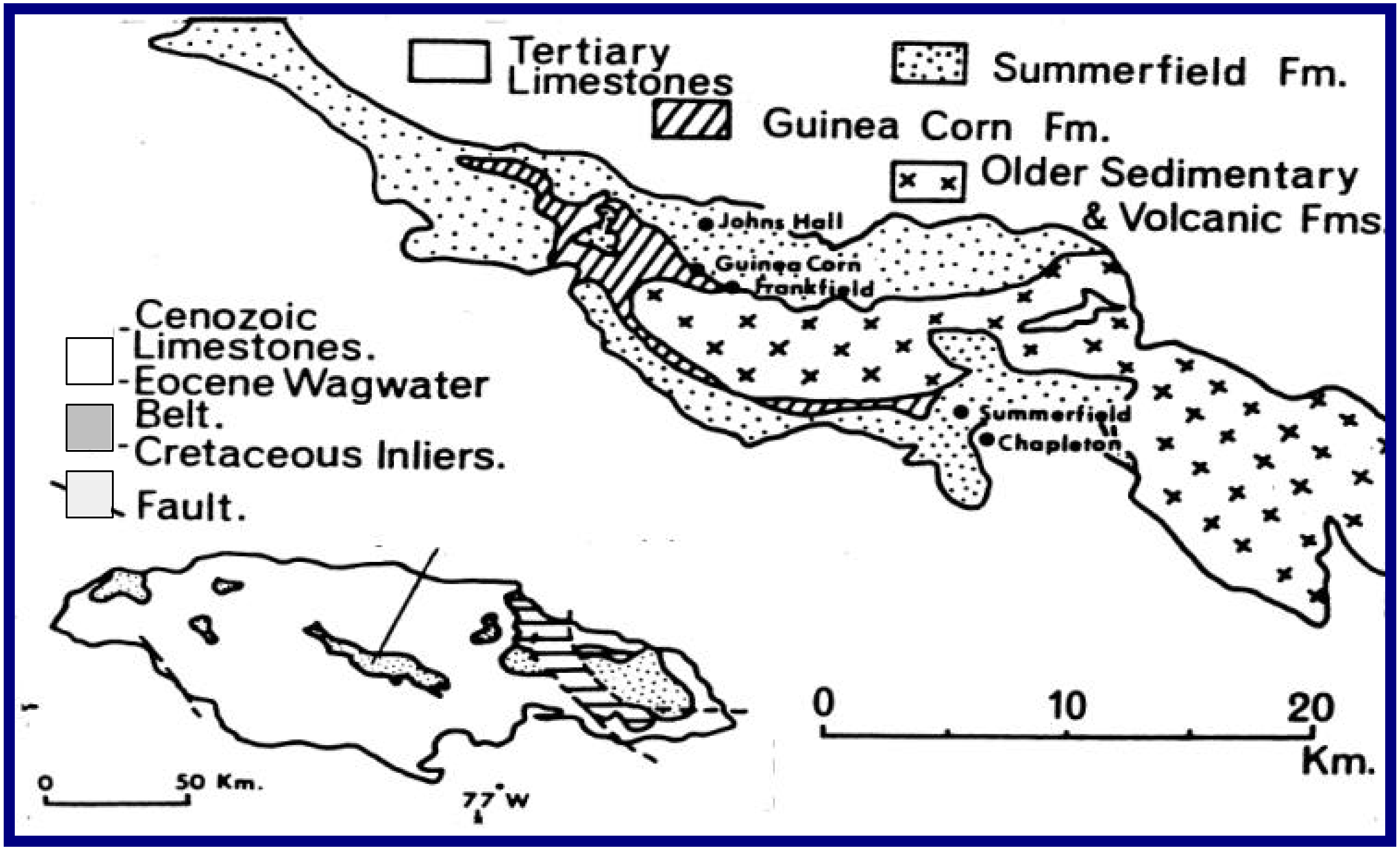

Figure 2.9b Simplified geological map of the part of Central Inlier, Jamaica (after Roobol, 1976).

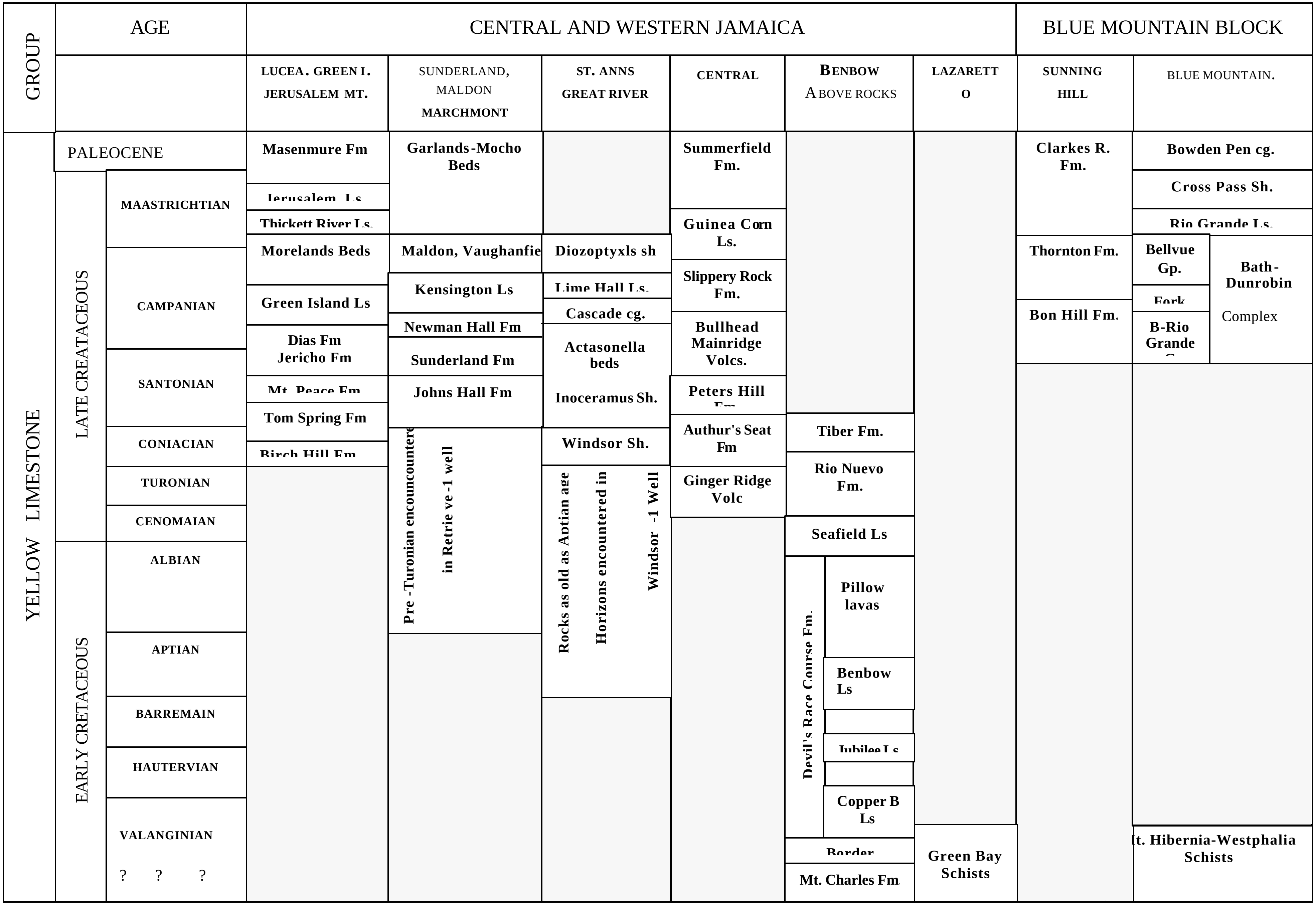

Figure 2.10 Correlation of Cretaceous to Lower Paleocene lithostratigraphic units of Jamaica (after Robinson, 1994).