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FIELD GUIDES

FIELD TRIP #3

A BAJAN POTPOURRI

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INTRODUCTION

This field trip covers the whole gamut of the Barbadian Geological experience. It will examine the biostratigraphy of the limestone terraces, and some aspects of the islands hydrogeology.

A visit to Harrisons Cave, one of the premiere tourist attractions on the island, will show some of the geology and hydrogeology of the older limestone terrace deposits.

This trip will examine the Chalky Mount area of the Scotland District, where we will discuss the geology of the tertiary turbidites of the eastern side of the island.

A visit to the Gays Cove area in the northeast of the island will examine the relationship between the Oceanic clays and the overlying limestone and the underlying Scotland turbidites.

The field trip will conclude by traveling along the western side of the island and having a broad overview of the west coast tourist area, including the Sandy Lane and Westmoreland Golf courses.

We will also see the spectacular view of the second High Cliff, along Highway 2a.

STOP 1

WOODBOURNE OILFIELD

The Woodbourne Oilfield is the main oil producing area in Barbados. It supports in excess of 280 oil wells about 90 flowing or pumping at one time. It occurs over 900 acres of plantation lands spanning the parishes of Christ Church and St. Philip in the south of the island.

The field was discovered in August, 1966, by the General Crude Oil Company who later sold their assets to Mobil Exploration Barbados Limited, who subsequently sold out to the present operators, the Barbados National Oil Company, in July, 1982.

Average daily production is currently about 1200 barrels, however it has reached as much 2 600 barrels per day. So far the field has produced over 9 million barrels of oil.

The BNOC occurs and operates its own drilling rig and service rigs, while such services as cementing, logging etc. are contracted out to international firms. The BNOC carries out the completion, maintenance and workover services.

The Reservoir Formations of the Woodbourne field are the extensively folded and thrust faulted beds of the Scotland Formation of early to middle Eocene age, and the overlying Intermediate Unit. These Reservoirs are capped by the relatively undeformed Oceanic marls and claystones and the Coral Formation.

The geology of this oilfield is complicated by the extensive deformation of the reservoir rocks which renders correlation of rocks or units almost impossible over most of the field. Structurally the area is envisaged as lying on the north dipping flank of a major basin or trough-like feature in the Scotland Formation which is further broken up into separate structural units or segments by north-east to south-west striking thrust faults. The Scotland Sands are interpreted as turbidite deposits of a deep sea fan, and the Intermediate Unit as redeposited sediments in the intra-slope basins of the accretionary prism.

The operations at Woodbourne, though small on a global or even a regional; scale go a long way to sustaining the economy of the island of Barbados and supplementing its fuel import bill, with self-sufficiency being the ultimate goal.

GENERAL GEOLOGY OF THE LIMESTONE CAP

The island of Barbados is situated atop the accretionary prism of the eastern Caribbean arc/trench system. This is a tectonic setting of general uplift. The island of Barbados has been experiencing subaerial tectonic emergence at variable rates (averaging about 30 cm per thousand years) for at least the past 700 000 years Interaction of this relatively slow uplift with relatively rapid and fall of Pleistocene sea level (figure 1.) has produced coral reef terraces representing the major high stands of Late Pleistocene sea level (Figure 2 and Table 1)

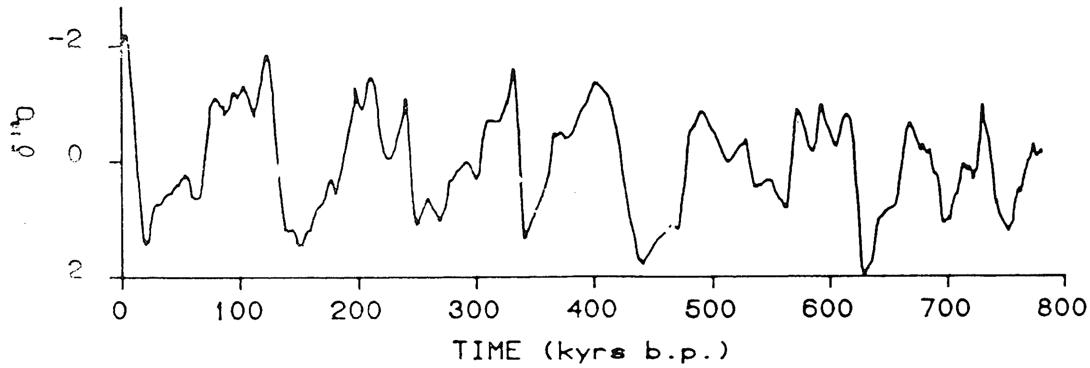


Figure 1. - Glacio-eustatic sea level curve for the last 700,000 years, as deduced from the deep sea oxygen isotope record. (After Prell et al., in

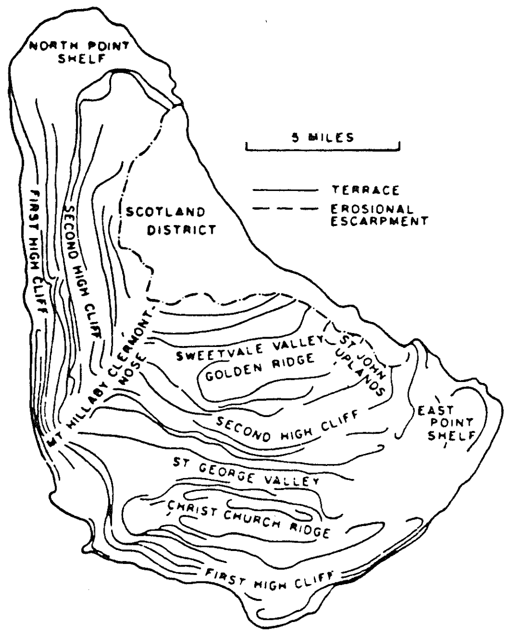


Figure 2. - Areal distribution of prominent Barbados reef terraces. Reef terraces grew during various high stands of the sea depicted in Figure 1. (After Mesolella et al., 1969).

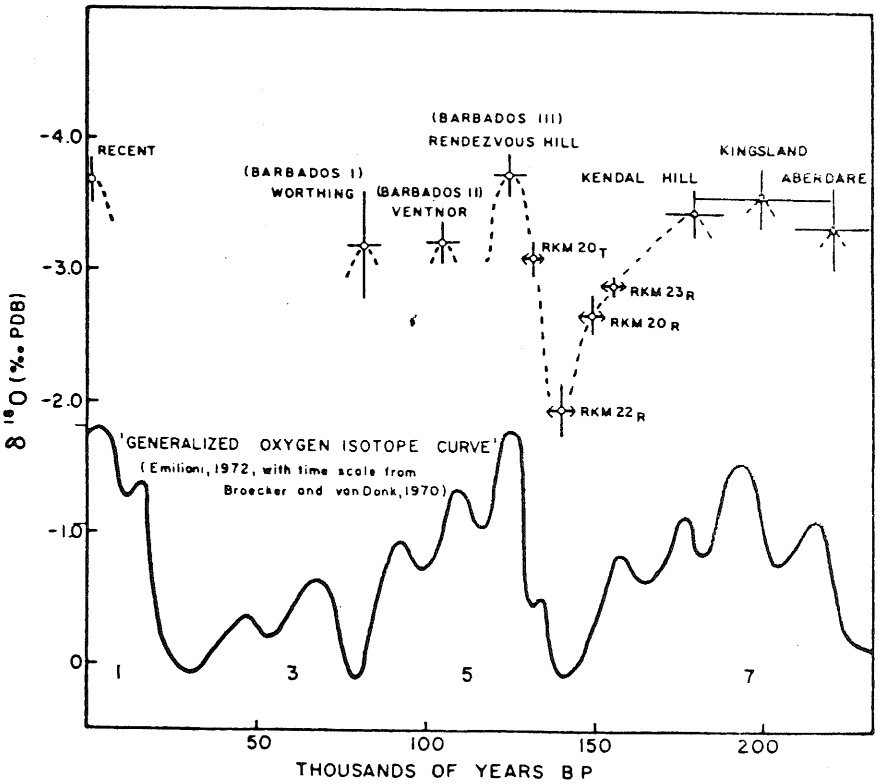


Figure 3. - Diagram indicating good relationship between Barbados coral isotope data and the deep sea oxygen isotope record for the last 250,000 years. (After Fairbanks and Matthews, 1978).

Correlation between the relatively young Barbados and the terraces and the deep sea isotope record has been established on the basis of physical stratigraphy and oxygen isotopic measurements on Barbados corals back to about 250 000 ybp (Figure #) (Fairbanks and Matthews, 1978). The precise relation of older terraces to particular Pleistocene high stands of the sea remains problematic (Bender et al., 1979)

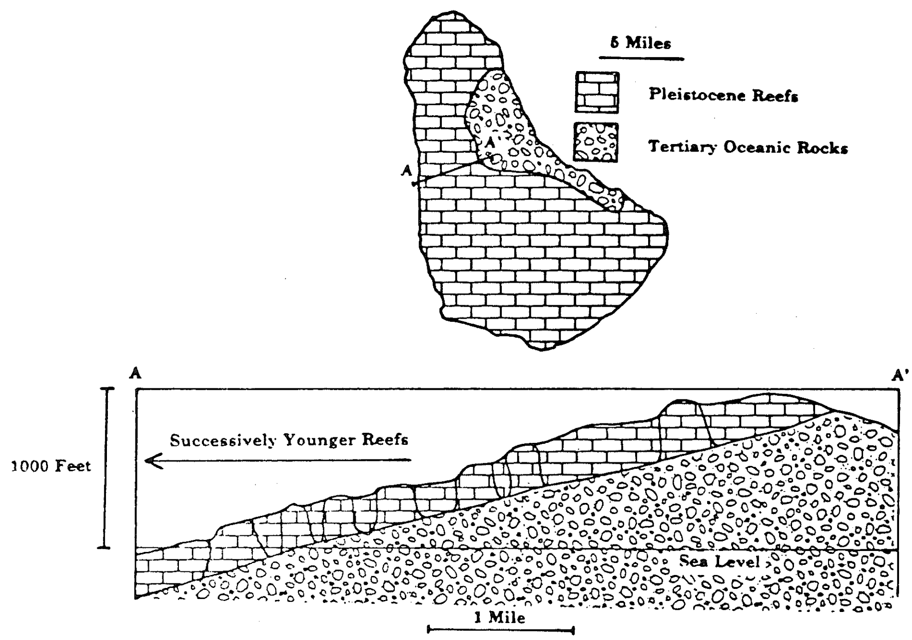


Figure 4. - Map and cross-section indicating relation of Barbados coral reef terraces to the underlying oceanic formation. Gradual uplift of the island places 700,000 year old reef tracts around 1,000 feet above sea level; successively younger high stands of the sea have placed successively younger reef tracts around the island.

Because of tectonic uplift, high stand terraces tend to be uplifted before the emplacement of the next younger terrace (Figure 4). In a more tectonically stable area, reef terraces resulting from these same sea level events would be stacked one upon the other at or below present sea level and thus accessible only by drill. Thus Barbados with its uplift history and with its numerous fine road cuts, provides an outstanding opportunity to study sedimentary facies and diagenesis in outcrop exposure

Figure 5 indicates the general scheme of facies geometry within a typical Barbados road cut. *A. palmata* reef crest facies holds up the terrace. Seaward of this is an *A. cervicornis* zone (sometimes replaced by *M. annularis* buttress zone). Still deeper than the *A. cervicornis* zone is the deep water head coral zone. Many roads do not reach sufficiently low into the fore reef to encounter the deepwater head coral zone.

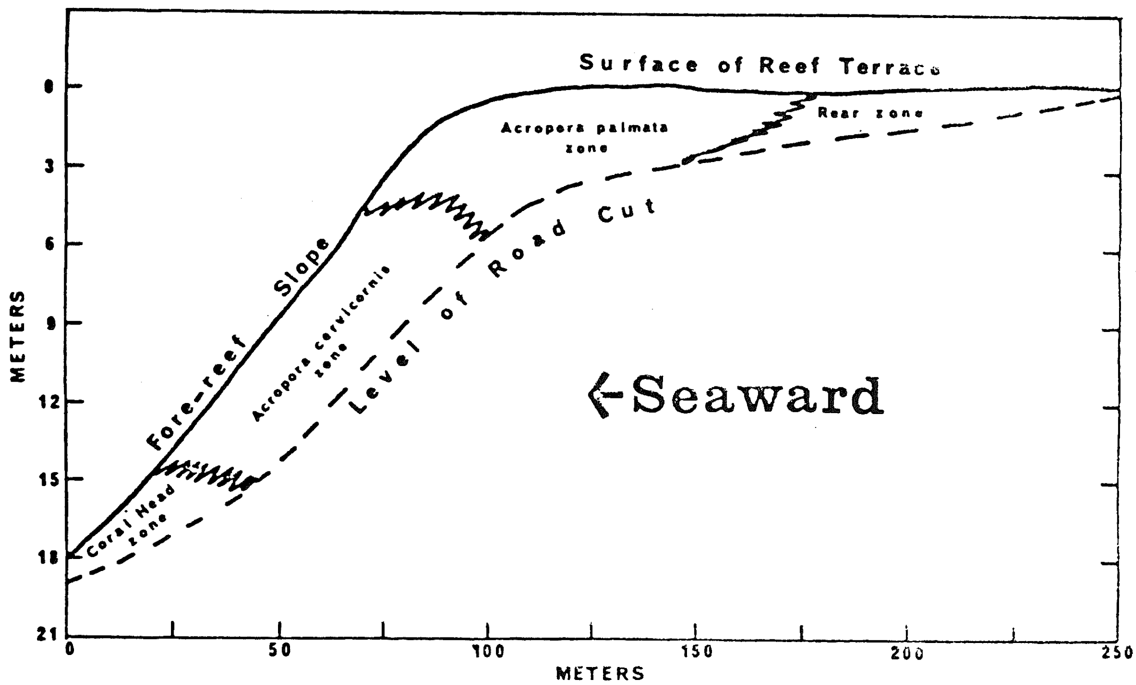


Figure 5. - Cross-section indicating average geometry of coral reef facies within Barbados terraces. (After Mesolella, 1967).

The limestones which have been developed from the Pleistocene reefs show considerable variation in lithology from coral bioherms to calcarenites and recrystallised micrites. The back and fore reef zones are largely composed of calcarenites while the reef crest zones are the biohermal limestones.

There is also some variation in hardness, which seems to be related to the amount of exposure they had to percolating groundwater as a result of being in a phreatic or vadose environment where considerable recrystallisation takes place.

Wave resistant structures comprising of in situ skeletons of frame building and sediment binding organisms – hermatypic corals and coralline algae- modified the depositional environment in these areas resulting in the formation of fore reef and back reef facies. Waves surging over these reef structures transported large quantities of sand sized material, back into the landward margins of the lagoon where it accumulated as shifting banks restricting the growth of coral and other organisms. The resulting back reef deposit is a very uniform calcarenite.

The fore reef deposits are composed of well washed medium to coarse grained cross stratified calcarenites. Compositionally, these calcarenites appear to be much the same as the clean calcarenites found in the back reef immediately behind the wave resistant features. However the cross stratification in the fore reef calcarenites is on a much more massive scale with high angle dips 20-35 degrees. Also the dips of the cross beds have a strong seaward component. Such sediments have been found in the proximity of what were once breaks or channels through the reef barriers. Transportation of back reef sands from directly behind the reef has taken place through the channels followed by deposition in the fore reef area as prograding deltas of calcarenite. This material is used as dimension stone in the building industry.

STOP 2

CHAPEL QUARRY

About ten major quarries were in existence in Barbados (see attached map) of these, four of them possessed good quality material for use in the limestone block industry. These are Ebworth- St. Peter, Hoytes- St. James, Mount- St. George and Chapel- St. Philip. The material in these quarries is well graded, good, soft quality and not with a great deal of cementation or recrystallisation which tend to make the rock too hard.

Chapel quarry has been in existence for a number of years and has produced various sizes of blocks for the construction industry. Two types of cutting machines have been used in the early operations at Chapel a vertical hand guided chain saw which produced the four sides of the block and a horizontal chain saw which produced the top and bottom faces of the block. These have now been superceded by a more modern rail guided machine which produces a more uniformly cut block. Coral blocks have been used in the construction of houses, ground sills, guard walls and decorative fronts for hotels. It has been found however that the limestone blocks have to be treated to prevent the growth of a fungus which discolours the rock after continued exposure to the atmosphere, and also to make them impermeable.

STOP 3

DAYRELLS REEF TRACT

Spectacular examples of coral complicated stratigraphy resulting from sea level fluctuations (320 KaBP).

This is a truly spectacular road cut through fore reef and reef flat facies. Work the road cut from the southwest 9fore reef) to northeast. Outcrop begins in a spectacular development of *M. annularis* buttress zone. In most places on Barbados, this immediate fore reef environment is occupied by *A. cervicornis*. Further up the outcrop, *A. palmata* reef crest facies is distinguishable and has interesting geometric relationships with other sedimentary facies. At other localities, a subaerial exposure surface is clearly recognised in the middle of Dayrells equivalent bank margin skeletal sand facies (locality UD, Videtich and Matthews 1980, for example). Can you locate a subaerial exposure surface within this road cut?

STOP 4

WATERFORD ROAD CUT

Road cut transecting A. *cervicornis* through subtidal lagoonal facies (194 KaBP).

Work the outcrop from southwest to northeast. Road cut begins in *A. cervicornis* facies which displays good examples of caliche crust development. *A. palmata* reef crest facies with encrusting red algae especially well exposed in this road cut. Because the matrix sediments are in places substantially uncemented, one gets a good three-dimensional view of *A. palmata* in growth position. Back reef lagoonal facies becomes quite sandy with corals such as *M. annularis.* Near the northeast end of the outcrop, note well-developed facies of branching coralline algae and *Porites porites.*

HARRISONS CAVE

Possibly the most striking feature of the Limestone cap of the island of Barbados occurs underground, within the Coral Rock Formation. Numerous subterranean caves, caverns and tunnels formed by the solution of the calcareous rock by ground water flowing through cracks and joints, form an intricate system which facilitates the flow of underground streams and waterfalls towards the sheet water zones and eventually the sea.

These caves have attracted the attention of adventures since the seventeenth century, but it has been only since 1970, that the Government of Barbados, with the assistance of a Danish Speleoloist, Ole Sorenson and Barbadian Tony Mason has been able to map its layout and open the cave to an even wider cross-section of not-so-daring adventurers. Extensive remodeling and excavations were carried out with extreme care, so as to maintain harmony with the natural surroundings, and to enable the curious visitor to view the previously almost inaccessible beauty of the stalactites, stalagmites and other rock formations in the relative comfort of an electric tram-cart.

Harrisons Cave is located in the parish of St. Thomas near the centre of the island and not far from the highest point, Mount Hillaby at 1115' (340m). The extent of its development limits go to about 300' below ground level, as it winds its way seaward, through the various reef deposits.

BRIEF OUTLINE OF THE STRATIGRAPHIC UNITS OF THE SCOTLAND DISTRICT AND THEIR GEOLOGICAL RELATIONSHIPS

It is now generally accepted that Barbados represents the exposed crest of the South-east Caribbean accretionary prism complex. This crest has been formed by the arcward rotation of sediments which after being deposited in the trench area, formed by the downsliding Atlantic plate (under the Caribbean Plate), which was then accreted in a fan like prism and rotated arcward. Additional uplift may also have been due to Neogene mud diapirism under the crest.

Modern workers, particularly R.C. Speed et.al, have proposed a geological model for Barbados which represents a serious of turbiditic sequences cut up by "packet bounding" faults. This accretionary prism complex is covered by deep sea Oceanic clays and Pleistocene limestones.

STRATIGRAPHY

The evolution of thought on the Stratigraphy of the island is indeed as intriguing as the actual complexity of the rocks themselves. Alfred Senn (1945) and other early researchers thought that they could recognise a serious of events and proceeded to erect a column based on both bistratigraphic and lithostratigraphic evidence.

Badsgaard (1955) however, recognised that "the sequence of dated units which Senn strictly related to widespread orogenic events may be a fallacy". He in turn, though recognising the validity of much of Senn's work, set up a lithostratigraphic column only for the Scotland group, acknowledging such problems as the "contradictory and confusing paleontological evidence", and "the lack of any real bed continuity".

Modern thought (1980-present) has shown that below the Coral Rock, the application of any widespread conventional type stratigraphy is invalid. The Oceanics can be subdivided biostratigraphically and is in fact quite widespread over the basal clastics. As we would expect however, the Scotlands only show some stratigraphic continuity within fault –bounded packets. This would be consistent with the accretionary prism model promulgated for the Barbados ridge.

We interpret the rocks as a set of turbidites (more proximal in the southern part of the Scotland District and more distal in the northern area) juxtaposed by accretionary prism faulting.

The intra-packet lithological similarities are such that we have adopted some Senn's nomenclature in describing these rocks.

The significance of age relationships of the various litho-units Morgan Lewis, Walkers, Chalky Mount and Joes River are all described further on in the text. Modern paleontological evidence suggests that these rocks cannot yet be easily grouped chrono-stratigraphically. Figure 1, a table of comparative Stratigraphy shows the various age relationships.

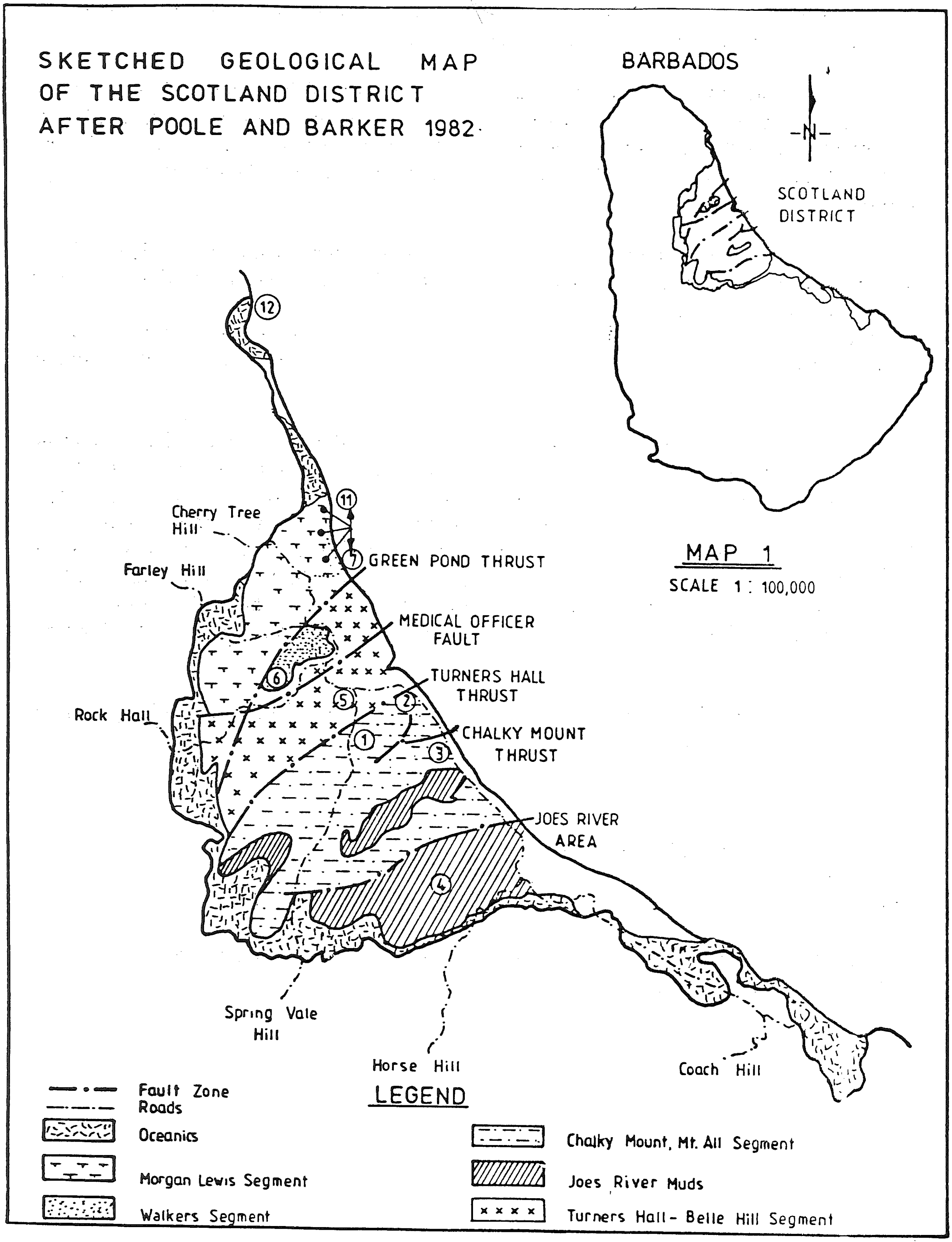
A new unit, the Intermediate Unit, is now being studied by Barker, L.; Speed, R.C.; et. al. It is believed that this Unit has been eroded from older Scotland rocks , and redeposited in trench slope or ridge crest basins.
Speed et. al. recognising some 43 fault bounded packets including some radiolarite strips – deep sea material faulted in between turbidite packets- in the main area of the Scotland District.

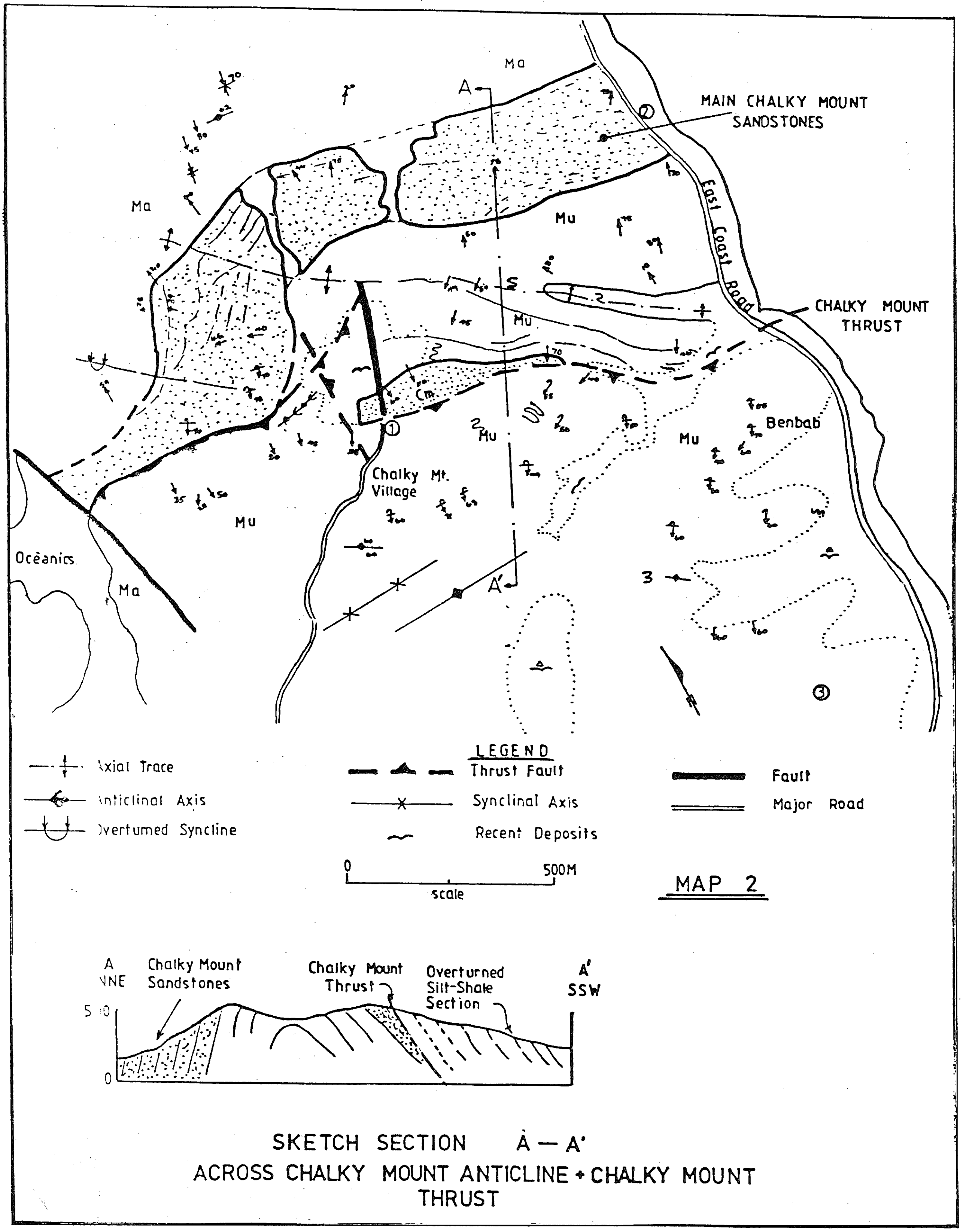
We recognise five main fault bounded areas, in the main body of the Scotland District. We also recognise that some areas formerly mapped as Oceanics may really be hemipelagic and radiolarite rocks as mapped by Speed R.C. et. al. We contend that the major basal complex units in the Scotland District are only well exposed over a total distance of 6-7km (see Map 1) and even if we allow for shortening with arcward rotation we cannot realistically expect to find too many accreted packets in this short distance. This is further corroborated if we bear in mind that recent seismic sections across the Barbados ridge show that present day fault bounded packets at the toe of the prism, measure some 5-10km between faults.

Map 1. A simplification of the geological map of the Scotland area, Poole and Barker 1982, shows the five areas:-

The Morgan Lewis Segment
The Walkers Segment
The Turners Hall- Belle Hill Segment
The Chalky Mount- Mount All
The Joes River- Frizers Segment

These segments, initially recognised by Dr. Senn 1945, may also be interpreted in the modern context of an accretionary prism.


SKETCHED GEOLOGICAL MAP
OF THE SCOTLAND DISTRICT
AFTER POOLE AND BARKER 1982
BARBADOS
N
SCOTLAND
DISTRICT
MAP 1
SCALE 1 : 100,000
12
11
7
6
5
2
1
3
4
Cherry Tree
Hill
Farley Hill
GREEN POND THRUST
MEDICAL OFFICER
FAULT
TURNERS HALL
THRUST
Rock Hall
CHALKY MOUNT
THRUST
JOES RIVER
AREA
Spring Vale
Hill
Horse Hill
Coach Hill
LEGEND
Fault Zone
Roads
Oceanics
Morgan Lewis Segment
Walkers Segment
Chalky Mount, Mt. All Segment
Joes River Muds
Turners Hall - Belle Hill Segment


Ma
A
MAIN CHALKY MOUNT SANDSTONES
East Coast Road
Ma
Mu
Mu
CHALKY MOUNT THRUST
Cm
Mu
Mu
Benbab
Chalky Mt. Village
Mu
Oceanics
Ma
A'
LEGEND
Axial Trace
Anticlinal Axis
Overturned Syncline
Thrust Fault
Synclinal Axis
Recent Deposits
Fault
Major Road
0
500M
scale
MAP 2
A
NNE
Chalky Mount Sandstones
Chalky Mount Thrust
Overturned Silt-Shale Section
A'
SSW
5 0
0
SKETCH SECTION A — A'
ACROSS CHALKY MOUNT ANTICLINE + CHALKY MOUNT THRUST

A rich variety of sedimentary and structural phenomena can be observed within these areas. A number of points of interest are instruction and some indeed problematic:- The high degree of synsedimentary deformation, and post depositional faulting; resedimentation of older basal complex material to form younger sediments which lithologically still resembles the older material; the general lack of fauna in the shales and the fact that much of the fauna in the coarser clastics have been resedimented; It is due to these factors that there is the high degree of complexity, and the obvious difficulty of establishing extensive stratigraphic units, in the Scotland sediments.

The other real problem in the interpretation of the Geology of Barbados is the nature of the Oceanic/Scotland contact. Many workers, particularly the older group (Senn et. al.) considered that the contact was either a slight unconformity or that there was some stratigraphic continuity, with Scotlands ranging up to mid Eocene up to Miocene.

Modern research (Speed et. al.) however has established that the Scotlands and Intermediate Unit may range up to Miocene while the Oceanics is definitely Mid Eocene-Miocene, thus giving considerable age overlap between the two groups.

Speed's Thesis is that the two were contemporaneously deposited, the Oceanics in the deep back arc basin of the Tobago Trough and the Scotlands as part of the accretionary prism complex to the east.

The Scotlands ("basal complex" of Speed) was then underthrust under the Oceanics, by the relative movement of the arcward rotating prism complex. Generally, good field evidence for proving the nature of the Oceanic/Scotland contact, one way or the other remains elusive.

THE CHALKY MOUNT – MOUNT ALL SEGMENT

STOP 6-8

The broad segment occupies the central portion of the Scotland District being bounded on the north by the Turners Hall thrust and on the south by the Joes River diapiric muds. The area is structurally very complex, with folds ranging from minor parasitic types to major anticlines and synclines, and faults from simple displacements to larger thrusts. The directions of the folds axes and the fault traces however do not vary very widely; there is a general east-north-east to west-south-west trend in fault traces and axial plane directions.

The main Chalky Mount Area appears to be structurally separated from the Mount All area. Field Stops 1-3 will examine only the major Chalky Mount anticlinal complex, the Chalky Mount thrust, and the overturned anticlinal section at Benab. (See Map 2).

Sedimentologically, the Chalky Mount area is instructive and interesting. It represents the most continuously visible sedimentary unit in the island, and is composed of a generally coarse grained, consolidated, quartzose sandstone with siltier parts and interbedded clays. Conglomeratic units are also seen in this complex. These beds are clearly turbiditic in origin representing mid to upper fan type facies. Coarse, graded bedding, poor sorting, convolute laminations, and water escape structures, generally place these beds in the Bouma "a" division. Mud clasts are also present not well seen in Chalky Mount. A finer grained, more darkly coloured unit (Senn's Murphy's) underlies the main Chalky Mount sandstones.

STOP 6

Examines the core of the anticline and some of the major structural features of the area, from a panoramic view on top of the Chalky Mount summit. The party will then proceed downhill in a rough, steep descent, seeing the major Chalky Mount sandstones, the conglomerates, and the finer grained beds in the core of the anticline. This downhill walk will be about 800m.

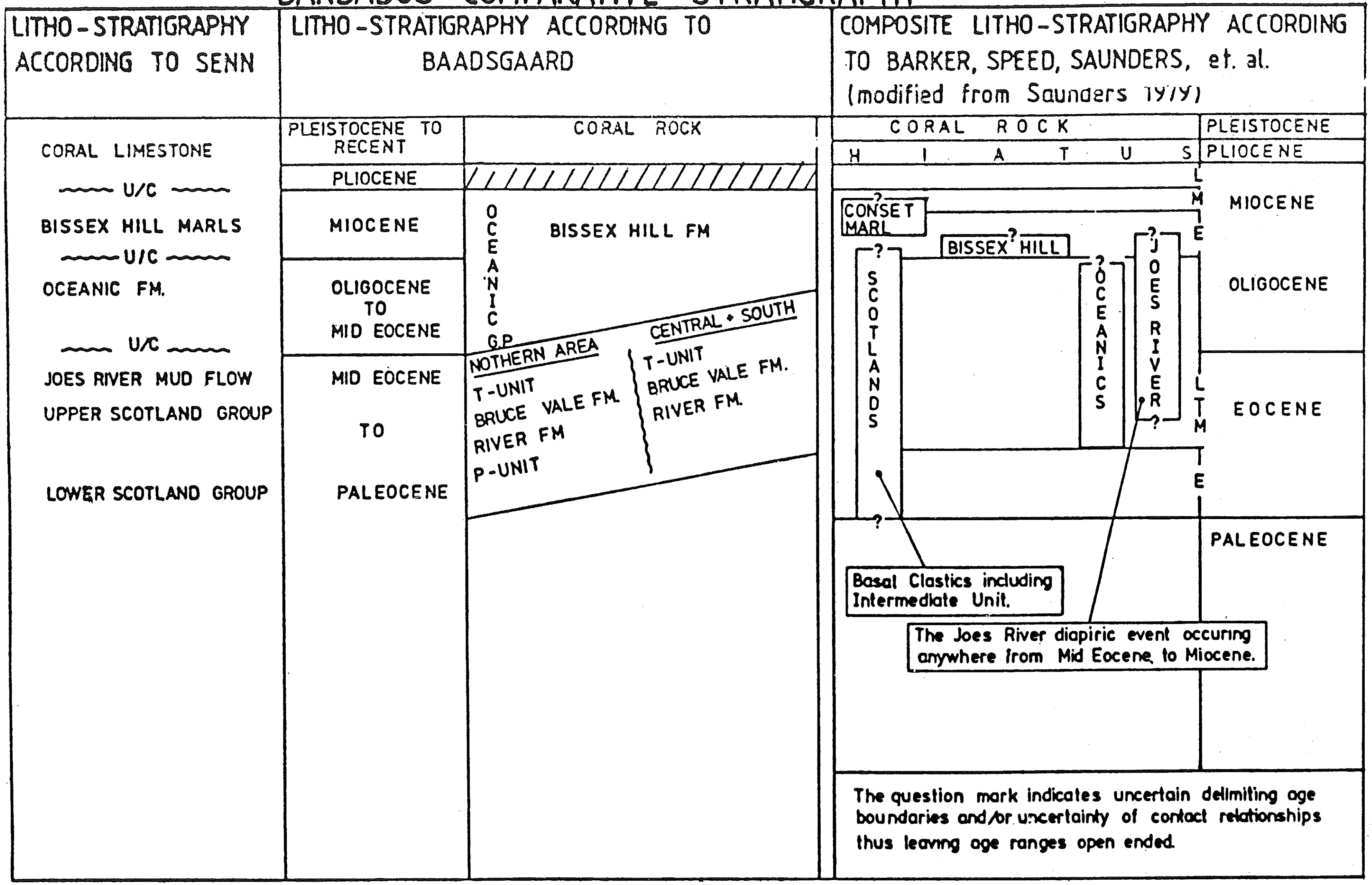
STOP 7

Will examine the Chalky Mount beds from a road cut along the East Coast Road noting coarse graded bedding and other sedimentary features.

STOP 8

The lithology and sedimentary features- particularly well exemplified water escape structures- will be observed at the Barclays Park area.

BARBADOS - COMPARATIVE STRATIGRAPHY



THE JOES RIVER SEGMENT

These rocks comprise dark grey to black, structureless, pervasively commonly oil soaked, (in some cases with the oil largely biodegraded) clays and silts, which include fragments, blocks and largely rafts of Scotland Group rocks and what may be either Oceanics or Radiolarites.

The main characteristic of this group of rocks is their lack of bedding planes or laminations, and the disrupted and broken nature of the material.

There have been numerous interpretations of this group of rocks. The early geologists, who described these rocks (Beeby Thompson 1925, Senn 1940), generally thought that the Joes River represented the product of mud volcanic activity. Baadsgard considered it as material representing a mobilised shear zone; Davies considered that the striking similarity to the Argille Scaglios of Italy and Sicily meant that the Joes River beds represented oliostostroma. Of the modern workers, Speed et. al, 1981, interpreted the Joes River sequence as a debris flow that moved downslope on the accretionary prism and could have settled in a lower slope basin. Barker and Poole, 1982, considered the Joes River to be the product of intrusive sedimentary activity, and from discussions with the French scientists (Mascle, Biju-Duval et. al.) this activity is now linked to the widespread mud diapirism along the Barbados Ridge. Speed now also recognises some of the Joes River to represent mud diapirism- personal communication.

The latest paper on the Joes River- Hans Kugler, Peter Jung, and John Saunders, 1984, describes the Joes River as being due to the mobilisation of over pressured beds within the accretionary prism, which diapirically broke through the paleo sea floor, with accompanying mud volcanic manifestations.

There therefore now seems to be some general agreement as to the origin of the Joes River material.

STOP 9

This examines an outcrop in the main Joes River area, the Frizers Valley. The typical lithology and structurelessness of the material is well observed here. Also, very noticeable here is the extreme susceptibility of the rocks to rill and gully erosion. This is due to two factors:

i) the oil impregnated material does not easily support any vegetation cover; and

ii) the structureless clays offer little resistance to running water.

One should note also from the geological map of the island, that the Joes River is localised in an area which represents the middle of the island. It also lies adjacent (and probably under) the highest part of the island. This is very significant when we consider that the mud diapirism may have caused the final uplift of the island.

STOP 10

THE OCEANICS

This stop will examine the Oceanic Clays, the deepwater pelagic deposits at Gays Cove, St. Lucy. Here we will see the Oceanics/ Coral Limestone unconformity and features such as the "ash beds" within the Oceanics.

STOP 11

The final part of the field trip will take us through St. Lucy, the most northerly parish of the island and then southwards along Highway 2A where we will see the Second High Cliff, the most prominently developed limestone cliff on the island. We will also see a number of modern cultural features here such as the tourist resort areas of Holetown, and the golf courses at Westmoreland and Sandy Lane.