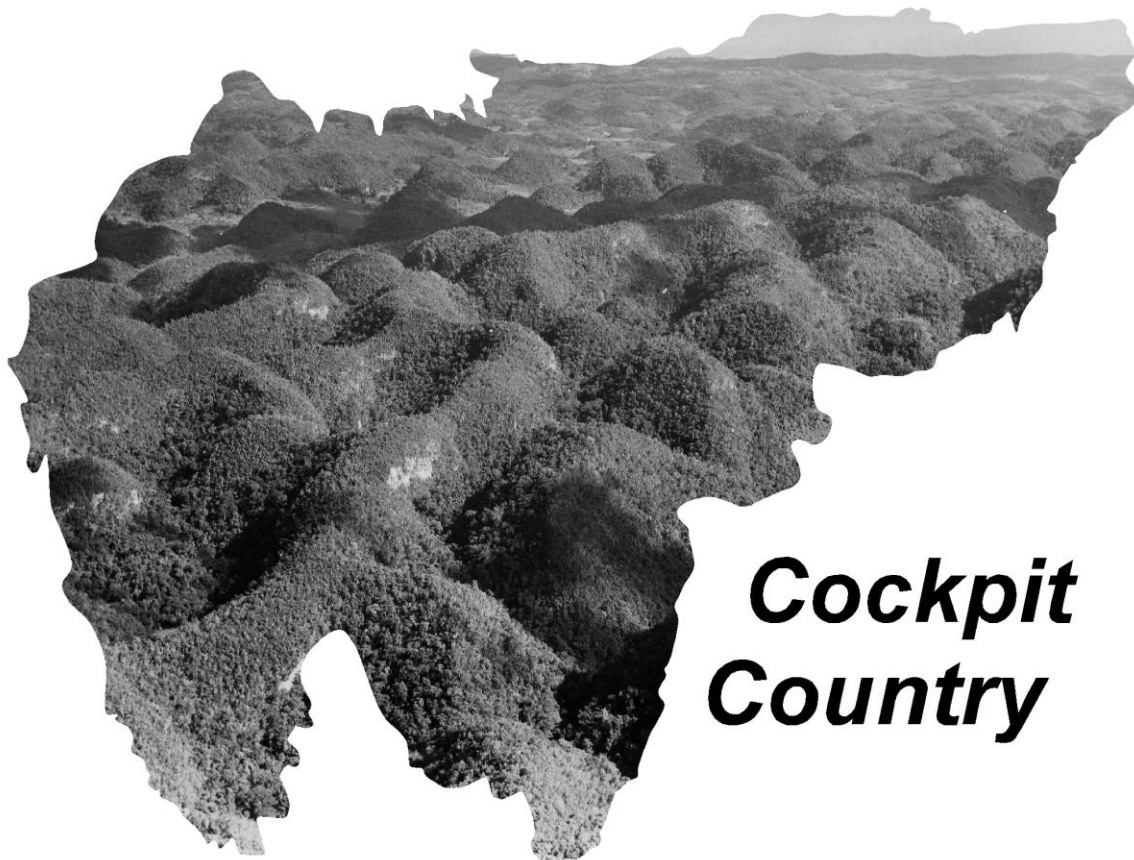


# Defining the Boundaries of The Cockpit Country

Final Report 9<sup>th</sup> October 2008

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## 1 Executive Summary

This consultancy study was commissioned by **The Ministry of Agriculture & Lands** to define the boundaries of the area regarded as **The Cockpit Country** in west-central Jamaica. The boundary was defined using geological, geomorphological and socio-historical criteria.

Geological mapping identified rocks belonging to Cretaceous limestones and clastics (mudstones, sandstones and conglomerates), the Yellow Limestone Group (including the Guys Hill, Chapelton, Ipswich and 'red limestone' formations), the White Limestone Group, and alluvium in and around The Cockpit Country. Geomorphological mapping and aerial photograph interpretation identified a range of landforms in and around The Cockpit Country including: cockpit karst, tower karst, doline karst and drainage basins. Cockpit karst was found to occur on rocks of the White Limestone Group as well as on the Ipswich and 'red limestone' formations of the Yellow Limestone Group. Where these rock types either overlaid Chapelton Formation Yellow Limestone or were buried by alluvium, tower karst was developed. The clastics of the Cretaceous, Guys Hill Formation and alluvium produced drainage basins, whereas the Chapelton Formation produced doline karst.

A direct relationship between land use, geomorphology and geology was identified. The cockpit and tower karst formed in the White Limestone and Yellow Limestone was characterised by tracts of primary forest, whereas the doline karst and alluvial valleys were characterised by extensive agriculture. This indicates that a physical boundary defined on geological and geomorphological criteria is a proxy boundary for high primary biological diversity as indicated by the distribution of primary forest.

Socio-historical studies considered the Maroon treaty of 1739 and the boundary of The Cockpit Country as defined by various stakeholders including the Accompong Maroons. The Maroon treaty is of little help in defining the boundary. Various stakeholder groups have suggested boundaries for The Cockpit Country and can be compared to our boundary.

We define The Cockpit Country as:

***A contiguous area, largely consisting of primary forest with little agriculture and a geomorphology dominated by cockpit and tower karst formed in the White Limestone Group and Yellow Limestone Group (Ipswich and 'Red Limestone' formations), but including small areas of the Yellow Limestone Chapelton Formation either as enclosed valleys or for socio-historical reasons. The boundary lies on or within the "Ring Road".***

***The boundary is defined by a change from relatively primary forest to agricultural lands and corresponds to geological/geomorphological boundaries that control land use.***

***This boundary is defined by contacts of the White Limestone/Yellow Limestone (with cockpit or tower karst) with the Cretaceous/Chapelton Formation (with internal drainage or doline karst) or alluvial deposits, or where such boundaries are not well defined by large-scale faults (defined from satellite imagery) or collapsed river cave systems.***

Our boundary delineating The Cockpit Country can be compared with other suggested boundaries. Our boundary lies within or on the “Ring Road”, which encircles The Cockpit Country and originally linked the British Colonial Army camps of the 17<sup>th</sup> and 18<sup>th</sup> centuries. The Ring Road has been used as a boundary on the Cockpit Country Website and by the Jamaican Caves Organisation. Sweeting’s (1956) boundary to The Cockpit Country, based on karst landforms, also broadly lies within the Ring Road.

The boundary described verbally by the Maroons at Accompong lies on or within the Ring Road. It excludes the large area of cockpit karst between the Barbecue Bottom road (fault zone) and the Alps road (fault zone).

The area of The Cockpit Country Forest Reserve is almost completely included within our boundary and within the boundary of the Ring Road. The only area of the Forest Reserve that lies outside of our boundary is a small section of alluvial ground near Bunkers Hill. However, since this small area is formed of agricultural land on alluvial deposits, it is unclear why it was included within the Forest Reserve in the first place.

The Cockpit Country Stakeholders Group (CCSG) boundary is much larger than any other proposed boundary. It specifically includes areas of cockpit and other karst in the Dry Harbour Mountains (Litchfield or Scarborough Mountain), the Nassau Valley, the Nassau Mountains, and areas to the west of Maggoty, Elderslie and the Maldon Inlier. This area includes more than just The Cockpit Country physiographical area, and includes extensive drainage areas that feed into the Great River, Montego River and Rio Bueno.

In summary, there is a broad agreement between our boundary and the Maroon verbal boundary, Sweeting’s boundary, the Forest Reserve and the Ring Road. There is, however, little correspondence between the CCSG boundary and any of the other boundaries, except on the northern side where all boundaries broadly follow the Duanvale fault zone.

## **1.1 Recommendations**

We make the following recommendations in relationship to the outcome of this consultancy.

1. There should be a period of Public Consultation to consider the proposed boundary for The Cockpit Country.
2. Communities either residing within or outside of the proposed boundary of The Cockpit Country should be recognised as “Cockpit Country

Communities” and as major stakeholders should be intimately involved in any decision making processes.

3. A process should be instigated to develop legal protection for the biological diversity and environment of The Cockpit Country through appropriate Government legislation. Protection methods and the implications for Cockpit Country Communities need to be fully explored, and any impacts minimised where possible.
4. The Government of Jamaica should look at the various alternatives for placing protection on The Cockpit Country. Given the public debate, such considerations should happen sooner, rather than later.
5. A Buffer Zone needs to be established beyond the boundary of The Cockpit Country. The Buffer Zone should minimise or preferably eliminate potential anthropogenic threats to The Cockpit Country. The size of the Buffer Zone that needs to be created should be a matter of informed scientific debate.
6. Once protection of The Cockpit Country has been achieved, the management of The Cockpit Country becomes an important issue. The Cockpit Country represents a large area of Jamaica and needs to be managed properly. Appropriate guidance needs to be put in place to determine the potential roles of government and non-government organisations. Ideally, management programmes that have worked in similar protected zones elsewhere should be employed.
7. Jamaica has relatively few pristine or relatively primary areas remaining. Several areas of cockpit karst landforms on White Limestone, which must harbour a significant biodiversity, exist in areas adjacent to The Cockpit Country. These areas should be surveyed for their physiography (geology and geomorphology) and their biodiversity and appropriate protection put in place.
8. Although this report has looked at the geology, geomorphology and social-historical context of The Cockpit Country, this should not be seen as anywhere near exhaustive. The studies presented here, strictly relate to the boundary issue and involved a limited amount of field data collection. There are, therefore, numerous areas that have not been appropriately researched. Since The Cockpit Country will become amongst Jamaica’s most important natural environments, it is only appropriate that research to maintain this position should continue.

## **2 Introduction**

This project was initiated as a consultancy from **The Ministry of Agriculture & Lands** to define the boundaries of the area regarded as **The Cockpit Country** in west-central Jamaica using historical, geological and geomorphological criteria. The team of consultants comprises Professor Simon F. Mitchell, Dr. David J. Miller, Dr. Savitha Ganapathy and Dr. Balfour Spence, who are all members of the Department of Geography and Geology, The University of the West Indies, Mona, Kingston, Jamaica.

**The Cockpit Country** is located in west central Jamaica and is an outstanding centre of the island's natural and cultural heritage, preserves a large area of primary forest and is home to a large endemic flora and fauna. It has high species diversity, and is a repository of economically important resources. Its name derives from the dense karstic landforms that consist of rounded peaks and bowl-shaped depressions and it is the type locality for 'cockpit karst'. The Cockpit Country contains one of the largest remaining areas of moist to wet limestone forest reserves in Jamaica. The boundaries of The Cockpit Country have not been clearly defined and have never been officially established.

This consultancy uses the expertise that is present within **The Department of Geography and Geology** to define the boundaries of 'The Cockpit Country' using the objective criteria of geology and geomorphology together with historical data. The historical boundary relating to the Maroon treaty of 1739 and the socio-cultural context of the area are also considered. The team comprises four co-investigators with skills in Geology, Geomorphology, Geographical Information Systems (GIS) and Social Geography.

The team collated existing high-quality geological, geomorphological and historical data, collected data where such data was absent, liaised with stakeholders (specifically the Maroons), and presents the data in a GIS format. The objectively defined boundary, taking into account historical information, is compared with other suggested boundaries, and these will be incorporated into the GIS project. Further, proposals for public consultation, the creation of a buffer zone and the future protection and management of Cockpit Country are made.

The consultancy began on 10<sup>th</sup> April, 2007, with a duration of three months. The draft report together with a CD with supporting data was submitted to the Ministry of Agriculture & Lands on the 10<sup>th</sup> July 2007. Subsequently with a change in government of Jamaica, the Mines & Geology Division took over the running of the project. Subsequently, considerable delays in reviewing the report have led to a long time lapse leading up to the submission of the Final Report.

### **3 Terms of Reference and Deliverables**

The Consultancy team will determine the boundaries of the area described as The Cockpit Country as defined in, but not limited to, the terms of reference as indicated by the Ministry of Agriculture & Lands.

#### **3.1 Terms of Reference**

The team will:

*A. Apply a scientific methodology for the delimitation of The Cockpit Country boundaries using geological and geomorphological parameters.*

*B. Define the boundaries of The Cockpit Country based on the parameters noted in (A) above.*

*C. Gather historical information on the boundary definitions of The Cockpit Country from historical documents, with particular reference to the Treaty signed between the British Colonial Authority and the Maroons in the 18th Century.*

*D. With reference to Item C above, consult with the appropriate stakeholders, including the Maroons, local land owners, local communities and the GOJ.*

#### **3.2 Deliverables**

*1. A Comprehensive Report with a full description and justification/explanation of the methodology utilised to delineate the area as per the scope of work outlined above, including any recommendations.*

*2. A digitised and geo-referenced map of the defined area and maps showing previously suggested boundaries (based on formal or informal studies).*

## **4 Methodology**

The team employs a range of appropriate methodologies in order to complete the consultancy. The methods used are briefly outlined below.

### **4.1 Geology**

The geological study includes four parts: 1, A review of published geological maps and other data from west-central Jamaica; 2, A compilation of unpublished geological maps and other data held specifically by the Department of Geography and Geology; 3, Geological fieldwork to examine the geology and how it can be used to determine the boundaries of The Cockpit Country; and 4, an analysis of structures from Digital Elevation Models (DEMs).

A range of geological maps is available from Jamaica at scales of 1:50,000 and 1:250,000. There is also an extensive literature dealing with the geology of Jamaica. Relevant information pertaining to The Cockpit Country will be compiled.

The Department of Geography and Geology has had two major geological projects that relate to the boundary region of Cockpit Country. The Central Inlier Project (run by Simon Mitchell) lasted seven years and resulted in the completion of a geological map of the Cretaceous and Yellow Limestone deposits in and around the Central Inlier. A Ph.D. investigation of Cretaceous inliers in western Jamaica was undertaken by Gavin Gunter (now at The Petroleum Corporation of Jamaica) under the supervision of Simon Mitchell. This project included a study of the Cretaceous and older Paleogene rocks in and around the Maldon Inlier, and was subsequently published (Gunter and Mitchell, 2005).

The collection of field data used traditional geological methods. Field sheets were prepared (1:12,500 scale) to record geological information. Field identification of rock types was used to refer rock outcrops to specific formations; this was backed up by the collection of samples for more detailed analyses. Boundaries between formations were determined in the field and drawn on the field sheets. Orientation data for beds, joints and faults was collected using a compass clinometer and recorded on the field maps. The distribution of superficial deposits (large alluvium areas) was also recorded. GPS coordinates were collected in the field for geo-referencing.

Digital Elevation Models (DEMs) allow the recognition of large-scale features that are related to geology. The integration of geological maps with DEMs allows fault systems and stress fields to be determined. This is particularly useful in areas that are difficult to access and where remote sensing data can be used to infer the geology.

The collection of geological data and geomorphological data was undertaken at the same time. This enabled the relationships between rock types and landforms to be related in the field.

## **4.2 Geomorphology**

Field mapping and aerial photograph interpretation were used to differentiate between contrasting karst landforms. Field mapping involved the use of standard geomorphological mapping techniques (Gardner and Dackombe, 1983) using specific symbols to identify features. The Survey Department 1:12,500 topographic maps were used as base maps for this purpose. Landform association maps were then constructed using the basic geomorphological maps, together with aerial photograph interpretation using 1:40,000 scale images of the area taken in 1999 for the Forestry Department. The photographs were studied using a Topcon MS3 mirror stereoscope with a 3× magnification in order to produce a 3-D image of the landscape. The karst landforms of the area in and around Cockpit Country were classified into landform associations, rather than identifying individual karst features which would have only limited significance in developing a boundary. Four principal landform groups can be easily identified and differentiated based on their overall geomorphological characteristics: cockpit karst; doline karst; tower karst; and poljes, alluvial plains, glades and pocket valleys. These associations were classified according to the dominant landforms within a given area, rather than mapping individual detailed features.

The areas of doline karst were defined as comprising predominantly circular to oval shaped depressions, where the negative relief elements dominate the landscape, with only small residual hills. Areas with more complex depressions, where the individual dolines coalesce were also placed in this landscape category. The areas delimited as cockpit karst were defined as being dominated by polygonal and elongated depressions between conical hills, where the positive and negative relief elements have roughly equal prominence. Each cockpit depression also has a contiguous arrangement with its neighbouring depressions. Mapping the areas of tower karst included both delimiting individual features associated with floodplains and Chapelton dolines, but also included mapping larger areas of continuous tower karst and limestone ridges (or pepino hills) interspersed with glades, pocket valleys and small poljes, particularly to the north of Cockpit Country. Areas of polje, alluvial plains, pocket valleys and glades were grouped together in the final geomorphological map.

In order to define a boundary on the basis of karst geomorphology, the geomorphological maps were used to delineate the outer continuous boundary of contiguous cockpit karst. Areas of polje and doline karst were generally considered to be outside the boundary of Cockpit Country, while many areas of tower karst can be placed inside the boundary, particularly to the northwest and north. This border of cockpit karst maps the outer continuous limit of the terrain type, but does not necessarily define a boundary to Cockpit Country as other criteria were taken into consideration to define the overall boundary.

### **4.3 Socio-Historical Context for defining Cockpit Country**

#### **4.3.1 Community Participation**

Delineation of The Cockpit Country is a first step towards the development of a comprehensive land management framework that can ensure sustainable use of the resources of the area. Such a framework will have implications for the livelihood activities of people who currently rely on the resources of The Cockpit Country and as such this component of the research adopted a participatory approach in which opinions of residents of Cockpit Country communities were sought in relation to the boundary of The Cockpit Country.

From a historical perspective Maroon activities and their relationship with the British Colonial Government in Jamaica is the dominant consideration of The Cockpit Country. However, in a broader social context, the socio-cultural and socio-economic character of other communities that rely on The Cockpit Country zone for their livelihood activities are as critical to the consideration of criteria for delimiting the area.

#### **4.3.2 Review of Documents/Maps**

Documents related to the history of The Cockpit Country, especially in relation to Maroon history, were reviewed in order to assess the sphere of influence of Maroon activities, especially during and since the Maroon Wars.

#### **4.3.3 Community Consultations**

Residents of the following Cockpit Country communities were consulted:

- i) Accompong
- ii) Quickstep
- iii) Elderslie
- iv) Albert Town
- v) Troy
- vi) Balaclava

Communities on the northern side of The Cockpit Country were not consulted during this exercise as there seems to be a reasonable level of consensus on the location of the boundary in that area.

#### **4.3.4 Consultation with Special Interest Group**

Consultation with special interest groups focused on the Southern Trelawny Environmental Agency (STEA), an NGO that has been operational in Cockpit Country communities since 1996 and whose project activities cover communities in the parishes of Trelawny, St Elizabeth, St James and sections of Manchester. In addition, an opportunity to discuss the issue of boundary was provided at a forum initiated by the Cockpit Country Stakeholders Group.

#### **4.3.5 Analysis of Land Information**

Land use and land tenure data were analysed in order to gauge the level of human interference relative to The Cockpit Country as well as to determine a possible buffer zone should protection of The Cockpit Country be an outcome of the delineation exercise.

#### **4.4 Other Boundaries**

Boundaries have been suggested at various times for The Cockpit Country. The various boundaries (described in writing, described verbally, or shown on maps) were studied and compared with the boundary determined in this study. These boundaries are included in the GIS database.

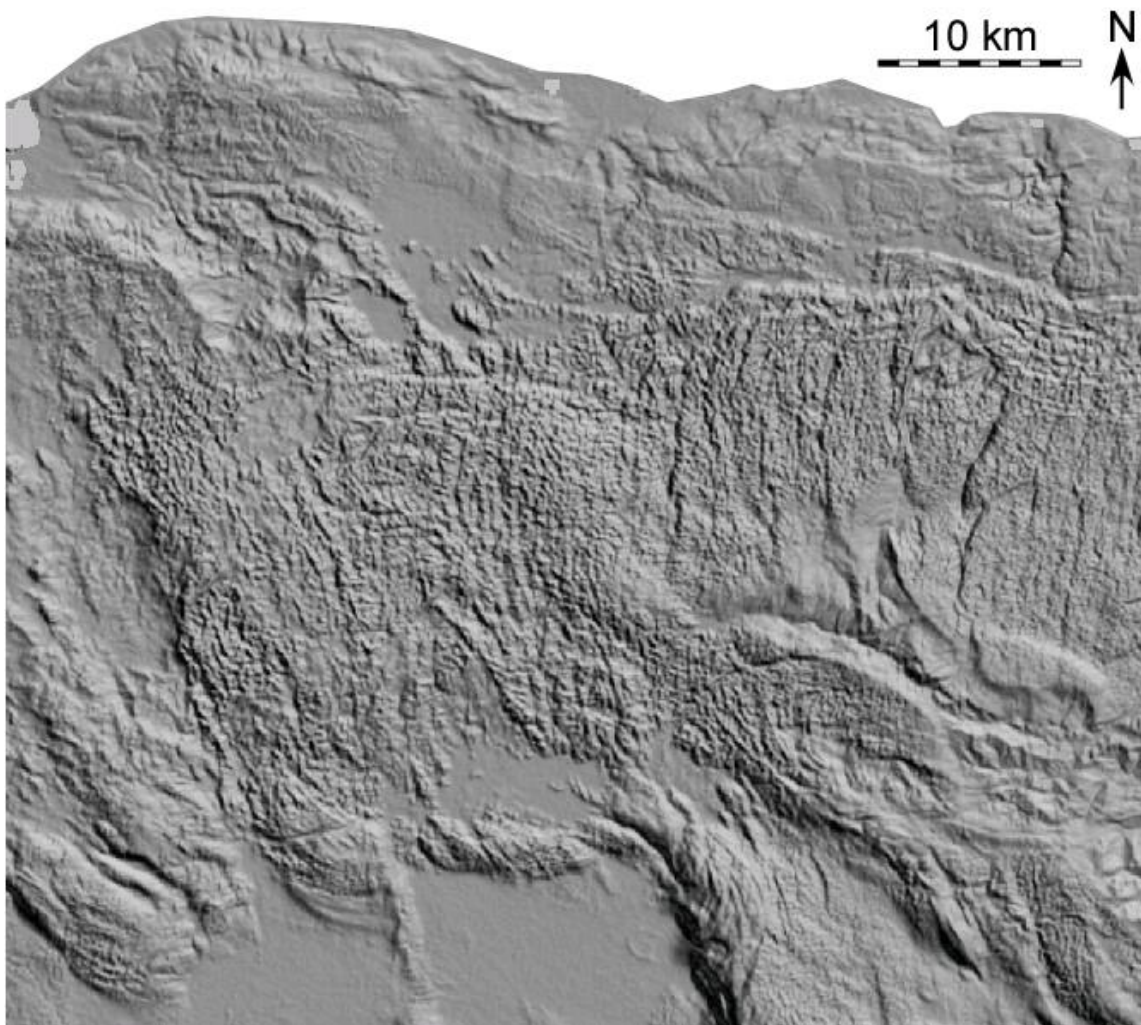
#### **4.5 Geographical Information Systems (GIS)**

The boundaries from previous studies together with our proposed boundary are captured in GIS using reference maps and the most accurate GIS themes available (1:50,000 topographic maps; for roads and streams; contours). Geological and geomorphological features are integrated in GIS for further analysis.

## 5 Physical Geography of West Central Jamaica

Cockpit Country must be seen as a distinct physiographic area of Jamaica, and must be distinct from other named physiographic regions such as the Dry Harbour Mountains, the Nassau Valley, the Nassau Mountains and the Central Inlier.

Digital Elevation Models (DEMs) can be used to rapidly access the physical geography of a region. A DEM image of central west Jamaica is shown in **Figure 1**. The highland 'plateau' region of this area is immediately obvious, as are alluvial filled valleys to the north and south. A detailed analysis of lineaments on the DEM is provided in **Section 6.2**.



**Figure 1.** Digital Elevation Model (DEM) of west-central Jamaica showing the area around Cockpit Country. Two main sets of lineaments, an E-W set and a N-S to NW-SE, set are defined principally by aligned depressions (cockpits). Extensive flat-floored interior valleys are associated with the E-W lineaments represented by the Rio Miho and Duanvale fault zones.

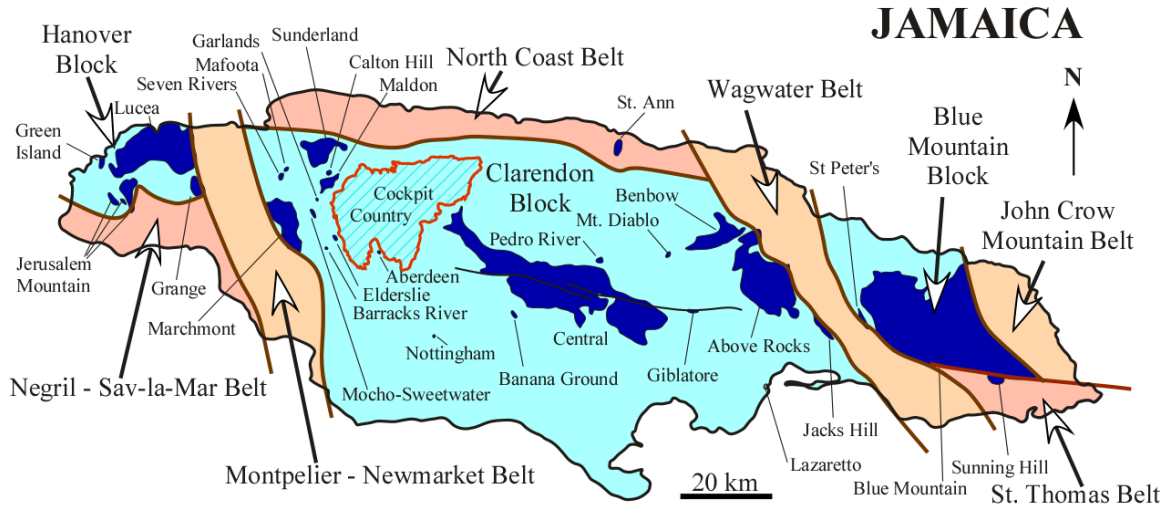
## **6 Geology**

Extensive geological investigations have been carried out in Jamaica ever since the earliest studies by De la Beche (1825, 1829). The first complete survey of the island was published by Sawkins in 1869, and included a geological map (the Brown and Sawkin's map) and geological descriptions parish by parish. Hill (1899) produced the next major work on Jamaican geology; he introduced formation names for many rock units and produced a revision (Hill's 1998 map) of the Brown and Sawkin's map. Little geological work relating to Cockpit Country appeared subsequently until the establishment of the Geological Survey Department in the early 1950s. It was during this period that extensive works on the Yellow Limestone and White Limestone resulted in a complex terminology of members that were largely based on fossil foraminifers (Versey, 1957a, 1957b, Hose and Versey, 1957). This culminated in the publication of the 1:250,000 scale geological map (the Zans' map) of Jamaica in 1958, and the accompanying explanation (Zans *et al.*, 1963) with the Yellow Limestone and White Limestone described by Versey. Renewed work in the 1970s resulted in further revision to the stratigraphy of the Yellow Limestone and White Limestone (Wright, 1974). This resulted in new maps at scales of 1:50,000: Sheets 5 (Bateson, 1972a), 6 (Bateson, 1972b), 8 (Bateson, 1974a) and 9 (Bateson, 1974b) and 1:250,000 (the 1977 McFarlane map).

Subsequent work on the Yellow Limestone and White Limestone groups has concentrated on foraminifer assemblages, formal lithostratigraphy and palaeogeography (e.g., Eva and McFarlane, 1985; Robinson and Wright, 1993; Robinson, 1996, 2004; Robinson and Mitchell, 1999; Mitchell, 2004).

### **6.1 Blocks and Belts versus Platforms and Troughs**

Jamaica comprises a series of morphotectonic blocks and belts that are defined by fault zones (Eva and McFarlane, 1985; Draper, 1987; Mitchell, 2004; **Figure 2**). Each block or belt is a structural feature and relates to tectonic deformation of Jamaica during the last 15 million years. Each block or belt broadly corresponds to a platform (shallow-water region) or trough (deep-water region) that existed in the late Paleogene to early Neogene (c. 45 to 15 million years ago). However, because of the subsequent deformation, faults defining blocks or belts may not be equivalent to the former boundaries between platforms and troughs. The Cockpit Country is found within the Clarendon Block (**Figure 2**) that broadly corresponds to the former Clarendon Platform. To the north of the Clarendon Block beyond the Duanvale Fault Zone lies the North Coast Belt, whereas to the west, lies the Montpelier-Newmarket Belt (**Figure 2**). It is on the Clarendon Platform that the rocks of the White Limestone Group were deposited that form the rugged karst topography of The Cockpit Country today.



**Figure 2. Structural map of Jamaica showing blocks and belts and Cretaceous inliers (dark blue) and fault zones (red). The Cockpit Country is located on the Clarendon Block, and its rocks were deposited on part of the Clarendon Platform.**

## 6.2 Large-scale structural features of the area around Jamaica

The DEM imagery can be used to recognise large-scale structural features that are shown up by well-defined lineaments (**Figure 3**). The North Coast Belt is separated from the Clarendon Block by the broadly east-west orientated Duanvale Fault Zone. This fault zone comprises several straight to arcuate faults that separate the continuous karstic terrain of Cockpit Country from alluvium-filled valleys between karstic limestone hills within the fault zone itself.

The upper and lower basins (morasses) of the Black River are bordered to the north by the Nassau Mountains and the Nassau Valley. There are strong east-west lineaments bordering the Nassau Mountains and the Nassau Valley that correspond to the westward extension of Rio Minho Fault Zone. As with the Duanvale Fault Zone, the westwards extension of the Rio Minho fault zone is therefore also associated with alluvium-filled valleys.

The Cretaceous and Yellow Limestone rocks of the Central Inlier on the eastern side of the map give rise to smooth imagery that has been heavily incised by river systems (**Figure 3**). To the north of the Central Inlier, a series of prominent north-south lineaments (including those of Barbecue Bottom and the Alps) are present and correspond to faults or monoclines (folds) mapped on the northern margin of the Central Inlier. On the western side of the DEM (**Figure 3**), a north-south string of Cretaceous inliers (Sunderland, Maldon, Sweetwater-Mocho, Elderslie, Aberdeen) occupies a fault-defined zone between well developed karstic terrain to the east and west. Further west are the Cretaceous rocks of the Marchmont Inlier and the deep-water White Limestone rocks of the Montpelier-Newmarket Belt. The central part of Cockpit Country forms a relatively uniform region with weakly developed north-south lineaments that probably correspond to a series of small-scale faults.

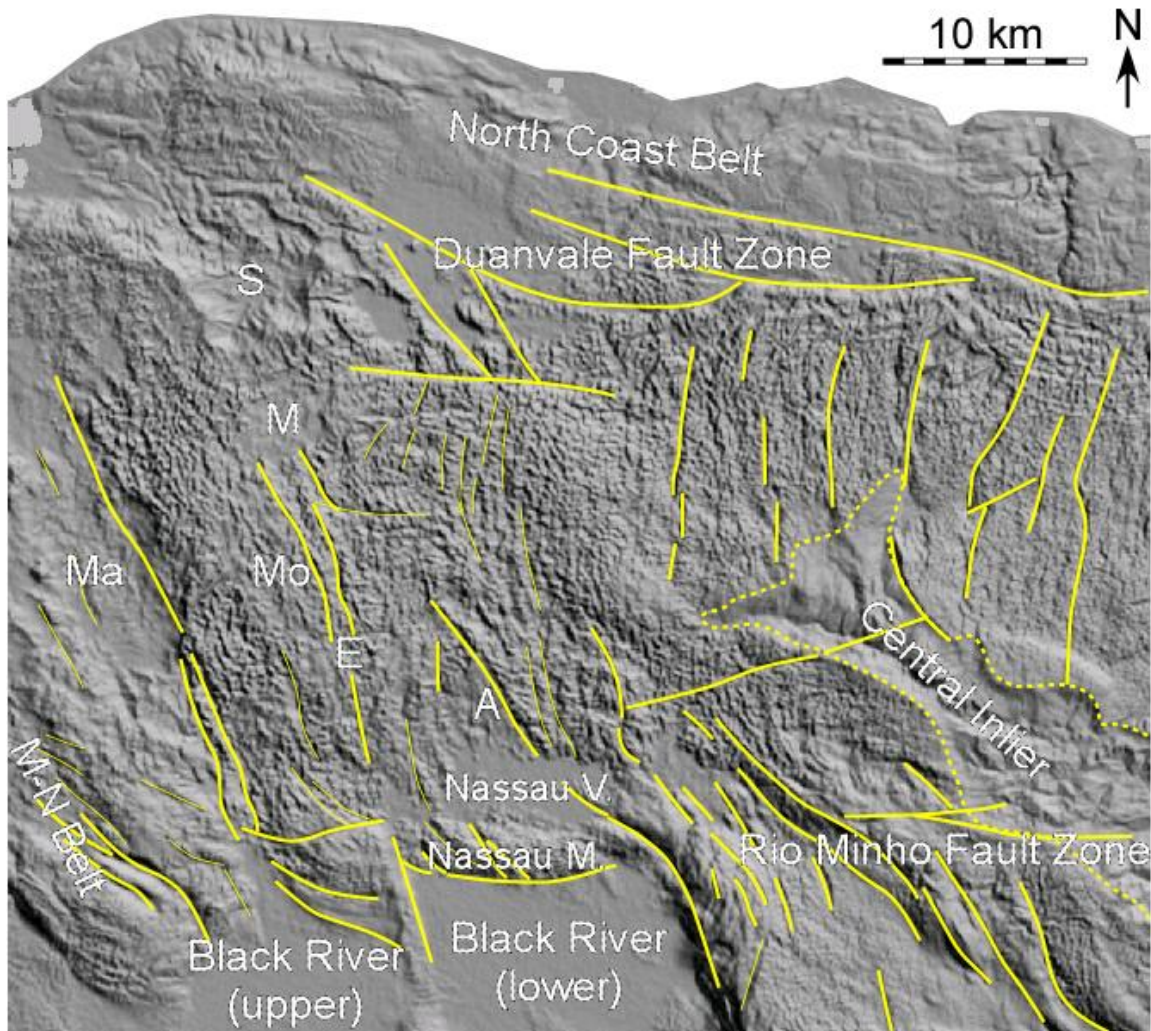
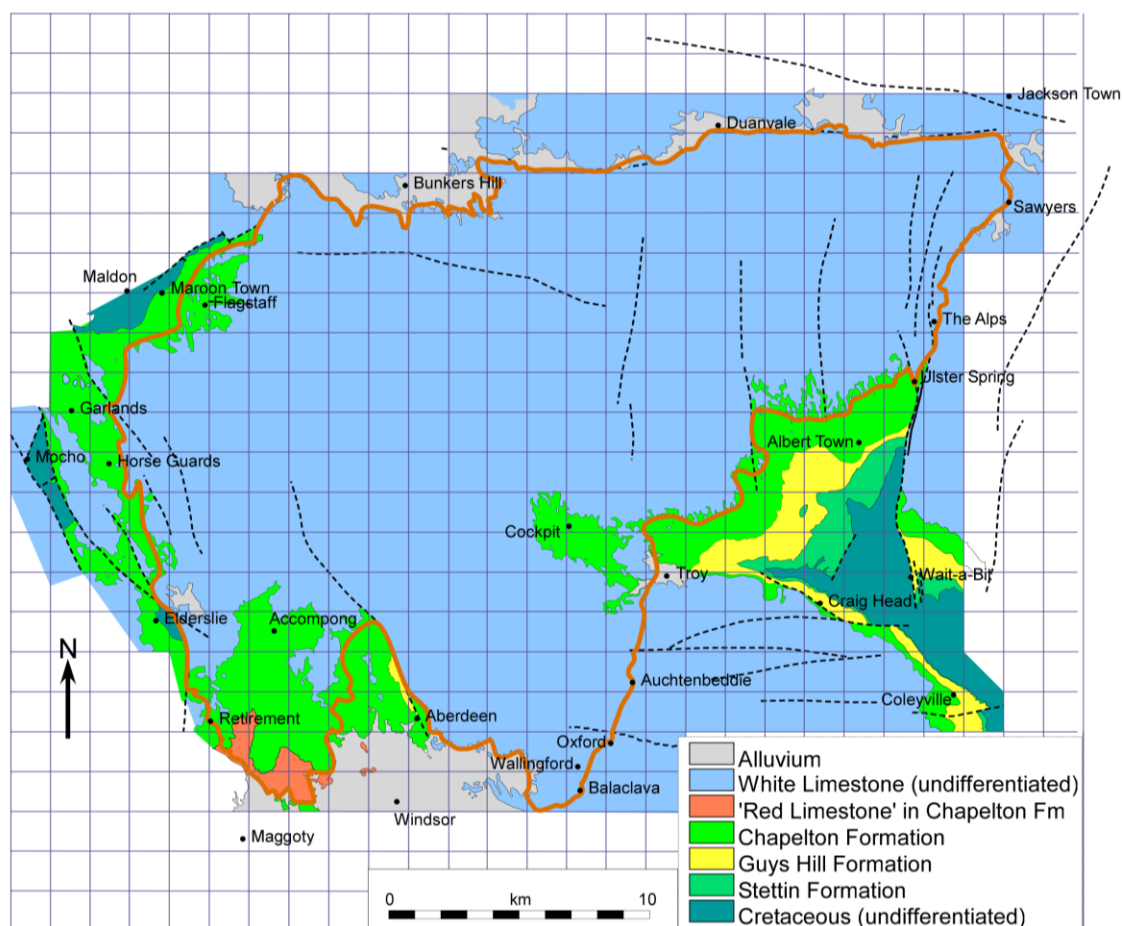


Figure 3. Digital Elevation Model (DEM) of west-central Jamaica showing the area in and around Cockpit Country with structural features highlighted (compare with Figure 1). Note the rough topography of karstic White Limestone in the central part of the image, and the contrast with the smooth topography of alluvial filled valleys (Black River) to the north and south, and the Central Inlier to the east. The major lineaments (faults and joints) are shown in yellow, and the names of features in white; the boundary of the Central Inlier is dashed in yellow. Ma = Marchmont Inlier; M = Maldon Inlier; Mo = Mocho-Sweetwater Inlier; A = Aberdeen Inlier; E = Elderslie Inlier; S = Sunderland Inlier; M.N Belt = Montpelier-Newmarket Belt. The east-west fault zones (Duanvale and Rio Minho) are shown by series of interior valleys to the south and north of Cockpit Country. To the south and north of the Rio Minho Fault Zone, the lineaments (largely defined by aligned depressions) are orientated from NS to NNW-SSE.

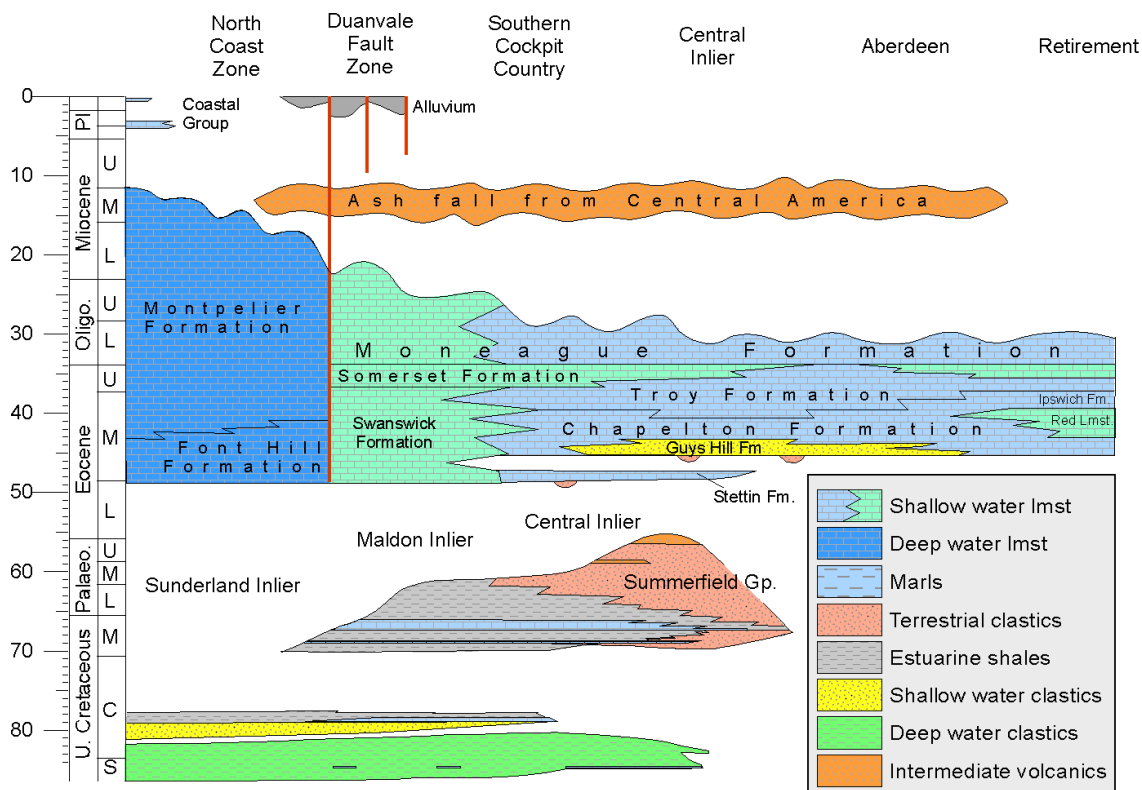
### 6.3 Geological map and geological evolution of Cockpit Country

The field mapping undertaken for this project has been integrated with geological maps created from the Central Inlier Project (Mitchell, unpublished) and studies in the Maldon Inlier (Gunter and Mitchell, 2005) to produce a geological map of the area in and around Cockpit Country (**Figure 4**). This area contains a suite of

rocks ranging in age from Late Cretaceous to Holocene (**Figure 5**). The Cretaceous (Maastrichtian) to Paleocene rocks are exposed as inliers (that is older rocks surrounded by younger rocks) and include the Central, Maldon and Sweetwater-Mocho inliers (E. Robinson, 1994; Mitchell and Blissett, 2001). Rock types include clastics (conglomerate, sandstone and mudstone) and limestones and these were deposited in shallow marine and terrestrial environments around an active island-arc volcano (much like in the volcanic islands of the Lesser Antilles at the present time). Following the demise of the volcanic centre in the late Paleocene, the area of western and central Jamaica was deformed producing an east-west fold belt that can be traced into Central America (Mitchell, 2003, 2006).



**Figure 4.** Geological map of area in and around Cockpit Country, with the proposed boundary for The Cockpit Country shown in red. The White Limestone Group has not been divided into formations due to uncertainties across much of Cockpit Country. The Yellow Limestone Group is divided into three formations in the Central Inlier (Stettin, Guys Hill and Chapelton), four formations in the southwest (Guys Hill, Chapelton, 'Red Limestone', and Ipswich) and two (Maroon Town and Chapelton) in the northwest. Faults are shown in dashed lines. Note the alluvium deposits to the north and south of Cockpit Country. The red line shows the proposed boundary for Cockpit Country. The grid lines shown are taken from the 1:12,500 series imperial grid which corresponds to the mapping sheets used. Names of communities are shown for reference.



**Figure 5. Simplified stratigraphy of Cockpit Country and surrounding areas (based on Mitchell, 2006, with additions). Vertical scale in millions of years, Cretaceous stages (second column): S, Santonian, C, Campanian; M, Maastrichtian.**

In the mid Paleogene, extension (stretching) produced a new platform and trough structure across Jamaica, and this dominated sedimentation until the mid Neogene (Eva and McFarlane, 1985; Mitchell, 2004). The platforms were emergent or shallow marine areas, whereas the troughs were deep-water regions with depths of up to a few kilometres (Underwood and Mitchell, 2004). The margins of the platforms accumulated carbonate sands and/or coral reefs, whereas the protected platform interiors were characterized by lagoons. Initially impure, mixed-clastic-carbonates of the Yellow Limestone Group were deposited, with the clastics derived from emergent parts of the platforms (Robinson and Mitchell, 1999). With time, these emergent areas were eroded and there was a gradual transition to the pure carbonates of the White Limestone Group (Mitchell, 2004).

In the mid Neogene, renewed tectonic deformation began to affect Jamaica and this continues to the present day (E. Robinson, 1994). This deformation has folded, faulted and uplifted Jamaica to produce the current island. Both platforms and troughs have been deformed and these are now represented by fault-defined blocks and belts (**Figure 2**) that only broadly correspond to the late Paleogene to early Neogene platforms and troughs. As uplift progressed, the rocks of the Yellow Limestone and White Limestone were karstified. During the late Miocene ash clouds produced from volcanoes in Central America deposited extensive ash deposits across the emergent area of Jamaica. Tropical weathering of this ash

has produced the distinctive, red-coloured, bauxitic soils found on the White Limestone of Jamaica (Comer, 1974). Subsequently, alluvial deposits accumulated in valley systems and have buried the karstic landforms.

A brief description of the geological units found in and around Cockpit Country is presented below. The various references cited provide more details.

## **6.4 Cretaceous-Paleogene geology**

The oldest rocks exposed around the periphery of Cockpit Country are of Cretaceous and Paleocene age (**Figure 5**). They are exposed in 'Cretaceous Inliers', the two largest of which are the Central Inlier and the Maldon Inlier. The geology of these inliers is briefly described below.

### **6.4.1 Central Inlier**

The Central Inlier is the largest inlier on the Clarendon Block, and the second largest 'Cretaceous' inlier within Jamaica (the Blue Mountains Inlier is the largest). The geology of the inlier has been extensively described before (e.g., Coates, 1964, 1969; Mitchell, 1999, 2003, 2006; Mitchell and Blissett, 1999, 2001). The succession in the NW part of the inlier, that is the area that borders Cockpit Country, is represented by rocks of the Summerfield Group (sandstones and conglomerates of the Mahoe Formation) (**Figure 5**). These give rise to steep-sided valleys with dense stream networks. The flatter areas of the Mahoe River Formation are used for agriculture.

### **6.4.2 Maldon Inlier**

The geology of the Maldon Inlier has been recently revised by Gunter and Mitchell (2005). The succession is dominated by shales and mudstones (Woodlands, Popkin and Flamstead Formations) with two thin units of Cretaceous limestone (Maldon and Vaughansfield Formations) (**Figure 5**). Fossil evidence indicates that all these rocks are of late Maastrichtian age. The Cretaceous rocks of the Maldon Inlier give rise to fertile soils and are extensively used for agriculture.

### **6.4.3 Garlands, Sweetwater-Mocho, Elderslie and Aberdeen Inliers**

These four inliers are small, and only expose clastic (usually mudstones, but also including some sandstones and conglomerates) rocks. They are brought to the surface adjacent to fault systems or within fault bounded blocks. The presence of these inliers, partly surrounded by Yellow Limestone outcrops, indicates the existence of a basement high (aquiclude) that extends southwards from the Maldon Inlier and controls both the geomorphology and hydrology of the region.

## **6.5 Yellow Limestone and White Limestone Groups**

The Yellow Limestone and White Limestone groups are intimately associated and are therefore described together here. The stratigraphy of the Yellow Limestone and White Limestone groups was discussed by Robinson and Mitchell (1999) and that of the White Limestone Group by Mitchell (2004) and Robinson

(2004). The account presented here is based on these studies together with additional unpublished data.

The Yellow Limestone Group can be divided into different units in different parts of the Clarendon Block. In the area bordering the Central Inlier, a threefold division into Stettin, Guys Hill and Chapelton formations can be achieved; in the south-western area between Aberdeen and Retirement, a four-fold division into: Guys Hill, Chapelton, 'Red Limestone' and Ipswich formations can be achieved; whereas in the northwestern region (Elderslie to Maroon Town), only a two-fold division into Maroon Town and Chapelton formations is possible. These divisions are shown diagrammatically in **Figure 5**. The White Limestone Group occurs within the 'heart' of Cockpit Country, where the Troy, Swanswick, Somerset and Moneague formations can be recognized. The various formations are briefly described below. Previous suggestion that The Cockpit Country is largely formed of cockpit karst of the Troy/Claremont Formation must be revised since The Cockpit Country while including extensive areas of the Troy/Claremont Formation also has extensive areas of Moneague Formation extending into its heart.

#### **6.5.1 Stettin Formation (Yellow Limestone Group)**

The Stettin Formation consists of a series of more or less evenly bedded, frequently nodular, dominantly fine-grained, fossiliferous, blue-grey, tan-weathering limestones. In the northern part of the Central Inlier the Stettin Formation has a thickness of about 150 m; towards the south it progressively thins and eventually pinches out along the southern margin of the inlier. The Stettin Formation gives rise to a subdued karstic topography. Dolines (or sink holes) are well-developed and between these are rounded, low residual hills. Within the Stettin Formation, the dolines are relatively shallow bowl to saucer-shaped depressions. Good soils are used for agriculture.

#### **6.5.2 Guys Hill Formation (Yellow Limestone Group)**

The Guys Hill Formation represents the clastic middle division of the Yellow Limestone Group in the Central Inlier and the lowermost division in the Aberdeen area. It consists predominantly of sandstones, heterolithics (mixed sandstones and mudstones) and mudstones, but fine-grained conglomerates and thin limestones are also present. The formation has a thickness of some 350 m in the north-western part of the Central Inlier, but thins towards the southeast. The Guys Hill Formation gives rise to gently gullied topography with shallowly incised stream systems of moderate drainage density. The Guys Hill Formation has fertile soils that are extensively used for farming, particularly for yams in the north-western part of the Central Inlier (Albert Town, etc.).

#### **6.5.3 Maroon Town Formation (Yellow Limestone Group)**

The Maroon Town Formation represents a clastic unit that occurs beneath the Chapelton Formation on the eastern side of the Maldon Inlier. It consists of a lower unit of conglomerates with reworked Cretaceous fossils, overlain by a sequence of mud rocks.

#### **6.5.4 Chapelton Formation (Yellow Limestone Group)**

The Chapelton Formation forms the uppermost division of the Yellow Limestone around the Central Inlier and Maroon Town Inlier, but occurs between the Guys Hill and 'Red Limestone' formations in the area from Aberdeen to Retirement. It consists of impure, medium to thickly bedded wackestones and packstones, locally interbedded with sandstones and grey mudstones. The karst formed on the Chapelton Formation consists of large, often steep-sided, dominantly cone-shaped dolines sometimes more than 125 m in diameter and 30 m deep (Sweeting, 1958). The Chapelton Formation gives rise to good soils and there is usually extensive agriculture developed.

#### **6.5.5 'Red Limestone' (Yellow Limestone Group)**

This un-named formation, which is described under open nomenclature, is only present in the south-western part of the area between Aberdeen and Retirement. It consists of red-coloured grainstones that are frequently cross-bedded. In the area mapped, the formation thickens towards the southwest. It gives rise to cockpit karst, with landforms (hills and dolines) on a smaller scale than those of typical White Limestone. It has underground drainage and is covered by good forest with limited or no agriculture.

#### **6.5.6 Ipswich Formation (Yellow Limestone Group)**

The Ipswich Formation is only identified in the same area as the 'Red Limestone' Formation. It consists of the pale-coloured fossiliferous limestones (micrites and wackestones) between the 'Red Limestone' and Troy formations. It also gives rise to small-scale cockpit karst.

#### **6.5.7 Troy Formation (White Limestone Group)**

The Troy Formation consists of pale grey, pale brown or pale pink carbonates in beds between 0.3 and 5.0, or more, metres thick. The mineralogy varies from limestone to dolostone and numerous textures are present. Prominent lithologies represented in the Troy Formation include: porcelaineous micrites, porcelaineous dolomicrites, and sucrosic dolostones. The porcelaineous micrites are well-developed where dolomitization has not occurred. The lithology typically consists of well-defined beds of micritic limestone, usually with well-developed irregular fenestrae in their upper parts. The Troy Formation gives rise to well-developed cockpit and tower karst. The Troy Formation has thin soils, other than in dolines, and little or no agriculture is present.

#### **6.5.8 Swanswick Formation (White Limestone Group)**

The Swanswick Formation consists of foraminiferal-peloidal grainstones. This lithology is very distinct and easily mappable. The type section of the Swanswick Formation was defined as "in the hill on which Swanswick House stands, one mile east of Clark's Town, Trelawny" (Versey in Zans et al., 1963, p. 33). This is just to the north of The Cockpit Country. The Swanswick Formation consists of white grainstones composed of the broken and worn tests of foraminifers and

algal fragments. Tower karst is well-developed in the Swanswick Formation, but may well simply be due to its close association with alluvial valleys. Peloids may also be present in abundance. Bedding is generally poorly defined, and sedimentary structures are absent.

#### **6.5.9 Somerset Formation (White Limestone Group)**

The Somerset Formation can be mapped as a fossiliferous packstone with subordinate foraminiferal and gastropod-bearing wackestones and carbonate mudstones. It is a thin formation, generally less than 20 m across The Cockpit Country, and has little significance for karst formation.

#### **6.5.10 Moneague Formation (White Limestone Group)**

The Moneague Formation consists of intense white limestones, but also coloured limestones in The Cockpit Country, in the upper part of the White Limestone Group. The formation consists of foraminiferal and molluscan grainstones and wackestones, with less frequent carbonate mudstones. The formation is well-represented along the northern margin of Cockpit Country and also in the valley (fault bounded?) that runs from Pullet Hall to Quickstep. The limestones of the Moneague Formation in The Cockpit Country are dense and show case hardening; they therefore show the same cockpit karst as developed on the limestones and dolostones of the Troy Formation.

### **6.6 Alluvium**

Alluvium filled-valleys exist to the north and south of The Cockpit Country. These valleys are structurally controlled and lie within the Duanvale and Rio Minho fault zones. Where faults have led to the formation of basins, the water table comes to the surface producing surface drainage and deposition of extensive alluvial deposits. The alluvial valleys are flat-floored and bordered by rocks of the White Limestone Group with tower karst (effectively buried cockpit karst). These flat floored basins had their primary forest cleared long ago and now have extensive agriculture (sugarcane); any primary forest is limited to 'islands' of White Limestone.

## **7 Geomorphology**

### **7.1 Introduction**

The Cockpit Country is famous worldwide for its spectacular karst topography, it being the type area for a tropical limestone terrain termed cockpit karst (kegelkarst). Cockpit karst is the most widespread landform type and occupies about 60% of all karst in Jamaica (Day, 1979). It comprises steep-sided, enclosed depressions with convex side-slopes, forming depressions which are star-shaped or polygonal in plan. Other common karst landform assemblages around The Cockpit Country are doline karst, where the landscape is dominated by oval- or circular-shaped depressions; tower karst, forming isolated residual hills rising above an alluvial plain, planed limestone, poorly-karstified or non-karstic rocks; and poljes, which are large structurally controlled depressions surrounded by a steep rim of limestone.

The White Limestone Group is more extensively karstified than the underlying Yellow Limestone Group because of its purity and as a result of the extensive development of a secondary permeability along lines of structural weakness, leading to directed dissolution of the limestones. Dissolution of the limestones along lines of weakness has formed a classic karst landscape within The Cockpit Country.

### **7.2 Historical Review**

Some of the earliest descriptions of the karst in Jamaica in general were related to early cave explorations (summarised in Fincham, 1997). The earliest descriptions of caves in detail were those by Edward Long (1774) who published a three volume "*History of Jamaica*", which contains descriptions of three caves. In his remarks on the geology of Jamaica, Sir Henry T. de la Beche (1829) described the Natural Bridge at Riversdale, which was the first surface karst feature to be documented (Miller and Donovan, 1999). James G. Sawkins (1869) provided a detailed account of the geology and hydrology of the island. The Cockpit Country is mentioned in this volume for the first time, where the cockpits, dolines and lightholes were described and attributed to collapse of the limestones into pre-existing caverns. Some thirty years after the publication of the memoir, a reassessment of the geology of Jamaica was produced by Hill (1899) and, although there was little consideration of the karst, he attributed the origin of the cockpits to solution, not collapse. A few years later, Daneš (1909, 1914) described the cockpits and other karst features, and also favoured solution, predominantly along joints and fissures, for the formation of the cockpits. His principal contribution to the development of karst studies was to add detailed observations of tropical karst in Jamaica to European investigations which had hitherto been the basis for karst evolution theories (Fincham, 1997). Lehmann (1954) examined the karst in northern Jamaica and also suggested a solutional origin to the development of cockpits.

In 1955, Marjorie Sweeting, a karst geomorphologist from the University of Oxford (Great Britain) conducted a two month programme of hydrological studies in Jamaica in association with the Geological Survey Division. These studies led to three publications on the hydrogeology and karst geomorphology of the limestones of the island, but specifically the White Limestone areas in and around Cockpit Country (Sweeting, 1956, 1957, 1958). Her 1958 publication was to become the seminal work on the karstlands of Jamaica and was the first major review of the limestone geomorphology and hydrology of the island, including the first general karst geomorphological map of the northern part of Jamaica (See **Section 10.2.6**). This stimulated a wider interest in Jamaican karst and established The Cockpit Country as a geomorphologically important tropical karst terrain-type. She published later reviews and descriptions of Jamaican karst in her 1972 book "*Karst Landforms*" where she also documented previously unpublished work by other authors, notably Conrad Aub. Other general descriptions of the karst of the island, including The Cockpit Country, were published in the 1950s by Doerr and Hoy (1957) and Urquhart (1958). Karl-Heinz Pfeffer (1967, 1969), worked on the cockpit karst landforms in the north of the island around The Cockpit Country and across southern St. Elizabeth. Pfeffer (1986) later described the polje and other karst features in the Queen of Spain's Valley to the north west of The Cockpit Country.

Versey (1972) also reviewed the karst geomorphology of the island from a geological perspective and examined the importance of lithology and structure to landform development on the limestone areas. Gardner *et al.* (1987) published a summary of Jamaican karst, chiefly based on the earlier reviews of Sweeting and Versey, and a more recent summary review was presented by Draper and Fincham (1997). Other investigations are related to karst landform evolution (for example, Pfeffer, 1986, 1997) and to karst landform development (for example, Smith *et al.*, 1972). Karst morphometric studies have also been published on relatively small areas within and around The Cockpit Country. These studies include the work of Day (1976, 1978), Brook and Hanson (1986, 1991), Draper *et al.* (1998) and Lyew-Ayee (2004).

### **7.3 Geological Background**

The karst of Jamaica provides a good example of both lithological and structural controls on its development (Gardner *et al.*, 1987), while the case-hardening of many of the limestones in the White Limestone Group has also had a significance influence on the development of karst landforms. There is a strong control on karst landform development related to lithology and specifically to certain material properties of the limestones. Sweeting (1958) noted that vertical relief development in the form of both cockpit and tower karst is confined to the areas of hard crystalline White Limestone, as well as to areas of high rainfall. In areas where the White Limestone is more 'marly', or where the rainfall amounts are relatively low, the landscape is dominated by doline karst. The karstifiable formations within the older Yellow Limestone Group also tend to support dolines. Within the Stettin Formation of the Yellow Limestone Group, the dolines tend to be relatively broad and shallow saucer- to bowl-shaped enclosed depressions,

often coalescing to form more complex uvalas, while the Chapelton Formation tends to support the development of deeper conical and funnel shaped forms (Sweeting 1958).

Sweeting further indicated a link between lateral relief development and lithology, as poljes are normally associated with the marly limestones, which promote extensive flooding and lateral planation. Urquhart (1958) also indicated that 'cockpit karst' is developed on the pure, hard and fissile limestones, whereas 'doline karst' is present on those which are marly or impure. White and Dunn (1962) also suggested the solubility, massive nature, and well-developed joints of the White limestones have been major factors in the development of karst topography in Jamaica.

Versey (1972) suggested that in terms of the importance of lithological properties to karst hydrology, three broad lithological divisions could be identified, each with differing hydrological regimes. The first group are the Montpelier Chalks which, according to Versey, are characterised by a primary, rather than diagenetic porosity. This, together with the paucity of fractures, leads to a well-developed primary permeability, such that groundwater movements occur through the body of the rock rather than via conduits (Versey, 1972; Gardner *et al.*, 1987). Versey's second rock division based on hydrological characteristics is the recrystallised limestones and dolostones, representing the oldest formations within the White Limestone Group. These rocks are characterised by no primary permeability and with groundwater movements entirely along fissures. Definite lines of groundwater flow have developed only along the largest fractures (Gardner *et al.*, 1987). Enlargement of joints and other lines of weakness is the result of directed solution and this has led to the development of secondary permeability. Versey (1972) characterised the rest of the White Limestone Group as a "rubbly limestone", having a widespread nodular texture, with occasional hard bands. The variable lithologies within Versey's "rubbly limestones" range from soft powdery textures which are nearly impermeable, to limestone conglomerates which are highly permeable.

The geological formations of the White Limestone Group are, for the most part, extremely pure carbonates and vary from moderately hard to very hard, with the dolomitic limestone of the Troy Formation being the hardest, recrystallisation having destroyed the original limestone texture and resulted in increased strength.

Day (1982) attempted to correlate purity, petrographic characteristics and mechanical strength with terrain type, and found that the most striking correlation is between terrain type and hardness of the rock types, where 'tower karst' tends to develop on the hardest rocks, and 'doline karst' on the softest. The correlation between purity, petrography and terrain type was less striking for the white limestone samples, but this is due to the fact that all are extremely pure and mostly micritic. Pfeffer (1986) indicated that cockpit karst occurs only on the 'pure' limestones and that the cockpit hills are steeper on the purest limestones. Limestones with marl layers tend to form less steep residual hills and dolines, whereas the impure limestones support doline karst only. Fieldwork conducted for this boundary study indicates that the relationship between lithology is not a simple

one, but is complicated by the fact that cockpit karst can be associated with formations within the Yellow Limestone Group. This is particularly the case towards the south-western boundary of The Cockpit Country to the south of Jointwood.

The relatively low porosity of many of the limestones is also important to karst landform development; as directed, rather than diffuse, dissolution occurs along lines of weakness with the development of secondary porosity along joints and fissures, leading to the development of karst terrain through enhanced rates of dissolution where joints are more frequent.

The overall tectonic evolution of the island and the resulting geological structures have imparted a significant control on the development of karst landforms within The Cockpit Country, not least, the block faulting and extensive east-west trending fault systems, the anticlinal folding of the platform carbonates and the erosional breaching of this structure, together with subsequent de-roofing of the Central Inlier to the southeast of the region.

East-west faults occur at the northern margin of the area, specifically the Duanvale fault zone, which exerts strong geomorphological and hydrological controls on karst development. Across The Cockpit Country, the faults are more or less perpendicular to those along its northern margin, and trend between northeast-southwest and northwest-southeast. Most of the major faults have clear topographic expression across the area. According to Versey (1972), to the north of the Clarendon Block, in the North Coast Belt, faulting gives way to folding in the deeper water carbonates of the Montpelier chalks, which display clear dips, and faults lose their clear topographic expression. The general absence of faults in the Montpelier Formation leads to low secondary permeability, which in effect acts as a barrier to the northerly groundwater flow from The Cockpit Country. It is also possible that impedance of drainage is caused by a reversal of the dip, or by the upfaulting of the karst base (Gardner *et al.*, 1987). Faulting had the effect of generally increasing the permeability of the limestones, though where the limestones were “initially so incoherent”, the faulting decreases the permeability as evidenced by the occurrence of fault-line ridges within the cockpit karst which have resisted dissolution (Versey, 1972).

Within The Cockpit Country, the regional groundwater flow is north or south through the limestones, with a flow direction parallel to the predominant north-south faults, which tend to impart a strong control, acting as lines of preferential groundwater flow (Versey, 1972). The Miocene to recent tectonic activity also produced many faults, which form numerous scarps, seen as strong lineaments on satellite imagery and aerial photographs (Draper *et al.*, 1998) (**Figure 6A**).

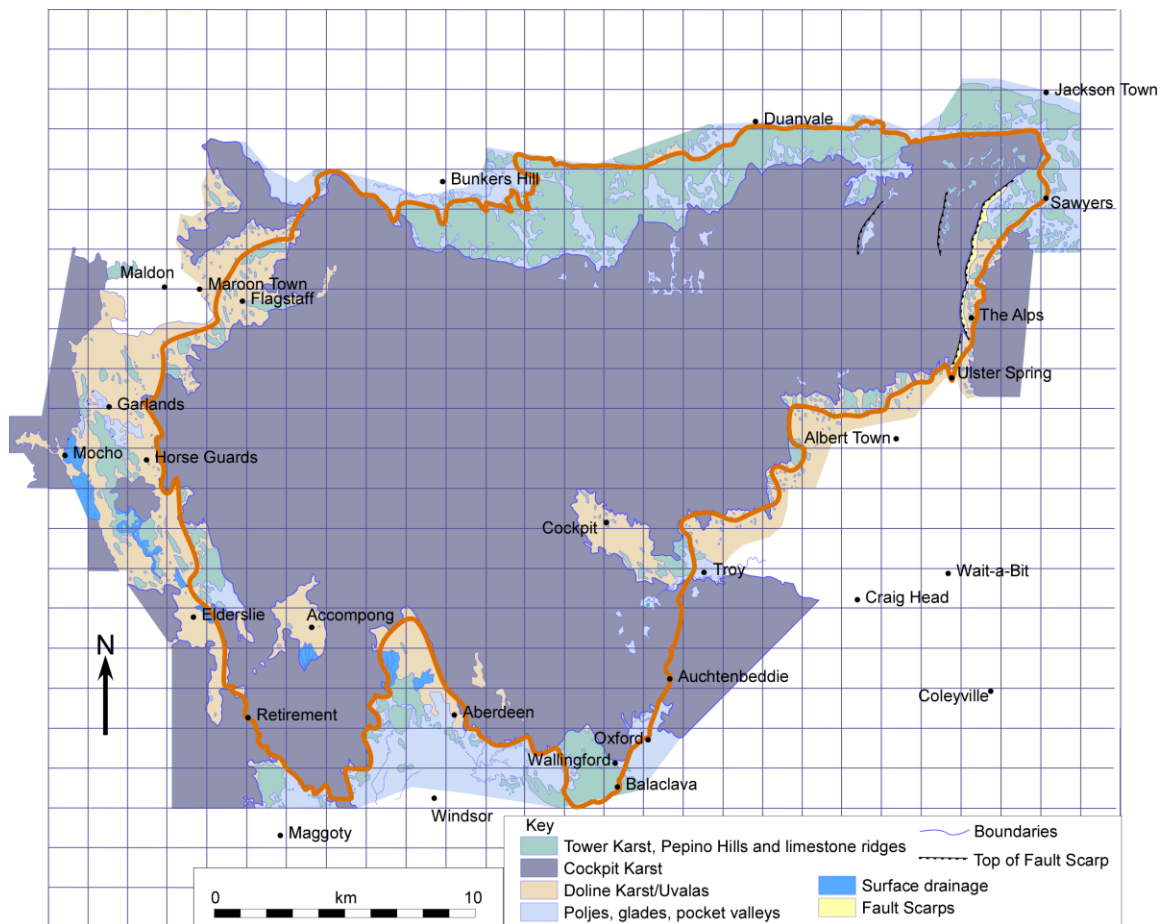
The origin of the karst landforms is closely related to the character and attitude of the limestones and their tectonic evolution (Versey, 1972; Gardner *et al.*, 1987). One of the main controls on the overall physiography of the limestones is their block-faulted structure. Basically, the karst features are superimposed on the block-faulted structural elements. According to Versey (1972) and Gardner *et al.* (1987), karst erosional processes have accentuated the structures in some areas, while in other situations, much of the original structure has been masked by deposition of alluvium, particularly in the interior valleys and poljes, which have been structurally depressed, rather than being the result of erosion.



**Figure 6. A, Fault and joint controlled linear alignments, near to the Alps, along the north-eastern boundary of The Cockpit Country (photograph by Mr. Jack Tyndale-Biscoe). B, Broad doline depression near to Niagara, western boundary of The Cockpit Country. C, Doline in Chapelton Formation south of Tangle River, western boundary of The Cockpit Country. D, Cockpit karst south of Barbecue Bottom, in the eastern part of The Cockpit Country. E, Elongate and asymmetric residual hills with cockpit depressions south of Barbecue Bottom, in the eastern part of The Cockpit Country**

Calcareous weathering crusts commonly occur on residual limestone hills and outcrops in tropical environments, and their significance for karst was first appreciated in the Caribbean region, where the phenomena is known as case hardening (Ford and Williams, 1989). Although there has been no systematic work completed on case hardening in Jamaica, it is common. Pfeffer (1969)

reported three distinct variations of cockpit karst in one small area in southwest Jamaica in relation to the presence of surface crusts. The limestone crusts, travertine and stalactites reported by Pfeffer (1969) represent reprecipitated calcium carbonate, which at least, in part, forms a case-hardened cap rock on some of the residual hills. The case-hardening effect is normal on all units of the White Limestone Group, but it is especially noticeable on those units, such as the Moneague Formation, which are soft, 'chalky' to granular micrites, when fresh. Thus, it would seem that case hardening may be more important in the development of karst topography on the rubbly and chalky limestone formations, rather than the older recrystallized limestones, some of which have been dolomitised and may account for the presence of cockpit karst on the southwest margins of The Cockpit Country within Chapelton Formation limestones.



**Figure 7. Geomorphological map the area in and around The Cockpit Country. Proposed boundary for The Cockpit Country is shown in red. The boundary of The Cockpit Country is largely coincident with the extent of cockpit karst, although it includes areas of tower karst and pepino hills in several areas. Cockpit karst is continuous across the boundary near retirement and between Troy and Auchtembeddie; the boundary in these areas, as well as between the Alps and Sawyers is placed along the “Ring Road”. Place names included for reference purposes.**

## **7.4 Geomorphic Description of the Karst Landforms**

The karst geomorphology of The Cockpit Country can be examined at several spatial scales. On the small-scale, there is a range of fine solution sculpturing present on many limestones surfaces, which is the product of dissolution of the limestones by slightly acidified rainwater and subsequent surface vertical trickle and flow under the influence of gravity. Collectively, these small-scale features are referred to as karren and a wide variety of such features is present, though they are not important in delimiting a boundary to the region and will not be discussed further. The larger-scale karst phenomena are more important, and there is a wide range of karst features, from cockpit karst and doline karst, both largely the product of vertically-directed dissolution, to tower karst, which is mainly related to laterally-directed dissolution or to lithological boundaries, to ridge karst and poljes, which have a strong structural control. Poljes also induce horizontal water movements at or near to the regional groundwater table.

A geomorphological map for Cockpit Country is shown in **Figure 7**. This was prepared using the 1:40,000 scale aerial photographs taken in 1999, backed up by field studies. The various karst landforms are described below.

### **7.4.1 Doline Karst**

Dolines are closed depressions of simple form varying in diameter from a few metres to hundreds of metres across and from shallow features to depressions more than 100 m deep. Dolines have a range of different forms, including dish- and bowl-shaped depressions, cones and cylinders (**Figure 6B-C**). An increase in size is generally accompanied by greater complexity of form as the circular to oval-shaped depressions expand and coalesce. Bedrock crops out on the sides and floors of some dolines although most dolines in the region are surfaced largely or entirely by soil and superficial debris. Many dolines are characterized by flat floors, which often contain an impermeable clay seal, leading to the occurrence of ponds.

Doline karst in the area is best developed within the Chapelton Formation of the Yellow Limestone Group. It occurs predominantly on the western margins of The Cockpit Country and around Accompong, where the dolines are mostly large, complex, bowl-shaped depressions, occasionally with small ephemeral stream channels draining to a sinkhole in the lowest part of the depression. Many of the dolines have also coalesced to form more complex uvalas. Doline karst is also an important landscape type on the Montpelier Formation to the north of the region (Sweeting, 1958). The largest area of doline karst on the White Limestone Group occurs in the north central part of the island to the north of The Cockpit Country, a few kilometres inland from the coast especially where it is underlain by the relatively soft, chalky limestones of the Montpelier Formation (Draper and Fincham, 1997).

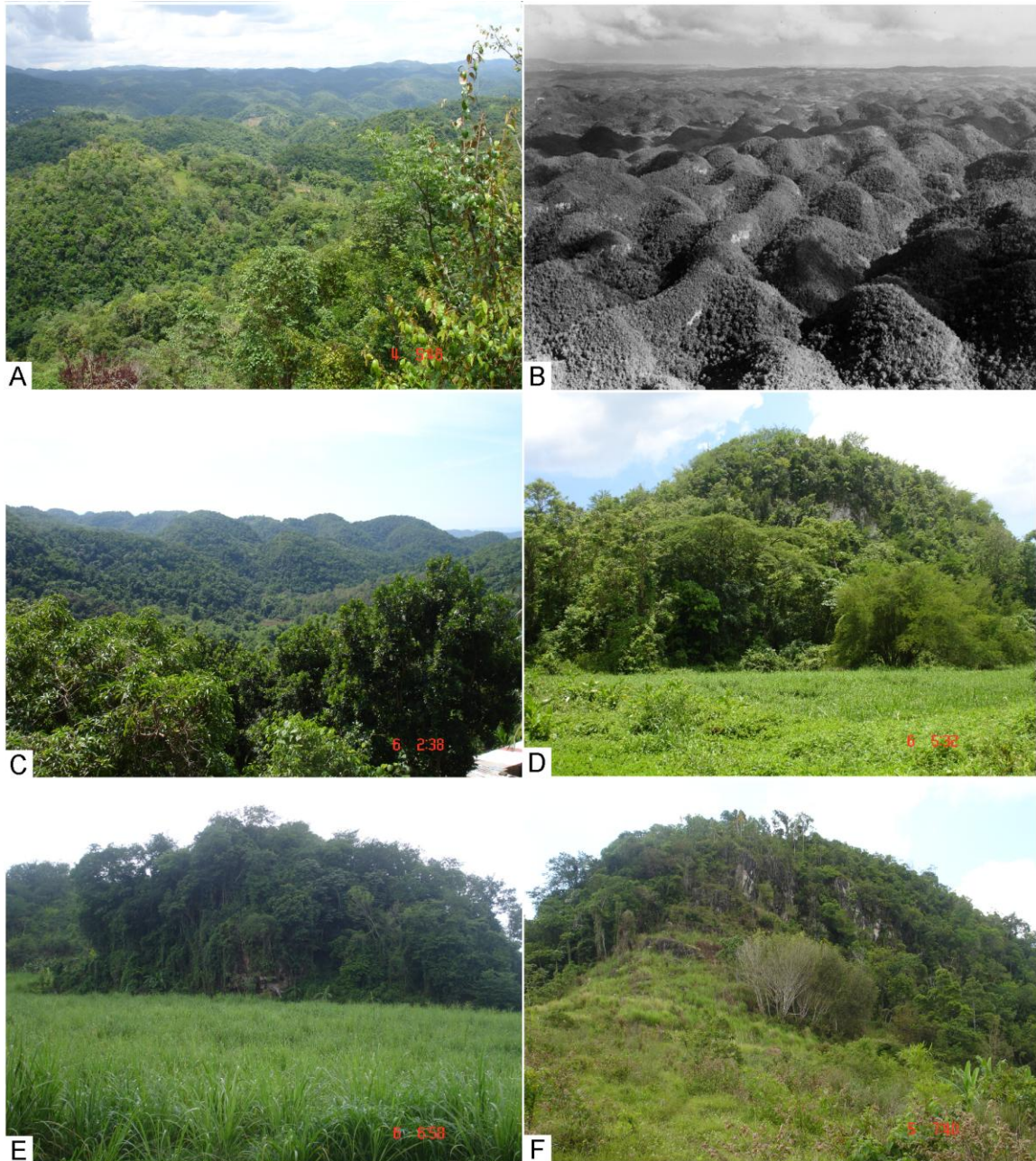
A number of karst processes are responsible for doline formation including dissolution, collapse and subsidence. Day (1976), in a study of doline karst in the Brown's Town area indicated that it is not possible to infer the dominant development process in the formation and subsequent development of the enclosed depressions he studied. Day suggested that small-scale collapse may

provide the initial form, which is subsequently modified by systematic dissolution. The enclosed depressions generally show a regular distribution which could suggest dissolutional activity, as collapse events may produce a more random distribution pattern. An investigation of the processes leading to doline development was beyond the scope of this study, but the morphology of the dolines would imply a dissolutional origin for the most part.

#### **7.4.2 Cockpit Karst**

Cockpit karst consists of a succession of cone-like hills and intervening enclosed depressions (Sweeting, 1958) (**Figure 6D**). Cockpit karst in Jamaica has also been termed kegelkarst, gerichteter karst (directed karst) (for example Lehmann, 1954) and cone karst (Sweeting, 1958, 1972), although Versey (1972) considered the term kegelkarst as inappropriate due to the fact that the Jamaican cockpits are modified by an over-deepening of the depressions. Cockpit karst was thought to be restricted to the hard, fissured and recrystallised limestones of the White Limestone Group (for example Sweeting, 1958, 1972), although our study suggests that it is not simply limited to the Troy and Swanswick formations, but it is more widespread than previously thought. The overall landscape is a highly irregular combination of positive and negative relief elements of roughly equal prominence (Day, 1979, 1982; Chenoweth and Day, 2001). This type of karst landscape is the most widespread in Jamaica (Sweeting, 1958), covering some 60% of all karst terrain (Day, 1979), The Cockpit Country being the type locality for cockpit karst (Sweeting, 1958, 1972; Versey, 1972).

The cockpit depressions are deep and have an average depth of 90-120 m, though they may extend to over 150 m deep and have a diameter of upwards of 1 km. The associated residual hills are broadly conical in shape, though some are elongated (**Figure 6E**), 30-130 m high and up to 1 km in diameter. In the larger cockpits, there is a marked break of slope at the base of the hillslope, while in the smaller depressions the floor and sides grade into one another (Sweeting, 1972). Although distinguishing between the depressions and hills of cockpit karst is essentially meaningless, since they are not separate, but integral components of the same landform, individual cockpits are described as being surrounded by three or more residual hills of a similar elevation to the depths of the depressions (**Figure 8A**). When the depressions are delimited on the basis of their topographic divides, the surrounding residual hills and ridges connecting the depressions constitute a cellular network (Day, 1979) that has been termed polygonal karst (Williams, 1971, 1972). The depression side-slopes are convex, which gives the overall landscape a star-shaped or polygonal plan, although Chenoweth and Day (2001) suggest that there is a range of cockpit morphologies from complex star-shaped patterns to simple circular forms. The cockpits are contiguous with a clearly identifiable col or divide between each depression (Barker and Miller, 1995; Miller, 1998), forming corridors and passages between hills that connect adjacent cockpits, though other divides form saddles, which are less pronounced notches between adjacent hills (Chenoweth and Day, 2001). Canter (1987) estimated a frequency of 15 cockpits per km<sup>2</sup> in the area around Quickstep, with an estimated 20 cockpits per km<sup>2</sup> in the centre of The Cockpit Country, totalling about 4,000-4,500 depressions.



**Figure 8. A, Cockpit karst at Rose Valley, near to the southern boundary of The Cockpit Country. B, Cockpit karst associated with glades and pocket valleys near to the northern boundary of The Cockpit Country (photograph by Mr. Jack Tyndale-Biscoe). C, Cockpit karst near Mulgrave, west of The Cockpit Country. D, Tower karst surrounded by an alluvial plain in the Nassau Valley, south of The Cockpit Country. E, Tower karst in the Nassau Valley near Thornton, south of The Cockpit Country. F, Troy Formation tower karst surrounded by Chapelton Formation dolines around Flagstaff, north west part of The Cockpit Country.**

The bounding slopes of cockpit depressions are extremely irregular, although Sweeting (1958) indicated they average about 30°-40°, consisting of chemically weathered and honeycombed blocks and scree. Where bedrock is exposed, the sides are steeper and form cliffs and precipices (Sweeting, 1972). Aub (1964a,

1964b, 1974a, 1974b) examined in detail the array of different slope elements associated with the cockpits and recognised six types of hillslope. These are defined by Aub (1964, in Sweeting, 1972) as; Staircase slopes, comprising small ledges and vertical steps, the latter being up to 2–3 m high and where bedding planes are conspicuous; Broken cliffs, consisting of higher steps and less uniform ledges, where the steps are intersected by widened joints; Steep even slopes of honeycombed limestone covered with loose talus and blocks; Major cliffs, of varying height but undercut by horizontal notches to depths of 2–3 m and often associated with springs; Cliffs of similar height but without undercutting, and Scree slopes covered with small limestone fragments. Chenoweth and Day (2001) also identified two basic hilltop morphologies in the cockpit karst in the area around Windsor; some are dome shaped and rocky, while other hill summits are flatter in plan view.

Normally the cockpit depressions and conical hills are more or less symmetrical, but some asymmetry occurs. Two explanations have been presented to account for the asymmetry. The first is related to the dip of the limestones, which when it exceeds more than a few degrees produces asymmetry with up-dip side of cockpits becoming steeper than the down-dip side. The second is to differential dissolution rates in response to exposure to the oncoming trade winds, as occurs near the north coast where north facing slopes are less steep (Sweeting, 1958). The cockpits and residual hills are often arranged in lines following faults or jointing (Sweeting, 1958) and cockpit karst often occurs in the form of winding sinuous chains or ridges separated by glades (Sweeting, 1972) (**Figure 8B**), though elsewhere no structural guide can be identified (Wadge and Draper, 1977). Aub (1964a) also indicated that the cockpits he studied showed no apparent fault or joint guide and that the morphology of the slopes and cones is variable.

Smith *et al.* (1972) also stressed that the cockpit areas show considerable variation in morphology and display irregular slope forms, though they have a mean slope angle of about 30°. According to Sweeting (1958), the summits of the hills tend to reach an even level, which she interpreted as a structural surface, or part of a more extensive peneplain surface, dissected by cockpits of variable depth, representing one-cycle and multi-cycle landforms. However, Smith *et al.* (1972) concluded there is no correlation between the elevation of hill summits or depression floors except where the depressions have eroded down to the underlying Yellow Limestone.

Most of the depressions ‘drain’ towards a deep vertical shaft in the lowest part of the depression eroded in solid limestone. In some areas the shafts may have a number of narrow entrances which unite at a relatively shallow depth (Smith *et al.*, 1972). Smith *et al.* indicated that it is possible to gain entry to some of the shafts, though others are blocked by debris or are too narrow for exploration, contending that it is rare for the shafts to be explored beyond 30 m depth. Versey (1972) indicated that many cockpits are floored with boulders, while others have solid floors with vertical sinkholes that connect with deeper horizontal caves. However, Baker *et al.* (1986) explored several of these to depths of 80 m, without intersecting the water table, and Canter (1987) in an attempt to estimate the

frequency of pits, indicated they reach a depth of up to 70–80 m, but without significant lateral passage development with most shafts bottoming out in narrow joints or debris chokes.

Sweeting (1956, 1958) further delimited cockpit karst into two variants which she termed “true cockpit” and “degraded cockpit”. According to Sweeting, cockpits become degraded when deepening ceases due to a “slackening” of solution processes. Degraded cockpits are shallower with slumped and gentle side slopes, the overall relief of the landscape becomes more “subdued and rolling” and there is a greater dissociation between surface and groundwater circulation (Sweeting, 1958). The basic morphological difference between the two relates to the accumulation of debris within the depression. The bases of ‘cockpits’ contain little superficial material and a near vertical shaft is evident, whereas in the ‘degraded’ form, the bases of the depressions are occupied by bauxitic material, commonly up to 10 m deep (Day, 1979). Degraded cockpit karst exhibits a wide variety of forms, in relation to the degree of accumulation of ‘soil’, from a nearly flat bauxitic plain with occasional protuberances of limestone, through a vermiform pattern of limestone ridges separated by bauxite infills, to cockpits where only the central portions of the depressions are filled with bauxite (Smith *et al.*, 1972).

The hydrology of the cockpits is now dominated by slow and diffuse percolation, which is the only contemporary connection between the cockpit depressions and underground drainage. Day also concluded that the degraded cockpit forms are currently experiencing greater solutional attenuation as dissolution is focussed beneath the superficial deposits. However, Aub, in a personal communication to Versey (1972), considered that an important difference between cockpit karst and karst areas elsewhere on the island was that there has never been a bauxite cover in the former and dissolution has a more powerful effect than in areas where the depressions are infilled with bauxite, thus inhibiting dissolution and impeding deepening.

A number of explanations have been given for the origin of cockpits, but they basically fall into either solution-related or collapse-related categories. The original collapse explanation for the cockpits was presented in the ‘*Memoirs of the Geological Survey*’ by Sawkins (1869), where in the first detailed descriptions of The Cockpit Country, the depressions were ascribed to the sinking of water through the cavernous structure of the limestones. Some thirty years later, a lengthy reassessment of the geology of Jamaica was published by Hill (1899) who, although there was little descriptive interest in the karst, ascribed the origin of cockpit depressions to dissolution rather than collapse. Daneš (1909, 1914) was the first worker to widely adopt the theory that the cockpit depressions originated predominantly by dissolution of the limestones along fissures and other lines of weakness, although he did concede that they may be further deepened by localised collapse of caves which would help to further enlarge them. Using evidence such as the regular distribution and linear arrangement of the cockpits, together with their dissociation from subsurface groundwater circulation, Sweeting (1958) also concluded that the cockpits are formed by dissolution with subsequent enlargement by collapse along fissures. Versey

(1960) suggested that the physiography of The Cockpit Country is closely related to the hydraulic and abrasive action of floodwaters in underground drainage systems, and that solutational and mechanical action of confined floodwaters was responsible for the enlargement of cockpits, along with collapse. Versey also noted that the deepest cockpits occur where underground water movement is close to the surface, and he further refined this theory by suggesting that a rise in water levels during rainfall brings groundwater circulation close to the bottom of the cockpits, eroding them, and that subsequent collapse then deepens the depressions and removes the soil cover (Versey, 1972). According to Versey, if the cockpits have developed over a long period of time, then the rate of erosion has matched the rate of uplift. In areas where uplift has been more rapid, water circulation becomes too deep to be effective, and dissolution takes over as the main erosive process and a soil cover develops in the depressions leading to the development of 'degraded cockpit karst'.

Other workers have suggested that dissolution alone is responsible for cockpit formation. Aub (1964b) suggested there is very little evidence of any widespread collapse or mechanical action, and that there is no correlation of cockpit shape or size with height above the underground drainage. Smith *et al.* (1972) and Day (1979) also supported a dissolution origin for the development of cockpit karst.

From the foregoing, it is clear that cockpit karst has a wide variety of form and several interchangeable terms have been used to describe the landscape, including 'cockpits', 'kegelkarst' and 'cone karst', while 'true' cockpit karst and 'degraded' cockpit karst were additionally introduced to differentiate between cockpit depressions devoid of, or with a soil and debris cover. Miller (1998) mapped three principal classes of cockpit karst in The Cockpit Country between Windsor and Troy, based on the size and shape of the intervening residual hills. The three types are, 1) cockpits with conical hills, 2) cockpit depressions with small elongate hills up to 50 m high, aligned in a general north-south direction, probably along faults and major joints, and 3) depressions with larger elongate hills in a beaded arrangement, grading into ridges. Cockpit karst does not necessarily mark the boundary of The Cockpit Country (**Figure 8C**).

### **7.4.3 Tower Karst**

Two types of tower karst occur around the margins of Cockpit Country. The first type of tower occurs as isolated residual hills, either singly or in clusters, surrounded by alluvial plains, glades or pocket valleys. The other type of tower karst occurs as White Limestone outliers, normally within the Troy Formation, surrounded by doline karst formed in the Chapelton Formation (Yellow Limestone Group). The first type of tower karst associated with alluvial deposits, is most prevalent to the north and south of The Cockpit Country. In the north, a broad band of tower karst stretches from Sawyers in the east to Spring Vale in the west, while it is prevalent in the Nassau Valley around the southern boundary of The Cockpit Country. The second type of tower karst occurs wherever the White Limestone has eroded down to the underlying Chapelton Formation of the Yellow Limestone group, particularly along the western boundary of The Cockpit

Country, and in the area from Troy to Albert Town, along the southern and south eastern boundary.

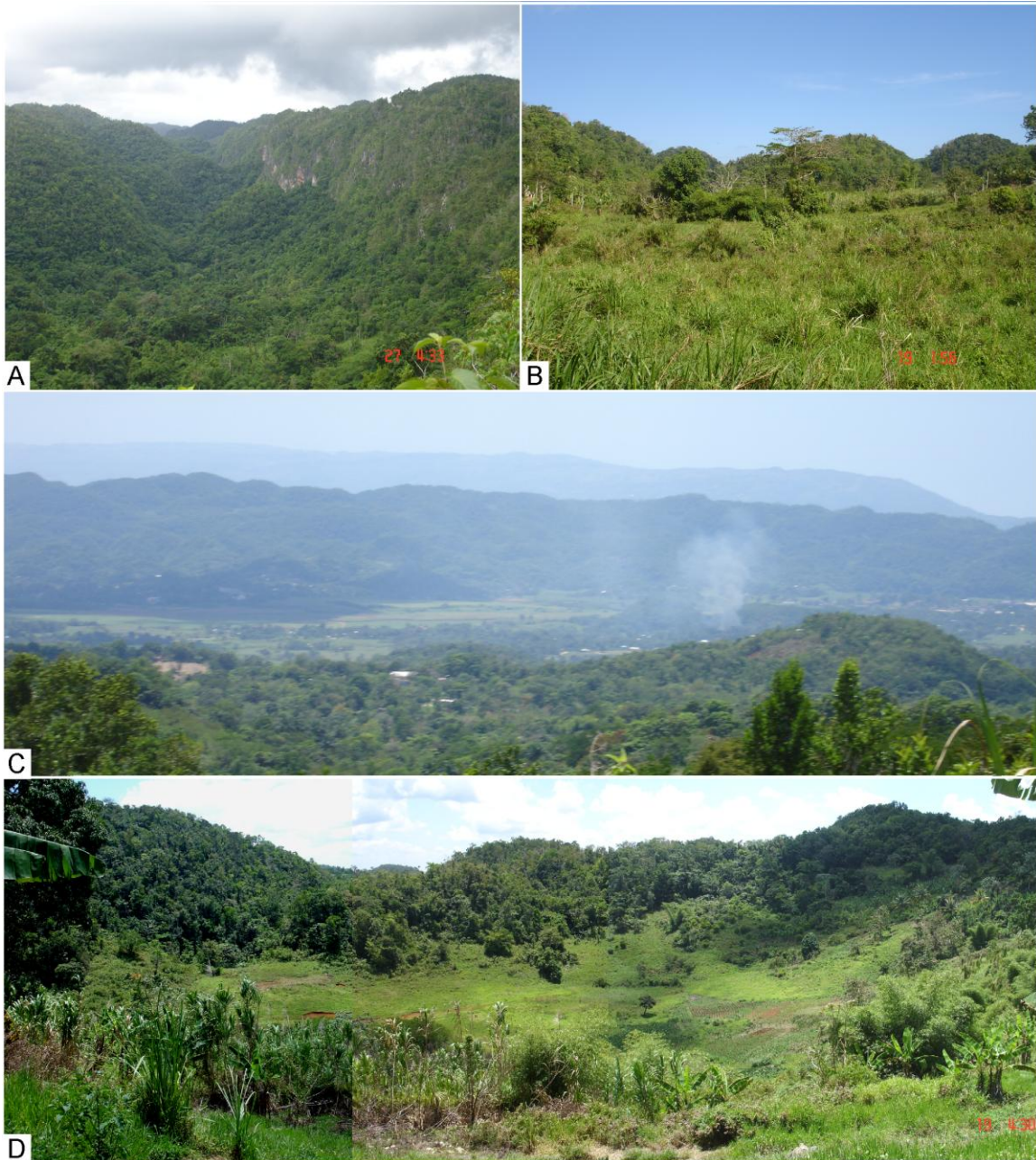
The first tower karst type comprises a landscape of residual hills scattered across a relatively flat plain (**Figure 8D-E**). Some of the residual towers are isolated and others occur in groups. The towers are steep-sided hills which slope up to 60°-90°, rising up to 100–150 m above a flat alluvial plain. The towers are sub-conical, though many have flattened tops and appear tabular in profile. The tower slopes are frequently broken and devoid of a soil cover, except for isolated pockets. Many tower bases are undermined and display undercut notches associated with well-developed foot-caves and springs. A well developed ring of sinkholes, which often become flooded in the wet season, commonly occurs around the base of the undermined and oversteepened towers. The second tower type is similar morphologically, as they form isolated, steep sided hills within exposed bedrock, though they tend not to be undermined by laterally directed water flow, but are the product of vertically directed dissolution (**Figure 8F**).

Two particular geological conditions favour tower karst development around The Cockpit Country. They occur near to the base of the White Limestone at the junction between the White Limestone and Yellow Limestone and within the crystalline facies of the White Limestone Group in close association with the marly Montpelier Formation. They are also associated with rapid spring-head recession, which gives rise to the flat-floored, steep-sided and steep-headed 'pocket valleys' which accompany tower karst on the northern margins of The Cockpit Country (Sweeting 1958). Sweeting (1972) further identified two main types of tower karst, which both occur within the White Limestone Group. One type of tower occurs as a visible remnant of limestone surrounded by alluvium, beneath which is a planed limestone. The other tower type is developed on a plain of non-limestone rocks, as occurs where towers within the White Limestone form outliers on the much less pure Yellow Limestone, though they may also occur where the White Limestone is in faulted contact with older Cretaceous rocks, especially in the Central Inlier to the east of the area. Draper and Fincham (1997) indicate that isolated towers of White Limestone formed by erosion down to the less soluble Yellow Limestone or older Cretaceous rocks are best developed around Maroon Town, on the western edge of The Cockpit Country.

In addition to undercut towers with notches, Sweeting (1958) identified a second tower type based on morphology, which she interpreted to be 'degraded tower karst', though this tower type is not found around the margins of The Cockpit Country.

#### **7.4.4 Ridge Karst**

A number of limestone ridges and Pepino hills are associated with cockpit karst entirely within the boundary of The Cockpit Country. Many of the ridges are broadly symmetrical, though others are asymmetrical across their axes. Most are aligned roughly along northwest-southeast and northeast-southwest axes, probably in response to major joint and fault trends.



**Figure 9.** A, Barbecue Bottom Glade, north east part of The Cockpit Country. B, Small 'Interior-Valley' at Cook's Bottom, western boundary of The Cockpit Country. C, The Nassau Valley 'Open-Polje', south of The Cockpit Country. D, 'Interior-Valley' near Arcadia, western boundary of The Cockpit Country.

#### **7.4.5 Glades**

A number of glades occur within The Cockpit Country, particularly towards the northern boundary of contiguous cockpit karst. These glades were first described by Sweeting (1958) as elongated and enlarged cockpit depressions, similar to uvalas, where individual cockpits extend by growth along lines of jointing and faulting and coalesce to form more complex forms along a well-defined tectonic line. Glades and cockpits tend to merge into one another (Sweeting, 1972).

Sweeting indicated that Barbecue Bottom, in the northeastern part of The Cockpit Country, is a typical glade formed in such a way along a north-northeast-south-southwest-trending fault line (**Figure 9A**). Glades are sinuous depressions with concave and angular contours, and are steep sided. The floors of glades also tend to consist of a series of shallow basins being separated by low divides which are much shallower than the passes leading out of the glades. Drainage in channels on the floor of the glade often disappears into caves and sinkholes at the margin of the glade. Glades have also been described as broad areas between residual hills that can individually be classified as either compound depressions, such as uvalas, or as dry and underdrained valleys (Chenoweth and Day, 2001). Accordingly, their cross-profile may be flat, convex, concave or undulating, and in plan view their shapes are either linear or sinuous.

#### **7.4.6 Poljes**

Poljes are large, flat floored enclosed depressions in karst terrain, commonly with ephemeral or perennial streams flowing across their surface (Ford and Williams, 1989). Poljes have three diagnostic criteria (Gams, 1978); a flat floor in solid rock or unconsolidated sediments such as alluvium; a closed basin bordered by a rim of steep marginal slopes, though the steep slope may be restricted to one side of the polje, with an abrupt break of slope between the floor and sides; and karstic drainage with stream sinks, especially at the margins of the polje. Many poljes occur to the north of The Cockpit Country exemplified by The Queen of Spain's Valley (Pfeffer 1986). The Nassau Valley has also been described as a polje, but in the strict scientific definition of the word it is not a polje. However, the term 'open-polje' has been used loosely to describe alluvial plains along rivers that enter and leave the plain in narrow valleys or gorges. The Nassau Valley could therefore be described as an open-polje (**Figure 9C**). Elsewhere around the margins of The Cockpit Country, poljes and small 'interior-valleys' are common to the north and along the western margin at Cook's Bottom (**Figure 9B**) and near Arcadia (**Figure 9D**).

The poljes or 'interior valleys' of the island have been described in general by Sweeting (1958) and Versey (1972). Specific poljes have also been studied in more detail, especially The Queen of Spain's Valley (Pfeffer, 1986) to the north of The Cockpit Country. Sweeting (1958) indicated that poljes occur in Jamaica where lithological, structural, or relief conditions permit flood water to collect and where rapid drainage is impeded. Accordingly, they are conspicuous along the northern margin of The Cockpit Country, where lateral water movement is promoted by the Montpelier chalks, and on the northern side of the Duanvale fault zone (Sweeting, 1958). Sweeting (1958) also noted poljes to be common where the White Limestone come into contact with the older Yellow Limestone Group, where flood water can be ponded due to poor drainage through the older rocks. Sweeting (1958) further suggested that as the poljes across the island occur at a range of elevations, local water table fluctuations were more important to their development than regional variations. She also noted the occurrence of drained poljes where flooding is absent or occurs infrequently due to changing

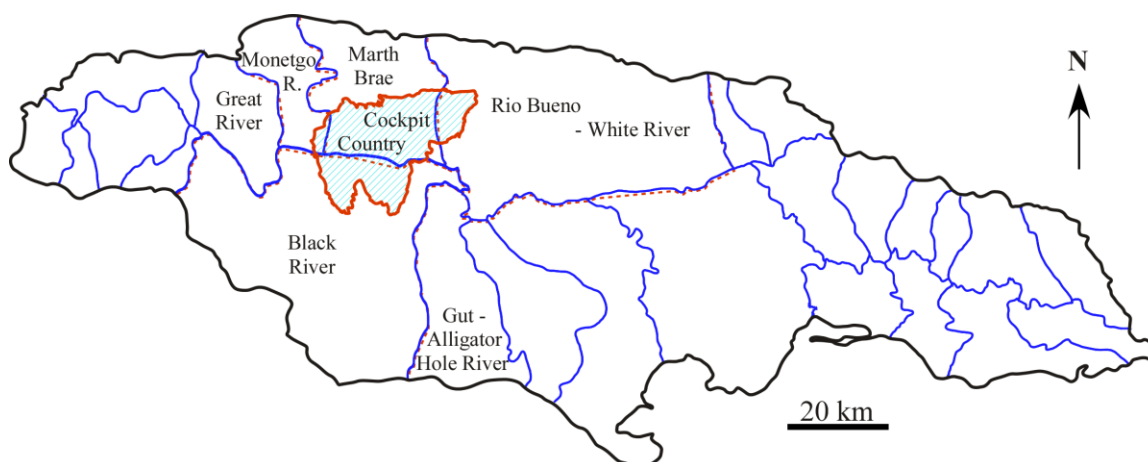
hydrological conditions and marginal poljes (border poljes) where they are not completely surrounded by White Limestone.

Versey (1972) described the Nassau Valley and the interior valleys of northern Trelawny. He considered that faulting and folding within the Nassau Valley forms a barrier to drainage and forces groundwater to the surface, which causes periodic flooding and leads to the deposition of alluvium. In describing the valleys of northern Trelawny, Versey (1972) indicates that the structural barrier which impedes the northerly flow of groundwater, leading to a series of springs, is a combination of an upfaulted block of Yellow Limestone beneath the valleys and the change of facies within the White limestones from the crystalline and rubbly limestone to the Montpelier chalks.

Pfeffer (1986) described the Queen of Spain's Valley as a large polje with an extensive plain, about 90–100 m elevation, surrounded by higher relief. To the south, the valley is bordered by steep limestone hills which rise abruptly to form cockpit karst, a well-defined boundary to The Cockpit Country, and to the north, east and west, the polje gives way to limestone hills and dolines. According to Pfeffer (1986), the polje floor is dissected by dolines, which may contain shallow ponds, also many karst springs rise on the polje floor near to the southern border to flow northwards as the Roaring River and Martha Brae River systems.

## 8 Hydrology

The distribution of Watershed Management areas in Jamaica (**Figure 10**) does not agree with river basin catchments that can be defined by the tracing between river sinks and resurgences (summarised in Fincham, 1997) around Cockpit Country. For this study, available data on the tracing was integrated with river drainage basins identified by geomorphological analysis of surface drainage systems to determine the various drainage basins that are present in The Cockpit Country.



**Figure 10.** Distribution of Watershed Management areas in Jamaica (source: Green Paper No. 2/99) showing location of proposed boundary for The Cockpit Country in red.

### 8.1 Basement – aquifers versus aquicludes

The sub-White Limestone basement is commonly considered to represent the basal aquiclude of Jamaica, and the White Limestone and units above (where developed) are considered to represent an unconfined aquifer. In reality, the Yellow Limestone, as well as limestones within the Cretaceous, act as aquifers, and the basal aquifer is more of a convenience than a reality at least in some parts of the island. The aquicludes developed in and around The Cockpit Country include: 1, the Cretaceous shales, sandstones and conglomerates; and 2, the mudstones and heterolithics in the Guys Hill Formation. The aquifers include: 1, the Cretaceous limestones in the Maldon Inlier (confined aquifers); 2, sandstones in the Guys Hill Formation that give rise to spring lines (confined aquifers); 3, the Stettin Formation (confined aquifer); and 4, the Chapelton Formation and White Limestone Group (unconfined aquifer).

### 8.2 Aquiclude distribution in and around Cockpit Country

The large-scale structural features of The Cockpit Country and surrounding areas control the distribution of basement highs and aquicludes. The complexity of confined aquifers in the pre-Chapelton rocks, means that such a simplistic

interpretation is not necessarily always correct, however, given the structural configuration, the distribution of sub-Chapelton basement gives a good first-order approximation to the control of catchments.

Given the distribution of the older parts of the White Limestone Group in Cockpit Country, a broadly east-west orientated 'anticline' can be assumed (younger rocks appear both to the north and south of The Cockpit Country, and at lower altitudes that in the centre of The Cockpit Country), and this 'anticline' would form the major (island) divide between catchments draining to the north and south. Because the central part of The Cockpit Country is formed of rocks of the White Limestone Group, the exact position of this divide is difficult to determine, and it may well not correspond to the highest topographic levels.

The Central Inlier represents a broadly NW-SE orientated anticline with impervious rocks at its core and effectively forms an aquiclude (Cretaceous limestones do not reach the surface in this part of the inlier) to the east of The Cockpit Country. Hectors River drains an area on the south-western side of the inlier and sinks beneath The Cockpit Country at Hectors River Sink-1 (Fincham, 1997, p. 45). Resurgence is made at Coffee River Cave, before it sinks again at Wallingford Sink (Fincham, 1997, p. 45). The river rises for a final time at Mexico Cave to form the One Eye River, a major tributary of the Black River (Fincham, 1997, p. 44). The Black River is mainly fed from Black River Head, which has conjectural flow from the NNW through the fault graben (with Moneague Formation) that extends from Pullet Hall to Quickstep (Sweeting, 1956; Fincham, 1997, p. 44). Additional resurgences feeding the Black River come from the Thornton area (Fincham, 1997, p. 44) and from Cook's Bottom (reported die trace by local farmer, no academic reference traced), and possibly the Niagara River. Surface drainage has also been recognised to the north of Johnsen (near Elderslie) and in a deep valley south of Accompong. Presumably these also feed into the Black River.

The horst block between the Barbecue Bottom and the Alps fault zones represents a basement high, and corresponds to the watershed boundary between the Martha Brae and Rio Bueno catchments. River systems draining the north-eastern margin of the Central Inlier (die traced for Quashies River Sink and Cave River Sink, conjectural for Lowe River Sink) feed into the Rio Bueno rising at Durnock Head. In contrast, the sink at Mouth Maze to the north of Rock Spring (and to the west of the Barbecue Bottom fault/monocline) was die traced to the rising at Fontabelle feeding the Martha Brae River. Thus the horst must represented the catchment boundary. Drainage from the horst block between Barbecue Bottom and the Alps Fault Zone could flow into either catchment, but no studies have been attempted.

To the west of The Cockpit Country the line of Cretaceous and Yellow Limestone inliers extending southwards from the Maldon Inlier indicate the existence of a basement high in this region. Numerous small drainage basins are developed in the Cretaceous and Yellow Limestone inliers in here with flow generally directed towards the east or west. Die tracing of several rivers has been undertaken in this region (see Fincham, 1997, for references), and can be used to determine the river catchments. The Tangle River forms an extensive

drainage system in the Maldon Inlier, and is fed from various other drainage networks via caves. Drainage in the Sweetwater-Mocho Inlier sinks at Mocho Sink, rises at Pumphouse Cave, sinks again at Banana Market Sink before rising at Flamstead Cave to feed the Tangle River. Drainage in the Garlands Inlier sinks at Garlands Sink and also rises at Garlands Cave to feed the Tangle River. The Tangle River itself sinks at Rota Sink to resurge at Deeside. Other small streams (e.g., Lemy River) sink in the Maldon inlier (e.g., at Lemy River Sink) and resurge elsewhere (Spring Vale Rising). All these risings that originate from the Maldon Inlier feed the Martha Brae drainage via the Roaring River.

In summary, the drainage that is related to The Cockpit Country can be attributed to only two river catchments, the Black River and the Martha Brae. Yet even saying this, both river systems are also fed from extensive surface runoff from Cretaceous Inliers to the east and west, respectively, which drain agricultural lands. Other rivers in central west Jamaica, such as, the Rio Bueno, Montego River and Great River, have little or no inputs from The Cockpit Country.

## **9 Socio-Historical Context of Delineating Cockpit Country**

While the area loosely referred to as Cockpit Country is often defined in terms of physical characteristics of geology, geomorphology, hydrogeology flora and fauna, the historical and socio-economic characteristics of the region reflect the culture and livelihood activities of people who utilize its resources. In that regard, the historical and socio-cultural context of The Cockpit Country must of necessity be an integral and critical component of any delineation process for the area. In other words, the criteria for delimiting The Cockpit Country cannot be divorced from its socio-economic, socio-cultural and historical relevance (Spense, 1999). Indeed, in the context of human – resource relationships, the physical definition of the area in terms of its geology, geomorphology and biodiversity can only be relevant within a social construct. Indeed, the physical definition of The Cockpit Country determines its social context especially with regard to the livelihood activities of The Cockpit Country communities. Irrespective of criteria use in definition, from an applied perspective, boundaries are relevant only as they relate to social mandates. It is in this context that the social context of delineating The Cockpit Country is central to the exercise.

### **9.1 Socio-historical Background**

The area loosely referred to as The Cockpit Country has long been recognized as one of Jamaica's most outstanding wilderness areas, is known internationally for its dramatic karst topography, high level of biodiversity and endemism with respect to ferns, flowering plants, birds, amphibians, reptiles and insects. The Leeward Maroons of Jamaica have lived on the south-western margins of the Cockpit since the 17<sup>th</sup> century and their history of battles with British soldiers and plantation owners is part of the mystique of the area. It is this uniqueness of the region that has generated constant calls for its preservation, so that present and future Jamaicans, as well as members of the international community, can continue to use and enjoy its beauty, diversity and natural and cultural history (Eyre, 1989).

### **9.2 Maroon Perspective on the Delineation of Cockpit Country**

Following the British invasion of Jamaica in 1655, and subsequent surrender of the Spanish governor, some African servitors of the Spaniards establish communities as free and independent people in the hinterlands and thus became the first Maroons of Jamaica. Accompong, which is a Cockpit Country community, is the oldest of the Maroon communities that survive in Jamaica today. The British Government in Jamaica remained in a constant state of War (Maroon Wars) with the Maroons until they were forced to treatise with the Leeward Maroons (now centred in Accompong) on March 1<sup>st</sup>, 1739, and with the Windward Maroons on June 23<sup>rd</sup>, 1739. The treaty guaranteed the freedom of

the Maroons and allocated land and a semi-independent status (C. Robinson, 1994). Land allocated to the Leeward Maroons by the treaty was situated in proximity to The Cockpit Country. Specifically the treaty states:

***“That they (Leeward Maroons) shall enjoy and possess, and their posterity for ever all the lands situated and lying between Trelawney Town and the Cockpits to the amount of fifteen hundred acres, bearing northwest from the said Trelawney Town”***

Generations of Leeward Maroons have debated this land allocation and in fact lay claim to much of the area referred to as The Cockpit Country (Spense, 1985). As such, the Leeward Maroons now based in Accompong are critical for any delineation of The Cockpit Country. It was in that regard that the consultants met with the Accompong Maroon Village Council and members of the public to discuss the location of the boundary of The Cockpit Country.

### **9.2.1 Maroon Perception of Cockpit Country Boundary**

During the discussions, the Maroons presented the consultants with a map produced by the Cockpit Country Stakeholders Group, showing the boundary of The Cockpit Country and indicated that they (the Maroons) were consulted in the production of that boundary. However when the members of the Council who claimed involvement in the production of that boundary were asked to verbally outline the boundary based on their knowledge of the region, there were significant discrepancies and contradictions with the map presented. For instance, in the southern part of The Cockpit Country, the perceived boundary of the Maroons does not incorporate the Nassau Mountains, but instead extends from Oxford through Balaclava, Raheen, Thornton and Bethsalem, to Retirement. On the eastern side, the Maroon boundary extends from Kinloss in Trelawny, through Barbeque Bottom, Ramgoat Cave to Albert Town, then through Warsop, Troy and Auchtembeddie, to Oxford. On the western side, the Maroon Boundary extends from Retirement through Jointwood, Elderslie, Niagara, Garlands and Flagstaff, to Dromilly. In the north, the boundary according to the Maroons, extends from Dromilly through Bunkers Hill and Duanvale, to Kinloss.

The consultants also asked about the significance of place names such as Cuffie Ridge, Congo Hill and Quashie's River, which lie outside of the boundary delineated by the Maroons, but which from all indications reflect the history of the Maroons and, in particular, the Maroon Wars. The explanation was that while the Leeward Maroons were based in The Cockpit Country, they operated outside of that area on a continuous basis, especially along the routes by which they maintained contact with the Windward Maroons. Indications are that these routes followed the spine of the island from the karstlands of The Cockpit Country to the ranges of the Blue and John Crow Mountains in the east. Maroon-related place names have thus emerged along these routes.

### 9.3 Perceptions of Other Cockpit Country Communities

Discussions with residents of other Cockpit Country communities except those in the north for the most part coincided with the general boundary outlined by the Maroons. Residents of communities, such as, Balaclava, did not regard themselves as being in The Cockpit Country, but acknowledged that they were dependent on its resources, especially for farming and water. Those in Quickstep, considered themselves Cockpit Country residents.

During the mapping of the geology and the geomorphology, farmers and shop keepers were asked whether they were in The Cockpit Country, or if not, where The Cockpit Country began. The following areas were regarded by locals as being outside of The Cockpit Country: Aberdeen, Elderslie, Garlands, half way between Flagstaff and Maroon Town. The following areas were regarded by locals as being within The Cockpit Country: Quickstep, Flagstaff, Maroon Town (by a returning resident who stated that it was important to be in The Cockpit Country because of the threat of bauxite mining), the eastern side of Cook's Bottom and The Alps.

A land management study undertaken as a part of the GEF-funded Cockpit Country Conservation Project in 1999 defined a core Cockpit Country area, largely defined by the Forest Reserve and an outer more loosely defined buffer zone where land use activities, especially farming, were heavily dependent on Cockpit Country resources (Spence, 1999). Some of the concerns raised by this study related to the unsustainable harvesting of saplings for yam sticks from The Cockpit Country. Beckford (1999) estimated the yam-stick demand of The Cockpit Country buffer zone as 18 million saplings annually, and that a significant proportion of this demand is satisfied from The Cockpit Country. Population growth (**Table 1**) in this buffer zone is likely to aggravate resource demand in relation to The Cockpit Country.

**Table 1. Population Growth in Cockpit Country Communities (from Spence, 1999)**

<i>Community</i>	<i>1960 population</i>	<i>1991 population</i>	<i>Percentage change</i>
Accompong	1560	2565	64.4
Balaclava	1553	2837	82.7
Bunkers Hill	1226	1830	49.3
Elderslie	1026	1104	7.6
Jointwood	1004	1469	46.3
Retirement	1157	1315	13.7
Troy	829	1056	27.4

### 9.4 Special Interest Groups

As previously indicated, discussions related to the boundary of The Cockpit Country were held with two special interest groups, the Cockpit Country Stakeholders Group (CCSG) and the Southern Trelawny Environmental Agency (STEA).

#### **9.4.1 Cockpit Country Stakeholders Group (CCSG)**

The Cockpit Country Stakeholders Group represents a “wide cross-section of local and overseas Jamaicans” who is leading the campaign to protect the biodiversity and endemism of The Cockpit Country from mining. The basic argument of the group is that mining in The Cockpit Country would destroy the “natural, cultural and archaeological resources of The Cockpit Country that are virtually untapped as a source of sustainable livelihoods, especially eco- and heritage tourism, for many rural communities in Jamaica” (Cockpit Country Stakeholders Group, 2007). The boundary proposed by this group reflects the mandate of their campaign and include communities such as Newton, Bogue, Craig Head, Albert Town, Lorrimers and Aenon Town in the south; Bryan Town, Gibraltar and Stewart Town to the east; Jackson Town, Clarks Town, Bunkers Hill and Wakefield to the North; and Cambridge and Chesterfield to the west.

#### **9.4.2 Southern Trelawny Environmental Agency (STEA)**

The Southern Trelawny Environmental Agency was established in 1996 with the mission to promote development in Trelawny and its environs by implementing environmental conservation and economic opportunity projects.

While STEA supports the campaign of the CCSG for the protection of the resources of The Cockpit Country, its proposed boundary is based on the pattern of land degradation warranting conservation interventions as well Cockpit Country communities that require project interventions in support of sustainable livelihoods and development and differs significantly from the CCSG boundary. In that regard the proposed STEA boundary for the most part coincides with the Ring Road. A notable deviation of the STEA boundary outside of the Ring Road occurs in south-eastern Trelawny where the boundary extends to the community of Lorrimers. This deviation was explained by a functional association between the community and the rest of southern Trelawny in the form of land degradation problems associated with Yam production. STEA has been active in all the Cockpit Country communities that outline their proposed boundary.

## 10 Descriptions of Previously Proposed Boundaries

This section looks at historical and recent commentary, discussion and proposed boundaries in order to determine the various perceptions different parties have had concerning the boundary of Cockpit Country. For most information, direct quotes are provided followed by a commentary relevant to the interpretation of the boundary.

### 10.1 The Maroon Treaty

The Maroon Treaty was signed between the British Colonial Powers and the leader of the Maroons, Captain Cudjoe. The appropriate parts of the Maroon Treaty of 1739 state

***“Thirdly, That they [the Maroons] shall enjoy and possess, for themselves and posterity for ever, all the lands situate and lying between Trelawney Town [=Flagstaff] and the Cockpits, to the amount of fifteen hundred acres, bearing northwest from the said Trelawney Town”***

and ***“Fourthly, That they shall have liberty to plant the said lands with coffee, cocoa, ginger, tobacco, and cotton, and to breed cattle, hogs, goats, or any other flock, and dispose of the produce or increase of the said commodities to the inhabitants of this island; provided always, that when they bring the said commodities to market, they shall apply first to the customs, or any other magistrate of the respective parishes where they expose their goods to sale, for a license to vend the same.”***

The fact that the Maroons were provided the right to grow crops suggests that the lands were suitable for agriculture; that is they are represented by soils derived from the Yellow Limestone rather than the White Limestone. The area of 1500 acres represents  $\approx 600$  hectares or  $6 \text{ km}^2$ . This is broadly the size of the Yellow Limestone area to the northwest of Flagstaff (=Trelawney Town) extending towards Maroon Town.

### 10.2 Cockpit Country as shown on maps and described

This section reviews the delineation of Cockpit Country in words or on maps. Citations that provide insight into the perceived understanding of Cockpit Country are also included.

Early topographic maps (1688-1787) typically call the central part of the island Spanish Quarters or Spanish Crawl, but on later maps these are shown to the north of Trelawny Town, and it is clear that the earlier mapmakers did not know what was in the centre of the island.

#### 10.2.1 Sawkins (1869).

Sawkins (1869) in his ‘Reports on the Geology of Jamaica’ writes for the parish of Trelawney (p. 216):

***“This valley [valley of the Martha Brae River] is more undulating than that of Fontabelle, descending from the north by four distinct***

*depressions before reaching the river in front of Windsor Pen Great House. It is here the Cockpit country commences"*

and (p. 218):

*"The south eastern part of the Black Grounds is more elevated than the northern, and as the former extends eastwardly the surface becomes almost impassable from the marshy nature of the soil; further to the east the windward Cockpit country expands out to the line of parish. By leaving the main road at Lintons Spring there is a road or track that leads to Elgin or Sterling Castle, which presents most of the characteristics of the Cockpit country; and this continues northward to Stewart Town."*

For the parish of St. James, Sawkins (1869, p. 238) writes:

*"Perhaps no country in the world presents a more rugged or uneven surface ... than those portions of this [St. James] and the adjoining parishes, called Cockpits, which in form resemble inverted cones"*.

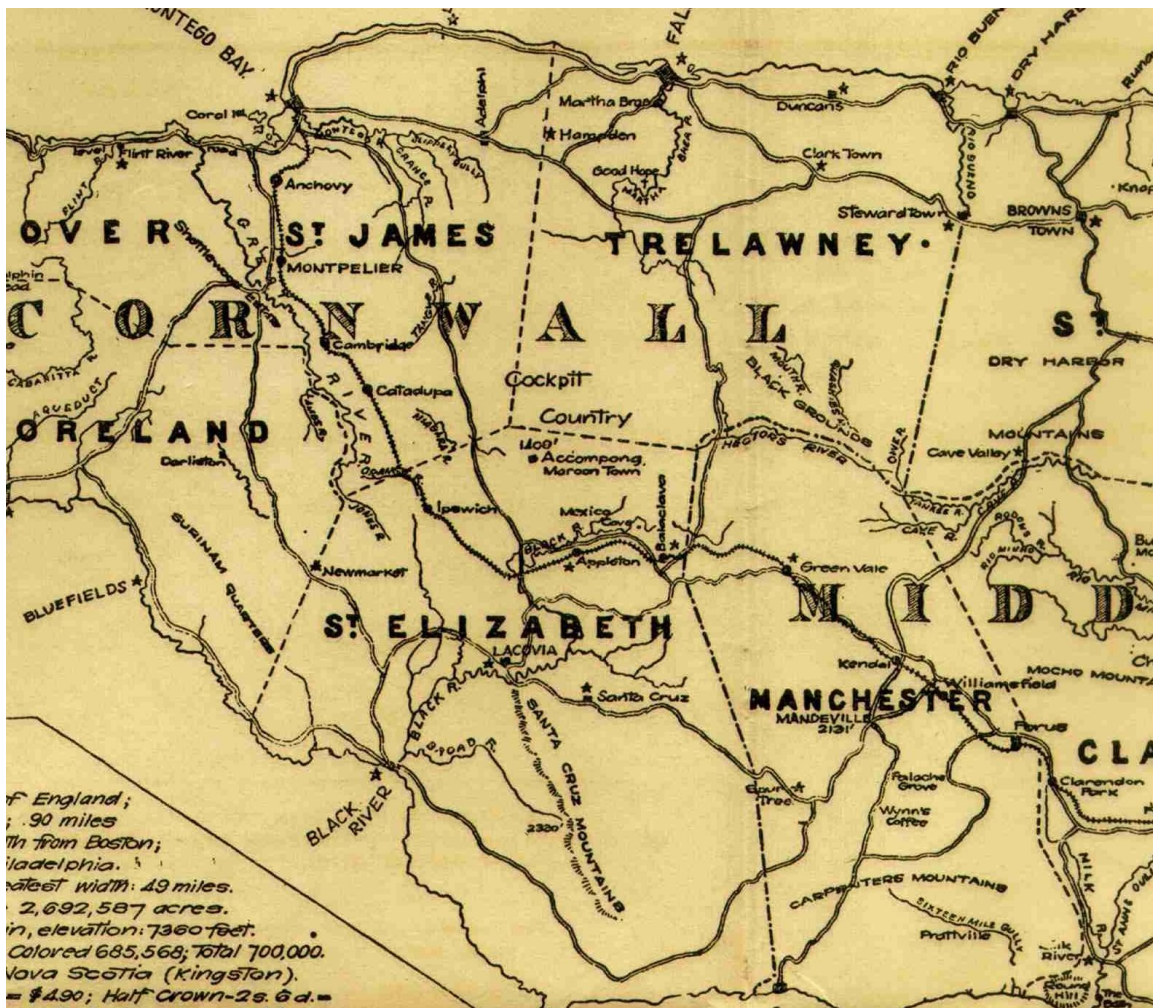


Figure 11. Extract from the d'Inville's map of Jamaica (1899) showing the first use of the term Cockpit Country on a map; also shown are the Dry Harbour Mountains, although no boundary is shown between these and The Cockpit Country. (Source: <http://prestwidge.com> [although prestwidge.com incorrectly assign this map to 1850])

### 10.2.2 D'Invilliers (1899)

The earliest maps on which “Cockpit Country” is marked are the 1899 d'Invilliers map (**Figure 11**) and the 1899 Hill map (**Figure 12**). The d'Invilliers map shows the name Cockpit Country in the Parish of Trelawney, with the name just extending into the Parish of St. James. The map also shows the Dry Harbour Mountains, although the boundary between the Dry Harbour Mountains and Cockpit Country is not indicated.

### 10.2.3 Hill (1899)

On the 1899 Hill map (**Figure 12**) the words “Cock Pit Country” are written in the south-western corner of Trelawney and just extends into St. James. Thus both the Hill and d'Invillier maps show essentially the same physical representation of Cockpit Country (presumably one was based on the other). In his book, Hill (1899, p. 25) described the area as follows:

*“The Cockpit Country. – The origin of the rugged summit topography of the White Limestones Plateau, and the evolution of the numerous interior valleys of which they are antecedent, can be best illustrated by a description of “the cockpit country,” as it is locally called; this with its modifications, includes the whole of the high interior portions of the parishes of St. Ann, Trelawney, St. James, Hanover, Westmoreland, Manchester and St. Elizabeth, to the west and north of the Clarendon ridges, although the cockpits are limited to a rough district embracing the corners of Trelawney and St. James.”*

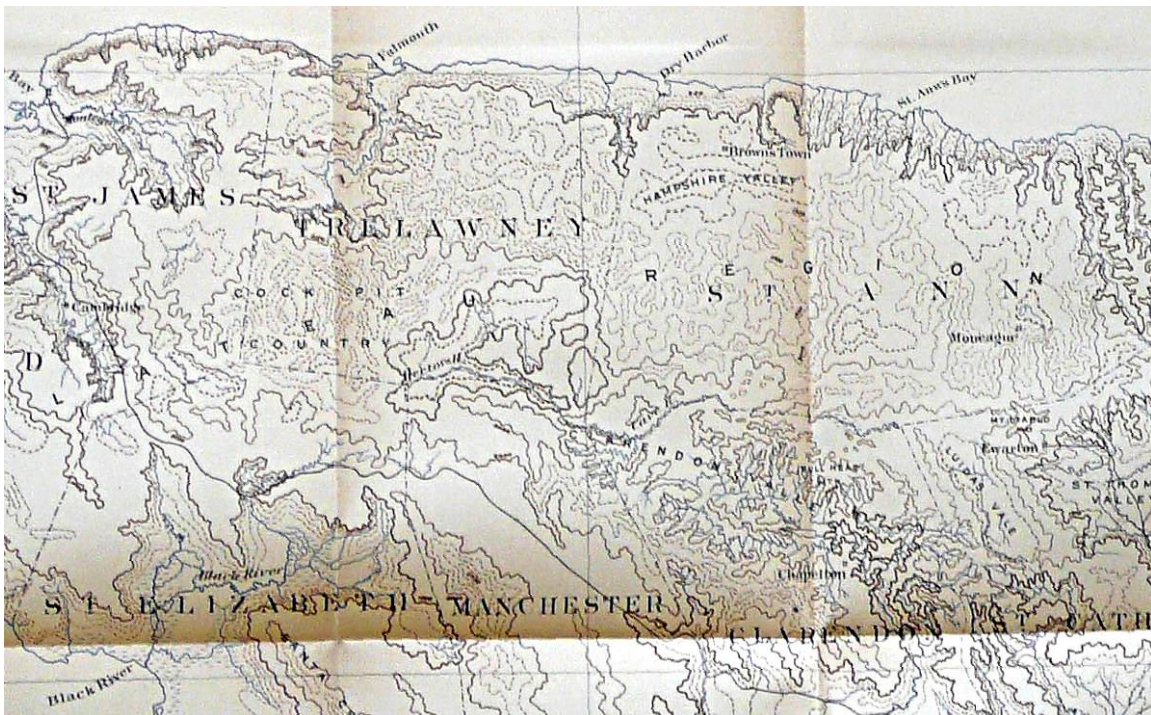


Figure 12. Detail of Hill's (1899) geographical map of Jamaica showing Cock Pit {sic} Country. Photograph by Grenville Draper (Florida International University, Miami).

Although he recognised the existence of extensive cockpit karst across the island, his use of “**the cockpits**” indicates a restricted geographic distribution for Cockpit Country.

#### 10.2.4 Trechmann (1922)

Trechmann (1922, p. 422) stated in a footnote:

***“Cockpit Country is the name given to an area in the northwestern central part of Jamaica, but sinks of more or less cockpit-like shape are developed wherever the White Limestone forms plateaux or elevated tracts.”***

Thus, Trechmann makes a similar distinction between cockpit karst and Cockpit Country.

#### 10.2.5 Zans (1963)

Zans (in Zans *et al.*, 1963) in his description of the 1:250,000 scale geological map of Jamaica (1958) makes a distinction between highlands and poljes or flat-bottomed valleys, as follows:

***“On the higher ground a mature kind of karst prevails, known locally as Cockpit Country”***

He identified flat-bottomed valleys at Queen of Spain's Valley, Spring Vale, Duanvale, Clarke's Town, Nassau Valley and Horse Savannah.

#### 10.2.6 Sweeting (1956, 1958)

Sweeting (1956, p. 4) described the boundary of Cockpit Country as:

***“The Cockpit Country is formed of crystalline White Limestone, about 1,000 feet thick, lying probably on a pre-Tertiary massive. It is bounded by the Duanvale Fault Zone in the north, and is separated from the Dry Harbour Mountains in the east, by the conspicuous faulted area trending NNE-SSW along the Alps road. On the south-east, the Cockpit Country extends around the western end of the Central Inlier. Its south-western boundary is marked by the interior valley of Raheen, while its limits in the west are picked out by the series of inliers of Yellow Limestone which stretch from Aberdeen to Maggotty in the south to Maroon Town in the north. The main watershed of the island passes across the Cockpit Country, probably a little to the north of its centre. Structurally, the Cockpit Country forms in a sense a group of synclines between the large anticline of the Central Inlier and the smaller inliers to the west”.***

Two years later, Sweeting (1958) published three summary maps showing the Geology (**Figure 13**), karst landforms (**Figure 14**) and hydrology (**Figure 15**) of Cockpit Country and the surrounding areas. All three maps show the positions of Cockpit Country and the Dry Harbour Mountains, but do not show the boundaries. The boundary has been placed on **Figure 13** using Sweeting's (1956) definition, although there are drafting errors that allow direct comparison between the geological and geomorphological maps difficult.

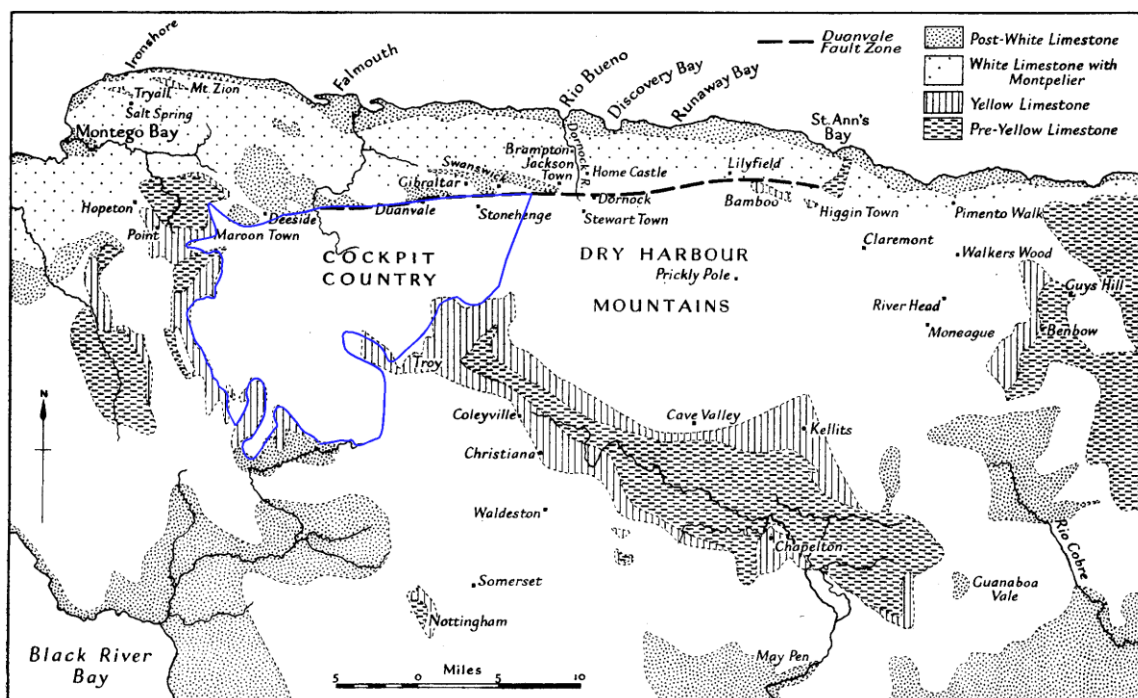


Figure 13. Geology of north central Jamaica (reproduced from Sweeting, 1958, fig. 1). Sweetings boundary is shown in blue.

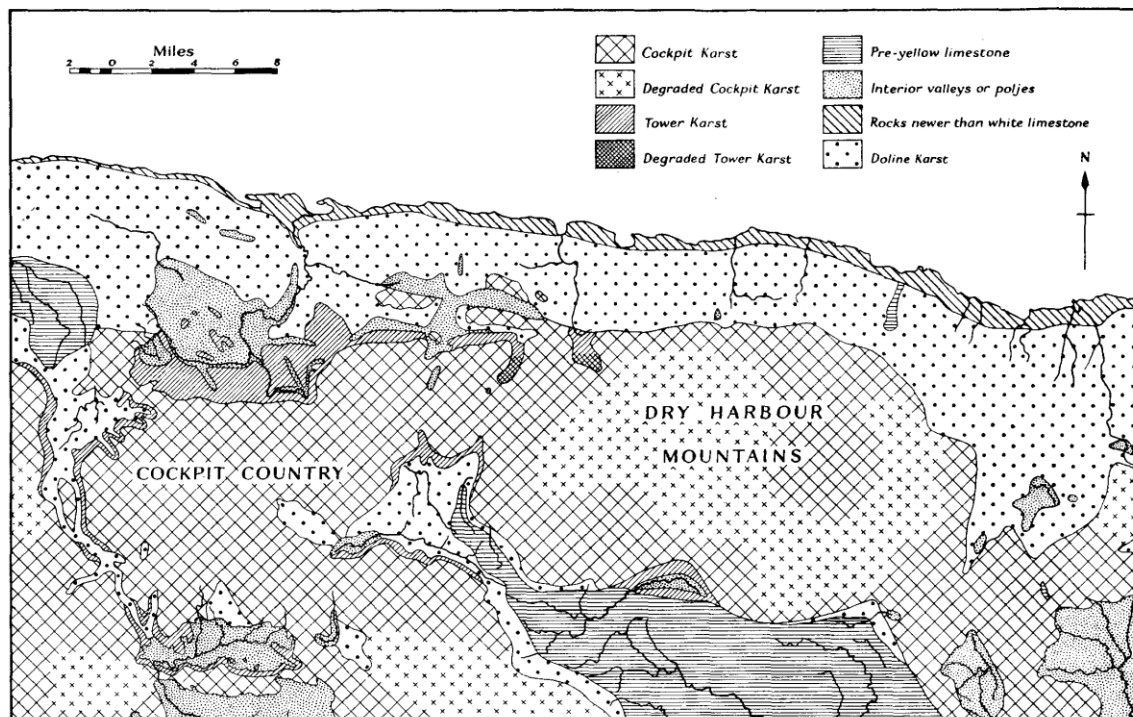


Figure 14. Geomorphology of central north Jamaica (reproduced from Sweeting, 1958, fig. 2).

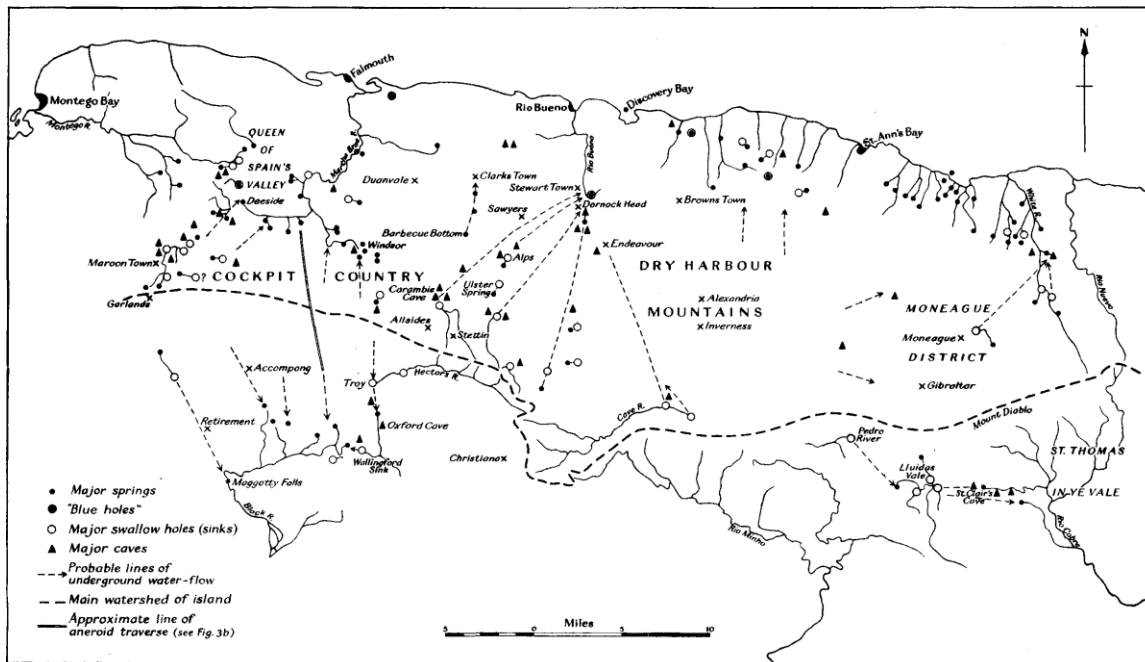


Figure 15. Hydrology of Cockpit Country (reproduced from Sweeting, 1958, fig. 3).



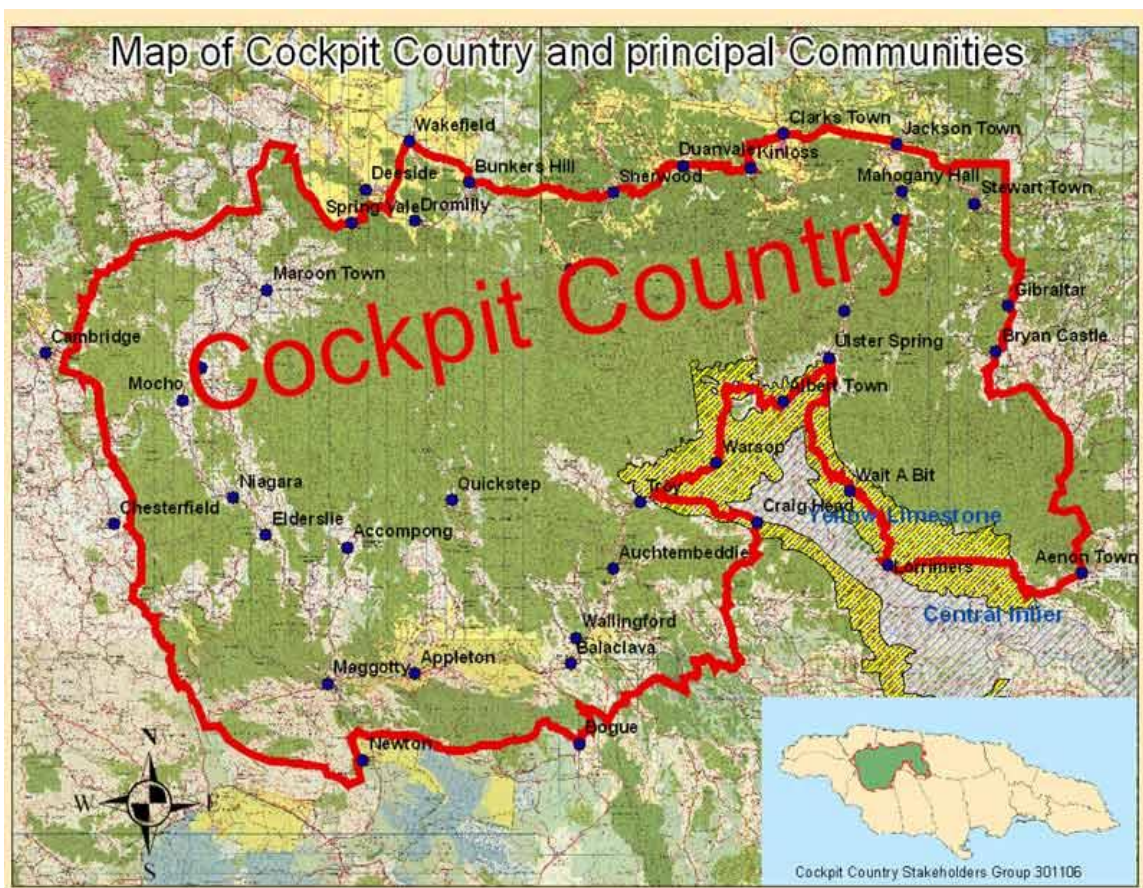
Figure 16. Cockpit Country as shown by the Jamaica Caves Organisation. Although no boundary is given, the limits of Cockpit Country can be estimated based on the area shown in the figure. (Source: <http://www.jamaicancaves.org/jamaica-maps.htm>).

### 10.2.7 Jamaica Caves Organisation Website

The Jamaica Caves Organisation provides a map of Cockpit Country on their WebSite (<http://www.jamaicancaves.org/jamaica-maps.htm>). Although the boundary is not shown, the area represented by the map is significant. It extends from the Alps Fault in the East to the Yellow and Cretaceous inliers to the west. To the south it shows the edge of the Nassau Valley and to the north the Duanvale Fault, and to the southeast the outline of the Yellow Limestone surrounding the Central Inlier (essentially the area defined by the Ring Road).

### 10.2.8 Cockpit Country Stakeholders Group, CCSG (2006)

The Cockpit Country Stakeholders Group consists of an association of organisations (**Appendix 3**) and individuals that have promoted public awareness about issues, specifically bauxite mining, in The Cockpit Country. The CCSG have also proposed a boundary (**Figure 17**).



**Figure 17. Boundary of The Cockpit Country as proposed by the Cockpit Country Stakeholders Group (CCSG). (Source: <http://www.cockpitcountry.org>)**

The Cockpit Country Stakeholders Website (<http://www.cockpitcountry.org>) states

***“In this website, we use the term Cockpit Country to refer to the anthropologically-defined area within the “ring road” (see map)”***

On the same website (<http://www.cockpitcountry.com/cultherit.html>) they show another map of Cockpit Country defined by the “Ring Road” (**Figure 18**). The Ring Road has a historical context, being defined by the British Colonial road that encircled The Cockpit Country in the 17<sup>th</sup> and 18<sup>th</sup> Centuries, along which military camps were set up.



Figure 18. Map of Cockpit Country defined by the Ring Road as shown on the Cockpit Country Website (<http://www.cockpitcountry.com/cultherit.html>).

## **11 Proposed boundary of Cockpit Country**

### **11.1 Cockpit Country Definition proposed here**

*A contiguous area, largely consisting of primary forest with little agriculture and a geomorphology dominated by cockpit and tower karst formed in the White Limestone Group and Yellow Limestone Group (Ipswich and 'Red Limestone' formations), but including small areas of the Yellow Limestone Chapelton Formation either as enclosed valleys or for socio-historical reasons. The boundary lies on or within the "Ring Road".*

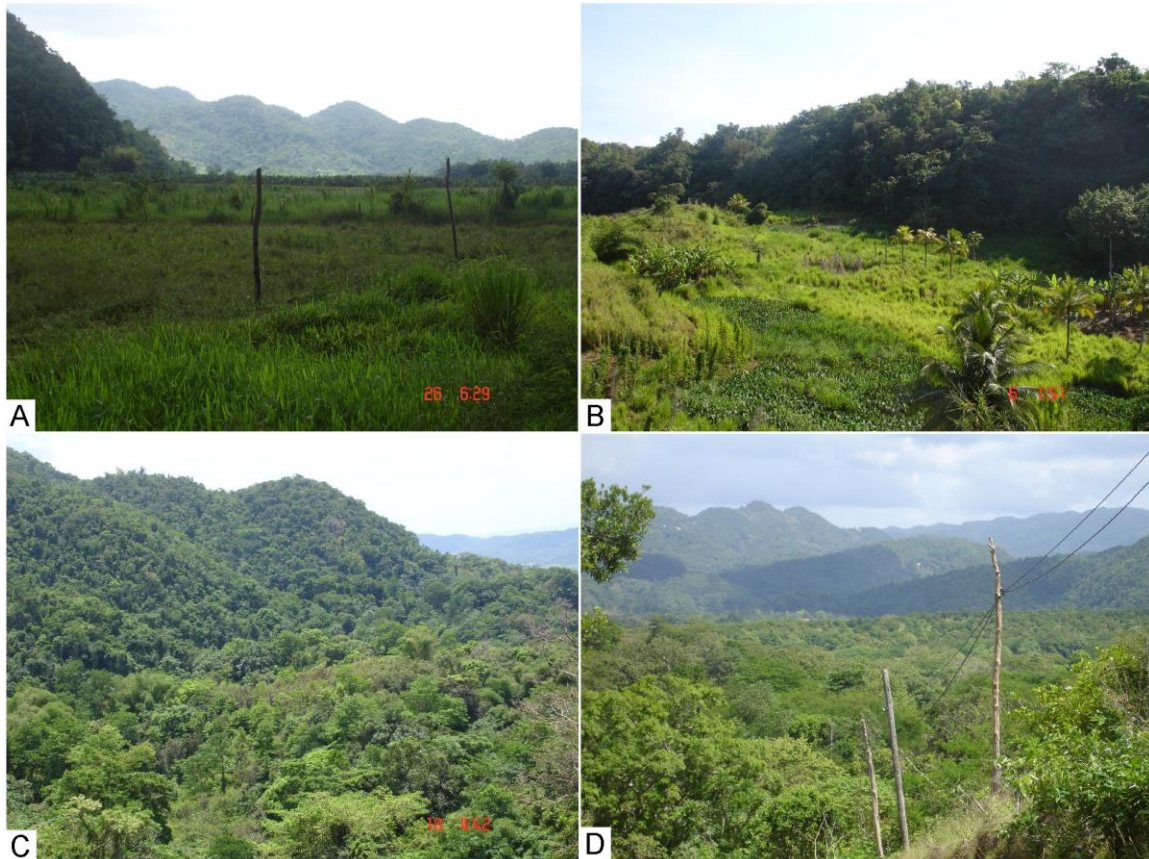
*The boundary is defined by a change from relatively primary forest to agricultural lands and corresponds to geological/geomorphological boundaries that control land use. This boundary is defined by contacts of the White Limestone/Yellow Limestone (with cockpit or tower karst) with the Cretaceous/Chapelton Formation (with internal drainage or doline karst) or alluvial deposits, or where such boundaries are not well defined by large-scale faults (defined from satellite imagery) or collapsed river cave systems.*

### **11.2 Tracing the boundary using geological and geomorphological criteria**

In this section we outline the proposed boundary of The Cockpit Country starting arbitrarily at Troy and proceeding in an anticlockwise direction.

From Troy, the boundary proceeds to the north on the eastern side of the outcrops of the White Limestone which form cockpit and tower karst. The large interior area which includes Cockpit Hill is included in The Cockpit Country because of the name of the hill and the fact that the area is enclosed by outcrops of White Limestone. North of Troy and passing north of Albert Town to Ulster Spring, The Cockpit Country boundary follows the boundary between the Yellow and White Limestone groups, with the boundary defined by a series of White Limestone towers situated away from the main White Limestone outcrop. The towers in much of this area are spectacular, preserve primary forest, together with endemic plants (George Proctor, personal communication to SFM). Throughout this whole area, the boundary corresponds to changes in land use, from agriculture (often Yam growing) to primary forest.

From Ulster Spring the boundary passes up the Alps fault zone. This fault zone marks a major change in both the geology and the geomorphology. Geologically, the Troy Formation to the west of the fault zone is faulted against the Moneague to the east of the fault zone. This is the largest fault displacement seen on the northern side of the Central Inlier. Geomorphologically, the characteristic cockpit karst of The Cockpit Country is terminated by the fault zone, to the east of which is an area of doline karst, pocket valleys and isolated towers. We have placed the boundary broadly along the 'Ring Road' for this part of the boundary.



**Figure 19. Views of the boundary to The Cockpit Country. A, Northern boundary near Spring Vale. B, Western boundary near Sealwood, south of Elderslie. C, Southern boundary near Aberdeen. D, Southern boundary near Oxford.**

Along the northern side of The Cockpit Country, the boundary is placed on various faults that form part of the Duanvale fault zone. At any point along the east-west orientated fault zone, individual east-west faults mark the the boundary between cockpit karst (to the south) and tower karst (to the north). We have placed the boundary at the first major expanse of interior valleys filled with alluvium that have extensive agricultural usage (**Figure 19A**). The boundary, therefore, migrates towards the south as it is traced to the west.

To the west of Bunkers Hill, we carry the boundary towards the southwest towards Maroon Town. Although there is an area of cockpit karst situated to the north of Maroon Town, this is only just connected to the main part of The Cockpit Country. The boundary passes between Flagstaff and Maroon Town, and is marked by outlying towers of White Limestone over Chapelton Formation. These towers are particularly spectacular.

To the southwest of Maroon Town, the boundary turns towards the south and passes towards the eastern side of the communities of Garlands, Horse Guards and Elderslie. The boundary here corresponds to a change in geology from White Limestone to Yellow Limestone and in geomorphology from cockpit or extensive tower karst to doline karst with isolated towers (**Figure 19B**).

The area to the south of Elderslie and Accompong sees major changes (of facies) in the Yellow Limestone Group. The limestones of the Yellow Limestone pass into grainstones ('red limestone formation') and purer micrites (Ipswich Formation) that develop cockpit karst. Geologically, therefore, this area would lie outside of the White Limestone Group, but geomorphologically it is characterised by cockpit karst that extends to the southwest outside of The Cockpit Country. Because of the historical context that relates the Maroons to Cockpit Country, we place this area within The Cockpit Country, and trace the boundary along the "Ring Road" here.

To the southeast of Retirement, the boundary is marked by the junction of cockpit karst in the 'red limestone' or Ipswich Formation with alluvial deposits in the Nassau Valley. To the east of this we carry the boundary to the north of industrial activities (formerly Western Cement and Appleton Estates).

To the northeast of Maggoty, we trace the boundary around the Aberdeen Yellow Limestone Inlier (**Figure 19C**). In many ways this is the most difficult area to trace the boundary as both geology and geomorphology have been based on remote sensing data due to the lack of access in this area. We have, however, removed the various alluvial valleys and glades with extensive sugar cane growing from Cockpit Country. To the east of Accompong, the boundary follows a prominent fault line situated immediately to the east of Aberdeen.

To the west of Aberdeen, we place the boundary along the main change from cockpit or extensive tower karst in various formations of the White Limestone Group and alluvial deposits of the Nassau Valley.

At Oxford (**Figure 19D**), we trace the boundary towards the north-northeast towards Troy via Auchtembeddie. In this area there is no change in either the geology or the geomorphology, and the boundary is placed along the "Ring Road" that follows the course of collapsed cave systems (Golding River Cave, Coffee River Cave and Oxford Cave: Fincham, 1997) within the Hectors River-One Eye River drainage system.

### **11.3 Comparison with other boundaries**

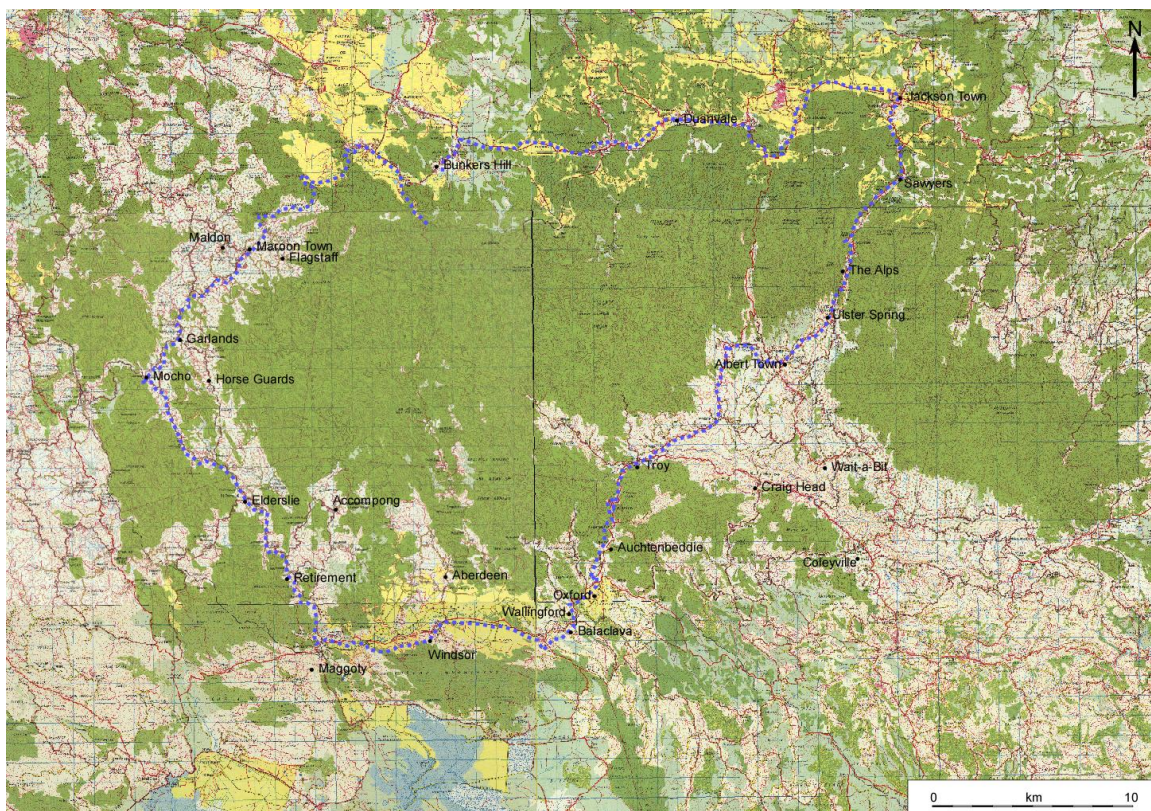
In this section we compare our boundary for The Cockpit Country with other proposed boundaries for The Cockpit Country. Where possible, we show these overlain on the 1:50,000 scale topographic maps. Each boundary is shown and commented on. Finally, all boundaries are shown on a single map.

Our boundary for Cockpit Country (**Figure 20**) lies within the "Ring Road" and is largely defined using geological and geomorphological criteria. The Chapelton Formation inlier to the north-west of Troy is included within Cockpit Country as it contains the hill called "Cockpit" and is also surrounded by deposits of the White Limestone Group.

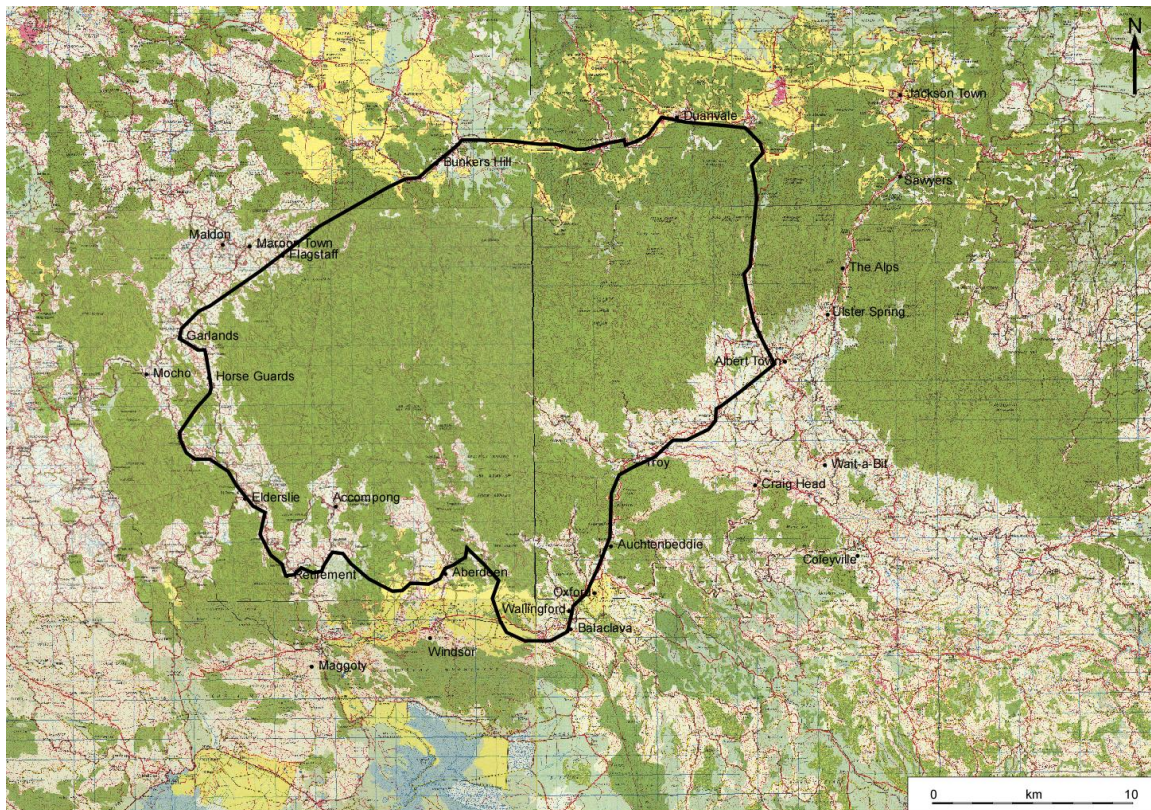
The Ring Road (**Figure 21**) has been taken as a proxy for the boundary of Cockpit Country for many studies. The Ring Road represents the road that encircles Cockpit Country; it originally linked the British Colonial Army camps of the 17<sup>th</sup> and 18<sup>th</sup> centuries.



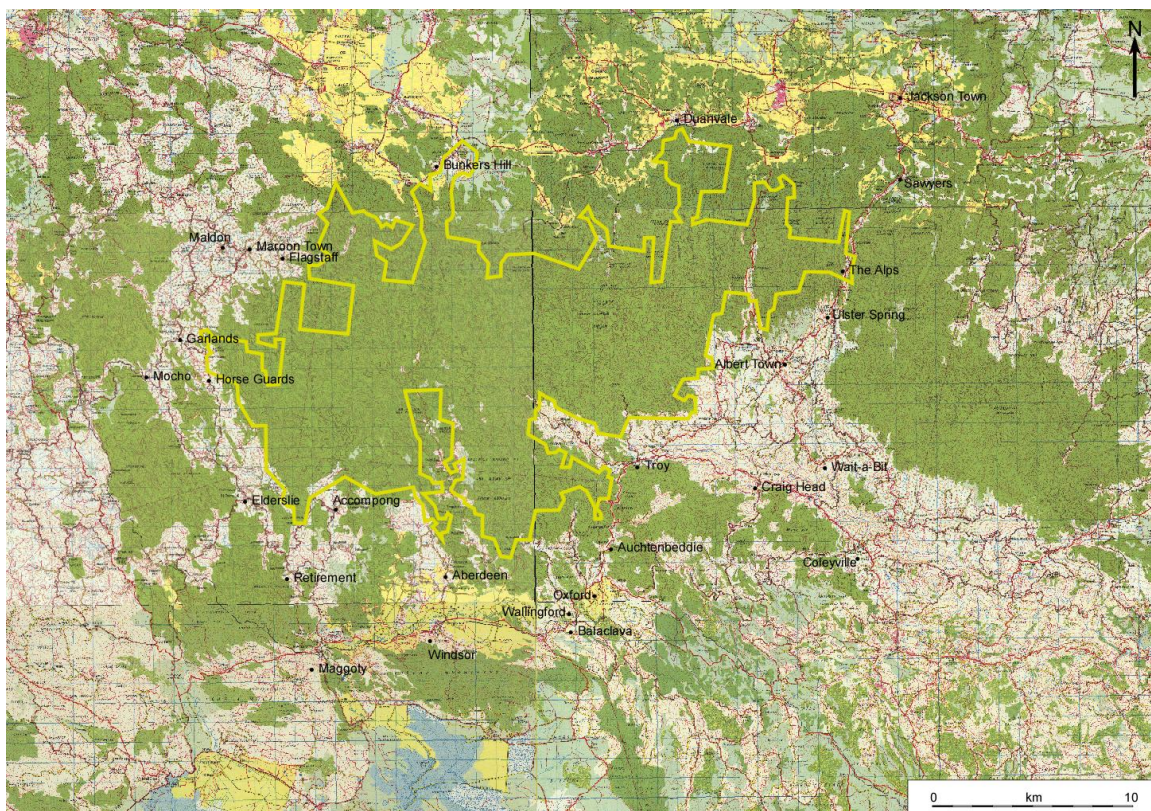
**Figure 20. Cockpit Country Boundary defined herein.**



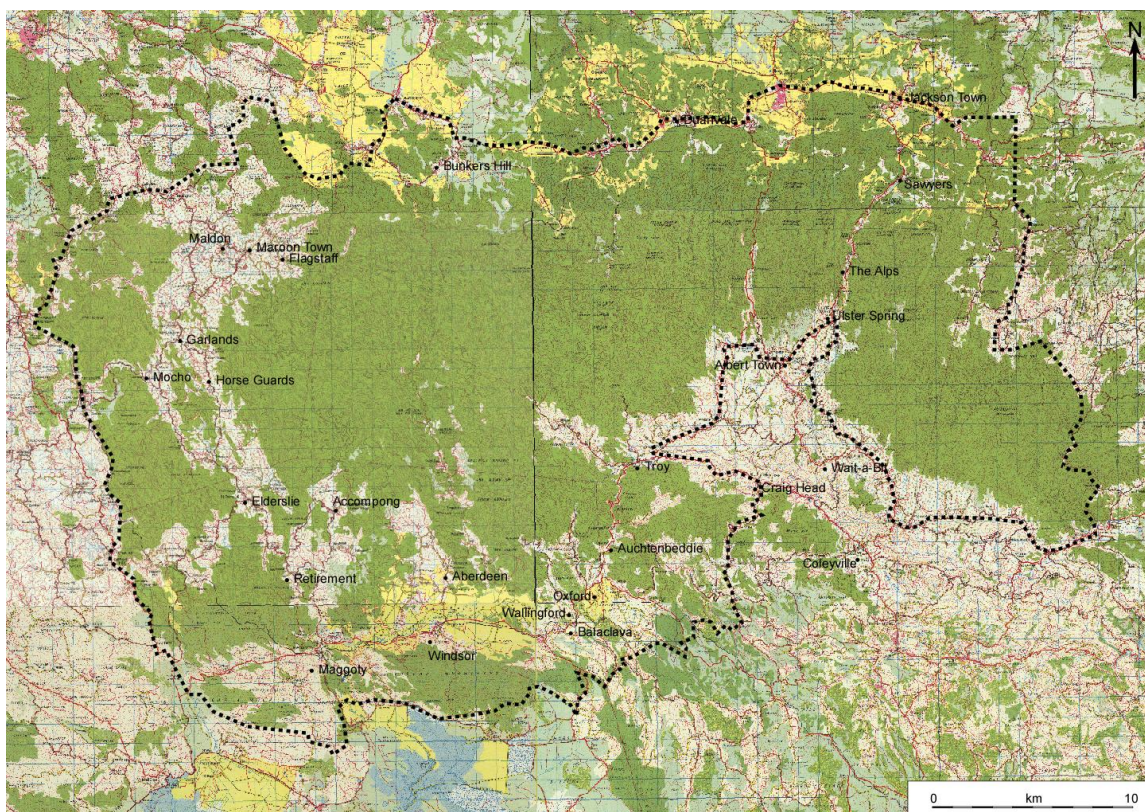
**Figure 21. Ring Road around Cockpit Country.**



**Figure 22. Cockpit Country Boundary defined verbally by Maroons at Accompong.**



**Figure 23. Outline of Cockpit Country Forest Reserve.**



**Figure 24. Cockpit Country Boundary defined by Cockpit Country Stakeholders Group.**

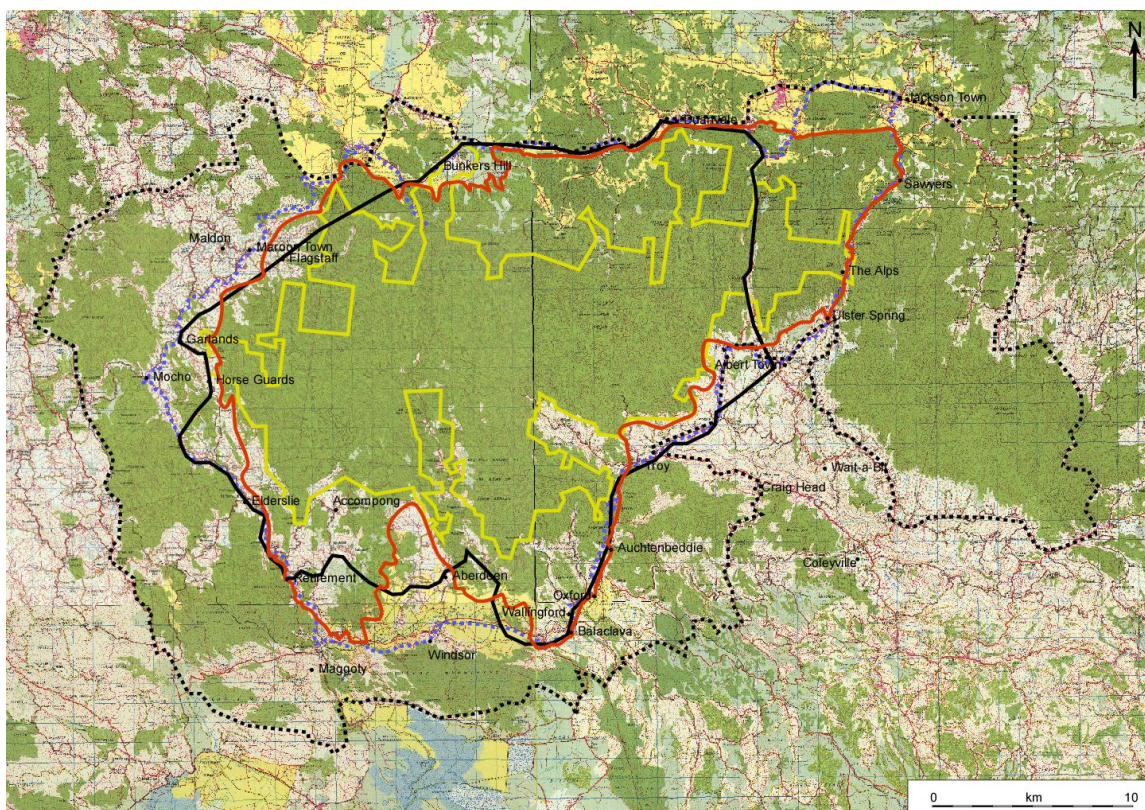
The boundary described verbally by the Maroons at Accompong (**Figure 22**) lies on or within the Ring Road. It excludes the large area of cockpit karst between the Barbecue Bottom road (fault zone) and the Alps road (fault zone). Along the western margin, this boundary includes Flagstaff and Accompong, but excludes Maroon Town and areas south of Retirement.

The area of The Cockpit Country Forest Reserve (**Figure 23**) is almost completely included within our boundary and within the boundary of the Ring Road. The only area of the Forest Reserve that lies outside of our boundary is a small section of alluvial ground near Bunkers Hill. However, since this small area is formed of agricultural land on alluvial deposits, it is unclear why it was included within the Forest Reserve in the first place. A large area of the Forest Reserve is present to the east of the road through Barbecue Bottom, and is excluded from Cockpit Country as defined verbally by the Maroons.

The Cockpit Country Stakeholders Group (CCSG) boundary (**Figure 24**) is much larger than any other proposed boundary. It specifically includes areas of cockpit and other karst in the Dry Harbour Mountains (Litchfield or Scarborough Mountain), the Nassau Valley, the Nassau Mountains, and areas to the west of Maggoty, Elderslie and the Maldon Inlier. This area includes more than just The Cockpit Country physiological area, and includes extensive drainage areas that feed into the Great River, Montego River and Rio Bueno. In fact The Cockpit Country website (which also features the CCSG boundary) and the Jamaica

Caves Organisation both cite the Ring Road as an approximation to the boundary of The Cockpit Country.

When all the boundaries are shown on the same map (**Figure 25**), there is a broad agreement between our boundary and the Maroon verbal boundary, Sweeting's boundary, the Forest Reserve and the Ring Road. There is, however, little correspondence between the CCSG boundary and any of the other boundaries, except on the northern side where all boundaries broadly follow the Duanvale fault zone.



**Figure 25.** Comparison of all the boundaries of The Cockpit Country. See Figures 19-23 for individual boundaries.

## **12 Conclusions and Recommendations**

### **12.1 Defining the Boundary**

The boundary to The Cockpit Country can largely be defined using geological and geomorphological criteria. This boundary lies on or within the “Ring Road” that encircles The Cockpit Country. The boundary can be defined unambiguously, except along two stretches (about 3 km at Retirement, and some 5 km between Oxford and Troy); in both these case cases the “Ring Road” is used as a boundary. The inclusion of Accompong within The Cockpit Country is due to the important socio-historical significance of the Maroons, and means that a boundary must be placed somewhere south of the Maroon village. The boundary between Oxford and Troy follows valley systems representing collapsed cave systems linking Hectors River and the One Eye River. It is these valleys, that allowed the building of the Ring Road along this course, and also along which we place the boundary.

The boundary proposed here has many similarities with those that have been proposed formerly. In particular, the boundary of Sweeting (1956) based on geomorphology is similar, while the boundary proposed verbally by the Maroons lies within our boundary. Other organisations of groups (Jamaican Caves Organisation; Cockpit Country Group) have used the Ring Road as a proxy boundary. The forest reserve also largely lies within our boundary.

The only boundary that has little in common with our boundary, or any other boundary, is the Cockpit Stakeholders Group Boundary which is significantly larger. This includes other physiographic areas of Jamaica (such as parts of the Dry Harbour Mountains, the Nassau Valley and Nassau Mountains) which we, and all other works, have placed outside of The Cockpit Country.

In summary, therefore, we suggest that our proposed boundary based largely on geology and geomorphology represents a good physical definition of The Cockpit Country. It includes the forest reserve area and the biological diversity that is included in that area, but excludes the extensive agricultural lands found to the east, west, north and south.

### **12.2 Recommendations**

#### **12.2.1 Public Consultation**

There is little doubt that the possibility of mining in The Cockpit Country has created a large amount of concern among the general public. Any suggestion for a boundary needs and should undergo public scrutiny and discussion at appropriate venues. Following the submission of this report, we suggest that public fora for discussion are entertained that should consider the boundary proposals along with the other recommendations suggested here.

### **12.2.2 Cockpit Country Communities**

Many communities either reside within or outside of the proposed boundary of The Cockpit Country. These communities may well have a natural affinity with The Cockpit Country and should be recognised as “Cockpit Country Communities”. Indeed, significant human resource relationships exist between these communities and The Cockpit Country, particularly with regard to livelihood activities. Such communities should be seen as major stakeholders within The Cockpit Country, and should be intimately involved in any decision making processes.

### **12.2.3 Protection of biological diversity**

The Cockpit Country has a high biological diversity including a large number of endemic species of animals and plants. In order to protect this biodiversity, protection methods should be put in place. Such protection should seek to limit use or exploitation of reserves in The Cockpit Country. Such protection obviously also has major implications on Cockpit Country Communities. Protections methods and the implications that affect Cockpit Country Communities need to be fully explained, and their impacts on the communities minimised where possible. Significant impacts might be in regard to yam stick harvesting, particularly if climatic change should have detrimental affects on The Cockpit Country.

The Government of Jamaica should look an the various alternatives for placing protection on The Cockpit Country. Given the public debate, such considerations should happen sooner, rather than later.

### **12.2.4 Buffer Zone for The Cockpit Country**

A Buffer Zone needs to be established beyond the boundary of The Cockpit Country. The Buffer Zone should minimise or preferably eliminate potential anthropogenic threats to The Cockpit Country. The size of the Buffer Zone that needs to be created should be a matter of informed scientific debate. There are different ways in which land can be used, and different usages may need greater offset from the boundary than others. In the first instance, there should be no change in land use (other for abandonment of current usage) adjacent to the proposed boundary of The Cockpit Country.

### **12.2.5 Management**

Once protection of The Cockpit Country has been achieved, the management of The Cockpit Country becomes an important issue. The Cockpit Country represents a large area of Jamaica and needs to be managed properly. Appropriate guidance needs to be put in place to determine the potential roles of government and non-government organisations. Ideally, management programmes that have worked in similar protected zones under similar political and region constraints in other countries should be employed.

### **12.2.6 Protection for other areas**

Jamaica has relatively few pristine or relatively primary areas remaining. Several areas of cockpit karst landforms on White Limestone, which must harbour a significant biodiversity exist in areas adjacent to The Cockpit Country. These areas include Litchfield (or Scarborough) Mountain, and karst areas situated to the west of Maldon and Retirement. Appropriate surveys should be conducted in these areas to examine their physiography (geology and geomorphology) and their biodiversity and make recommendations for protection.

### **12.2.7 Further studies**

Although this report has looked at the geology, geomorphology and social-historical context of The Cockpit Country, this should not be seen as anywhere near exhaustive. The studies presented here, strictly relate to the boundary issue and involved a limited amount of field data collection. There are, therefore, numerous areas that have not been appropriately researched. Since The Cockpit Country will become amongst Jamaica's most important natural environments, it is only appropriate that research to maintain this position should continue.

## **13 Acknowledgements**

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## **Appendix 1. List of Organisations that are members of the Cockpit Stakeholders Group**

Archaeological Society of Jamaica  
Bird Studies Canada  
Birdlife International  
Birdlife Jamaica  
Bluefields Bay Fishermen's Friendly Society  
Bluefields Peoples Community Association  
Caribbean Coastal Area Management Foundation  
Council of Overseas Maroons  
Countrystyle Community Tourism Network  
Couples Ocho Rios  
Dolphin Head Trust  
Earthwise Management Consulting  
Farquharson Institute for Public Affairs  
Gideon Education Centre/NEED  
Hotel Mockingbird Hill  
International School of Jamaica  
Jamaica Environment Trust  
Jamaica Hotel and Tourist Association  
Jamaica Orchid Society Ltd  
Jamaican Caves Organisation  
Jamaicans For Justice  
JHTA South Coast Area  
Louis D'Amore - IIPT  
Manchester Environment Protection Association  
Manchester PDC  
Natural History Society of Jamaica  
Negril Environment Protection Trust  
Northern Jamaica Conservation Association  
Plant Conservation Centre  
Portland Environment Protection Association  
Protecting Animals Welfare Society (PAWS)  
Southern Trelawny Environmental Agency  
Sustainable Communities Foundation  
The Nature Conservancy  
The Council of Overseas Maroons  
Windsor Research Centre