The geology of the western part of the Northern range of Trinidad

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ABSTRACT

The results of geological mapping in the western part of the Northern Range of Trinidad are shown on 1:25,000 maps. The stratigraphy of the Caribbean group, low grade metamorphics more than 2500 m thick, has been revised. Type sections of the Maraval, Maracas and Chancellor formations are established. Correlation with neighbouring areas is suggested.

The Maraval formation is the oldest in the area, probably Upper Jurassic; it consists of more than 500 m marbles and limestones. The base is not seen. The Maracas formation, also probably Upper Jurassic, lies above the Maraval formation. It is approximately 1500 m thick and consists of slates, quartzites and phyllites. Rare volcanic ashes are found. Sedimentary structures suggest palaeocurrent directions from north to south and deposition as turbidites. The Chancellor formation lies above the Maracas formation and is probably Lower Cretaceous in age. It is approximately 500 m thick and consists of bedded limestones and phyllites with rare quartzites. It has been divided into four members. On the Island of Monos it contains channels of conglomerates in the Upper Limestones member.

The Laventille formation, Lower Cretaceous, lies along the south flank of the Northern Range and is less metamorphosed than its equivalent the Chancellor formation. There are two facies - massive limestones and a predominantly shale succession. Evaporites occur. Autobrecciation occurs in the limestones and a zone of contemporaneous dislocation lies along the eastern edge of the massive limestones. The Morvant beds consist of shales, sandstones and exotic blocks. They are probably the extension of the Upper Cretaceous Galera formation.

Recumbent anticlines overturned to the north form the main part of the Northern Range. Three phases of folding can be recognised. Thrusting occurs parallel to the axes of the folds. The El Pilar

fault and similar major E-W faults developed later. These have been described as wrenches but horizontal displacement is unclear, although major vertical movement is described. The main metamorphism is believed to be tectonic, contemporary with the major folding at the end of the Lower Cretaceous. Further deformation occurred in Upper Cretaceous time. Faulting continued through the Tertiary.

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A preliminary account of the stratigraphy and structure of the eastern part of the Northern Range, Trinidad. 1968. Separate from Trans. Fourth Carib. Geol. Conf., Trinidad 1965.

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5 Notes on the plunge of minor folds, with equal-area projections.

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Introduction

The area described as the western part of the Northern Range includes the northwestern peninsula, sometimes known as Diego Martin Peninsula, the offshore islands to the west in the Dragon's Mouths, the islands lying south of the peninsula, and the main part of the Range as far east as the Maracas valley. It also includes the Laventille hills along the south flank of the Northern Range. This area has been chosen for description because it turned out to be the key area both stratigraphically and structurally. Here the structure is relatively simple - a northward overturned anticline. This has allowed the preparation of stratigraphic sections, and the setting up of type sections of the Maraval, Maracas and Chancellor formations - the main part of the Caribbean group.

It is ironical that field mapping should have started in 1963 at the eastern end of the Northern Range to correlate the fossiliferous sediments of the Toco area (mapped by Barr 1963) with the adjoining metamorphic rocks. This proved to be difficult because of structural complications, and because exposures of the metamorphic rocks are poorer in the east. Although the eastern part has been mapped and will be transferred to 1:25,000 base maps as soon as these become available, it is considered that the western part should be presented first.

The area is shown on the published topographic maps made by the Directorate of Overseas Surveys for the Government of Trinidad and Tobago, on sheets 3, 11, 12, 13 and the northern part of sheet 23. Map references are metric, but elevations and contours are in feet.

Acknowledgements

Work in this area was carried out with the help of a NERC research grant which covered field costs, air travel from the U.K., and the provision of a land-rover, both in this area and the adjacent area to the east.

Advice and help were provided by H.G. Kugler, J.B. Saunders and K.R. Barr. H.G. Kugler also provided copies of his correspondence with W.H. Bucher and H.H. Hess. J.B. Saunders with the courtesy of Texaco Trinidad Inc. carried out micropalaeontological examination of the writer's samples, and also supervised the draughting of the type sections in Texaco's laboratories. K.W. Barr provided the writer with copies of his field notes on the Lady Young Road and with personal comments on his observations on exposures now badly weathered.

The Trinidad government helped by providing advance 1:10,000 base maps, permits to visit closed areas and transport to the leprosarium at Chacachacare. The Trinidad Coastguard also provided transport to certain areas. The Government Petroleum Geologist's section provided information and also help in getting access to certain areas.

Dominion Oil Ltd. (Standard Oil Company of California) provided copies of various reports, and had provided other help in the way of transport and palaeontological examinations during the survey of adjacent areas. Shell Oil Company had kindly carried out a palynological examination of samples from adjacent areas.

Dr Elliott of the British museum (Natural History) advised on possible algae in thin sections and Dr Howarth examined the ammonites from the Hollis damsite in the B.M. collection. R. Young provided the writer with a copy of his field observations in the area between San Juan and St Joseph. C. Gonzalez de Juana sent copies of his team's unpublished geological maps of Paria Peninsula, Venezuela.

Method of work

Field mapping was carried out during University vacations with the help of a N.E.R.C. research grant. Unfortunately the vacation period coincides with the wet season in Trinidad; however in the western part of the Northern Range the rainfall is less than in the east - approximately 1000 mm. per annum compared with 3000 to 4000 mm.

The area is unique in the Northern Range in having a number of good roads and footpaths providing fairly easy access. The road cuttings are most important because as everywhere in these mountains the thick cover of vegetation effectively covers any possible exposures, and on the steep slopes hill creep is so marked that only major exposures can be accepted as revealing bedrock structure. Therefore mapping essentially relies on rivers, road cuts, coastal exposures, and man-made exposures such as quarries and building sites. Along the north coast and around the islands boats were used to reach otherwise inaccessible exposures. But some large cliffs could not be reached because of the lack of landings and the heavy swell on the lee shore. An unfortunate consequence of the tropical climate is that road cuttings and quarries deteriorate rapidly once exposed. This is particularly true of shales and phyllites. Sedimentary and structural features seen in the fresh exposure may be invisible a year later.

At the beginning of the survey no detailed maps were available, and streams, paths etc. had to be paced and sketched. However, during the work D.O.S. prepared 1:10,000 preliminary plots and both they and the Trinidad Government kindly provided dye-line prints of these, which have been used as field slips with geological data transferred to them. In making the geological maps photogeological overlays were prepared using aerial photographs flown in 1957 at an approximate scale of 1:28,000.

Physical Features

Physically the area can be divided into a number of geographical units. In the south there is the alluvial plain of the Caroni basin, near sea level, with remnants of a Quaternary terrace rising 50 feet (15 m) above it along the boundary with the hills. North of the plain but south of the mountains proper there is a line of low hills which reach their broadest extent of 2 kms and their maximum height of just over 500 feet (150 m) in the Laventille Hills east of Port of Spain. This line of hills follows the outcrop of the Laventille formation - the western extension is represented by the islands of Gaspar Grande, Gasparillo, Cronstadt, Carrera, the Five Islands and by the peninsula of Pointe Gourde. The northern limit of this line of hills is a fault boundary and forms a clear topographic feature.

The range of mountains itself can be divided into three zones. There are northern and southern zones of angular peaks with very steep northern slopes and somewhat gentler southern slopes. These two chains of peaks follow the southern upright outcrop of the Maracas formation and the northern overturned outcrop of the same formation. The southern peaks include Morne D'Or, St Ann's Peak and Cumberland Hill; the northern peaks include El Tucuche and La Vigie. In between these two chains are lower rounded hills along the outcrop of the limestones of the Maraval formation. Some of this outcrop shows Karst topography as in the Diego Martin-Paramin area (Plate 1). It is also noticeable that along the Maraval formation outcrop there are broad tributary valleys with alluvial floors, and a number of dry valleys.

The major rivers are consequent and flow southward down the general dip slopes. The main watershed lies in the northern chain of peaks. Only short streams flow down the precipitous northern slope of the mountains, with many waterfalls over the vertical cliffs of Maracas quartzites. The southward flowing rivers (Maracas, San Juan-Santa Cruz, St Ann's, Maraval, Diego Martin, Tucker Valley) lie in deep valleys with gravel floors. In general they are 'V' shaped except where gravel floors fill the bottom of the 'V'. The valleys include both narrow gorges where the streams cut through resistant quartzites in the Maracas formation and broad plains where the rivers flow through the outcrop of the Maraval limestones. This outcrop coincides with marked changes in trend of the different valleys, and also with the development of major tributaries as mentioned above.

There is a suggestion of decreasing elevations of valley floor alluvium from east to west. At Maracas village 300 ft. (90 m), at Cantaro 250 ft (75 m), Maraval 200 ft (60 m), Diego Martin 100 ft (30 m), Tucker Valley 75 ft (23 m) and then further west the valleys through the range are drowned and appear as the various straits of the Dragon's Mouths, generally known as 'bocas' using the Spanish term. Guppy (1877) noted this and remarked on the fact that the valleys are broad in the west and become progressively narrower towards the east. He also pointed out that conglomerate fans are not found west of Port of Spain, and that these fans become higher eastwards. In fact there is a buried conglomerate fan at the mouth of the Diego Martin valley, but this does not disprove Guppy's argument. He did not try to date the tilting to the west that formed the Dragon's Mouths, but the evidence of valley shapes, alluvium elevations and fan development suggest that the tilting may have continued through the Quaternary period.

An interesting feature in the Northern Range is the way the ridge tops seem to reach a general level. It is often the case that one climbs out of the valley to walk along a gently undulating ridge at 1000 ft or 2000 ft elevations. In the wilder central and eastern parts of the range most of the hunting trails are on the ridges. It is suggested that the ridges represent old erosion surfaces. A comprehensive study

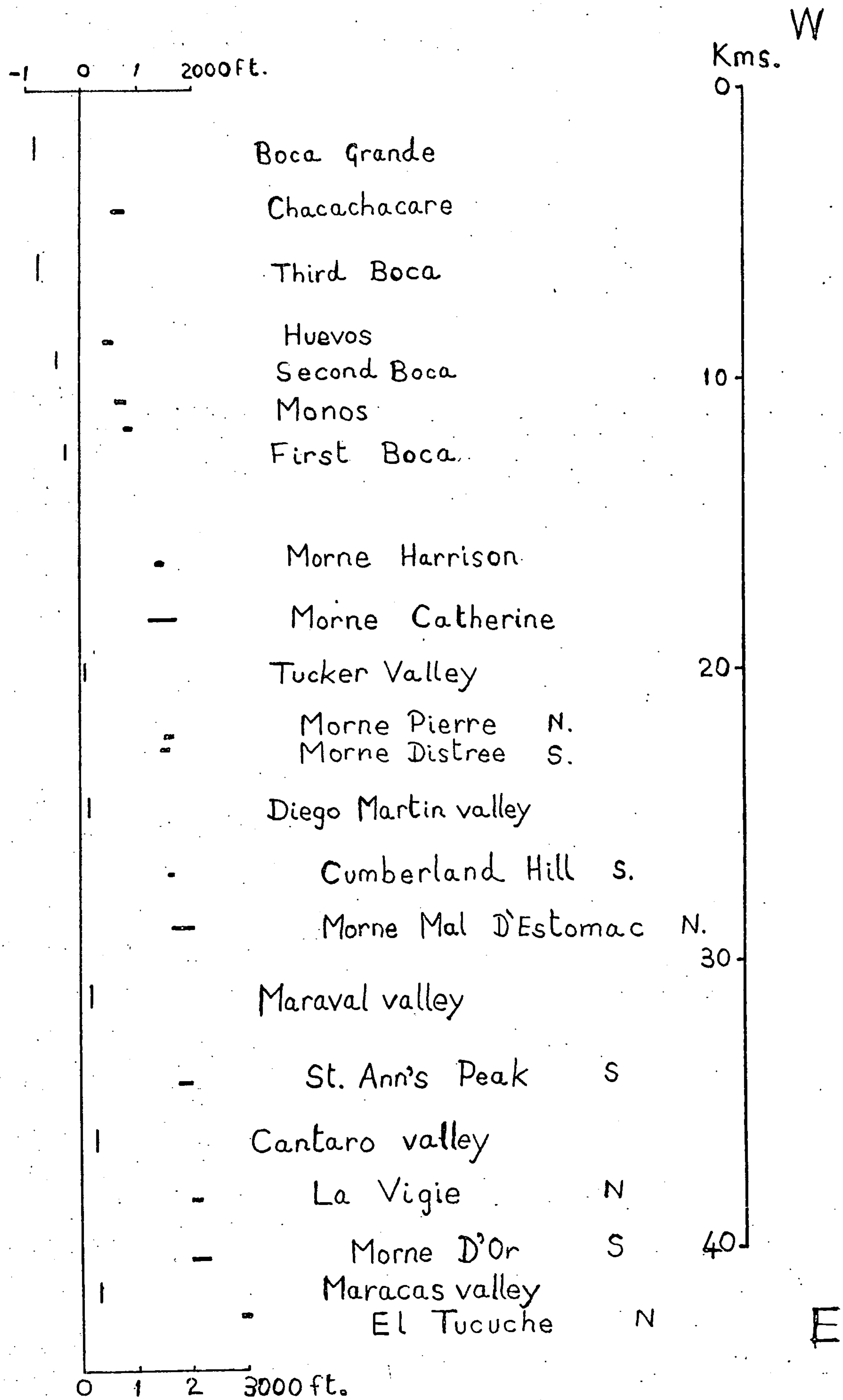


fig. 1. Scale diagram showing heights of peaks and ridges, elevations of valleys and depths of straits.

of the whole range may be worthwhile when maps are available, meanwhile Fig. 1 is an attempt to show ridge heights in the area presently described. The length of the bar in each case represents the variation in elevation of the ridge. There does seem to be a decrease in elevation to the west suggesting tilting in that direction. However there is another trend not clearly shown by the diagram. Each ridge itself appears to be higher at the north end than at the south, and where there are separate northern and southern chains (marked on Fig. 1) the northern chain has higher ridges than the southern. This may suggest tilting to the south.

The question of north-south tilting may also concern the differences between the northern and the southern coastlines. The southern coastline has a coastal plain along most of its length, small deltas at the mouths of the Maraval and Diego Martin Rivers, and deep bays at Chaquaramas and Carenage.

The north coast is very different. For much of its length it is an almost unbroken wall of cliffs, with rock debris at the base. Bays are small and rare in the western part of the area. East of Saut D'Eau Island however there are a number of large bays which seem to occur where the sea has broken through the outer line of quartzites and excavated the slates and phyllites lying behind. However only Maracas Bay has a true beach and an alluvial floor. There may be some evidence to suggest uplift along the north coast. At Biscayne Bay (Monos) and Macqueripe Bay the alluvium lies at approximately 30 ft (9 m) and 50 ft (16 m) respectively. However these terraces cannot be considered as true raised beaches, but rather as upstream alluvial plains of the consequent streams. Therefore uplift is not absolutely clear.

The linear outline of the north coast certainly suggests faulting, and uplift along a series of faults may be suspected. However only one fault, that south of Saut D'Eau Island, can be proved. Larger faults

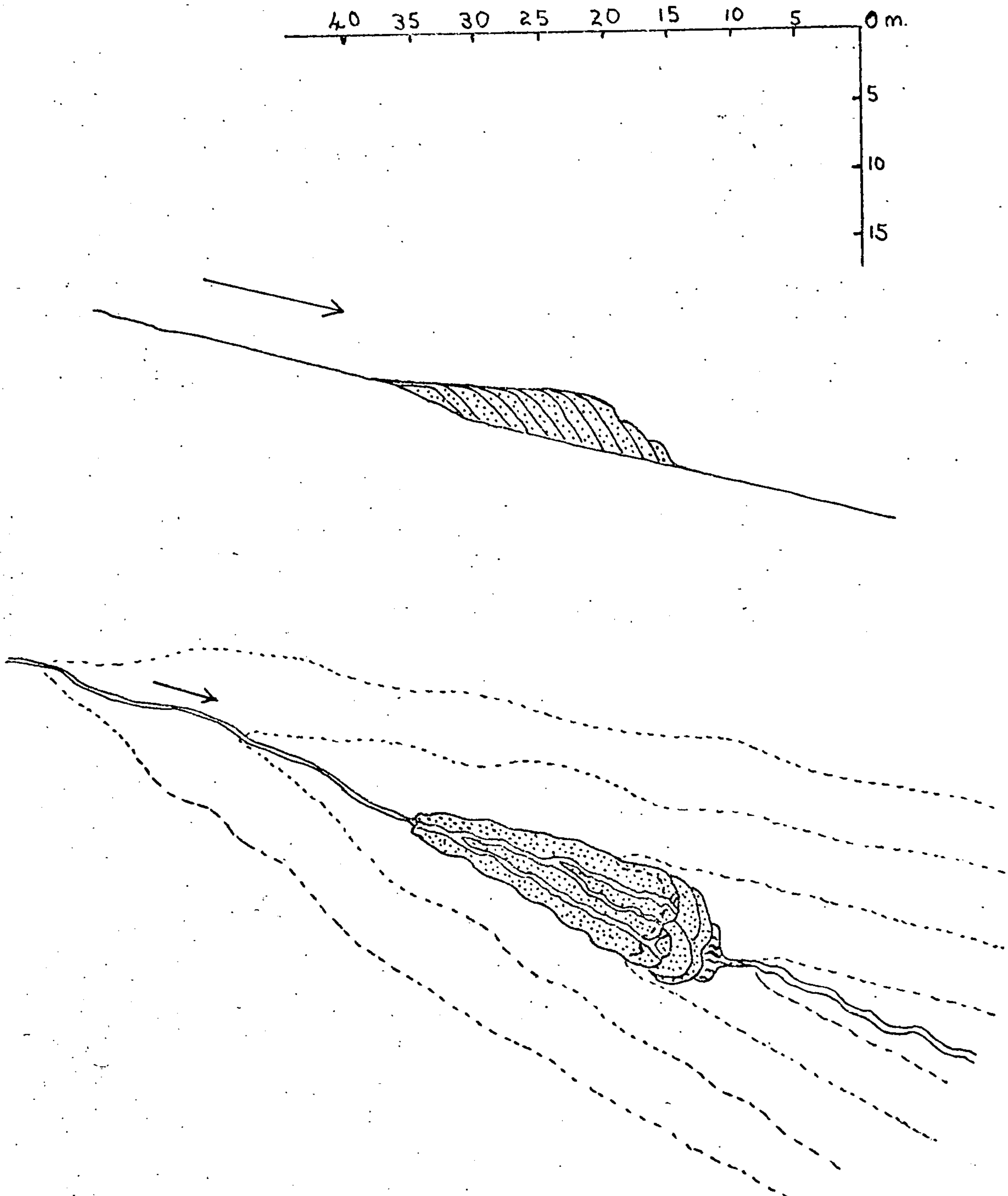


fig.2. Typical calcareous tufa delta. Inthe sketch map the contours are 5m. approx. The slope inthe cross-section is exaggerated.

may lie offshore to the north. However when considering whether the modern topography provides evidence for southward tilt of the Northern Range or uplift of the northern edge, the explanation may lie in the combination of dominant south flowing consequent streams cutting back to the north; and the rapid southward erosion of a scarp coast exposed to the prevailing Trade Winds.

There is one river valley phenomenon that may be dealt with briefly in this section. In streams flowing off limestone outcrops in the Northern Range, calcareous tufa is commonly deposited. It may occur as sheets overhanging rock exposures, but the most interesting mode of occurrence is as 'deltas' in the stream bottom. The 'deltas' are usually flat topped with a steep fore slope which dips up to 50°. The layers of tufa dip parallel to the fore slope near the front of the 'delta', but dips seem to be flatter on the upstream part of the structure. The calcareous tufa is extremely porous and fibrous; characteristically it is layered with bands of cellular open material with vertical pillars perhaps 1 cm high alternating with somewhat denser horizontal mats. In the tufa are boulders of bedrock carried down by the stream. In the area described there are only relatively small examples, one 1.5 m high shown in Plate 12 and two more, one 5 m high and the other 20 m high and 30 m wide. The largest 'delta' is diagramatically illustrated in Fig. 2. There are even larger and higher examples elsewhere in the Northern Range.

Typically these features occur up to 1 km south of the Maraval limestone outcrop. There is a suggestion that they may be located on existing small waterfalls, where agitation may have reduced carbon dioxide content of the stream water, leading to deposition of calcareous tufa. One wonders whether carbonate structures like these are often preserved - they ought to be recognisable, and if buried by later sediment, might provide local aquifers or reservoirs for hydrocarbons. But it may be that most of them are destroyed during the fimal stages of the erosion cycle.

Vegetation

Much of the mountains is covered by Lower Montane Forest and only the upper slopes of El Tucuche are classed by the Trinidad Forestry Department as true Montane Forest. The southern slopes are classed as Deciduous Seasonal Forest which extends in a dryer type westwards through the peninsula to the islands. Along the north coast are small areas of Semi-Evergreen Seasonal Forest, and along the south coast some Littoral Woodland and palm swamp, with small mangrove swamps at the mouths of the Maraval and Diego Martin rivers. Although there has been some clearance around settled areas, the watershed forests have been preserved for water reserves. The forest cover of the whole of the western part of the peninsula was protected by the presence of a U.S. naval base from 1943. In the valleys the dominant vegetation is citrous fruit - chiefly grapfruit. Cocoa is grown on many of the mountain slopes that are not forest reserve. Between Maraval and Diego Martin vegetables are grown on the outcrop of the Maraval limestones and this can be seen on Plate 1.

Settlement

Major settlement is confined to the east-west strip along the southern edge of the hills from St Joseph through San Juan and Laventille to Port of Spain and westwards to Carenage. The flat valley floors are also settled. There is only one small fishing village on the north coast at Maracas Bay. The islands are only settled with holiday villas except for Chacachacare, a leprosarium and Carrera a prison. Outside of the industrial area of Port of Spain there is a floating dry dock at Chaquaramas, bauxite transhipping stations at Carenage and Pointe Gourde and a chemical store on Cronstadt Island.

Historical Background

The place names of the area include words of different ethnic origins: Amerindian, Chacachacare and Macqeripe; Spanish, Santa Cruz and San Juan; French, Laventille and Saut D'Eau; British, Fort George and Cumberland Hill. Only Hindu names are missing, and this may be due to the thorough settlement of the area before the arrival of the Indian labourers in the middle of the nineteenth century. It is unfortunate that the new topographic maps have ignored local practices. Places that are known and sign-posted as La Seiva and Petty Valley have been returned to the correct spelling of La Ceiba and Petite Vallee.

Prehistoric settlement is attested by the presence of middens with ceramics and by finds of artefacts along the southern boundary of the area and on the north coast. The first Spanish landings were in western Port of Spain, and after several battles with the Indians the first Spanish fort was built there.

Later the capital was moved to St Joseph and a typical Spanish town plan laid out on the high terrace. It was to St Joseph that Raleigh marched, captured the Spanish governor de Berrio and took him off as an unwilling guide in the ill-fated search for El Dorado.

The British invasion of 1795 took place here too. The German infantry landed very close to where the Spaniards had first come ashore in western Port of Spain. Further west the Spanish admiral destroyed his fleet in Chaguaramas Bay. Some years afterwards the island of Chacachacare became the base for the various unsuccessful revolutionary invasions of the Venezuelan Main.

Many years later Chaquaramas and the peninsula played an important part in World War II as the key U.S. naval base in the central Atlantic, and the ostensible price for fifty U.S. destroyers handed over to Britain.

Now the naval base has been turned back to Trinidad, and there are high hopes of tourist benefits. But it was in the old base, at Teteron Bay, that a darker episode occurred when part of the Trinidad Regiment mutinied in 1970.

A writer who observed the rocks and minerals of the Northern Range as well as life in Trinidad generally, was Dauxion Lavaysse (1813) in 'Voyage aux iles de Trinidad'. There is a copy of this work in the British Museum Library, as well as a copy of an English translation which does not appear to give full weight to this French Republican's account of General Picton's deplorable governorship. A fuller version of the sad story of his tyranny has been provided recently, by V.S. Naipaul in 'The Loss of El Dorado'.

Now the Northern Range has attained a different notoriety, even in the British press. It was the refuge for groups of 'black power' guerrillas opposed to the present Trinidad government, who recently made periodic raids on nearby police stations and banks. These groups have now been harrassed into dispersal. The defence forces must have been grateful that the guerrillas chose as their base area the high relatively simple ridges of the Aripo and Cauro forests rather than the heavily forested headwaters of the Matura and Oropuche rivers.

Stratigraphy

With the exception of the alluvium and the presumed Quaternary deposits all the rocks fall into what has been described as the Caribbean Group. The account of that group provides an opportunity to review earlier work on the geology of the Northern Range. Where the present study has allowed the preparation and description of type sections (Maraval, Maracas and Chancellor formations) the description of those type sections will be given separately, followed by an account of the development of the formation throughout the area.

The division of the Caribbean group as here presented is shown in Fig. 3. Because the bottom of the Maraval formation is not seen and because the upper part of the Morvant beds cannot be measured, it is probable that the thickness of the Caribbean Group reaches at least 3000 m. The locations of the different stratigraphic sections mentioned in the text are shown on the map (Fig. 4). The writer is not convinced, however, of the importance of type sections other than in newly mapped inaccessible areas.

The Caribbean Group

This group was first named and described by Wall & Sawkins (1860). They say "the most prevalent beds of this series consist of mica slates" - and they describe graphitic mica slates. A variety of sandstones and quartzites are noted. The different limestones are described - "Calcareous rocks are represented by two varieties in this series, viz., crystalline limestones contained in the slates and alternating with them; and compact limestones, either quite unconnected with the schistose group, or only associated with its upper strata." This division fits with the distinction between the Maraval and Chancellor formations on the one hand, and the Laventille formation on the other, as described below. A separate 'Older Parian' group of probable Lower Cretaceous age was established in the Central Range.

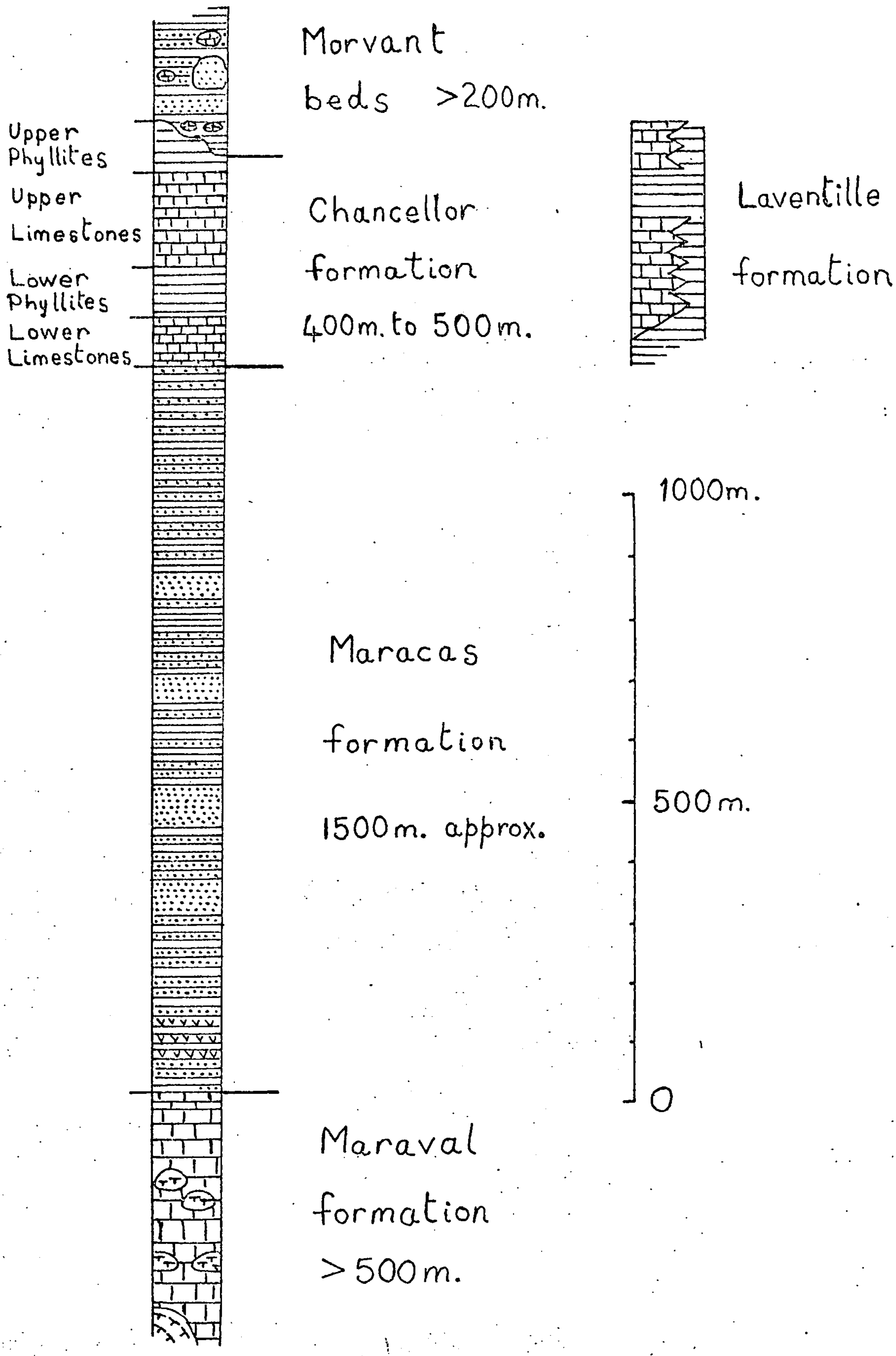


Fig.3. Stratigraphic column of the Caribbean group.

After discussing the difficulty of establishing an order of succession, they suggested a sequence as follows:

4. Quartzitic, sandstones with micaceous slates and shales, with the 'compact limestones' as the highest member

3. Thin bedded limestones and micaceous slates

2. Sandstones, green mica slates and massive crystallised limestone

1. Slates, graphitic slates and quartzites

This sequence is that one would describe from north to south neglecting any tectonic complication i.e. 1. would be Maracas formation, 2. Maraval formation, 3. Maracas and Chancellor formations, 4. Chancellor, Laventille formations plus Morvant beds. Wall & Sawkins found it difficult to estimate thickness and suggested 10,000 to 12,000 feet - a very shrewd estimate. They were unable to indicate an age for the Caribbean Group in the absence of fossil evidence, but suggested that the presence of graphitic schists pointed to "the formation of this group subsequent to the introduction of organised existences".

Guppy (1869, 1877) describes fossils from the Laventille formation and also from a limestone in slates at a locality the present writer would consider to lie in the Chancellor formation. Guppy considered the Caribbean group possibly to be Palaeozoic; he thought the Laventille limestone to be younger than the rest of the series, possibly Upper Palaeozoic.

Cunningham-Craig (1907) emphasised the importance of intensive folding in the Northern Range and suggested a remarkable decrease in the estimate of thickness of the Caribbean group to 1000-2000 feet. He considered the limestones to be the lowest part of the series, but thought all the limestones were the same age, and suggested a fan structure with the axis lying along the southern b oundary of the Northern Range. He considered the oldest rocks to be limestones associated with graphitic schists which were overlaid by coarse siliceous grits. His comments on the age of the series are most interesting - he points to the similarity between the Caribbean group and the 'Older Parian' group of Wall & Sawkins, and suggests that the former may be the metamorphosed equivalent of the latter. On the question of the fossil content he examined a cephalopod that Guppy had described as a goniatite, and pointed out that it was an ammonite of a type not earlier than Jurassic. Unfortunately this fossil, along with others, was destroyed in a fire during the riots of 1921.

Dalton (1912) describing the geology of Venezuela, says of the Caribbean series in Trinidad "the relation of the Cretaceous of Venezuela to them shows that they are at least early Mesozoic, and may be Palaeozoic, or even Archaean, while it is very possible that parts of the Andes are older than the strata exposed in the Caribbean hills."

Trechmann (1925) described Mesozoic fossils from the Laventille limestone. He disagreed with Cunningham-Craig both as to the similarity between the Caribbean group and the Older Parian group and as to the position of the Laventille limestone, which he could not accept as the oldest part of the group.

Parkinson (1925) described the petrography of schists and phyllites from the Port of Spain area and from the path to Cerro Tucuche. He did not draw any broad conclusions from his study, but compared the rocks with others he had examined from the Cumana area of northern Venezuela.

Waring (1926) disagreed with Cunningham-Craig's view that the limestones were all the same age and oldest rocks in the Caribbean group. He accepted the sequence put forward by Wall & Sawkins but divided it into an upper series and a lower series. The lower series was described from the northeastern part of the Range, and the upper series from the central part of the mountains. He emphasises the difference between

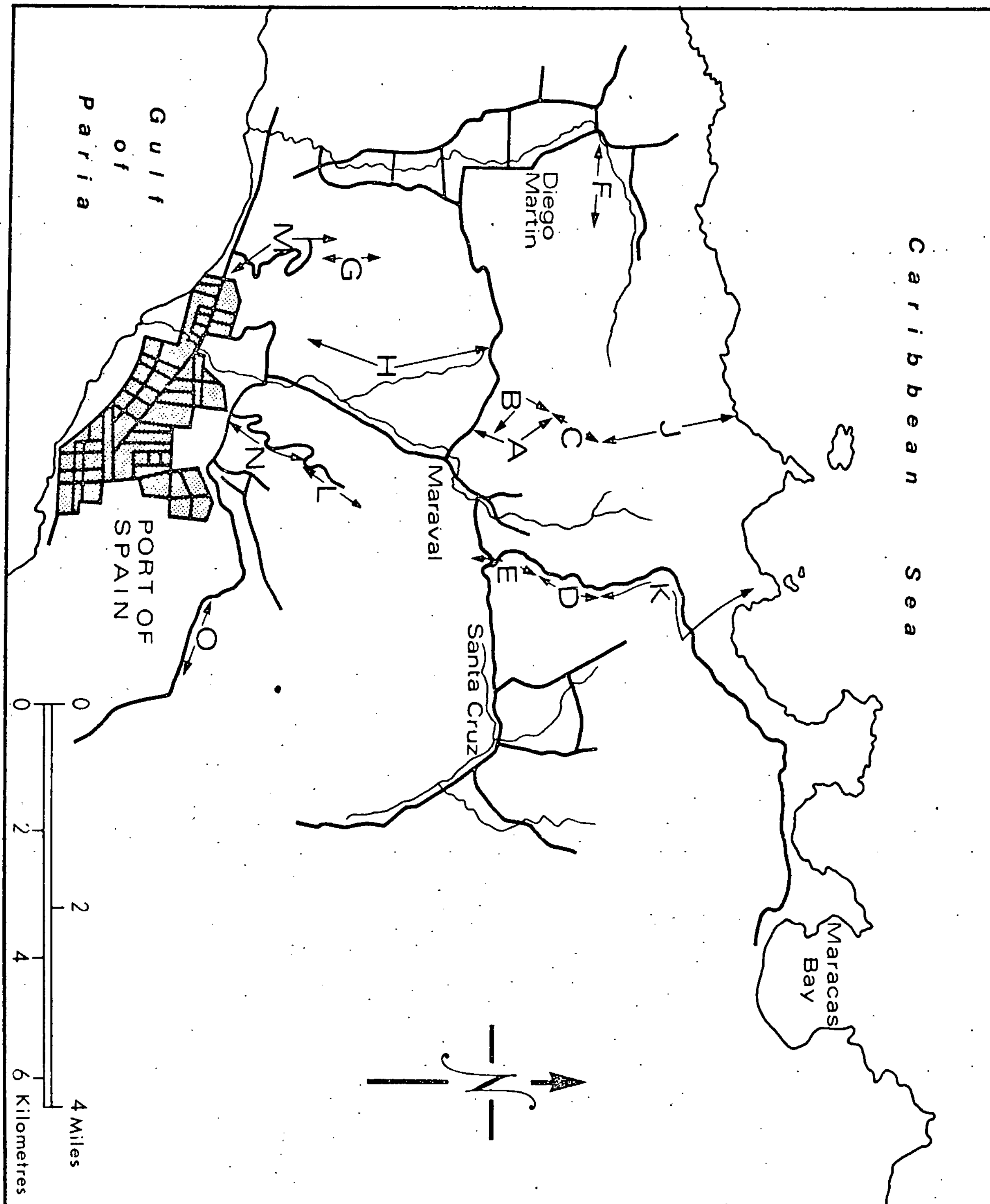


fig.4. Map showing the location of stratigraphic sections A to O.

the Laventille limestones and the crystalline limestones of the main Range, as did Wall & Sawkins, and quotes Professor G.D. Harris as inclining to believe that the fossils collected from the Laventille limestone suggested an early Mesozoic age

Liddle (1928, 1946) accepted a Cretaceous or early Mesozoic age for the upper part of the Caribbean group but thought that these rocks had been folded and faulted into older Palaeozoic schists, overlying a granite core. He suggested a thickness of 2,500 to 3,000 feet.

Trechmann (1935) recognised a fault between the Laventille limestone at Point Gourde and the schists to the north. He found Nerinaeas in the Laventille limestone near Laventille. Finally he concluded that the metamorphic rocks of the Northern Range comprised one series equivalent in age to the Toco beds and the LaVentille limestone i.e. Mesozoic to Upper Cretaceous.

Hutchison (1938, 1939) found ammonites in a limestone lens at the damsite on the Cuare River, and these were identified as Tithonian by Spath (1939). No other ammonites have been found in the main part of the Range, but Barr (1951) found an ammonite fauna at Tompire Bay in the Toco area, and this was identified as Barremian by Imlay (1954). Later references will be brought up in the detailed discussion of individual formations.

The Maraval Formation

After naming and defining the Caribbean Group, Wall & Sawkins (1860) say: "Calcareous rocks are represented by two varieties in this series, viz., crystalline limestones contained in the slates and alternating with them; and compact limestones, either quite unconnected with the schistose group, or only associated with its upper strata. The former occur sometimes in massive beds, varying from white to blue in colour, often with scattered spangles of silvery white mica, and distinguished by decided crystalline structure."   It is the massive beds of crystalline limestone which form what is now the Maraval Formation.

Suter (1951) first used the term 'Maraval' in his description of the Caribbean series along the North Coast Road.   He says: "The Maracas beds are then overlain by the Maraval beds, which begin with similar phyllites and contain several layers of epi-zone marbles and recrystallised limestones (Cameron, Maraval, Aripo); which assume locally considerable thicknesses.   The series continues right to the south foot of the range.   ......the upper boundary is transitional, to the Laventille limestone complex."   In this description Suter appears to include in the Maraval beds what will be described here as the southern outcrop of the Maracas formation and the Chancellor formation, as well as the Maraval formation as here defined.

In the International Stratigraphic Lexicon, Trinidad, Kugler (1956) raised these beds to the status of a formation.   The type section was given as the "Road leading from Port-of-Spain to Maracas Bay on the North Coast."   It was stated that "The Maraval beds are overlain by the Laventille formation and pass downwards into the phyllites of the Maracas Beds."   Thus the same stratigraphic extent is implied as in Suter's original description.   Kugler (1953) and (1956) restricted the term Maraval beds to the type area north of Port-of-Spain until future mapping should show the relationship with the Aripo-Cuare section of the Northern Range.

In the second edition of Suter (1960), Higgins in a revisionary appendix referred to additional work in the Toco district, Barr (1963) and considered that the Rio Seco formation, defined by Barr in the Toco area, appears to overlie the more massive limestones and marbles of the Maraval formation.   Thus Higgins seems to have restricted the stratigraphic thickness of the Maraval formation in more or less the same way as the present work.

However after working in the Toco area, Barr (1962) extrapolated that stratigraphic succession from the east end of the Northern Range to the Arima-Blanchisseusse road in the middle of the Range, by correlating the marbles of Verdant Vale with the Rio Seco formation. The same practice was followed and extended westward by Kugler (1961) in the "Geological Map of Trinidad". The Maraval limestones of the west end of the range are there shown as part of the Rio Seco formation.

In the eastern part of the Northern Range, Potter (1968) felt unable to correlate the Rio Seco formation with the Maraval limestones. He described the differences between the massive recrystallised limestones and the calcphyllites of the Rio Seco section itself, and suggested both a stratigraphic succession, with the crystalline limestones being the older, and also a facies change from calcphyllites to limestones in the younger part.

In the western part of the Northern Range it is now considered that field mapping on a scale of 1:10,000 has allowed the Maraval formation to be sufficiently well defined for the type section to be described. The stratigraphic position of the formation has, however, been changed. The recognition of a large recumbent anticline overturned to the north, forming the essential structure of the western part of the Northern Range, has meant that the described outcrop of the Maraval formation is, in fact, two limbs - a northern overturned limb and a southern upright limb. This has reduced measured thicknesses; it has also meant that the Maraval formation is the oldest formation in the western part of the Northern Range. It underlies the Maracas formation. The base of the Maraval formation is not seen in the western part of the Northern Range.

The thickness of the Maraval formation as measured appears to be 500 m. This can be compared with former estimated thicknesses of approximately 7000 feet (2100 m). Of course the structural interpretation would

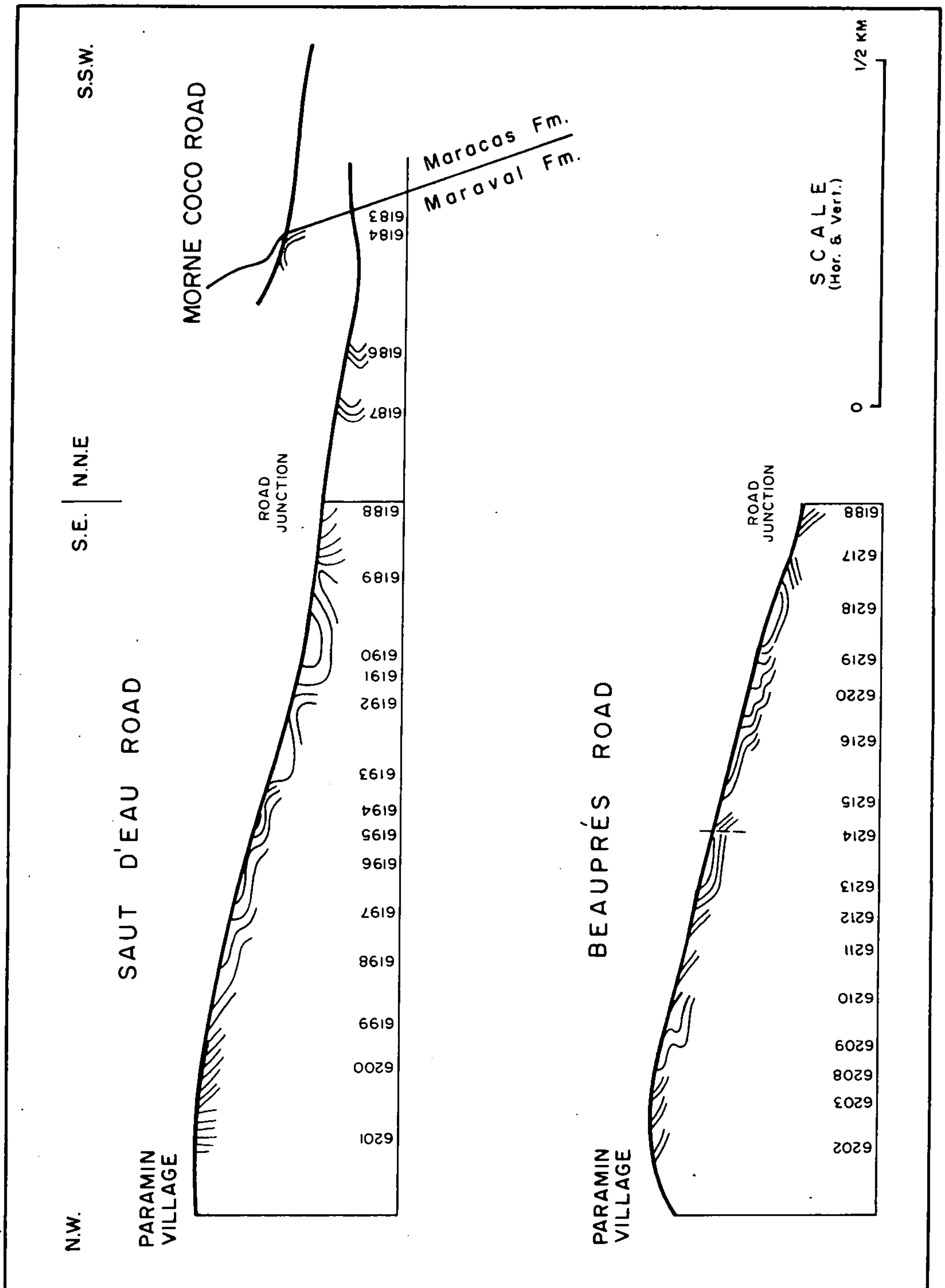


fig.5. Structural cross-sections along the type section of the Maraval formation.

change those estimates to approximately 1000 m, but that is still twice the writer's estimate. It seems that the difference is due to detailed dip measurements, the use of the new contoured maps and allowance for minor structures. This last factor involves personal interpretation. In order to show what this means, structural cross sections are included (Fig. 5). Inherent in the sections is the assumption that the local folding is true minor folding and not near surface collapse features such as will be mentioned on the North Coast Road. The presence of a neighbouring parallel road helps to establish this. It is readily admitted that structural interpretations may change; in fact this has happened in part of the section described below and an interpretation of the structure in an unexposed part of the Saut D'Eau Road, 624847, which had been extrapolated from observations in the western part of house sites in Haleland Park, 629847, has now been changed because those structures are now considered to be local shallow features. The result has been to increase the estimated thickness of the section from 430 m to 500 m. It is not expected that any other similar situations may arise.

As mentioned above the original type section for the Maraval formation was suggested as the North Coast Road to Maracas Bay. There are a number of good exposures on this road, and the visitor can see them by driving northwards from The Saddle (643849) at the beginning of the road to the corner south of Milepost 1½ (647867). In this 1½ mile drive he will have crossed the outcrop of the Maraval formation.

Much better exposures can be seen on the Saut D'Eau Road and the Beaupres road to Paramin (an important village centre at 620857, which is unfortunately not shown on the new topographic maps). These exposures are so much better than those on the North Coast Road that it was decided to describe a type section along the Saut D'Eau Road, with that along the Beaupres Road shown for comparison. Although these are not main roads, they are quite easily accessible by car from the Morne Coco Road near

fig.6. Location map Maraval formation type section.

Maraval as shown on the enclosed location map (Fig. 6). This is the southern, upright limb of the anticline.

Other large exposures of the Maraval formation may be seen in quarries near Diego Martin such as La Fontaine Quarry, 588846, Blanc's Quarry, 590845, and an old quarry at 593845 and at 594846. There are also quarries with good exposures in the Santa Cruz Valley such as Sokinosko Quarry, 657866, La Pastora Quarries, 676858, Bagan's Quarry, 666856, San Antonio Quarry, 681861, and quarries along the Cutucupano Road, 6685, and on the Saddle Road at 667848. In the eastern part of the area there are good exposures in the old quarry above Maracas village at 718848 and in the old quarry north of San Juan at 677816.

In the type section (Fig. 7) the lowest part of the formation occurs near Paramin village at 621856, exposure no. 6201. This is a massive recrystallised limestone, or marble. No internal structures were seen, and it looks very like a recrystallised reef. By using the nearest bedded exposures, the thickness appears to be approximately 50 m. The idea of a reef is reinforced by the fact that the exposure is in the side of a rounded knoll which does not extend to the Beaupres Road 200 m to the west. This reef is not found on the Beaupres Road, and the equivalent horizon is represented by bedded limestones as described below.

Above this, the exposures in both the Saut D'Eau Road and the Beaupres Road consist of bedded recrystallised limestones or marbles as far as the junction between the two roads. The stratigraphic thickness is estimated to be 230 m. Individual beds range from 1 cm to 10 cms generally, with thicker beds often 0.5 m thick and one bed of 3 m thickness on the Beaupres Road at no. 6215. In the lowest 50 m on Saut D'Eau Road are numerous 'reef' patches of formless massive recrystallised limestone about 1 m in diameter and 0.5 m thick.

Calcphyllites are subsidiary in this part of the section, except in

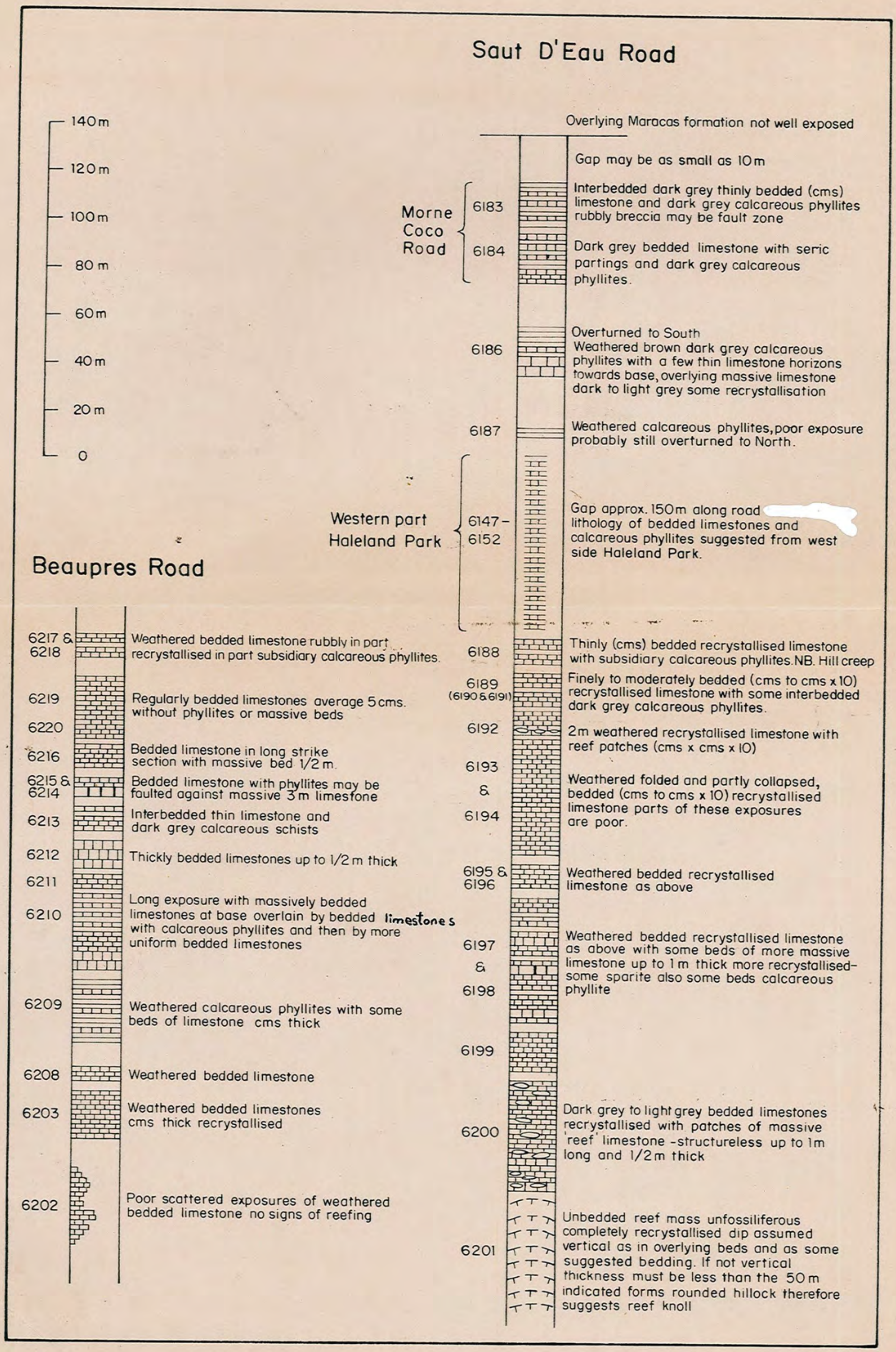


fig.7. Type section Maraval formation

exposure no. 6209 on the Beaupres Road. However it may be assumed that all the gaps are probably argillaceous. In addition a proportion of the long gap on the Saut D'Eau Road, south of the road junction with Beaupres Road, must be calcphyllite by comparison with the lithology of the same rocks exposed in house sites and housing roads in the western part of Haleland Park. Altogether argillaceous rocks appear to represent less than one quarter of the Maraval formation. This may be an under-estimation. Certainly some quarries that appear to be in solid massive to bedded limestones find that the crushed rock contains a relatively high proportion of fine material which must be washed out rigourously before using the stone for roadmaking. In thin section the presence of widespread sericitic surfaces is clear, even in the most massive-looking rock, as well as along bedding planes in the bedded limestones.

Despite this emphasis on the presence of sericite, all thin sections reveal relatively pure marbles, (but this may be due to the selection of 'good' samples). Textures are commonly granoblastic-elongate, more or less parallel to what appears to have been the original bedding planes. There are some samples with granoblastic-polygonal texture. Grain sizes seem to range from 20 μ for short axes up to 100 μ for long axes. Layers and clusters of larger crystals of sparite and quartz occur. The association of quartz and sparite is noticeable and suggests that the quartz has been introduced into the rock during metamorphism. In two samples, 6193 and 6215, which may be correlatable between the two roads, recrystallisation seems incomplete. There are what appear to have been original fossil fragments or ooliths, discernible through the general texture.

On the whole the section seems to represent quiet water shelf sedimentation indicated by the purer marbles at the bottom of the section and the concentration of reef patches there, changing gradually by the introduction of increasing amounts of argillaceous material towards the upper

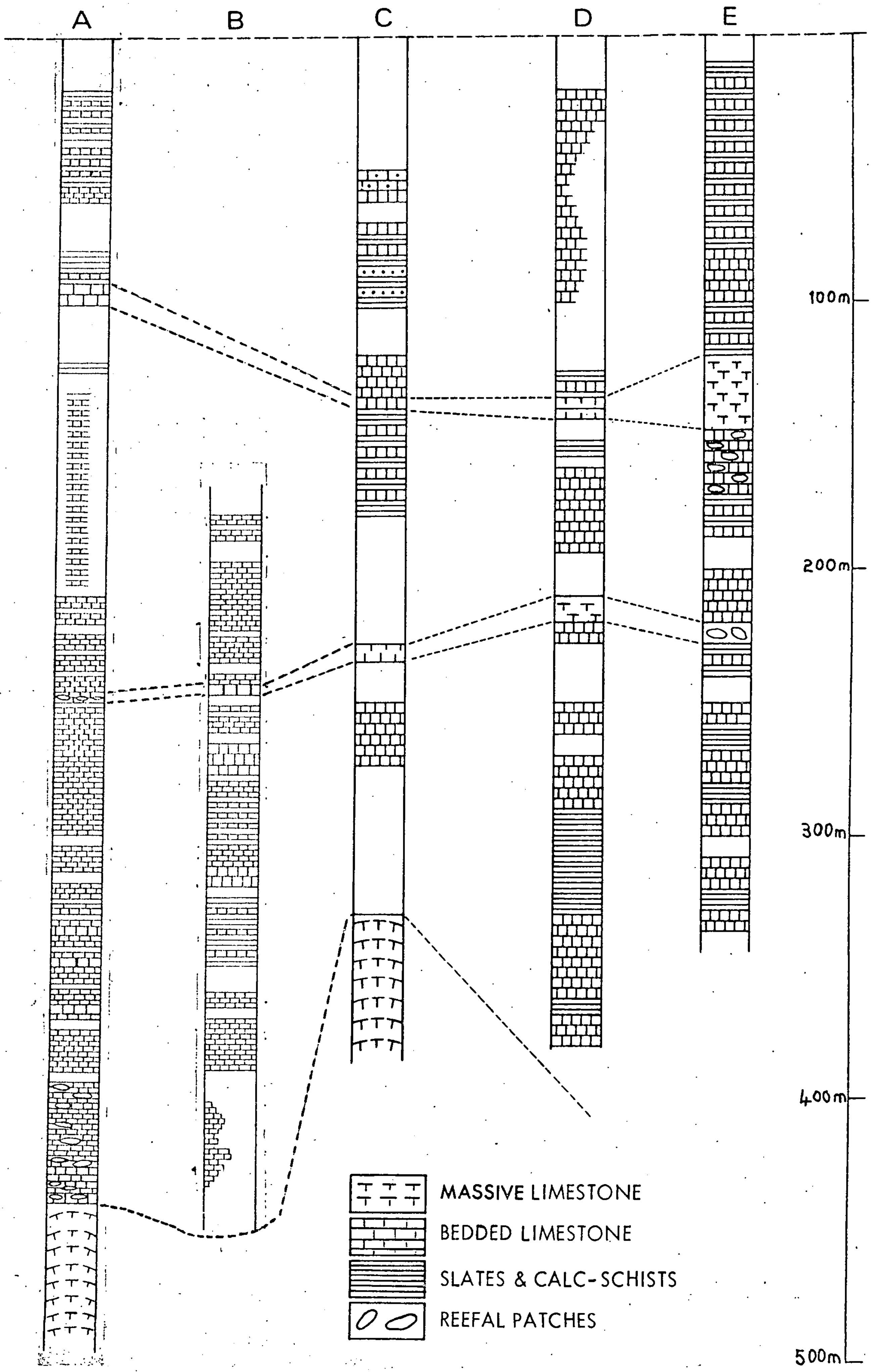


fig.8. Stratigraphic cross-section of Maraval formation.

part of the section. It may be thought that this suggests a transition from the limestones of the Maraval formation to the flysch of the Maracas formation. This only appears to be true in a broad sense. The contact with the overlying Maracas formation appears to be generally sharp, although there are thin limestone beds near the base of the Maracas formation in some places.

Some of the limestones that occur in the Maracas formation may, however, be exotic blocks of Maraval limestone which have slid into the Maracas flysch. Particularly this may be true of the outcrop on the ridge at 698870. This is an outcrop of massive limestone, nearly one half kilometre long, resting with apparent conformity on non-calcareous phyllites of the Maracas formation. It could be either a klippen carried on the thrusts mapped further south, or an exotic block as mentioned above. Similar occurrences have been mapped elsewhere in the Northern Range. It has therefore been mapped as Maraval formation, and in view of the lack of tectonic evidence is provisionally regarded as an exotic block. In Figure 8 the type sections of the Maraval formation, A and B, are compared with the overturned limb on the Saut D'Eau Road, C, and with the upright and overturned sections D and E on the North Coast Road. Although there are a few possible correlations between individual beds of massive marble, the impression is one of local variations. There does not seem to be any regional trend except that, based both on the sections shown and on other exposures, there does seem to be an increase in reefing towards the southwest. There also appears to be a stratigraphic change overall from more massive carbonates at the base of the Maraval formation to calcphyllites at the top. The sections on the North Coast Road seem to be exceptionally pelitic in the lower part.

In the Haleland Park area (629847) mentioned above, and in the southern part of the Maraval outcrop on the North Coast Road in the area of The Saddle, there are many superficial folds in the upper bedded limestones of the Maraval formation. Although these folds could have been caused by movement following decalcification, it is suggested that they may have overlain what was an evaporite sequence in the Maraval formation which has been completely dissolved. Such postulated evaporites are not exposed anywhere in the outcrop of the Maraval formation in the Northern Range.

The Maracas Formation

Describing the Caribbean series, Suter (1951) mentions a typical sequence along the North Coast Road and says: "It begins at the sea with the Maracas beds, consisting of grey to black sericitic-chloritic, red-weathering phyllites with intercalated layers of grits, followed by a zone of some 1500 ft of fine-grained, homogeneous, dense epi-quartzites, overlain by a sequence of phyllites". Thus the Maracas beds were assumed to be the oldest in the Caribbean series. A thickness of 22,000 ft (6700 m), was tentatively suggested.

In the International Stratigraphic Lexicon, Trinidad, Kugler (1956) raised these beds to formation status, suggested a type section along the North Coast Road to Maracas Bay and estimated the thickness as 10,000 ft (3350 m). Kugler (1953, 1956) considered that the Maracas beds merged downwards into the Dragon gneiss, but Gonzalez de Juana, Muñoz and Vignali (1965) considered that the Dragon gneiss was interdigitated with the Macuro formation (equivalent to the Maracas formation), and Kugler (1971) suggested that the Dragon gneiss might be a slip-mass.

In one way, the term 'Maracas' is confusing because there are two different places bearing the name; Maracas Bay on the north coast and Maracas Valley north of St Joseph. The original type section was intended to start in Maracas Bay; there are however sections of the formation in Maracas valley and particularly in a tributary containing the Maracas

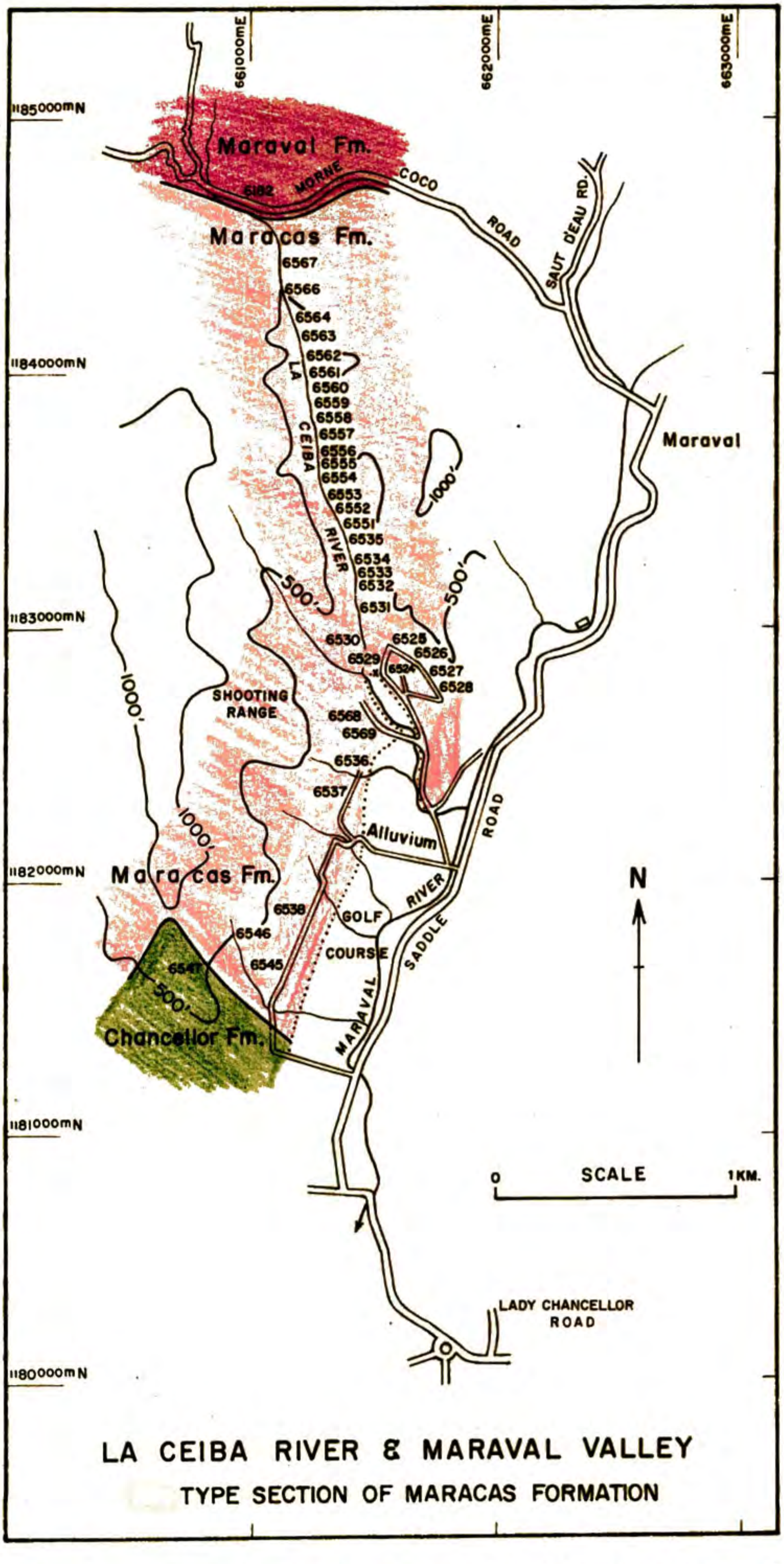


fig.9. Location map type section Maracas formation.

waterfall. The term has become well established, and it is not proposed to alter it.

It can now be seen that the Maracas formation is not the oldest formation in the Northern Range, and that it succeeds the Maraval formation with apparent conformity. The Chancellor formation, in turn, overlies the Maracas formation, apparently conformably. The thickness of the Maracas in both the upright and the overturned sections has been measured as slightly under 1500 m. Rather more variation in thickness had been expected in flysch like this.

Now that mapping has been completed in the area, the original type section of the Maracas formation is seen to be an overturned sequence on the north flank of the main anticline. Of course it is possible to describe a type section on an overturned limb; however the North Coast Road runs mainly along the strike of the beds as it approaches Maracas Bay. There are excellent exposures in cliffs cut along this road, but a coherent section cannot be followed. (Plate 8) The top of the formation is not reached in Maracas Bay, and there is also a major thrust there. Therefore a new upright type section is proposed, Fig. 9.

This section follows La Ceiba River (La Seiva on local signposts) near Maraval. The river rises in Maraval limestones north of the Morne Coco Road and then flows through the Maracas formation in a deep valley. Unfortunately the river joins the Maraval River before reaching the top of the formation, and therefore the continuation of the type section is suggested along the western bank of the Maraval valley. Here numerous house sites have been cut, revealing exposures of the Maracas formation. The junction with the overlying Chancellor formation can be seen both in a quarry and by inference between adjacent house sites.

A co-type section is also suggested partly on the North Coast Road and then down the Negre Marron trail to the sea, Fig. 10. It is an overturned sequence starting at the Maraval limestones and ending at the

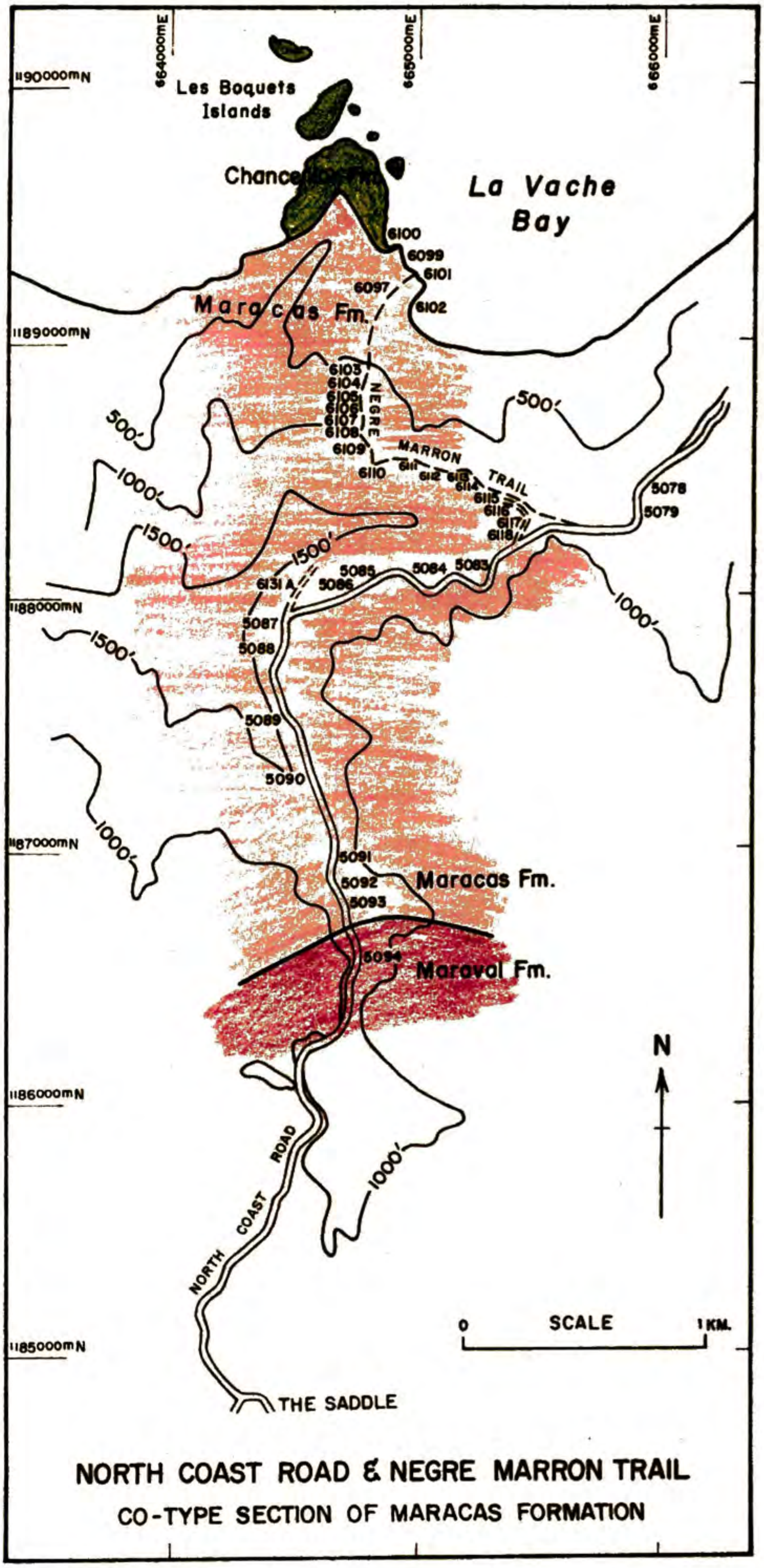


fig.10. Location map co-type section Maracas formation.

Chancellor formation at the coast. It has been included partly for the visitor who tends to travel by road from Port of Spain to Maracas Bay, and partly because a volcanic rock is exposed along this road at no. 5092 - now an epidote schist, but originally a tuff (647868). The proposed type section is shown as a stratigraphic column in Fig. 11 and the co-type section in Fig. 12. A number of stratigraphic sections are shown in Fig. 13, in which the type section is column H and the co-type section column K (locations are shown in Fig. 4). It is striking that although the thickness of the Maracas formation is remarkably constant in sections H, J and K, there is little correlation between the sections. Possibly the phyllites and slates 100 m thick in the upper part of columns J and K can be expected to lie in the appropriate gaps in H and K. Another possible correlation lies in the fact that at several localities the lowest exposures of the Maracas formation are in phyllites and slates. This has been observed not only in the area shown but as far as 40 kms to the east. The occurrence of quartzites near the base of section K is unusual, possibly minor faulting may be present.

There are three main kinds of lithology; but the lateral extent of individual units is limited. The first kind of rock is black to dark grey slate or phyllite, often graphitic, sometimes with pyrites. In nearly all exposures of this kind of lithological sequence there are occasional thin beds or horizons of schistose quartzites. Entirely different from the slates are beds of thick massive quartzites, forming cliffs and gorges, and underlying the highest peaks in the western part of the Northern Range. Individual massive quartzites may reach 100 m in thickness, but lateral extent is limited. Separate quartzite members may be named in future.

Although both the quartzites and the slates form distinctive parts of the Maracas formation, and the quartzites, in particular, form spectacular cliffs like those along the North Coast Road, it is probable that the major

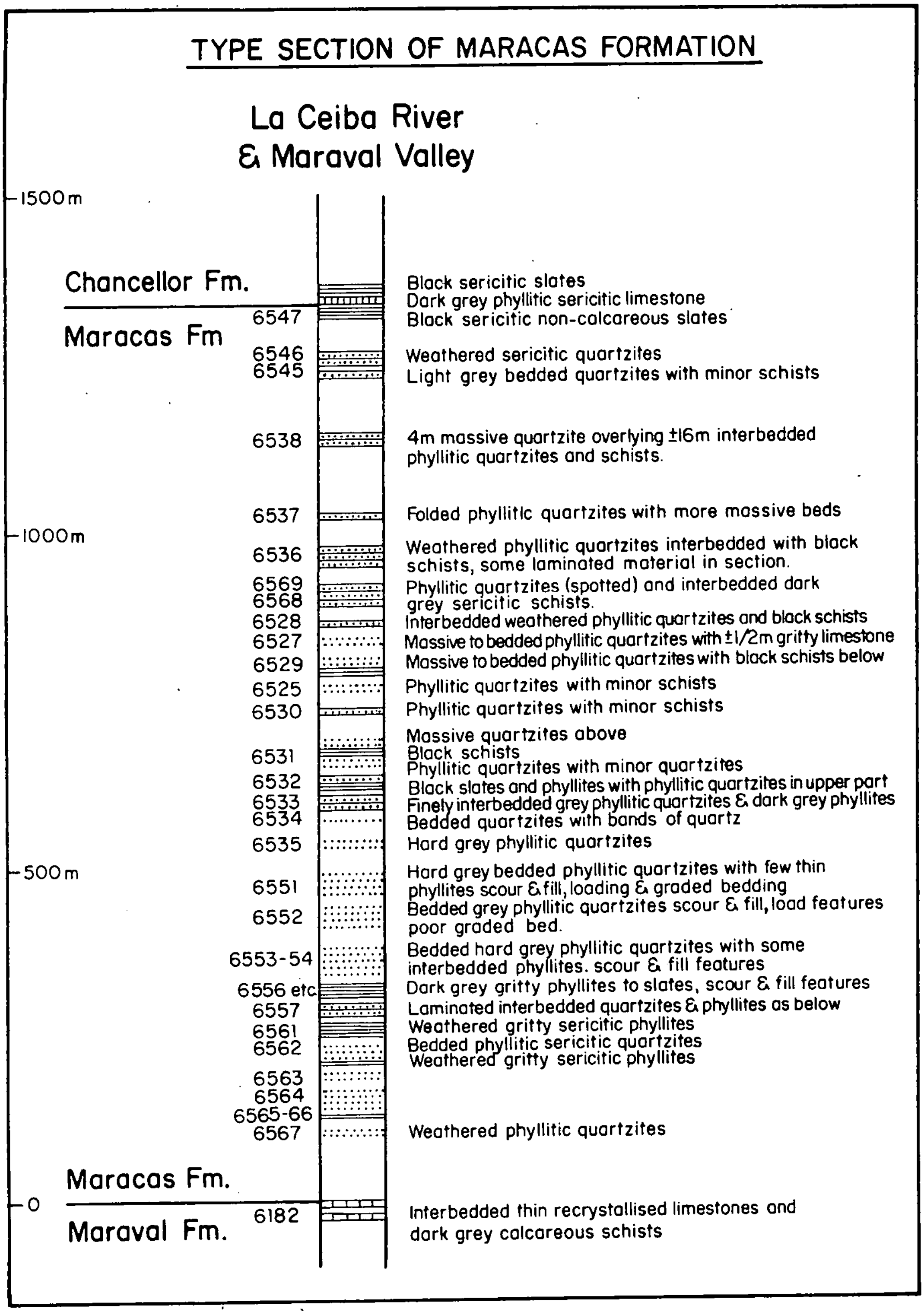


fig.11. Type section Maracas Formation.

part of the formation is composed of thinly interbedded quartzites and phyllites with individual laminae ranging in thickness from millimetres to centimetres. In this kind of material there are occasional bimodal layers in which quartz grains up to 2 mm in diameter lie in a fine grained matrix.

In the laminated material, especially in the more pelitic sequences, a number of sedimentary features can still be seen, graded bedding, convolute bedding, ripple load casts and ripple flow marks, and slump folds. All indications both in the upright and the overturned limb suggest a palaeocurrent direction from north to south. There may have been much more graded bedding than can now be recognised, because metamorphism may have obscured it.

A few thin limestones occur, but not in either of the type sections shown. These are dark grey recrystallised limestone or marble very like the Maraval limestones. Some of these beds seem to be in place, but in other parts of the Northern Range there are outcrops of massive marbles identical to those in the Maraval formation as mentioned above. But the outcrops may be only a few hundred metres in length, so that they may be either depositional lenses of contemporaneous limestone, klippe of Maraval formation or exotic blocks of Maraval formation. Field examination suggests that all three kinds of outcrop may occur.

On the North Coast Road at 647868, about 100 m north of milepost 1½, there occurs an epidote greenschist, weathered reddish-brown, about 6 m thick. This rock is about 60 m above the base of the formation, and is shown in exposure no. 5092 in the co-type section. It was first observed by K.W. Barr (personal communication) who also observed similar thinner beds in the phyllites to the north of this exposure. These are no longer visible. In thin section the rock appears to contain porphyroblasts of epidote and chlorite in a groundmass of quartz, calcite, muscovite and biotite. Mica layers seem to follow foliation - some

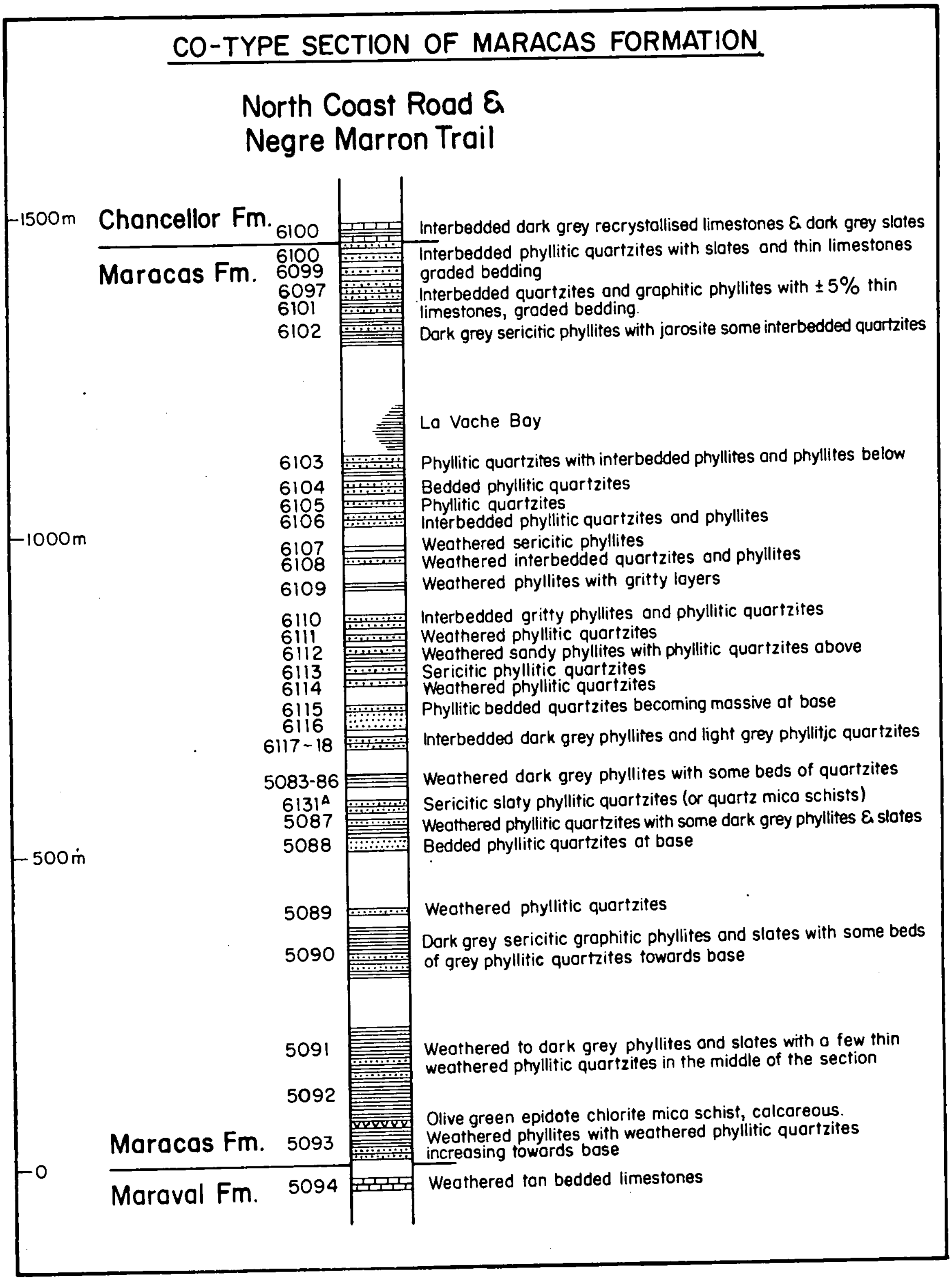


fig.12. Co-type section Maracas formation.

crenulation can be seen. The rock appears to have been a volcanic ash and together with the other thinner ashes, and a similar exposure some 9 kms to the west (553874), it suggests a volcanic episode, of more than local significance, early in the history of deposition of the Maracas formation. Convolute bedding on the base of the tuff (now overturned to the top) suggests palaeocurrent direction from north to south, therefore the volcanic material seems to have come from the same direction as the rest of the sediments. (plate 15)

In thin section the quartzites appear to be fine grained with long axes less than 0.1 mm as a rule. Textures are granoblastic-elongate quartz with subsidiary albite; bands of sericite outline the foliation; pyrites is common as an accessory mineral; what appear to be phyllonitic structures have been observed. Along the North Coast Road a succession of green quartzites and greenschists can be observed in a spectacular overhanging cliff at Milepost 3½ (660885). Among these chloritic quartzite beds there is a calcareous chlorite-mica-schist. (plate 8)

The Maracas formation gives the impression of being flysch. From consideration of lithology and observation of sedimentary features it is suggested that the major part of the formation was deposited as turbidite flows. This suggestion was first made by Kugler (1953). The volcanic ashes are also presumably submarine in origin.

It will be observed that the type section appears to be markedly more quartzitic than the co-type section. This illustrates the irregularity of sedimentation, because there are a number of massive quartzites in the peaks east of the measured co-type section which do not reach the measured section. The co-type section therefore appears to represent a more argillaceous sequence flanked by relatively quartzitic sequences. It has not been possible to investigate the quartzitic developments in detail because of poor exposures, partial inaccessibility and the effects of metamorphism; however it is suggested that if this flysch sequence is

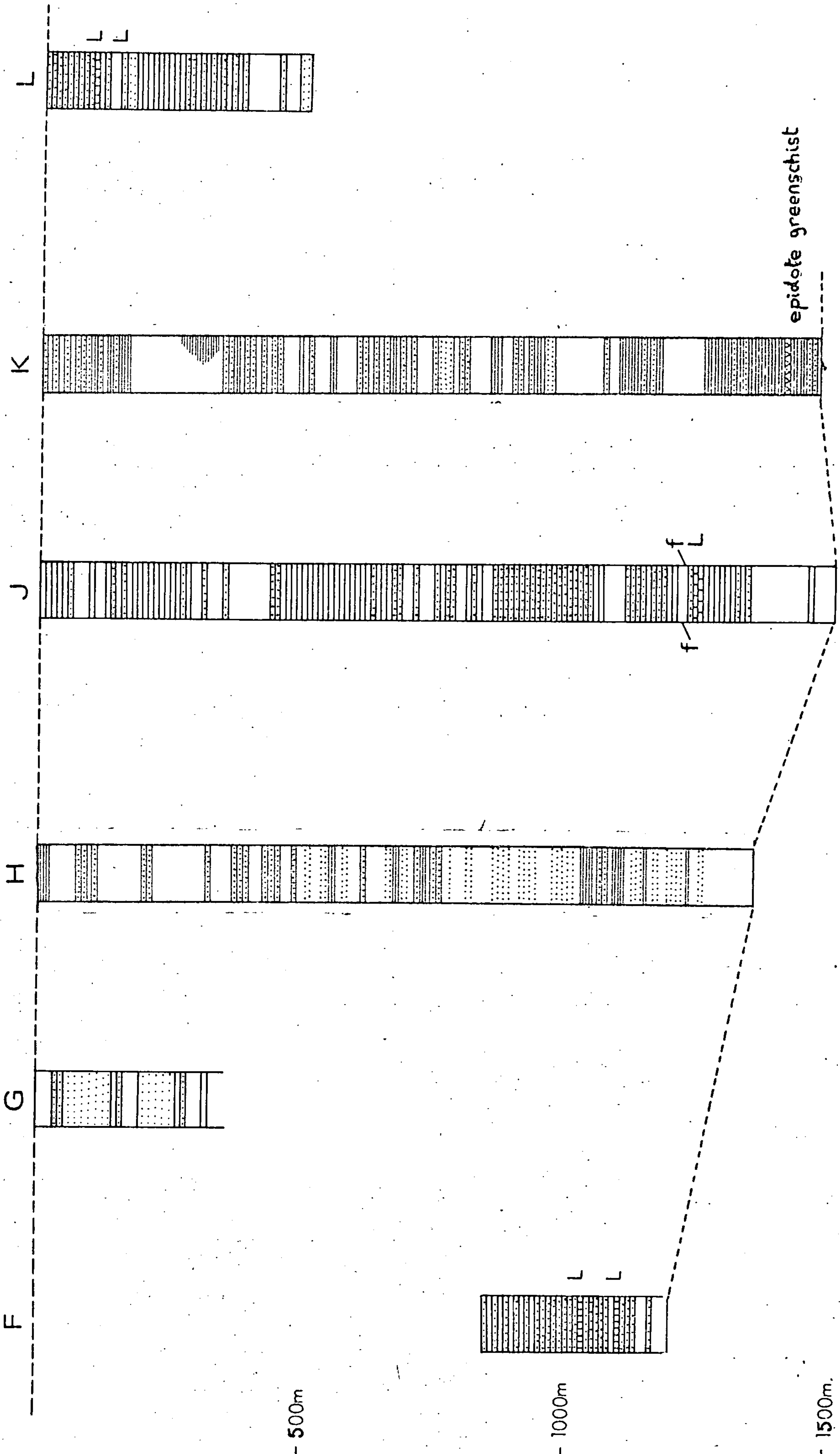


fig.13. Stratigraphic cross-section Maracas formation.

considered to be probably composed of turbidites, then the quartzitic sequences may represent the axial parts of submarine apron fans. It has not been possible to study submarine channels within fan complexes, but at different localities along the Northern sea cliffs and in the western islands, there are quartzites that may represent individual submarine channel sands.

The type section of Maracas formation in the Maraval valley and La Ceiba River was shown by Kugler (1959, 1961) on the 1:100,000 geological map of Trinidad as lying in Grande Riviere formation, by extrapolation from the Toco area (Barr 1963). The Grande Riviere formation is not now recognised in the western part of the Northern Range. The general position of the Grande Riviere formation will be discussed below.

The Chancellor Formation

The first published use of the name Chancellor appears to be in the 1:100,000 Geological Map of Trinidad (Kugler 1959, 1961), where the uppermost member of the Grande Riviere formation is described as 'Chancellor Beds'. The term was not used in the Stratigraphic Lexicon (Kugler 1956), nor in Higgins' appendix to Suter 2nd ed. (1960). However rather than introduce a new term the writer has proposed raising the Chancellor beds to formation status. Justification for this lies in the distinct lithology of the unit, which can be mapped throughout the western part of the Northern Range, the four recognisable members, the thickness of 500 m, and the fact that it may be correlatable with a formation, the Toco formation, already described in the unmetamorphosed rocks of the Toco area (Barr 1963). The Grande Riviere formation is not now recognised in this area, because part of it lies in the Maracas formation, and part in the Chancellor formation.

There is a fairly good type section of the Chancellor formation well

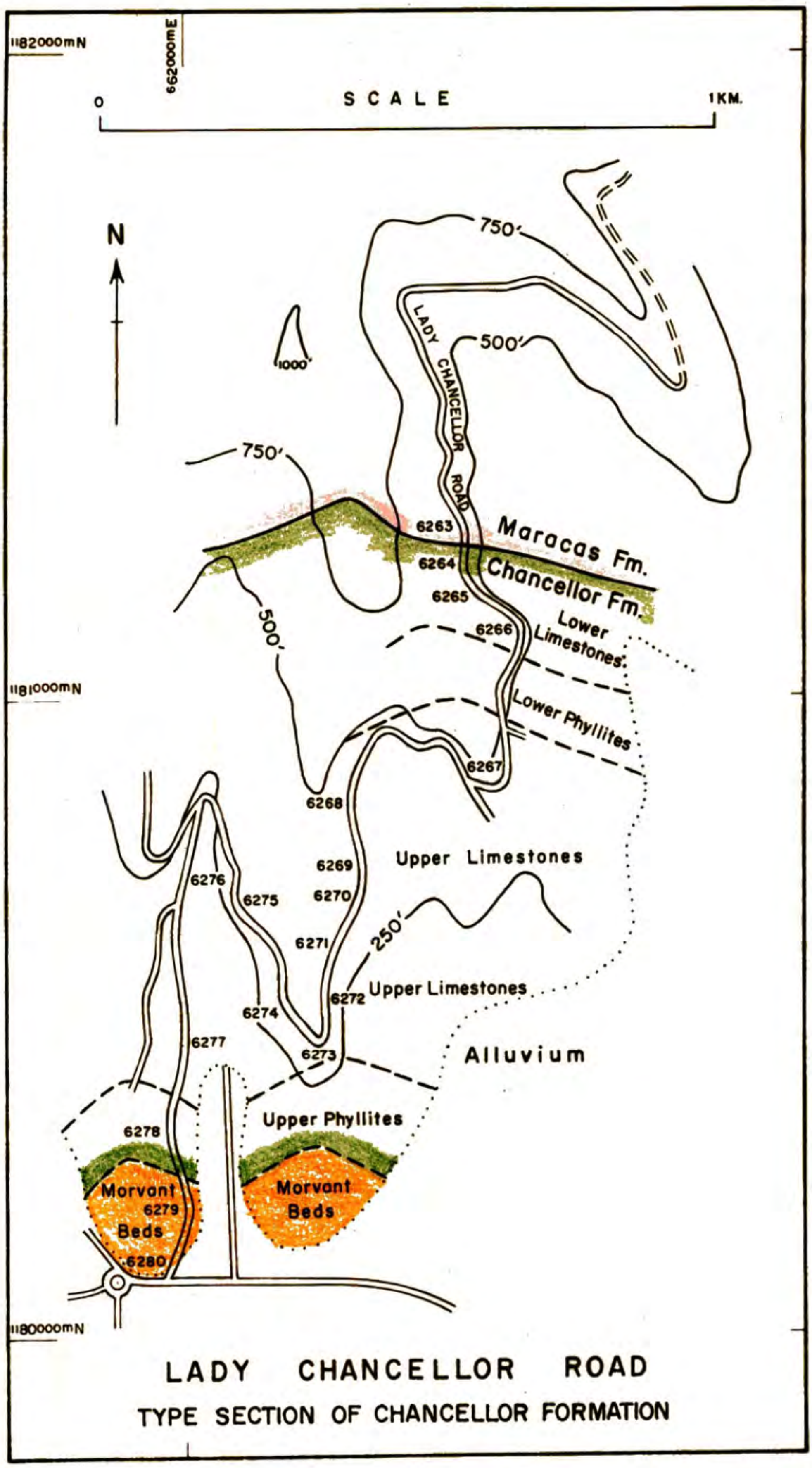


fig.14. Location map type section Chancellor formation.

exposed along the Lady Chancellor Road which leads northward, uphill from the northwestern corner of the Queen's Park Savannah in Port of Spain, Fig. 14.

The Chancellor formation lies on the Maracas formation, and the contact appears to be conformable in the western part of the Northern Range, although this may not be true everywhere. In the west the Chancellor formation is overlain unconformably by beds described by the writer as the Morvant beds, but which are probably equivalent to the Galera formation (Barr 1963). The unconformity is well exposed on the Lady Young Road at 651796 (see below). In the general Port of Spain area the thickness of the Chancellor formation is about 400 to 500 m, although the apparent thickness varies because of the overlying unconformity.

Fig. 15 is a stratigraphic column of the type section on Lady Chancellor Road, and Fig. 16 is a stratigraphic section from Fort George Road (5981) through the type section, to Lady Young Road (6480). There appear to be four easily distinguished members, which are, starting at the base: Lower Limestones, Lower Phyllites, Upper Limestones and Upper Phyllites. In the limestone members the characteristic lithology is that of thin dark grey recrystallised limestones from perhaps 1 cm to 1 m in thickness, interbedded with dark grey slates, phyllites or schistose quartzites. However quartzite beds are relatively rare except near the base of the formation and in the Upper Phyllite member. The proportion of pelitic material in individual exposures varies from thin streaks separating limestone bands, to perhaps five times the limestone thickness.

The Lower Limestone member has a number of sedimentary structures in the phyllites and quartzites similar to those found in the underlying Maracas formation. These are graded bedding, ripple flow marks, and scour and fill structures. In the field it is sometimes difficult to

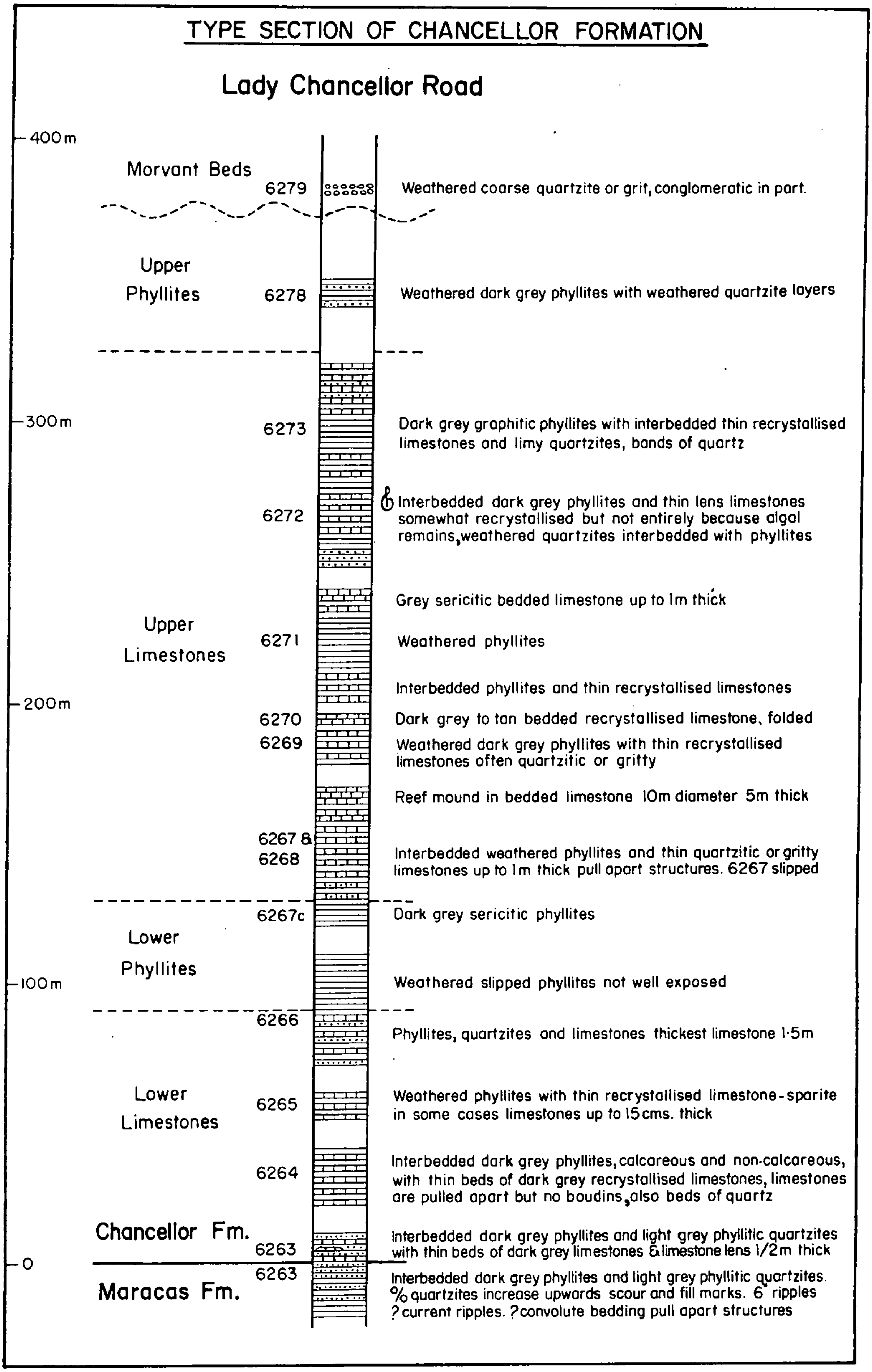


fig.15. Type section Chancellor formation.

distinguish between limy quartzites and quartzitic limestones. It is noticeable however that although thin sections show different limestones with quartz ranging from a trace up to 50% of the rock, the percentage of calcite in the quartzites does not exceed about 10%. It is suggested therefore that the quartz has been introduced after deposition, probably during metamorphism. The Lower Limestones member appears to be 90 m thick on Lady Chancellor Road and approximately 100 to 110 m thick on Fort George Road i.e. the thickness seems fairly constant.

The Lower Phyllites member seems to be about 40 m thick on Lady Chancellor Road but increases to about 190 m on Fort George Road only 3 kms to the west. Exposures are poor and weathered; and are of dark grey sericitic phyllites without any distinguishing characteristics. Thicknesses have been estimated with reference to the nearest limestone exposures. Unfortunately this member is very poorly exposed in the western islands.

Like the Lower Limestones member the Upper Limestones member is relatively constant in thickness and this is approximately 190 m on both Lady Chancellor Road and Fort George Road. At 622808 in exposure no. 6268 in the lower part of this member there is a reefal mound approximately 5 m thick and 10 m in diameter. The mound is surrounded by bedded limestones without interbedded phyllites. In the upper part of this member, especially in exposure no. 6273 (622805) there appear to be algal remains preserved, and it is possible that these may allow dating of the rock.

The Upper Phyllite member is poorly exposed on Lady Chancellor Road. In the section some 50 m thickness has been suggested, but there is only one exposure, no. 6278, and a poor weathered one at that. So the actual thickness could be as small as 30 m. However on Lady Young Road near the Lookout car park along the road from 649797 to 651736 the Upper Phyllites are well exposed although folded, in a series of upright folds. They can be seen to overlie the Upper Limestones which occur in the cores

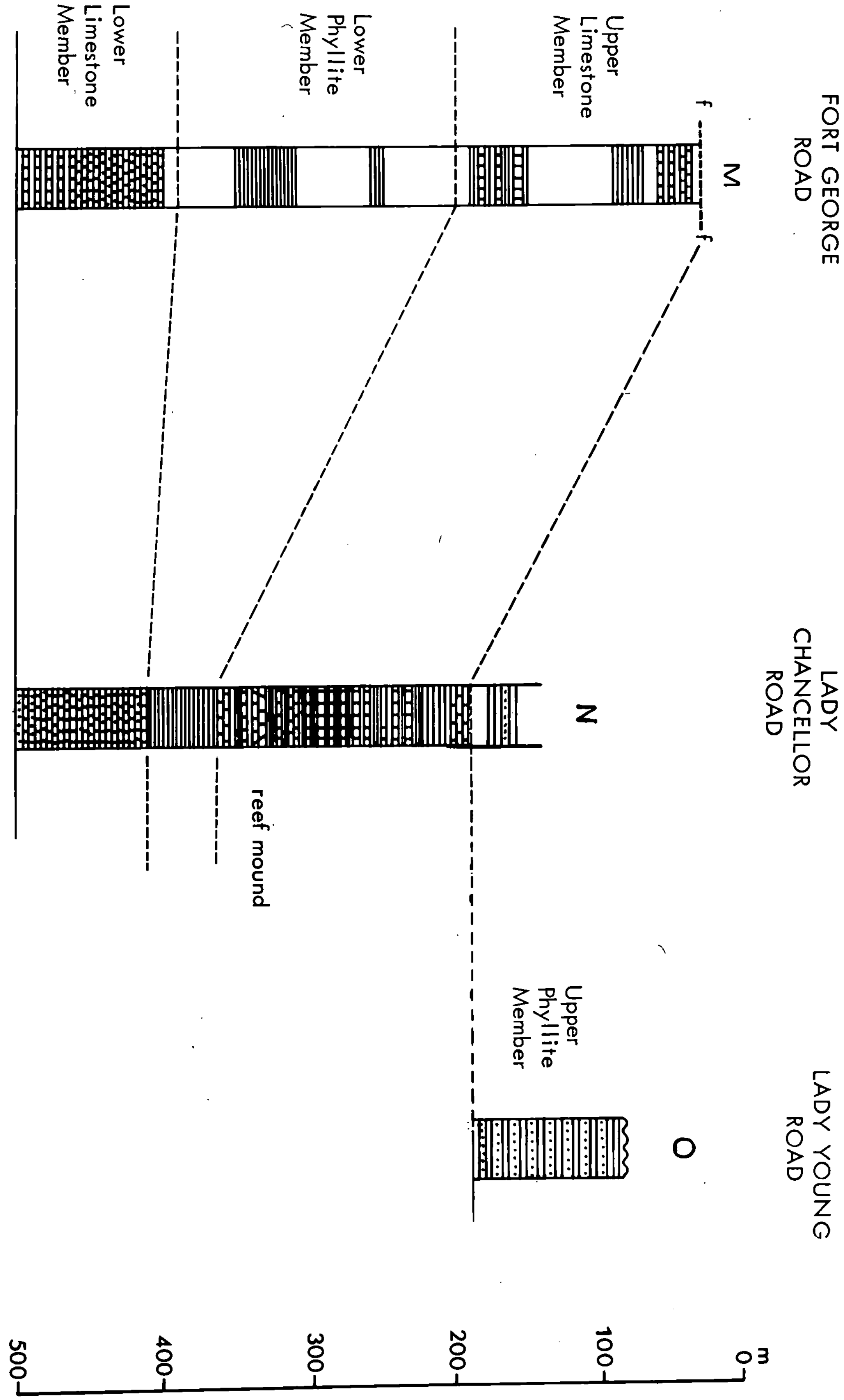


fig.16. Stratigraphic cross-section Chancellor formation.

of the small anticlines. About 100 m of weathered grey phyllites with minor interbedded quartzites were observed. At widely scattered localities the Upper Phyllites seem to weather lilac to purple.

Just east of the car park on the north side of the road at 651796 the unconformity between Chancellor formation and Morvant beds can be seen as a gently warped surface dipping south at approximately 40° (Plates 39-41). On this surface are limonite nodules and pebbles. Under the unconformity are the Upper Phyllites of the Chancellor formation, folded in upright folds as described. Across the road, and also just visible above the unconformity, are south dipping black shales contorted, and containing pebbles and boulders of dark grey limestone and quartzites, which may be from the Chancellor formation. These beds have been considered to be the lowest part of the Morvant beds, which are probably equivalent to the Galera formation (Barr 1963) and which will be so named when palaeontological evidence can be provided. Higher up the slope on the north side of the road, approximately 1 m of Morvant beds are found overlying the unconformity.

Other good exposures of Chancellor formation can be seen on Lady Young Road west of the section described, i.e. between the summit and Port of Spain, and also on Fort George Road, between the quarry behind the cemetry 599804 and the fort itself, 593817. On Fort George Road the rocks are weathered to a purple or lilac colour, but this seems to be either a local feature or to apply particularly to the Upper Phyllites.

In thin section the Chancellor limestones appear generally less pure than the Maraval limestones, and are finer grained. Quartz is present in nearly every Chancellor limestone in isolated grains, segregated bands, irregular patches and occasionally as porphyroblasts up to 1 mm in diameter. Sericite is common in irregular bands. Pyrites and iron staining are also common. Although the rocks seem to have been changed to impure marbles with granoblastic elongate texture, there are several exceptions which appear porphyroclastic with ooliths and bioclasts not yet fully recrystallised. It may be that the higher pelitic content of the formation and the thinner bedding has meant that the Chancellor limestones have not been metamorphosed as much as the Maraval limestones. The quartzites are generally coarser than the Maracas quartzites. Mortar texture is common. Albite is a minor constituent.

It may seem strange that the characteristic Chancellor formation had not been recognised throughout the Northern Range earlier. One factor hindering this was decalcification. At nearly all exposures the bedded limestones become decalcified during weathering. They look exactly like the weathered quartzites and phyllites of the Maracas formation. Within one to two metres of the surface there is no acid reaction. In the central and eastern parts of the Northern Range one can observe what appear to be quartzites with interbedded phyllites in the roadside, but when the same beds are followed down into adjacent stream valleys, they are revealed as bedded limestones. It is suggested that this is a particular feature of tropical weathering.

West of the Port of Spain area there are no well exposed cross-sections through the Chancellor formation, although some individual exposures are good. Near the village of Carenage, at 532815, behind the fuel tanks the conformable contact between the Chancellor formation and the underlying Maracas formation is well exposed.

The division of the Chancellor formation into members can be recognised as far as the most westerly outcrops here mapped. On Chacachacare Island the Lower Limestones member lies north of Chacachacare Bay. The Lower Phyllites member lies under the bay itself and can be seen in the isthmus, while the Upper Limestones member outcrops on the southern limb of the island. The shape of Chacachacare Island is striking testimony to the difference in lithology between the limestones and the phyllites of the Chancellor formation. The Upper Phyllite member does not outcrop on the island and must lie to the south. On this island the structure is rolling and stratigraphic measurement is difficult, however an estimate can be made: the Lower Limestones appear to be about 100 m thick, the Lower Phyllites about 150 m, and the outcropping part of the Upper Limestones also about 150 m, suggesting an overall thickness of 400 m without the Upper Phyllites.

On Heuvos Island only the Lower Limestones member outcrops, and appears to be about 100 m thick.

On the Island of Monos the exposures of Chancellor formation are significantly different from anywhere else, because of the development of conglomerates at a number of horizons. The Lower Limestones member is well exposed in the two small southeastern capes and appears about 160 m thick. In the second cape (at 442813) there are conglomerates interbedded with the lower 60 m of the member. These conglomerates do not appear in the most southeasterly cape 500 metres to the east nor in the exposures west of Grand Fond Bay 900 metres to the west. In fact these conglomerates do not appear in the eastern side of the cape 200 m to the east. The components of the conglomerate appear to be pieces of bedded limestone and bedded calcareous quartzite.

The Lower Phyllites member is not well exposed on Monos Island. It is exposed at the head of Dumas Bay and is believed to lie under the alluvium there (423813). It does appear in exposures in the western coast, which unfortunately proved to be inaccessible (421814). It is assumed to outcrop in the western side of Grand Fond Bay (433811), but is not exposed.

The Upper Limestones member is well exposed in the bays and on the capes along the coast of the southwestern 'foot' of Monos. At Cape Cola (416809) about 20 m of the Upper Phyllites member is found overlying the Upper Limestones.

In the eastern part of the 'foot' of Monos the Upper Limestones member is developed normally except for the occurrence of layers of autobrecciation in the bedded limestones. However in the two southwestern peninsulas i.e. to the east and west of Dumas Bay different lithologies occur. Here the bedded limestones are interbedded with conglomerates. These conglomerates contain well rounded pebbles up to 150 mm in diameter composed of light grey quartzites and of limestones like those in the Chancellor formation plus a few smaller pebbles of black chert. They occur throughout the whole of the Upper Limestones member, and form about half the thickness. It is not possible to correlate individual horizons across Dumas Bay. The conglomerates are confined to this extreme southwestern corner of Monos Island, an area approximately one kilometre from east to west. In detail as suggested by the enclosed photographs (Plates 21,22,23) the conglomerates appear to penetrate bedded limestones as well as being interbedded. It is suggested that they represent a local system of channels cutting through the shelf carbonates of the Upper Limestones member. A detailed discussion of correlation will be given below but in passing one may note similarities with the Patos conglomerate, and with conglomerates in the Guinimita formation of Venezuela.

In general it is suggested that the lower part of the Chancellor formation represents 'limy flysch' and may have been deposited as turbidites - the last phase of the Maracas flysch trough. On the other hand the upper part of the Chancellor formation represents a return to shelf sedimentation, with reef development in isolated localities, and conglomerate channel facies occurring in other areas.

One of Saunders (1971) samples (643796) lies within the Chancellor formation, in the Upper Phyllites member north of the main fault of the El Pilar system. He reports a fauna of micromolluscs and Globigerina Kugleri, which he compares with the Toco formation of the Barremian-Aptian age, and assumes that the sample lies in the Laventille formation.

The Laventille Formation

Many observers of Trinidad geology have been attracted by these easily accessible rocks and an account of their ideas covers much of the ground already covered by the introduction to the Caribbean group. However the stratigraphic views advanced should be presented here.

In describing the Caribbean Group, Wall & Sawkins (1860) noted the difference between the 'crystalline limestones contained in the slates' of the Northern Range, and the 'compact limestones, either quite unconnected with the schistose group, or only associated with its upper strata.' They stated that 'the compact limestones form a portion of the Leventille Hills, and several of the islands of the gulf'; and decided that 'the sections in general are not such as to indicate the precise relations of the compact limestones to the micaceous series'.

Guppy (1869, 1877) after describing poorly preserved mollusca from the Laventille limestones, decided that these limestones lay unconformably on the older phyllites and schists of the Northern Range. He considered the Caribbean group to be possibly Palaeozoic and the Laventille limestone to be younger i.e. possibly Upper Palaeozoic. But he also mentioned that Professor Tate, after examining the fossils, thought that the whole series might be Jurassic.

As mentioned earlier Cunningham-Craig (1907) examined these fossils and observed that a cephalopod described by Guppy as a goniatite was actually an ammonite, not older than Jurassic. Unfortunately the fossils were destroyed in a fire during the riots of 1921. Cunningham-Craig suggested that the Laventille limestones were the oldest part of the Caribbean group.

Trechmann (1925) described the Laventille limestones at Laventille Hill - 500 feet thick (152 m), and considered that a Nerinea occurring in the limestone was of probable Middle Jurassic age. He disagreed with Cunningham-Craig's suggestion that the Laventille limestones were the oldest part of the Caribbean group. In 1935 he recognised a fault between the Laventille limestone at Pointe Gourde, and the schists to the north, and suggested that the Laventille limestone was equivalent in age to part of the Caribbean group to the north, and to the Toco beds.

Waring (1926) agreed with Wall & Sawkins' original description of the Laventille limestones as being different and probably younger than the rest of the Caribbean group. He introduced the term Laventille limestone and quoted Professor G.D. Harris as inclining to believe that the fossils from the Laventille limestone suggested an early Mesozoic age.

Liddle (1928) proposed the term "Laventille formation" and suggested a Silurian age for it. In the later edition (1946) he revised this and suggested an early Mesozoic to Cretaceous age.

Suter (1950) mentions the Laventille Limestone and its extension on the western islands. He appears to include the phyllites below the limestone in the 'Laventille limestone complex' and mentions gypsum at St Josephs and Gonzalez (see below). He states: 'the lower boundary is transitional to the Maraval beds; the upper boundary is erosional and indeterminate', and also 'there are lithologic transitions between these limestones and the Maraval marble, and one could easily be a metamorphic facies of the other'. When one considers that Suter includes in the Maraval beds all those rocks the present writer defines as Maraval formation, the upright limb of Maracas formation and also the Chancellor formation, it is clear that the present suggestion of correlation between Chancellor formation and Laventille formation was foreshadowed by Suter's statement. These descriptions were not altered in the second edition, although Higgins (1960) in a table shows the Galera formation lying unconformably above the Laventille formation, again foreshadowing the writer's conclusions, and although he also says that the position of the Laventille limestone and associated shales is problematic.

Kugler (1953) describes the Laventille formation as being of about 270 m thick, and of consisting of 'various limestone members separated by sericitic phyllites'. He names an upper limestone, the Picton Limestone, after nearby Fort Picton (643778, near pt. 402), from which Trechmann (1926) collected a Nerinea of 'a decidedly Jurassic aspect'. Kugler noted the extension of the Laventille limestone westward through Five Islands and Gaspar Grande to Patos Island in Venezuela. He considered Patos to be composed of Picton Limestone and described the different components of the Patos conglomerate which he considered to be in the upper part of the Picton Limestone, i.e. part of the Laventille formation. In 1959 Kugler included some of the phyllitic shales along the south flank of the Northern Range in the Laventille formation.

It will be seen that nearly all the previous work was palaeontological in nature, concerned with the age and correlation of these beds. The outcrop lies close to Port of Spain and good exposures were available in the limestones which have been quarried since early in the nineteenth century. One structural study was carried out in the Laventille quarries for Dominion Oil Ltd. by I.P. Rumsey and P. Verrall. Unfortunately the work has not been published, but the results were provided to Kugler for inclusion in his Geological Map of Trinidad (1959) and Standard Oil Company of California allowed the writer to make a copy of the report and map. Rumsey & Verrall interpreted the structure of the Laventille quarries area as a NNE plunging syncline with parallel subsidiary folds. The limestones were shown as faulted against shales to the north and east. Other minor faults and folds on other axes were mapped. These workers estimated a stratigraphic thickness of 1647 feet (502 m).

Saunders (1971) found microfaunas with micromolluscs and Globigerina Kugleri in shales associated with the limestones within the Laventille quarries and also within phyllitic shales north of the quarries area. He compares these faunas with those found in the Toco formation -

Barremian-Aptian in age.

In the area here described there are three distinct outcrop zones of the Laventille formation. These are (a) the Laventille Hills, the classic area; (b) the islands and Pointe Gourde lying south of the north-western peninsula; and (c) the belt of low hills lying along the southern edge of the Northern Range. The Laventille formation consists of two distinct lithofacies. In areas (a) and (b) there is a succession of bedded to massive limestones (the Laventille Limestone) with only subsidiary shales and phyllites. In area (c) however the Laventille formation consists of phyllitic shales with only thin bands of limestones, quartzites and occasional gypsum and anhydrite.

The Laventille Hills consist of a single dissected hill about 1.5 kms long NE-SW and about 1 km wide; it reaches a height of 570 feet at Fort Chacon (645782). The hill is honeycombed by a large number of old quarries with good exposures, and practically all the published material refers to this area. Structurally the area is a complex syncline, and the limestone succession appears to be partly younger than the surrounding shales and phyllites. A succession can be determined. At the base of the hills up to 60 m of shales and phyllitic shales are exposed under the limestones. These shales have thin bands of recrystallised limestone and quartzites interbedded with them. Above the shales lies a lower limestone unit which will be discussed in more detail below; where undisturbed it reaches about 70 m in thickness in the south but may reach 250 m in the western part of the hills. Above the lower limestone unit lies a phyllitic shale series of variable thickness - 100 m might be taken as an average. Finally, occupying the axis of the syncline occurs an upper limestone unit, the Picton limestone described by Kugler (1953) of which about 60 m can be seen.

The lower boundary of the lower limestone has been mapped as the boundary of the Laventille Limestone in the Laventille Hills (Fig. 17).

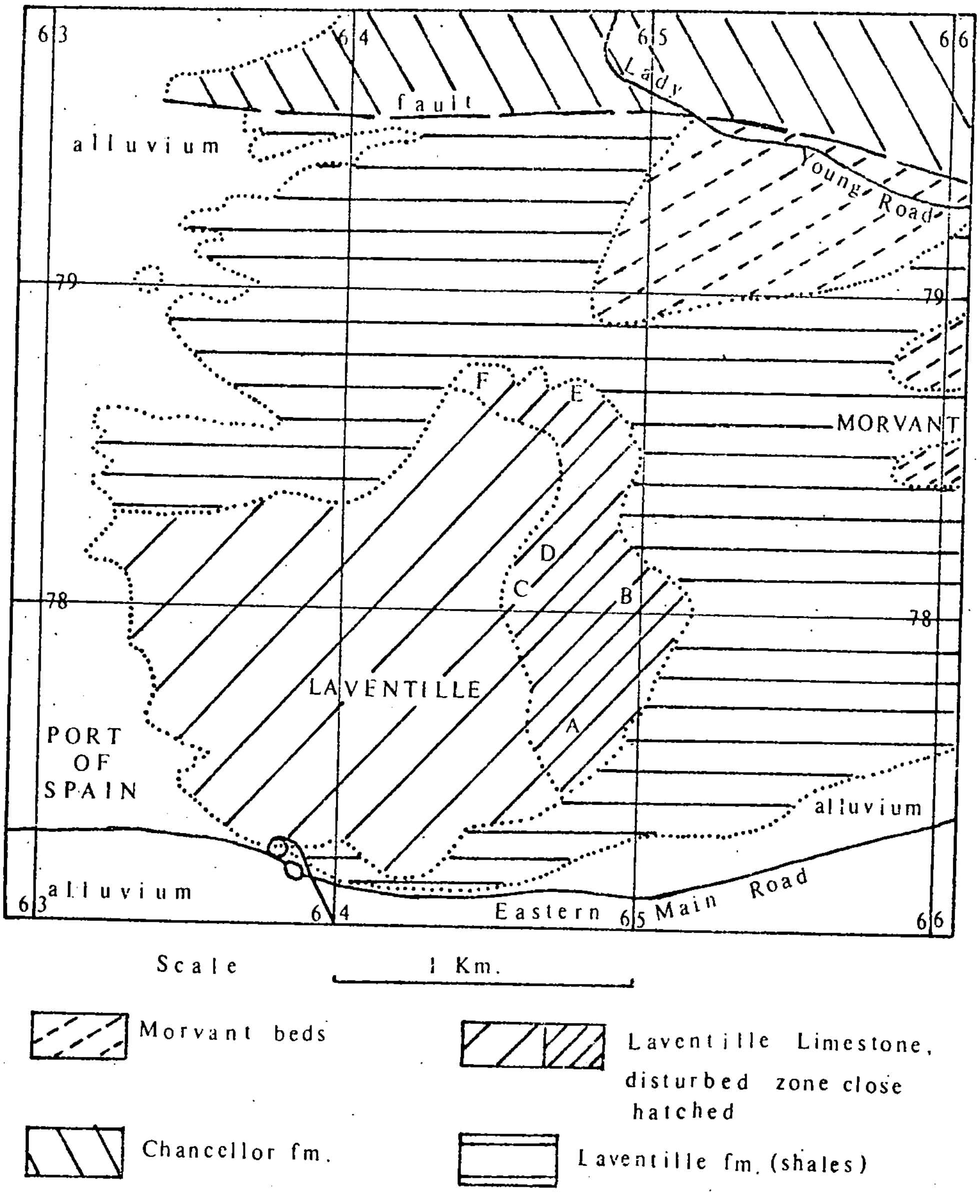


fig.17. Geological sketch map of the Laventille area, showingdisturbed zone in the Laventille Limestone, and quarries A to F described in text.

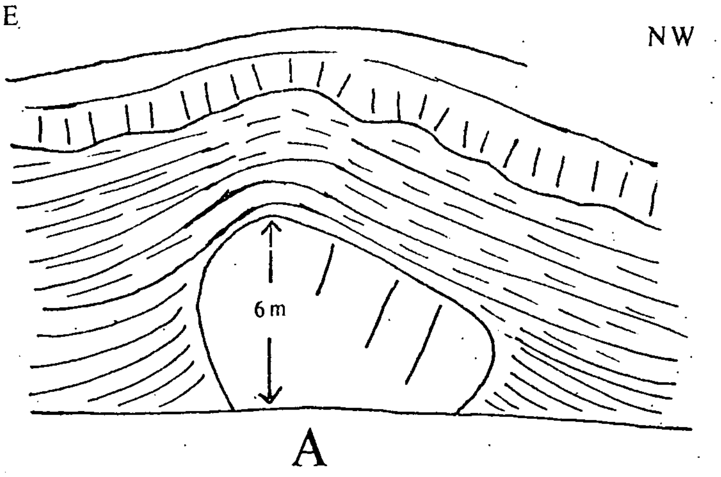
This fits with older descriptions; however this is now mapped as a stratigraphic boundary - the faults shown by Rumsey & Verrall, and reproduced by Kugler (1959, 1961) bounding the Laventille formation on the north and east are not now recognised. The Laventille Limestone appears to form a crumpled saucer-like structure and lies stratigraphically above the surrounding shales and phyllites.

The relationship between the upper and lower limestones is not entirely simple. There is a zone of disturbance along the eastern edge of the Laventille limestone outcrop. This is shown in the geological sketch map, Fig. 17, together with the locations of quarries A to F, where this phenomenon can be best observed. Sketches of the geological features in quarries A and C are shown in Fig. 18 and these and other quarries are illustrated in Plates 32-37.

In quarry A, exposure 7142 at 648776, a block of massive recrystallised limestone without any obvious internal features except joints lies in a section of weathered phyllitic shales. The block is some 6 m high and the shales 8 to 9 m thick. Overlying the shales is some 2 m of bedded limestone, thickening irregularly to the northeast. The shales are draped over the block, and to the north contain an increasing proportion of thin limestones. This is not a single block: several of the surrounding quarries show similar ones (exposure 7143 at 650778 and 7144 at 649776).

At B (exposure 7156 at 649780) approximately 5 m of bedded limestones, jointed and partly boudinised, lie in a fossiliferous shale succession. This appears to be a faulted block with unfaulted shales draped over it. Some 100 m to the east there is a similar exposure (no. 7155) in which shales are draped over disturbed and tilted limestones; however here some of the phenomena could be due to hill creep, which is not so at B.

C is a large exposure, no. 7157 at 646781, and contains a series of bedded limestones repeatedly faulted down to the southwest and tilted to



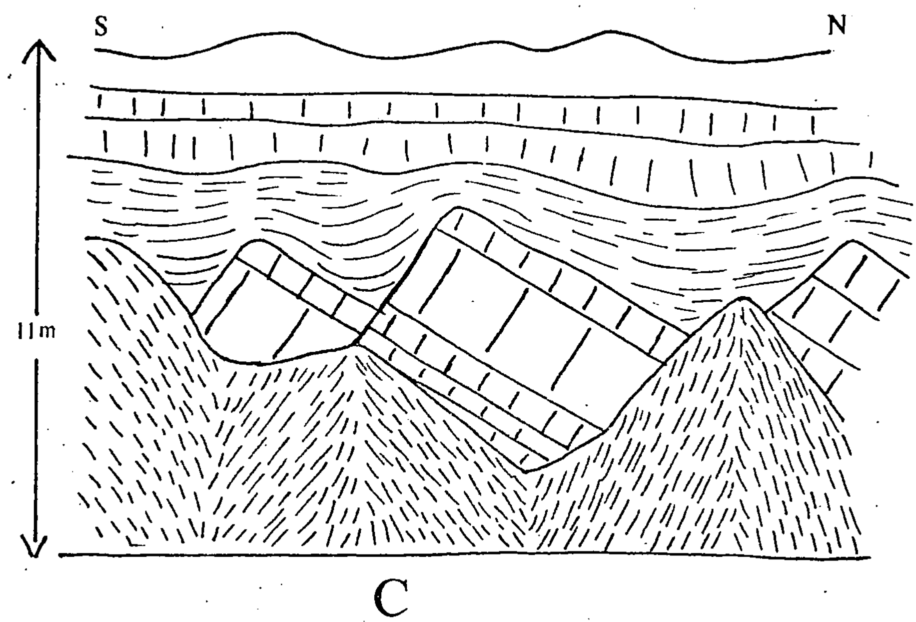


fig.18. Sketches of two quarries in the Laventille area. A, isolated limestone block lies in draped shaleunder an upper limestone. C, faulted limestones under draped shales covered by unfaulted upper limestones. Locationsin fig.17.

to the northeast, with unfaulted shales lying draped over them. The shales are overlain by 1.5 to 3 m relatively flat cavernous rubbly chalky limestone which also caps surrounding quarries.

Some 150 m to the northeast, at D (647782), the lower limestones appear to be faulted in the same way as in C, but the overlying shales have given way to thinly bedded limestones and shales which lie irregularly and apparently draped over the lower limestones. The upper part of this exposure, (no. 7160), was inaccessible.

In the northeastern corner of the Laventille limestone outcrop at E (no. 6888 at 648787) approximately 8 m of bedded limestones lie conformably on phyllitic shales, and are overlain apparently unconformably by 3 m contorted purple shales which are themselves overlain with apparent conformity by approximately 6 m cavernous chalky rubbly limestone. The 'unconformity' here could be interpreted as a flat fault.

Finally, at F (no. 7104), the northernmost limestone exposure in the Gonzalez quarries (644787), lilac to purple shales and white to red rubbly chalky limestones are faulted twice against two 12 m blocks of bedded to massive limestone. The dip is here southeast and the faults appear to be downthrown to the northwest, i.e. at right angles to the throw in quarry C.

These disturbed exposures cannot be explained by hill creep, because the faulted blocks are capped not only by draped shales, but also by bedded limestones. At first it was thought that there might be a thrust or flat slide and indeed there is evidence for some tectonic movement in the shales. However the spatial relationships between the quarries does not seem to fit such a feature.

The 'unconformity' cannot be of a regional character because it seems to be confined to a narrow zone. Moreover Saunders (1971) reports that the same Lower Cretaceous microfauna occurs in the shales associated with the quarry limestones as in the phyllitic shales north of the limestone mass. The disturbances are confined to the lower limestones. A few hundred metres west of this zone, the upper limestones are uniformly and thickly developed in the axis of the syncline, forming the highest ground along the crest of the Laventille Hills. A stratigraphic explanation is preferred. It is suggested that the zone of disturbance represents the edge of a platform or reef. No systematic investigations into the presence or absence of reefal organisms has been undertaken; however this zone does seem to represent the eastern limit of thick development of the lower limestones. This edge may have stood higher than the muddy sea floor to the east, and frontal blocks may have cambered, and slid forward forming the present disturbed zone.

Although it was suggested above that there does not seem to be an important unconformity between the upper and lower limestones there is some evidence for a possible local unconformity. The lower limestones both in exposure and in thin section appear to be more deformed and more recrystallised than the upper limestones. At 644783 the lower limestones turn from horizontal to vertical through northeast dip over 150 m exposure, and appear to be overlain immediately by gently dipping upper limestones. Although these exposures could be read as showing northwestward thrusting, they could also suggest folding of the lower limestones before deposition of the upper limestones.

Area (c) is the belt of low hills along the southern edge of the Northern Range east of Port of Spain. It extends eastwards as far as Arima outside the area now described. Here the Laventille formation consists of phyllitic shales with thin beds of limestones and quartzites and also a few occurrences of anhydrite and gypsum. One of the thickest limestones is 7 m at Champs Fleurs (721783). The old quarry at 722784 contains a 10 m limestone which is probably the same bed. Over the rest of the outcrop limestones rarely exceed 1 m in thickness and shales predominate. A series of good exposures may be seen along Riverside Road, east of Maracas River (738786 to 738780). Although exposures of Laventille formation in this outcrop resemble the Chancellor formation, the decision to extend the outcrop at least to the Maracas River was not difficult to make because the metamorphic grade is everywhere lower than that of the Chancellor formation. There are shales rather than phyllites, and the limestones do not appear as recrystallised as the Chancellor limestones - there is no reason to consider calling them marbles. This section will be discussed below.

The position of the evaporites is interesting. The largest exposure is near St Joseph at 727779, where some metres of anhydrite and gypsum lie vertically in contorted weathered shales. The length of the occurrence is difficult to estimate. It may not have been more than 50 m before excavation. There are certainly a number of barren test pits in extension of the exposure.

Another occurrence of anhydrite lies in a newly cleared site at Trotman Street School (654775) (Plate 38) 8 m of contorted anhydrite and gypsum are bedded with vertical shales and limestones. Kugler observed lenses of gypsum at the foot of Gonzalez Quarry (644787) on the northern side of the Laventille Hills (Suter 1952). These cannot now be seen.

These anhydrites could possibly be fault slivers enclosed in the Laventille formation. However there is an evaporite sequence 20 m to 120 m thick in the Patao member of the Cariaquito formation of eastern Paria, Venezuela (Gonzalez de Juana et al. 1965). The Patao member is fossiliferous and has been described as 'Neocomian-Barremian'. This compares with a Barremian-Aptian age for the Laventille formation, see below, and suggests that the anhydrites could either be in place in the Laventille formation or slightly older fault slivers. The suggestion has been made above that there may have been evaporites in the Maraval formation. One piece of evidence strongly supports the supposition that the anhydrites are in place. Unfortunately the facts are unpublished. An offshore well in the northern part of the Gulf of Paria encountered limestones of probably Aptian age, and underlying them an evaporite section which is reported to contain the same flora as the evaporites of St Joseph Quarry i.e. probable Lower Cretaceous. Therefore the evaporites of the Laventille formation outcrop may represent only the edge of a larger evaporite basin.

The outcrops west of the Laventille Hills are on the islands of Gaspar Grande, Gasparillo, Cronstadt, Carrera, The Five Islands, and on the peninsula of Pointe Gourde. Practically all the exposures are Laventille limestone with only subsidiary shales. The island of Patos in Venezuela some 21 kms west of Gaspar Grande consists of limestone which has been referred to the Laventille formation (Kugler 1953). Shales occur on Gaspar Grande in what appears to be an anticlinal axis and similarly on Pointe Gourde, as well as interbedded with the limestones. Thus there is a suggestion that the limestones are underlain by shales as in the Laventille Hills.

It may have been assumed that these islands represent only the exposed peaks of an overall limestone development that stretches all the way from Laventille to Patos. But the sharp boundary between the limestones and shales in the Laventille area can be used as a model, and the flat sea floor around the islands suggests that most of the sea floor covers shales.

The vertical character of the edges of the islands indicates that some erosion may have taken place, but it may not have been great - limestone debris seems limited in area. It is suggested that in general the outlines of the present islands represent the extent of the original limestones, allowing for only minor erosion. This may not be true of the area between Gaspar Grande and Pointe Gourde, where irregular sea floor and structural continuity suggest a limestone connection now eroded. The whole group of islands may represent a general platform or reefal development like the Laventille Hills although Cronstadt and Carrera may be preserved synclines, and Five Islands and Gasparillo may be either exotic blocks or fault slivers.

There are two lithological phenomena which appear to be prominent in these western island outcrops of the Laventille formation: these are widespread breccias and also the occurrence of haematite. Polymict conglomerates have been described from the Laventille formation on Patos Island (Kugler 1953) and this has been correlated with conglomerates in the Guinimita formation of Venezuela (Gonzalez de Juana 1968) and with conglomerates in the Chancellor formation, mentioned above and in Potter 1973b. However in the western islands of Laventille formation there is widespread development of what appear to be boulder beds or breccias (Plate29) within the massive limestone. The components are all limestone, often in large angular boulders separated by weathered soft calcareous material. In some exposures the boulder beds are overlain by undisturbed limestones. These breccias are chiefly developed in the eastern part of Gaspar Grande, Gasparillo and the southern part of Pointe Gourde. This feature appears to be a collapse phenomenon, but whether it is due simply to solution of limestone and collapse of caverns,or to the solution of underlying evaporites, is not known. There does not seem to be any connection with either dolomitisation or de-dolomitisation.

Ferricrete haematite appears to be widely associated with the breccias in Gaspar Grande, Gasparillo and Pointe Gourde. The concentration of ore appears to be too low to suggest economic possibilities except at two locations on Gaspar Grande. In Goodwill's Bay (478795) and at Reyna Pointe (479793), there are similar vertical zones each about 10 m wide in which the concentration of haematite appears to exceed 50%. (Plate 30). Presumably the iron was leached from overlying soils into voids in the limestone. The two richer zones may follow major joints.

Joubin (1965) correlates the iron occurrence with magnetic anomalies shown by a private aeromagnetic survey and suggests that there is a narrow E-W band of enrichment across Gaspar Grande. Another anomaly lies at Winn's Bay (469788) and coincides with the occurrence of a small area of yellow fluorite enrichment, in the limestone. This fluorite occurrence appears to lie near one of the El Pilar system faults, and to be in the general area of Upper Jurassic to Lower Cretaceous evaporite deposition. There do not appear to be other hydrothermal minerals present, and the origin of the fluorite is not clear.

The Morvant Beds

Along the southern edge of the Northern Range a series of sandstones and shales occurs at a number of localities, above the Chancellor formation. In the generally poor exposures these sandstones and quartzites can be distinguished from the Chancellor and Maracas formation by their coarseness, and their yellow to buff colour. Individual units are usually several metres thick, by contrast with the quartzite bands in the Chancellor formation. Provisionally these rocks have been called the Morvant beds. It is expected that when palaeontological evidence becomes available they will prove to be equivalent to the Galera formation.

The best exposure of these beds is on Lady Young Road between the summit (651796) and the edge of the Quaternary terrace (661793). At the summit the unconformable contact between the Chancellor formation and the Morvant beds is well exposed; it has been described above. The contact is a gently warped surface dipping south at approximately 40^{o} (Plates 39-41). At first it was taken to be a fault plane; indeed there is an east-west fault passing through this area. At this locality it seems at first as if the Chancellor formation were entirely confined to the north side of the road, and the Morvant beds to the south side, with

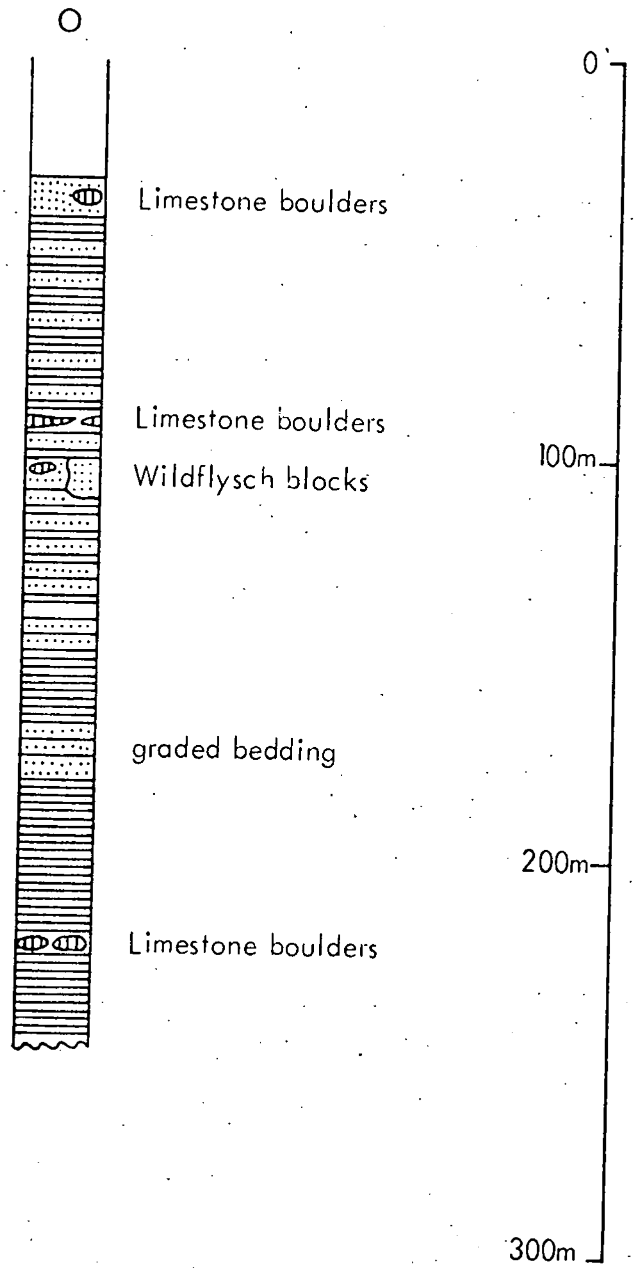


fig.19. Stratigraphic column of Morvant beds along the Lady Young Road.

the fault in between. However, after examining the 'plane' itself it appeared to be much more like an unconformity. There was no evidence of relative movement. The limonite layers and pebbles appeared to be sedimentary in origin rather than tectonic. Finally at the top of the 'plane' a locality was found on the northern side of the road, where approximately 1 m Morvant beds lay over the folded Chancellor beds, and the nature of the contact could be seen as an unconformity.

On the location map, Fig. 4, the section along the Lady Young Road is shown as location O. The stratigraphic column of these beds is shown in Fig. 19. This is an incomplete column because repeated folding in the upper part makes measurement too difficult to be meaningful, Above the approximate 200 m of section shown there is at least 100 m of interbedded shales and sandstones.

The lowest part of the Morvant beds, as exposed at the summit on Lady Young Road, consists of black pyritic gypsiferous shales and slates, partly calcareous and partly graphitic. These shales do seem to be markedly less metamorphosed than the underlying phyllites of the Chancellor formation. There are occasional fragments of limestone at some horizons. They look like small boulders of Chancellor limestone, but in these somewhat contorted exposures they could conceivably be the pulled-apart remnants of thin limestone bands. This lowest shale unit appears to be about 70 m thick. These lower shales are usually weathered purple or lilac, and in the absence of exposures, mapping the boundary with the similarly weathered Upper Phyllites of the Chancellor formation may be somewhat arbitrary.

Above the lower shales the section consists of similar shales and slates interbedded with laminae and beds of sandstone. The coarse sandstones are frequently argillaceous and occasionally calcareous. There are three main sandstone units in the section, and they may be worth describing separately.

The lowest major sandstone is 15 m thick (653795). It is generally coarse and grades upwards from a basal conglomerate through conglomeratic massive coarse sandstone, to interbedded sandstones and shales. Graded bedding and load structures are prominent.

Some 60 m higher in the section a very different sandstone unit occurs (655795). The most obvious element is a massive to bedded, coarse sandstone mass some 7 m thick and 11 m long, dipping conformably with the surrounding shales and slates. It appears to be the only large isolated block, although small boulders of recrystallised limestone are found in the surrounding shales. The sandstone block itself appears to be only poorly sorted; although many grains reach gravel size there is a considerable amount of argillaceous material throughout. In addition there is a conglomerate of dark grey flattened mudstone pebbles in the block itself, It is suggested that this exposure represents wildflysch, and that this is an exotic block of Morvant sandstone The limestone boulders may be Chancellor limestones. Similar large blocks have been seen in the Galera formation of the Matelot area in N.E. Trinidad and have been reported by Barr (1963) in the Toco area. There is a second similar block on the Lady Young Road.

Through the upper part of the section interbedded shales and fine to coarse sandstones predominate. The highest sandstone that could be included in the stratigraphic column occurs in a tight syncline and resembles the lowest sandstone unit, but appears to be in place (659793).

A number of other exposures of Morvant beds have been observed - along the southern edge of the mountains but none is as good as the Lady Young Road section. At the junction of Lady Chancellor Road and Queens Park Savannah (620801), and beside the new road near the bottom of Fort George Road at S. James (594801) coarse sandstones of the Morvant beds may be observed. In excavations in the eastern Morvant area, (673786 and surroundings), folded Morvant beds may be seen with many large boulders of what appears to be Chancellor bedded limestone lying on the surface, suggesting that wildflysch conditions existed here too.

There are two other exposures which should be mentioned. At San Jose Point (471806, not named on map) and on the coast road east of Carenage (554808) there are interbedded quartzites and phyllites contorted and faulted against Chancellor formation. At first it was considered that these exposures might represent Morvant beds, but re-examination suggests that both areas represent the Upper Phyllites member of the Chancellor formation. However the exposures do lie on the extension of an important fault in the El Pilar system.

It is believed that the Morvant beds are the western extension of the Galera formation, described by Barr (1963) in the Toco area. Lithology is very similar, and the stratigraphic position is equivalent, but as yet palaeontological evidence is lacking. The Galera formation appears to range in age from Campanian to Maestrichtian (Barr 1963, Saunders 1971).

Regional Correlation

The Caribbean group in the western part of the Northern Range can be correlated with the equivalent rocks in the eastern part of the Northern Range, and in the Paria Peninsula of Venezuela. A correlation chart is attached (Fig. 20).

The succession in the eastern part of the Northern Range was described in the Toco area by Barr (1963) and this information was used by Kugler in the Geological Map of Trinidad (1959) and by Higgins (1960) in his revisionary appendix to Suter. Saunders (1971) has described fossil faunas from this area and from other areas, and has discussed correlations.

The Toco area remains important because of the juxtaposition on either side of a major fault of fossiliferous sedimentary sections and the most easterly outcrops of the metamorphosed Caribbean group. The writer remapped part of the western Toco area and this was included in a preliminary paper (Potter 1968). This mapping has now been revised in the light of increasing stratigraphic knowledge.

The Rio Seco formation as described by Barr, on the river of that name, is a succession of calcareous phyllites and thin limestones. It underlies a series of quartzites which Barr described as Grande Riviere formation. These formations were part of the metamorphic succession, and their relationship to the Lower Cretaceous Tompire, Toco and Sans Souci Volcanic formations across the Grande Riviere fault was unclear. Barr assumed that the metamorphic rocks were older than the fossiliferous sediments. The youngest formation, lying unconformably on all the older rocks, was the Upper Cretaceous Galera formation.

Kugler (1959) correlated the Rio Seco formation with the limestones of Aripo and Cuare, and by further extension with the Maraval limestones. Incidentally the correlation was also made with the limestone lenses at Hollis reservoir, from which Hutchison (1938) recovered ammonites dated

	VENEZUELA Paria Peninsula		TRINIDAD, NORTHERN RANGE Western part		Toco area		
UPPER CRETACEOUS			Morvant beds		Galera formation		
LOWER CRETACEOUS	Guinimita formation		Upper Phyllites	Chancellor formation	Laventille formation	Rio Seco formation	Toco formation & Tompire formation
			Upper Limestones				
	Cariaquito formation	Yacua member	Lower Phyllites				
		Patao member	Lower Limestones				
UPPER JURASSIC	Macuro formation	Guatay member	Maracas formation				
	Uquire formation						
	Horqueta Limestone ?		Maraval formation				

fig.20. Correlation chart of formations in the Northern Range and the Paria Peninsula.

as Tithonian (Spath 1939) and described as *Perisphinctes transitorius* Oppel (now *Virgatosphinctes transitorius*). Thus the Rio Seco formation came to be regarded as Upper Jurassic in age.

Lithologically however the Rio Seco formation appears to be very like the Toco formation, the Chancellor formation and the phyllitic development of the Laventille formation. It is quite different from the massive marbles of the Maraval formation. In the headwaters of the western branch of the Rio Seco the writer has mapped outcrops of true Maraval formation not shown on Barr's (1963) map, so that a facies change is not a likely explanation of the differences between Maraval and Rio Seco limestones. Saunders (1971) considers the possibility that the Rio Seco formation could be the equivalent of the Toco formation, without being able to reach a definite conclusion. However he describes Toco formation faunas from the writer's samples both along the north and south flanks of the Northern Range and suggests a correlation between Toco formation and Laventille formation. These outcrops on the south side of the Northern Range, the writer has mapped with the Rio Seco section and the Chancellor formation. The faunas include *Trocholina infra-granulata* and *Globigerina kugleri*. One of Saunders' faunas occurs in an exposure mapped by the writer as Chancellor formation as mentioned above.

The Toco formation contains a massive limestone member, the Zagaya limestone, and this invites comparison with the Laventille limestone in the Laventille formation. The Tompire formation as described by Barr resembles the phyllitic members of the Chancellor formation, and Saunders (1971) after describing the same microfaunas from both formations, suggests that the Tompire formation should be included in the Toco formation, possibly as a member.

It is now suggested that the Rio Seco formation may be correlated with the Toco formation, Laventille formation and Chancellor formation (and with the Guinimita formation of Paria, Venezuela, see below). This suggestion has been made by Potter (1973b).

In the Toco area Barr (1963) described the Grande Riviere formation above the Rio Seco formation. Mapping by the writer leads to the conclusion that in the southwestern part of the Toco area the Grande Riviere formation is the lightly metamorphosed equivalent of the Galera formation as described by Barr (1963). This suggestion was made by Potter (1968). Unfortunately further observations to the north actually in the Grande Riviere valley indicate that this outcrop of Grande Riviere formation is really Maracas formation. It is the writer's view therefore that both Maracas formation and Galera formation had been mapped as Grande Riviere formation. The use of Grande Riviere formation should be discontinued.

Kugler (1959) extended the use of Grande Riviere formation to the western end of the Northern Range and included the Chancellor beds in it. This is now seen to be the upright limb of Maracas formation, and the Chancellor beds are separated as a formation in their own right.

Those massive limestones previously described as Aripo Limestone and Platanal Limestone are considered to lie in the Maraval formation and will be shown as such on future maps prepared by the author. The position of the bedded limestones and calcareous phyllites from which Hutchison (1938) collected Tithonian ammonites is doubtful. Lithologically those beds resemble the Chancellor formation and the Rio Seco formation as originally described. They appear to be quite different from the Maraval formation. There are excellent exposures of massive Maraval limestones only 1.5 kms north of the damsite and therefore there can be little likelihood of a facies change in the Maraval formation. On the Cuare Road and Cuare River south of Hollis damsite the writer has mapped folded Chancellor limestones and it may be that the Hollis damsite is in this formation. Indeed faulting has been mapped which might bring this about. But there is also a possibility that these beds are simply a local calcareous development in the Maracas formation. This suggests therefore that the Maracas formation may be Upper Jurassic in age and the Maraval formation somewhat older.

The Morvant beds were named provisionally in the absence of palaeontological evidence. It is thought that they belong clearly to the Galera formation.

Correlation with the published work in the Paria Peninsula of Venezuela (Gonzalez de Juana et al. 1968) presents some difficulties. Those detailed stratigraphic columns are important because they are based on work in relatively well exposed terrain in dry scrubland. Moreover the upper limestones are abundantly fossiliferous and ages have been established. However the geological maps (Gonzalez de Juana kindly provided the writer with unpublished 1:50,000 maps of the whole peninsula) show a simple south dipping flank without any major or minor folding. During two visits to the eastern part of the peninsula the writer saw minor folding and some indications of major folding - part of the Dragon Gneiss appeared to be overturned. Based partly on these visits and partly on experience in the Northern Range it is questioned whether such a simple structural picture as that shown can be true. Thicknesses may be much less than those shown. The identity of the Uquire formation may also be questionable - it may be part of the Macuro formation and actually equivalent to the upper part of that formation. Similar pelitic sequences occur in the Maracas formation of the Northern Range and are seen as graphitic phyllites and slates.

Work in the western part of the Northern Range has not led to the development of any new insights into the nature of the Dragon Gneiss of Paria. The main hypotheses are that the gneiss is a basement ridge, that it is metasomatic (Gonzalez de Juana et al. 1968) and that it is a slip-mass of Triassic basement orthogneiss (Kugler 1972). The last hypothesis is not contradicted by the evidence for turbidites in the Maracas formation.

There does not appear to be any Maraval limestone in the eastern part of the Paria Peninsula, but further west the Horqueta Limestone is exposed in Fila el Paujil near El Pilar. Gonzalez de Juana and associates map the Horqueta Limestone in the Macuro formation, but the changes in width of outcrop suggest structural axes or thrusting. It may be that the Horqueta Limestone is the equivalent of the Maraval formation.

In the Cariaquito formation the lowest member is the Guatay, described as quartzites, phyllites and quartz graphitic schists. This member seems to fit into the upper part of the Maracas formation. The Patao limestones are described as dolomitic, massive to bedded. There are two limestone sequences separated by schists altogether 450 m thick. Above the upper limestone there are beds of gypsum. Sparse fossils suggest a Neocomian-Barremian age. The highest member of the Cariaquito formation is the Yacua and this consists of calc-schists and thin limestones, altogether 630 m thick. Above the Cariaquito formation is the Guinimita formation, 270 m thick. This consists of sandstones, phyllites and fossiliferous limestones. A rich fauna indicates Barremian-Aptian age. Gonzalez de Juana considers the Patos Limestone and Patos Conglomerate to be a reef and reef talus within the Guinimita formation.

Correlation with Trinidad is difficult if the measured Venezuelan thicknesses are accepted. It may be mentioned that the Guinimita exposures are somewhat contorted. Gonzalez de Juana suggests that the Patao member is correlateable with the Maraval limestones and the Guinimita formation with the Laventille formation. On age grounds it seems unlikely that the Patao and the Maraval can be correlated, and the Patao must be the equivalent of part of the Chancellor--Laventille--Toco formations. However there are two possible correlations. Either the Patao formation could represent only the Lower Limestones of the Chancellor formation or it could represent the Lower Limestones, the Lower Phyllites and the Upper Limestones of the Chancellor formation. If the former were true the Guinimita formation would be equivalent to the Upper Limestones, whereas if the latter were true the Guinimita formation would be missing from the western part of the Northern Range, but might be equivalent to the upper part of the Toco formation. These possibilities are shown below:

Correlation No. 1.

Paria, Venezuela		Western Northern Range	
		Upper Phyllites	
Guinimita fm.		Upper Limestones	
	Yacua mbr.	Lower Phyllites	Chancellor fm.
Cariaquito fm.	Patao mbr.	Lower Limestones	
	Guatay mbr.		
Macuro fm.			Maracas fm.
Uquire fm.			
	Horqueta Lst.		Maraval fm.

Correlation No. 2

Paria, Venezuela		Western Northern Range	
Guinimita fm			
	Yacua mbr.	Upper Phyllites	
		Upper Limestones	Chancellor fm.
Cariaquito fm.	Patao mbr.	Lower Phyllites	
		Lower Limestones	
	Guatay mbr.		
Macuro fm.			Maracas fm.
Uquire fm.			
	Horqueta Lst.		Maraval fm.

It is difficult to decide which of these suggested correlations is the better. Without knowing what lies above the Guinimita formation we may accept the lithological similarities between the Upper Limestones and the Guinimita formation and note that in parts of the Guinimita outcrop there are phyllites overlying the limestones which may be equivalent to the Upper Phyllites. Therefore the first correlation seems the better one. It could also be argued that because Galera formation equivalent has not been preserved in the Paria Peninsula, although present further west, correlation No. 1 is more likely to be the correct one.

In Trinidad south of the Northern Range there are Lower Cretaceous rocks exposed in the eastern part of the Central Range. This is the Cuche formation which consists of dark shales with thin limestones and has been estimated as 2000 to 5000 feet thick (610 to 1525 m). Large, possibly exotic blocks of massive limestone have been described in this formation. The Cuche formation resembles the Toco formation both in lithology and palaeontology (Suter 1960). The base of the formation is not exposed, and it is the oldest rock exposed in Trinidad south of the Northern Range.

In eastern Venezuela there is a well developed series of Lower Cretaceous sediments in the Interior Ranges south of the Coastal Ranges. These include limestones, sandstones and shales and reach some 1200 m in thickness. There seems to be a tendency for these rocks to start with nearshore sediments including lignites and plant beds passing upwards to marine limestones and shales; however the whole succession seems to represent shelf sedimentation (Guillaume et al. 1972).

Since the observations on the correlation between the rocks of the Northern Range and those of the Paria Peninsula were written, a later work on the geology of the whole of the Paria Peninsula has been published by Gonzalez de Juan et al. (1972) and a copy reached London late in 1973. From the point of view of stratigraphy the later paper is a step back, and

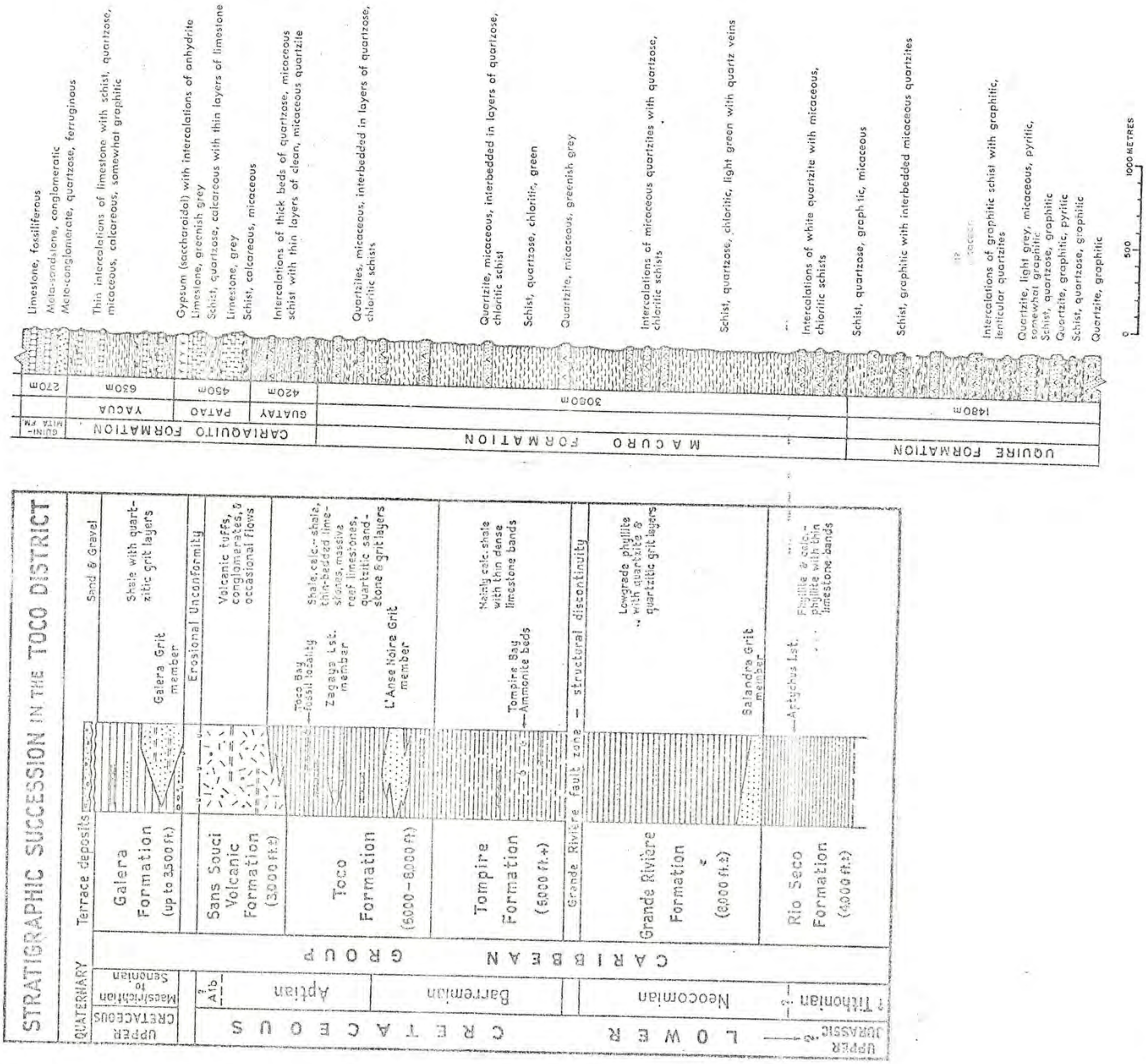


fig.21. Published stratigraphic columns for reference, Toco area (Barr 1963) on left and Eastern Paria, Venezuela (Gonzalez de Juana et al 1968) on right.

therefore the comments on the earlier paper given above seem to be worth retaining. In the later paper the authors recognise isoclinal polyphase folding, which will be discussed elsewhere, and for this reason they refrain from giving stratigraphic thicknesses or stratigraphic columns. However they maintain intact the general stratigraphic succession previously published; one would have thought that the relationship between the Uquire and Macuro formations would have been the first thing to come under scrutiny following the recognition of structural complexity. The authors do describe the relationship between the Uquire and Macuro formations as transitional without discussing the order of succession.

Gonzalez de Juana et al. include both the Horqueta Limestone and the Yaguaraparo Limestone in the Macuro formation without discussing the stratigraphic position(s) of these limestones. They also move the Guatay member from the Cariaquito formation into the top of the Macuro formation. This is welcome because the Guatay quartzites always did seem to belong there rather than in the calcareous Cariaquito formation, and agrees with the Maracas-Chancellor formation boundary as mapped by the writer.

The Cariaquito formation now consists of only two members; the lower, calcareous Patao member with gypsum and anhydrite deposited locally (Newman de Gamboa y Gonzalez de Juana 1966), and the upper, phyllitic Yacua member. The original thickness estimates are dropped, and the only figure mentioned is a thickness of some 350 m in the eastern part of the Paria Peninsula (originally 1080 m for the two members). This compares very well with the measured thickness of the Lower Limestone member and the Lower Phyllites member of the Chancellor formation in the Northern Range.

The Guinimita formation is now described as being possibly unconformable on the Yacua member below it; however the maps do not show this and the reason given for this suggestion is the change in grain size and mineralogy indicated by the presence of conglomerates in the limestones of the Guinimita. This very clearly invites correlation with the Upper Limestone member of the Chancellor formation. It is interesting that in the western part of the Paria Peninsula the Guinimita conglomerates are reported to contain igneous components and gneisses. This is the area where igneous and metasomatic rocks occur in the Macuro formation, suggesting erosion of the Macuro formation during deposition of the Guinimita formation, just as the quartzite cobbles in the Upper Limestones of the Chancellor formation may have been derived from the Maracas formation. From the descriptions of the Guinimita formation in the western part of the Paria Peninsula it does appear that these authors have included non-calcareous phyllite sections that may be the equivalent of the Upper Phyllite member in Trinidad or could even be the equivalent of the Galera formation. Altogether the amended stratigraphic information provided by Gonzalez de Juana et al. in 1972 does help to confirm correlation No. 1 shown above.

Structure

In all the many accounts of the geology of the Northern Range written during the last hundred and ten years the structure is very rarely mentioned. Only Cunningham-Craig (1907) suggested that there were structural complications. He hypothesised fan folding with the axis of an anticlinorium lying along the southern edge of the mountains. There do not appear to have been any systematic structural observations and most writers both before and after Cunningham-Craig seem to have assumed that the structure was that of a relatively simple upright south flank with the anticlinal axis lying out to sea north of the mountains. The same kind of concept seems to have been accepted in the Paria Peninsula of Venezuela, with the exception that Maxwell and Dengo (1951) descfibed overturned folding and thrusting in the Carupano area.

Bucher (1952) included Trinidad in his study and map on the structure and orogenic history of Venezuela, but the section on the Eastern Caribbean Mountains and the Northern Range of Trinidad is hampered by lack of data. However on a visit to Trinidad in 1958 Bucher observed minor folds, considered them 'flow folds' and suggested that gravity folding had taken place from south to north (pers. comm. H.G. Kugler).

In Trinidad W. Brown prepared an unpublished geological map of part of the Northern Range for Standard Oil Company of California. The results of this work were included by Kugler (1959) in the Geological Map of Trinidad, and a copy has been provided for the writer. Brown recognised some of the tectonic indications of overturning, but did not record the stratigraphic evidence, and so interpreted the structure of that part of the Notthern Range as the upper limb of an anticline overturned to the south. He envisaged the range as cut by several E-W wrenches, and

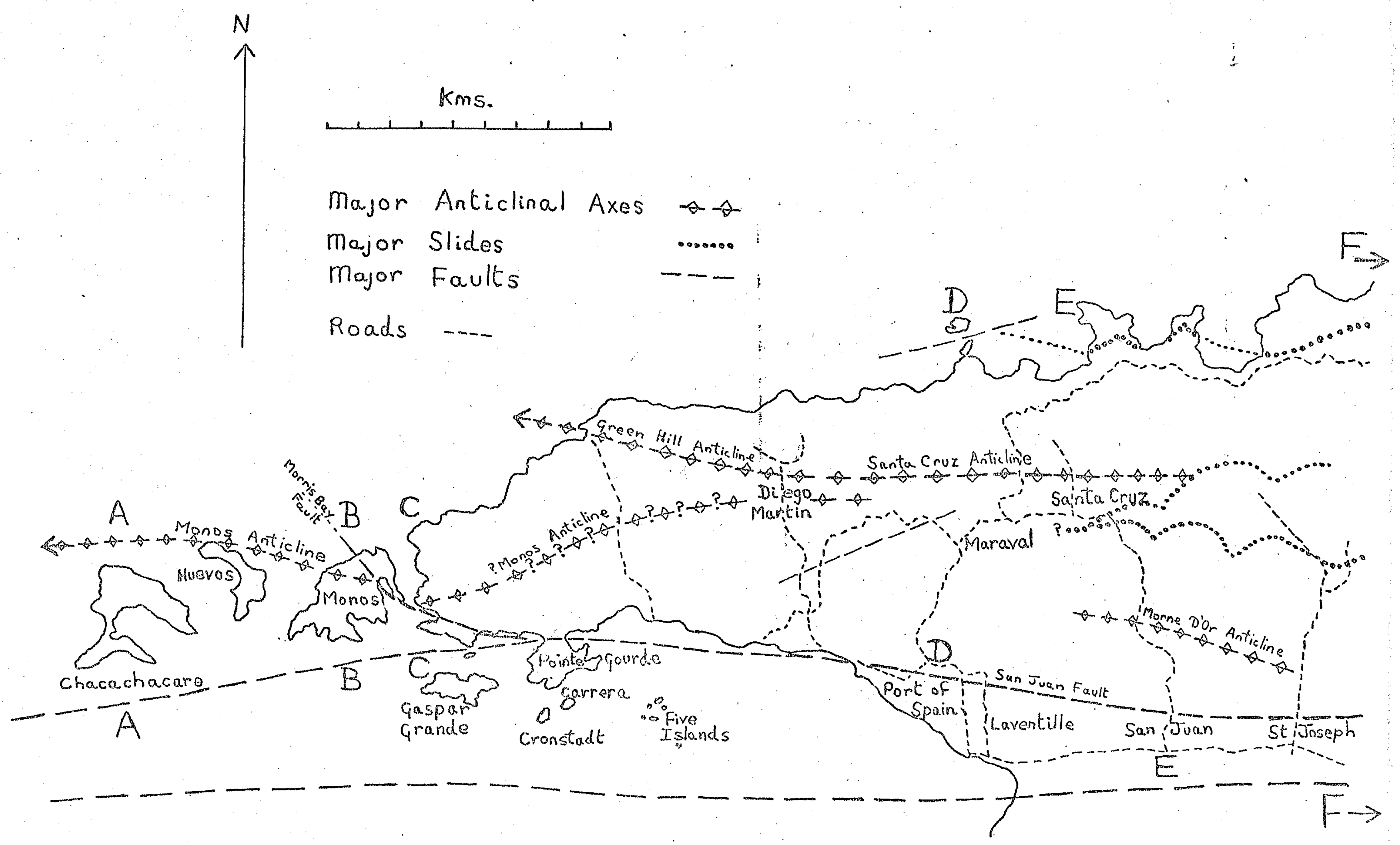


fig.22. Structural sketch map of the area.

showed different folds within each block. Such faults are not mapped by the writer. Barr (1962) showed a structural cross-section through the Northern Range east of the present area. He recognised thrusting but drew the picture of an upright flank without showing the overturning in that area which the writer has mapped on unpublished sheets.

Folds

In the present survey normal and overturned limbs were found to be recognisable. There are abundant structural data but the stratigraphic evidence on which to establish the succession is very sparse indeed. However all major folds have been based on both structural and stratigraphic evidence. The structure is seen to be that of folds overturned to the north, becoming recumbent northwards. Thrusts or slides are associated with the folds. The present major block-like outline of the Range has been determined by later E-W faults. A structural sketch map (fig. 22) shows the location of fold axes and major faults.

From west to east the same structural style can be seen with changes taking place progressively. Diagrammatic cross sections through the western islands demonstrate this (fig. 23). Section A runs north-south across the island of Chacachacare. Attitudes are flat to rolling; the general dip is to the south although more or less horizontal Maracas formation underlies the main northern part of the island while the overlying Chancellor formation makes up the southern part and presumably lies under the central bay. Dips steepen to nearly 30^{o} south along the southern coast. There are many minor folds with axial surfaces flat or gently south dipping. All minor folds face northwards and indicate that the whole island lies on the upper normal limb of a recumbent anticline overturned to the north. The hinge of this fold is presumed to lie beneath the sea floor north of Chacachacare island.

The structure of Huevos Island is similar to that of Chacachacare

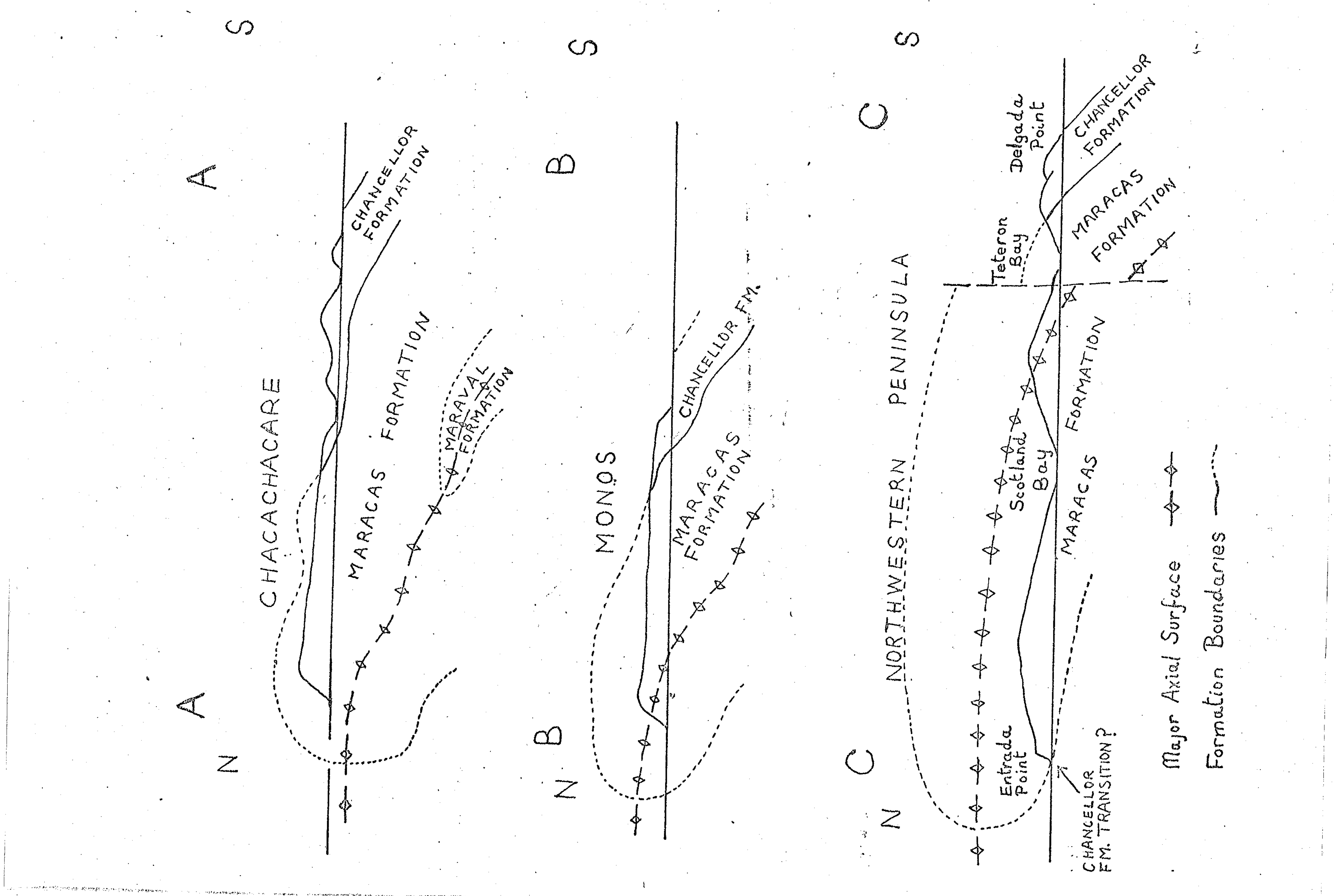


fig.23. Diagrammatic structural cross sections
A, Band C.

and a separate cross-section is not shown. South dipping Chancellor formation limestones lie in the south and more or less horizontal Maracas formation to the north. Minor folds indicate that the whole island is on the upper normal limb of the recumbent anticline overturned to the north that underlies Chacachacare Island. This fold will be called the Monos Anticline.

Monos Island itself shows an important structural difference which is illustrated on diagrammatic cross-section B (fig. 23). Dips are somewhat steeper than on Chacachacare and reach 45° along the south coast. There is at least one local fold in the Chancellor limestones of the southern bays. Towards the north there is progressive flattening in the Maracas formation as in Chacachacare. The most northwesterly exposures are overturned, at Point au Diable (427831) and the next cape to the south (425827). This indicates that the hinge of the main fold lies in the north cliff. On two visits it was not possible to land on the north cliff to locate the axial surface, and indeed it is doubtful whether one could climb up to see it.

The northeastern peninsula of Monos island is cut off by a NW-SE fault; the whole of the Maracas formation in this northeastern corner appears to be overturned. It seems therefore that the fault, which is presumed to be younger than the folding, is a dextral wrench which has brought the overturned limb of the structure southwards on the eastern block. A lateral movement of about 750 m is suggested by the displacement of the Maracas-Chancellor formational contact near Chaguaramas but there must have been at least 1 km displacement on Monos island, bringing the hinge of the main fold southward into the Chaguaramas area. This will be called the Morris Bay Fault.

Thus moving eastward from Chacachacare to Monos the axial surface of the Monos Anticline has risen. Crossing to the western end of the main northwestern peninsula it appears to rise further as shown on diagrammatic section C (fig. 23). Part of the upright south flank has been cut out by the fault discussed above. Most of the western end of the peninsula lies in the overturned northern limb of the fold. There is some control on the shape and size of the fold because at the foot of the cape (454843) east of Entrada Point the overturned quartzites and phyllites of the Maracas formation are underlain near sea level by interbedded phyllites, thin limestones and thin quartzites. This is believed to be the boundary with the Chancellor formation.

The successive sections A, B and C indicate a plunge to the west which will be discussed below. It is difficult to estimate the amount of plunge, but it seems to be in the order of 1 km in 10 kms distance. The eastern extension of the Monos Anticline is in doubt. It could simply die out or end in a thrust which has not been recognised in the Maracas formation. The trend from Teteron Bay northeast to Tucker valley shown in fig. 22 is based partly on fragmentary evidence of overturning in squares 4882 and 4984, and partly on topography. The broad valley floors through the Maraval formation have been mentioned above. It is suggested that the alluvium in the broad E-W valley east of Tucker Valley in 5284 and 5384, together with that in the broadening of the Diego Martin valley at 5684 may overlie outcrops of eroded and partly dissolved Maraval limestone. This indicates that the axial trace trending westward from Monos may join the axial trace of the E-W fold through Santa Cruz which will be described next (the Santa Cruz Anticline).

The upright southern limb is steep and along the southern edge of the Range there are near vertical dips in the Chancellor formation and Morvant beds as on the Lady Young Road. Dips decrease somewhat northward from Port of Spain to Maraval. In this south flank there are a number of local folds with wavelengths of 100 m to 500 m. Examples occur on the Lady Chancellor Road, 6281, in La Ceiba River, 6183, and St Ann's Peak area, where eastward from 6383 Chancellor formation is found preserved in an overturned syncline.

The Maraval formation in the core of the main fold shown in section D has both an upright and an overturned limb within the outcrop. There are local folds and south of Paramin, in 6185 and 6285, these occur as steplike folds with alternating horizontal and vertical flanks on east-west axes 10 m to 100 m apart.

The overturned outcrop of the Maraval formation is generally steeper than the upright part (except on the North Coast Road), but the overturned Maracas formation outcrop is markedly flatter than the upright limb and appears to become flatter still going northward. This illustrates the fact that this fold appears to become recumbent to the north. In the overturned limb local folds are not apparent, although there are many minor folds. In this sector of the Northern Range overturned Chancellor formation phyllites and limestones lie under the Maracas formation, along the north coast from Saint Cite Bay 6188 to La Vache Bay 6689.

The main Santa Cruz Anticline appears to develop two separate axial traces to the west. The northern fold appears to trend WNW across Diego Martin valley and to reach the sea at Macqueripe Bay (5087). The line of the southern axial trace through Tucker Valley has already been mentioned as the possible extension of the Monos Anticline. The northern fold will be called the Green Hill Anticline.

The Green Hill Anticline seems to plunge to the west, and some 2 kms west of Diego Martin valley the Maraval limestones disappear beneath the Maracas formation. This indicates that the plunge from Paramin village westwards is about 500 m in 7 kms. Although it has been suggested that Maraval limestones may lie under the alluvium in the Tucker Valley, this could only be a small outcrop and does not invalidate the idea of a western plunge on the Monos Anticline. The tentative estimate of 1 km western plunge in 10 kms distance has already been given for this fold through the western islands. Of course these two very tentative estimates of plunge are not properly comparable, one being stratigraphically derived.

The subject of plunge has been dealt with at some length. Kugler (1953) supposed that the Northern Range plunged to the east because the Dragon Gneiss lay to the west in the Paria Peninsula, while the fossiliferous part of the Caribbean group lay to the east in the Toco area. This cannot be accepted now. The stratigraphic positions of both the Dragon Gneiss and the Toco area section has been discussed above. There appears to be a western plunge from the Maraval area to the Dragon's Mouth and possibly to the Paria Peninsula where Maraval formation does not outcrop at the eastern end. There may be other culminations in the Northern Range as well as that at Maraval. The Apipo area some 30 kms west of Port of Spain may well be such a culmination. The west plunge of the structures invites comparison with the western tilting in the Quaternary surfaces mentioned above. Possibly the Dragon's Mouth dates from the late Mesozoic as a low feature.

The presence of Chancellor formation along the north coast together with the symmetrical distribution of both normal and overturned limbs of the other formations illustrates the fact that from Chacachacare island to the Santa Cruz area the structures consist of true folds albeit overturned and recumbent. These folds have both upper and lower limbs unlike some nappes and major recumbent structures described from other mountain areas. From Santa Cruz eastwards there appears to be some change in structural style, and thrusts or slides become more important.

Diagrammatic section E (fig. 24) has been drawn northward from San Juan, though the eastern part of the Santa Cruz area, to the eastern shore of La Vache Bay. Licence has been taken to include data which are not exactly on the line of the section.

The most obvious new feature in section E is the Morne D'or Anticline, a second fold lying south of the Santa Cruz Anticline. It has a core of

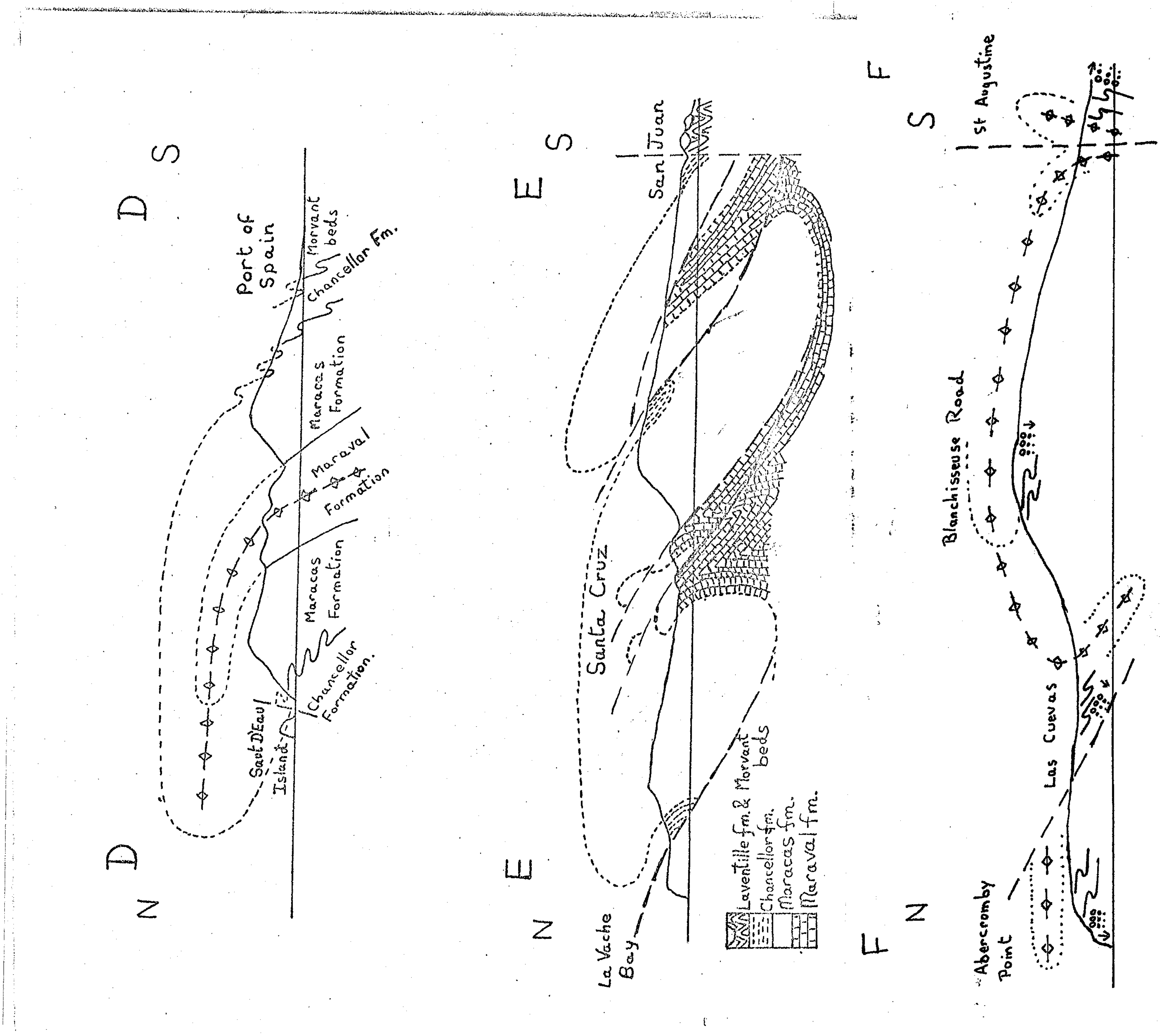


fig.24. Diagrammatic structural cross sections D,E and F.

Maraval limestone over a distance of some six kilometres. At the western end, and apparently also at the eastern end, it appears to be a true fold with an upright limb, but in the middle of the outcrop the upright limb has been covered by Maracas formation and only the overturned limb of Maraval limestone is exposed. A slide is hypothesised, but direct field evidence is lacking. A syncline of Chancellor formation, overturned and thrust, has been interpolated into the section between this southern anticline and the main structure.

The simple Santa Cruz Anticline changes to the east and splits into two folds just as it seems to do to the west. However the eastern folds seem to be associated with slides which have overthrust part of the Maraval formation outcrop. Further east the northern fold cannot be followed, but the southern fold can be seen as the overturned outcrop of Maraval limestone continuing eastwards outside the mapped area. It is usual in the central and eastern parts of the Northern Range to see only the overturned outcrop of the Maraval formation.

The lowermost beds of the Maracas formation in most places are graphitic mica phyllites and must be relatively incompetent when compared with the massive limestones below them and the bedded quartzites above them. It is suggested therefore that the upper limb of Maraval limestone does exist underground and that the slide occurs in either the phyllites at the base of the Maracas formation, or in the calcareous phyllites at the top of the Maraval formation, where collapse structures have been noted.

We can see the effect of these slides at the formation boundary, but there may be unrecognised slides and other structures in the outcrop of the Maracas formation which cannot be located because of poor lithological control. This is one reason why the relatively simple structure of the Maraval area is important It can be checked because of the high number of exposures and this has allowed the construction of stratigraphic columns, and type sections.

At the northern end of cross-section E a thrust or slide occurs. Over much of its length it lies in Maracas formation and is difficult to follow. On aerial photographs there is a marked change in strike across this thrust and in La Vache Bay, as shown in the section, the Chancellor formation is caught up in this feature. To the east it is difficult to locate this slide accurately. A similar slide occurs at Las Cuevas (fig. 24, F) but this may be the eastern continuation of a line of dislocation which roughly follows the line of the new road east of Maracas Bay and has been mapped as a slide. It is interesting that there have been several large landslips along this section of the road (Plate 42). On the whole this southern slide seems to pass westwards under the alluvium flooring the valley of the Maracas Bay River and then westwards to a point on the North Coast Road at 668893 where truncation of several units occurs. Unfortunately the evidence was not strong enough to map that part of the slide. However the two slides may join under Maracas Bay. In passing one notes that one of these slides lies along the boundary of the Chancellor formation phyllites and limestones, while the other follows a zone of slates and graphitic phyllites in the Maracas formation. There appears to be lithological control in the location of these surfaces of failure.

It may be significant that as opposed to the situation where a simple anticline without much sliding occurs as in the Maraval area, it is where a second anticline develops, as in the eastern part of sheet 13, that we also find extensive sliding or thrusting not only in the core of the main structure but also in both north and south flanks. Perhaps one may think that the additional structure in Maraval limestones has produced increased stresses leading to failure on several surfaces rather than simple folding. On the other hand increased stress may have produced a second fold and more sliding.

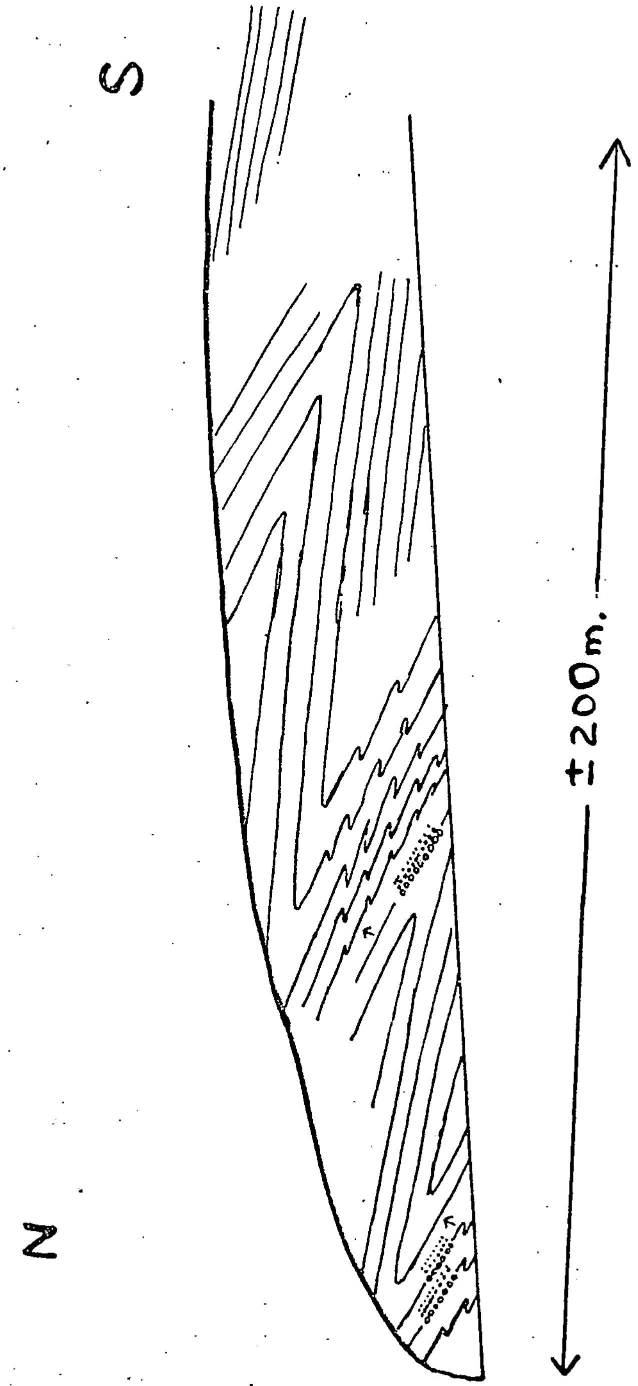


fig.25. Sketch of Maracas formation exposures at Las Cuevas.

Although Sheet 3 ends at the western end of Las Cuevas Bay it was thought that it might be interesting to show diagrammatic cross-section F in fig. 24 (Potter 1972) which runs N-S a few kilometres east of the edge of the map. At the south end near St. Augustine the Chancellor formation is overturned to the south then turns over northward. The St. Augustine structure may be a separate fold overturned to the south forming a fanlike feature, but this question will not be dealt with now. On the high peaks of the range horizontal beds of Maracas formation are found inverted and showing overturning to the north. Maraval limestone is even found isolated on one peak. Whether this represents a klippe, the axis of the fold, or an exotic block is not clear.

Further north again at Las Cuevas in a series of large good exposures of Maracas quartzites and phyllite sketched in fig. 25 we find that a combination of several graded beds and many minor folds indicates a downbent fold as shown on cross-section F. One of the thrusts mentioned above is seen north of this, and then at Abercromby Point lies in the inverted limb of the main recumbent fold. It is interesting to recall that Dauxion Lavaysse (1813) thought that the rocks at Las Cuevas might provide the key to understanding the geology of the Northern Range.

The structure of the Northern Range at depth is not entirely certain. Presumably the upright south flank root zone can be safely extrapolated to a depth of some kilometres, but the nature of the beds beneath the overturned north flank is not clear. The youngest overturned beds are in the Lower Limestones of the Chancellor formation. There is no evidence that the whole of the Chancellor formation is present overturned under the north coast. Certainly farther east the Galera formation and Chancellor formation outcrop in a different structural style - upright asymmetric folds. It is possible that the major part of the Maracas formation in the overturned limb has slid northwards on the incompetent beds of the Chancellor formation. At depth under the north coast there may be upright Maracas and Chancellor formations separated by a slide from the overturned limb. It is always possible that Galera formation could underlie the overturned recumbent limb, but for other reasons discussed below it is suggested that the main folding may have preceded the deposition of the Galera formation, so that only the Chancellor formation and older beds can be expected with certainty.

The structure in the outcrop of the Laventille formation appears to be quite different from that in the main range. Fold axes trend ENE-WSW - the prevalent trend in the Cretaceous sediments of the Servania del Interior of Venezuela, and in the Central Range of Trinidad. The folds seem generally upright with steep to vertical limbs. The synclines of Morvant beds appear less folded than the surrounding Laventille formation, presumably because of the unconformity separating the two. There may be more faulting than has been recognised by mapping; the exposure of gypsum near St. Joseph (727779) and the reported older exposures appear to lie in an east-west line that could be another fault in the El Pilar Fault system.

Although it is possible to relate this fold pattern to movement between individual faults of the El Pilar fault system, and to suggest that dextral wrench movements have led to the formation of ENE-WSW fold axes, this is probably only one aspect of movement within these fault blocks. There are more complicated folds such as minor recumbent folds, overturned to the south, in the Morvant area, which may be related to vertical movements on the San Juan fault. It has not been possible to work out the details of these folds in the absence of sufficient clear unweathered exposures.

History of Folding

There are only a few refolded folds exposed. This may be due to poor exposures, but that does not seem likely. In the south flank of

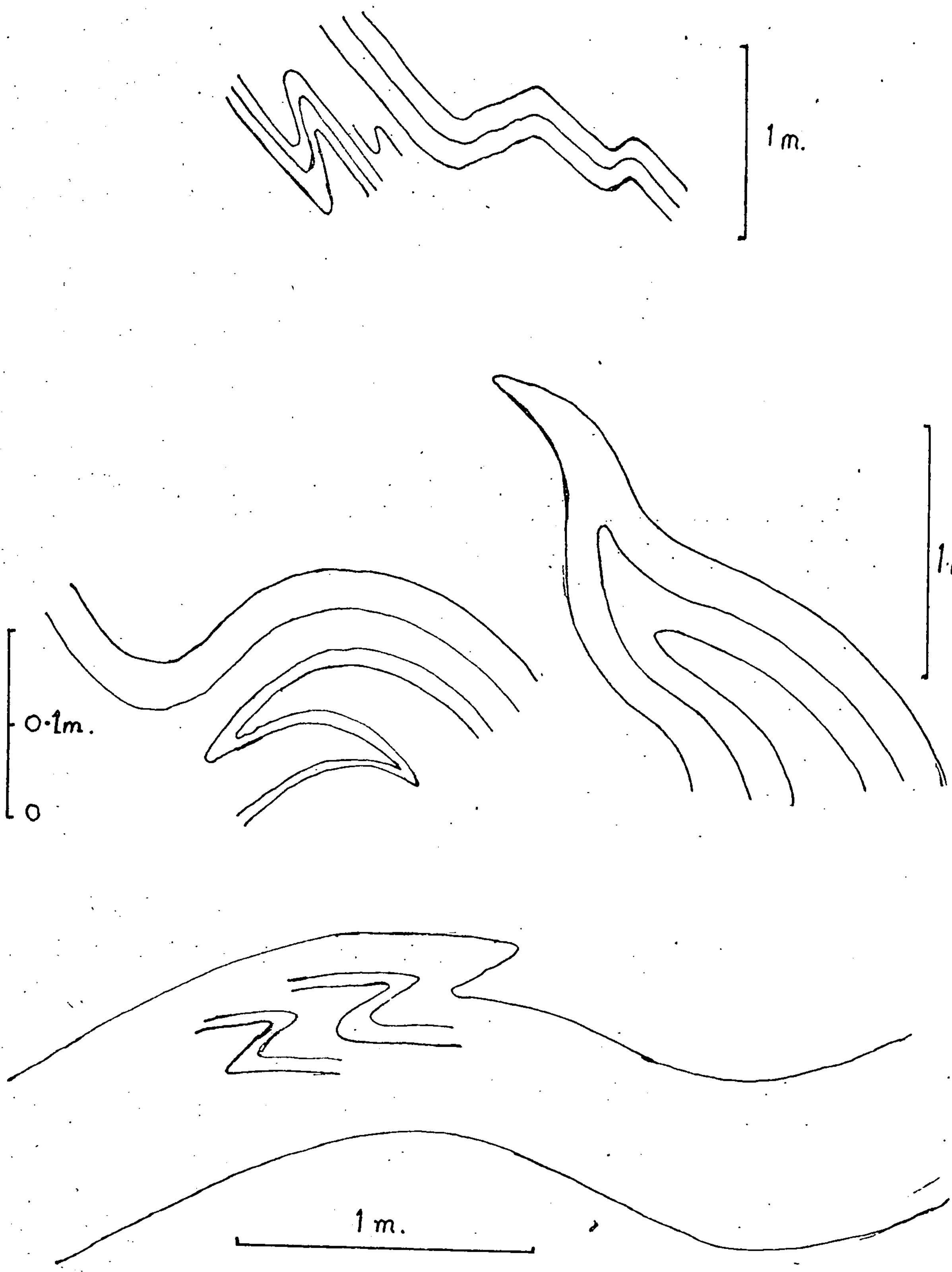


fig.26. Examples of refolded folds in the Chancellor formation on the Lady Young Road.

the Range there is evidence in a number of exposures, especially along the Lady Young Road, that as the main folding developed, minor folds were refolded on essentially the same east-west axes as shown in Fig. 26. The early axial surfaces are folded, the later ones are vertical, unfold

There is some indication of later folding almost at right angles to the predominant minor folds. This is seen as a gentle warping along the south flank of the Range, edpecially well exposed along the Lady Young Road in Chancellor formation. This warping seems to be later than the main folding.

On Saut d'Eau Island there is one example of an overturned fold which has been refolded by a fold at right angles, but this was the only exposure showing this.

Cleavage

Over most of the area cleavage is not an obvious feature, even in good unweathered exposures. In the southern upright limbs of the folds the cleavage often appears to be parallel to bedding surfaces. However in a few exposures we can see the two surfaces cutting one another. In a few exposures of slates and in some sequences of interbedded phyllites and quartzites there are indications of folding before the development of cleavage. In all cases the cleavage seems to be parallel to the axial surfaces of the minor folds. This suggests that the cleavage developed at the same time as the folding of the first minor folds.

In one exposure at 471806 west of Chaguaramas crenulations are well developed in the steeply dipping Upper Phyllites of the Chancellor formation (Plate 27). This is the only crenulated exposure on the south flank of the mountains.

In the overturned northern flank cleavage is developed rather more clearly. The thick quartzites often have cleavage and when thin phyllites horizons are present, the cleavage is seen to be flatter than the bedding.

Crenulations occur both in the overturned Chancellor formation and in the overturned Maracas formation, but clear crenulation cleavage has not been observed in this area although it is present further east.

Jointing

Jointing is common, especially in the thicker quartzites. In the Maracas formation it is suggested that major joints have determined the courses of many minor streams and a number of cliff faces such as the major N-S cliff over which the Maracas Waterfall tumbles (743864). By far the major number of joints are approximately N-S and nearly vertical, and can be considered as ac-joints. Quartz filling of these joints is common.

Faulting

The part played by slides has already been mentioned. They appear to be south dipping and frequently cut out the southern upright limb of Maraval limestone in the main folds. There does not seem to be any brecciation connected with these slides but contortion of bedding is common. The poor exposure of these features suggests that there may be other slides unrecognised during mapping. These features appear to be contemporaneous with the last phase of the main folding.

There are a few relatively small dextral wrenches trending NW-SE. These are the same trend as the Grande Riviere Fault (Barr 1963) and the Los Bajos Fault (Wilson 1958). There is some tendency for these faults to turn E-W at their south ends. The Morris Bay Fault running from Monos Island to the Chaguaramas area, with about 750 m to 1 km lateral displacement, is one of these and has already been mentioned.

Although it may not be obvious from the geological map the shape of the Northern Range seems to be controlled by the El Pilar Fault system. One important branch of this fault system separates the Laventille limestone from Chancellor formation north of Point Gourde and Gasparillo, then passing under Port of Spain trends eastward separating the Laventille formation from the more metamorphosed rocks to the north, here named the San Juan Fault. South of this, under the Gulf of Paria and the alluvium of the Caroni River valley, there are at least two other parallel faults which were located by unpublished reflection seismic work and by structure drilling. All three faults appear to be downthrown to the south. The second fault is shown on the sketch map (fig. 22), but the southernmost fault of the three lies off the area shown in fig. 22. Drilling across this third fault showed a minimum throw of 1750 m down to the south (fig. 27). These data will be discussed below.

The linear outline of the north coast looks as if it must be fault controlled, but evidence for east-west faults is difficult to see. A normal fault with approximately 200 m throw down to the north lies between the north coast and Saut d'Eau Island, and other similar faults have been observed to the east outside the mapped area. But large scale faults have not been observed onshore. Bassinger et al. (1971) record E-W faulting along the northern edge of the mountains with younger sediments downthrown on the north against the metamorphic rocks of the Northern Range. Ball et al. (1971 a and b) describe similar faulting on a large scale north of Venezuela.

The El Pilar fault system was named by Liddle (1946) and originally mapped in northeastern Venezuela, where it separates the Aroya and Paria peninsulas from the Serrania del Interior. It is interesting that the idea of faulting here was first suggested by Alexander von Humboldt who visited the area in 1799. The fault crosses the Gulf of Paria and is the most important factor in forming the southern boundary of the Northern Range of Trinidad. Finally after reaching the east coast of Trinidad it appears to continue out to sea (Bassinger et al., 1971). Liddle (1946) and other writers e.g. Barr (1955) used the name also for the western extension of this fault under the Caribbean Sea and then into north central Venezuela, but now the name El Pilar is chiefly used to describe the fault system eastwards from Cumana, Venezuela. This fault system appears to be important in defining the boundary between the Caribbean plate and South America. Hess (1938) suggested that the Caribbean had moved eastwards with respect to South America and that the El Pilar Fault system was therefore a large scale wrench. Rod (1956) analysed the faults of northern Venezuela and concurred. Alberding (1957) went further than the suggestions of 100-150 kms lateral movement already made, and suggested 475 kms. However these sizes of displacement are difficult to see and Metz (1968) after mapping the El Pilar area in some detail was led to conclude that lateral displacement on the fault zone was probably 10-15 kms and might be as little as 5 kms. Potter (1968b) was able to describe a vertical throw near Port of Spain, but was unable to show large lateral displacement, and suggested evidence for no post-Pliocene lateral movement.

The well data obtained by drilling two deep holes across one part of the El Pilar Fault system are unpublished, but the results were included in the cross-sections accompanying the Geological Map of Trinidad, Kugler (1959) and illustrated in fig. 27. Briefly, one well (Domoil Laventille No. 1) drilled through 2200 feet (670 m) of gravels and then bedded sands, presumably Plio-Pleistocene, then encountered 300 ft (91 m) limestones and then phyllites and shales which appear to be Laventille formation or Cuche formation to a total depth of 7523 feet (2287 m). The second well (Domoil Puerto Grande No. 1) 4 km to the SE i.e. 2 kms across the regional strike, encountered gravels, bedded sands and clays and then massive conglomerates to a total depth of 7922 ft. (2417 m). The lowest beds in this hole did not appear to be older than Upper Miocene, therefore depth to Lower Cretaceous is unknown, and the throw on the fault between the holes is at least 1750 m. Structures in cores

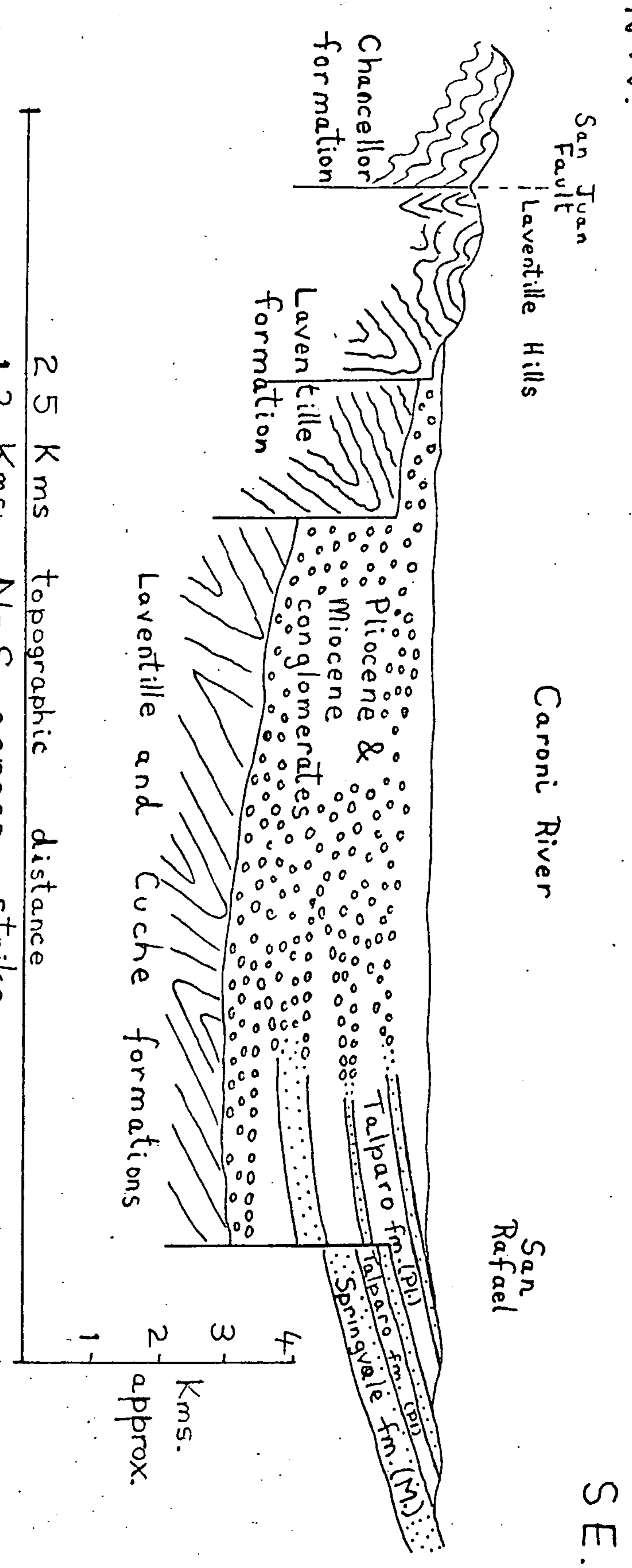


fig.27. Diagrammatic cross section of El Pilar faults near Laventille.

from the northernmost hole suggested folding overturned to the south.

The necessity of using data outside the mapped area and of referring to unpublished data is regretted, but the regional nature of the faulting requires it. South of the faults mentioned above there is a major fault system downthrown to the north (fig. 27). This forms a linear graben along the south side of the Notthern Range, the existence of which has been concealed by the alluvium in the Caroni valley. In this graben conglomerates have accumulated to a thickness of some 2400 m from Upper Miocene, to Quaternary time. These conglomerates invite comparison with a similar feature along the San Andreas Fault, the Violin Conglomerates, and could be taken as some evidence for lateral movement, but they might equally well be deposited in a subsiding fault trough. It seems unlikely that enough palaeontological or lithological information will become available to study these conglomerates in three dimensions, to answer this question. The conglomerates thin very rapidly south of the graben towards the Central Range.

It is interesting that the concealed graben south of the Northern Range should be so like the depression separating the Coastal Ranges of Venezuela (Araya and Paria Peninsulas) from the Interior Ranges, the Cariaco Trough, and also the submarine graben in Unare Bay west of Araya Peninsula mapped by Ball et al. (1971a and b).

One line of thought gives some evidence about lateral movement, on the El Pilar Fault. There are a number of buried conglomerate fans at shallow depth beneath the alluvium of the Caroni plain, along the south side of the Northern Range. There is no clear evidence of age; but they must be earlier than Quaternary. It is believed that they may be equivalent to sands in the upper part of the Talparo formation, present in the San Raphael area some 25 kms SE of Port of Spain, i.e. probably Upper Pliocene (fig. 27).

These piedmont fans are located (a) at the mouth of the Diego Martin

River, (b) under Port of Spain in line with the Maraval River, (c) opposite the mouth of the San Juan River and (d) south of St. Joseph where the river makes a bend. In every case these presumed Upper Pliocene fans lie opposite the rivers that must have brought the sediment. It seems therefore that there can have been no lateral movement since Upper Pliocene time.

More evidence dating the last movement of the faulting can be found in the San Raphael area, where sands in the Talparo formation are faulted by the fault forming the southern boundary of the graben mentioned above. As shown in fig. 27 the lower sands in the Talparo formation are faulted, but the upper sands are not. This appears to date the last fault movements as Upper Pliocene. The measured movement on this fault is of course vertical, but isopach studies suggested that there may have been sinistral horizontal displacement.

It had been expected that small scale field features like minor folds might show the extent of horizontal displacement. Unfortunately in the western part of the Northern Range small scale structures along the line of the San Juan Fault do not show any indications of horizontal movement at all. It is interesting that in the Northern Range as a whole the best indications of lateral movement are in the extreme south eastern part, at Matura Point, along the south side of the point for 500 m. In beds overturned to the north there are many reclined folds all suggesting that the northern beds have moved eastwards. This could be indicative of an E-W wrench south of Matura Point, underwater.

Summing up, there is no clear evidence of lateral displacement on the El Pilar Fault in Trinidad, but there is evidence of vertical movement both on the northern and southern edges of the Range, which has left the Northern Range standing out as a linear block. The faulting appears to have been completed by Upper Pliocene.

Southern Slides

In his study of the El Pilar area Metz (1968) describes the outcrop of a thrust zone along the line of the El Pilar Fault. The thrust carried metamorphic rocks southward, and some of these now lie as klippen on the Cretaceous rocks of the Serrania del Interior. Thrusting predated movement of the El Pilar Fault. No such feature can be recognised in Trinidad on that scale. The slides already described appear to have an opposite sense of movement. There are however features which do appear to have slipped southward and which it is difficult to distinguish from the superficial collapse features of the Maraval area which will be described separately below.

Near Carenage in a side road at 544813 (plates 44 and 45), in badly weathered phyllites and quartzites of the Maracas formation, there is slide plane dipping 17^{o} south. There is fault gouge 20 to 50 mm thick and below the plane the beds are broken and incoherent. Above the plane the beds are reasonably regular but folded sharply. This is an isolated feature and could be (a) a superficial collapse structure, (b) an indication of evaporites in the Maracas formation which have since dissolved, (c) an example of south dipping slides along the southern edge of the Northern Range.

There is one other example of southward sliding, on the Riverside Road east of St. Joseph at 735787. In weathered Maracas quartzites and phyllites a flat dislocation plane suggests sliding to the south or southwest. It may be significant that both these exposures lie on the upthrown side and close to the San Juan Fault of the El Pilar Fault system. It may be that these features, unusual minor folds described in the Morvant area, the thrust zone described by Metz (1968), and the slumping described by Ball et al. (1971b) in the sediments of Unare Bay are all features formed by slumping of incompetent beds along these faults of the El Pilar system which have such large vertical throw.

Metz also suggested that based on his observations in Venezuela, the southern edge of the Northern Range of Trinidad might not be controlled by the El Pilar Fault system, but by southward thrusting. He further suggested that the El Pilar Fault system might not extend to Trinidad. This contention does not seem to be true - the El Pilar Fault system does appear to form the southern boundary of the Northern Range of Trinidad, although the different component faults have been obscured by later piedmont deposits, terraces and alluvium.

Although southward thrusting is not really obvious along the southern edge of the Northern Range, there is a major change from northward overturning and thrusting in the Northern Range itself and the universal southward overturning and thrusting everywhere to the south. The axis between the two directions must lie very close to the southern edge of the Northern Range, because in the subsurface south of Laventille as mentioned above there was evidence for this, and in the Northern Range itself east of St. Joseph there is overturning to the south as shown in diagrammatic section F, just off the eastern boundary of the mapped area.

Superficial Collapse Structures

In the Maraval and Santa Cruz areas in the upper part of the upright limb of Maraval limestones there are a number of minor structures which appear to have been caused by the sliding of the upper beds southwards. They do not look like hill creep. Typically movement occurs on a gently south dipping plane. These exposures are of bedded limestones with some interbedded phyllites, and they are all weathered. The beds involved in these structures have become broken and incoherent, suggesting that these structures occurred late in the geological history of the area. This is particularly noticeable because in nearby exposures are upright minor structures formed by coherent beds.

In the Saddle area at 644847 there are open upright folds which seem to have been contemporaneous with the collapse structures. It is suggested that these upright folds were caused by the upper Maraval beds slipping southwards against the resistant mass of the Maracas formation.

The reason for these collapse features being so localised is not clear. This could be an area where weathering is particularly strong, but it is also suggested that there may have been evaporites in the upper part of the Maraval formation, which have been dissolved leading to collapse.

Metamorphism and Petrology

Although the rocks of the Northern Range of Trinidad have always been described as metamorphic, it is clear that the original sediments have been less altered here than in the more westerly parts of the Caribbean coastal ranges. It is only in limited areas that the rocks seem to reach a grade of metamorphism that could be described as greenschist facies. Yet all the older pelitic rocks have been sericitised and appear as slates or phyllites, practically all the limestones have been recrystallised, and all the quartzites show metamorphic textures. In addition graphite has developed in the carbonaceous phyllites, and even the pollen and spores have been carbonised as was shown in a palynological study that Shell Oil Company kindly carried out on 80 of the writer's samples from the Arima area immediately to the east of this one.

In view of the low grade of metamorphism it is suggested that texture may be more important than mineral composition when considering the Caribbean group in the Northern Range.

There does seem to be a systematic variation in the metamorphic grade of the Caribbean group in this area however. The older rocks seem to have been more metamorphosed than the younger rocks, and the Morvant beds in particular seem to have been less affected than all the older rocks. This suggests that the process of metamorphism began after deposition of the Chancellor formation (? Lower Cretaceous) and before the deposition of the Morvant beds (? Upper Cretaceous). There is also increasing metamorphism from south to north; but whether this is a regional change or whether it represents the difference between the upright and the overturned limbs of the structure is a matter for further consideration.

True greenschists occur along the North Coast Road in the overturned Maracas formation and are particularly well exposed at the $3\frac{1}{2}$ milepost (660885). Scattered localities in the northern part of the area appear to contain minor amounts of chlorite in the finer quartzites but there is no overall impression of a green colour, and the two exposures of epidote greenschists believed to be tuffs, (a) on the North Coast Road at 647868 and (b) at 553874 are markedly different from other exposures. Chlorite is present in several samples of Maraval limestone and also in a quartzite in the Chancellor formation from the southern part of the area, as well as occurring as a rare mineral more widely.

The petrology of the limestones and marbles from the different formations shows differences which must be due partly to differences in original composition, but which may be partly due to differences in metamorphism. The Maraval marbles are almost entirely recrystallised and show granoblastic-polygonal to granoblastic-elongate texture. Grain sizes are commonly 20μ x 100μ, but coarse samples have grains up to 700μ in diameter. Sericite is common in very undulating horizons which may represent the original bedding planes. As mentioned above in the stratigraphic descriptions, two thin sections of Maraval marble out of the 26 examined were incompletely recrystallised and showed signs of fossil relicts including possible cell structure. Dr Elliott has confirmed the presence of algae in the Chancellor formation, but did not find any that could be used to date the formation. Sparite and quartz are present in most of the Maraval samples, the former as veins and the latter both with sparite in veins and also as grains and irregular patches. Pyrites is a common accessory mineral.

The Chancellor limestones are also generally granoblastic-elongate marbles but they are less pure than the Maraval marbles and contain bands of quartzite, muscovite and occasionally biotite. Albite and pyrites are common accessory minerals; carbonaceous bands, possibly graphite, occur in some samples. Some quartzite beds show mortar structure; quartz porphyroblasts up to more than 1 mm diameter occur. The micaceous layers seem to have controlled recrystallisation of the calcite, which does not usually become as regular as in the Maraval formation. Although the overturned Chancellor formation samples from the North Coast do show appreciably more contortion than those from the southern part of the Range there is no appreciable mineralogical difference except for the occurrence of scarce chlorite in one sample from Saut d'Eau Island. 36 thin sections of Chancellor limestones were examined.

These descriptions suggest the basis for the writer's contention that in perhaps nine out of ten cases it is possible to distinguish between Maraval limestones and Chancellor limestones in thin section. The differences are due to differences in original lithology and not to differences in metamorphism.

When the few limestones in the Maracas formation are examined, difficulties arise in distinguishing them from limestones in the other formations. Four samples from two thin limestone beds in the basal part of the Maracas formation south of Blue Basin River (580866 to 592864) appear very like the Maraval limestones, and despite being in beds only 1.5 m and 4 m thick are rather pure granoblastic-elongate marbles, with scattered quartz and rare chlorite. In the case of two thin limestones near the top of the Maracas formation on Lady Chancellor Road (627818 and 628816) there is very little similarity to the nearby Lower Chancellor limestones. One sample is a granoblastic-polygonal marble with porphyroclasts of sparite and quartz, that resemble recrystallised and replaced fossils. The other sample appears to be made up of 50% quartzite and 50% ferroan calcite and dolomite. This is rather unusual because dolomite is very rare in these limestones and marbles. In connection with this last statement it should be added that stained peels were made of various samples of limestone from the Arima area immediately east of that now described and dolomites were not found in these samples. Furrer (1968) recorded dolomite in one of the writer's samples from further north near the village of Brasso Seco some 20 kms to the east. The

Laventille limestones are quite different from the Maraval, Maracas and Chancellor limestones. 26 thin sections of Laventille limestone were examined. Although some samples appear as largely recrystallised granoblastic-elongate marble, other samples seem to be still micrites. Yet others are in the process of recrystallisation. These last samples consist of a ground-mass of coarse recrystallised material perhaps 20-50μ in diameter, containing whisplike aligned relicts of micrite showing rotated and contorted tips. Fossil fragments are common; shell fragments (possibly rudists), cellular material which may be algal, recrystallised foraminiferal tests, and echinoid spines usually recrystallised, are all seen. Samples of oolitic limestone occur in which the ooliths have been distorted to ovals. One rudist-bearing limestone had the shells not only aligned but clearly elongated.

One of the most striking differences between the Laventille limestone and the other limestones is the fact that while the Maraval, Maracas and Chancellor limestones all appear to contain quartz in appreciable amounts (5-50%) as veins, bands, clusters and individual grains, the Laventille limestone contains no quartz in other than trace amounts. It seems therefore that although differences between the limestones of the Northern Range must be ascribed largely to differences in original composition, the position of the Laventille limestone is different; it has not been metamorphosed in the same way as the other rocks, and it has not been injected by mobile quartz as the other rocks were, during metamorphism.

Insufficient thin sections of slates and phyllites have been examined to form any conclusions, but those few did not appear to be rewarding. Both collection and cutting were hampered by weathering and by poor exposures.

The quartzites from the different formations present a somewhat confusing picture On the whole, Maracas quartzites appear to be finer grained than Chancellor quartzites; and Morvant quartzites appear to be coarser than either Maracas or Chancellor quartzites. In the field one of the criteria evolved for picking the boundary between the Chancellor formation and the Morvant beds is the coarseness of the quartzites - and it seems to work very well.

However, all three appear roughly similar in that mortar structure is common. Bands of sericite with occasional biotite, and chlorite as mentioned above, occur in the Maracas and Chancellor quartzites, and do provide a point of difference from the Morvant beds. As regards the difference between the Maracas and Chancellor, the latter is somewhat coarser, and quartz augen up to 1 mm in length occur. But whether this difference is due to original grain size, or whether the quartz in the Maracas formation has been more reduced in size by dynamic metamorphic processes is not clear.

It is concluded that in this part of the Northern Range we are seeing the results of dynamic metamorphism which took place without deep burial and without the development of the temperatures which would be expected during regional metamorphism. Metamorphism seems to be confined to the 'block' of the Northern Range, limited to the area north of the El Pilar Fault. It is difficult to understand this, because the fault is, of course, younger than the metamorphism. It may be coincidence that the fault lies along the southern limit of metamorphism, but this line coincides with the root zone of the original folding along which uplift occurred, and so it may have been the limit of metamorphism and also the locus of future faulting because it lay at the junction between folded rigid rocks to the north, and sediments to the south. In Venezuela the boundary between the metamorphic rocks of the Coastal Ranges and the Cretaceous sediments of the Interior Ranges (Sucre group and Guayuta group) also seems to lie along the El Pilar Fault, although Metz (1968) thought that the real boundary may be a thrust. It is suggested that the thrust may have caused some local metamorphism leading Metz to that conclusion.

Metamorphism seems to have affected the Maraval, Maracas and Chancellor formations equally, and to be most advanced in the areas where tectonic activity was most pronounced. These areas lie in the overturned northern limb of the main structure and also in some of the local folds of the southern limb, and near the major slides.

As mentioned above, the Morvant beds are less metamorphosed than the older beds. This leads to the conclusion that metamorphism mainly occurred during the folding of the older rocks of the Caribbean Group, which must have been post-Aptian and pre-Maestrichtian. The Morvant beds were then laid down on the metamorphosed and folded older rocks, and further folding took place. It seems reasonable to exclude the Laventille formation and the Morvant beds from the metamorphic rocks of the Caribbean Group, the former by reason of location, the latter because of stratigraphic position. Unfortunately historical usage prevents their removal from the Caribbean Group.

In the Toco area (Barr 1963) at the extreme eastern end of the Northern Range, we find Toco formation (Lower Cretaceous) folded with Galera formation (Campanian-Maestrichtian), all unmetamorphosed. At first sight this appears to cast doubt on the proposed Cretaceous age for metamorphism. But these fossiliferous sediments all lie east of the Grande Riviere fault where lateral movement has caused the juxtaposition of fossiliferous sediments to the east and metamorphic rocks to the west. In the eastern part of the Northern Range, west of the Grande Riviere fault, Potter (1968) has mapped upright folds of Galera formation. Toco/Chancellor formation occurs in the cores of some of these folds. However the presumed Lower Cretaceous rocks are always contorted and moreover Galera formation is never found in the overturned limb (or the main upright limb) of the main fold. Therefore it is suggested that these major recumbent folds with their accompanying metamorphism predated the deposition of the Galera formation.

In the Paria-Araya area of northeastern Venezuela various igneous and metasomatic rocks occur. The Dragon Gneiss mentioned above has now been mapped as a paragneiss and the transitional boundaries described (Gonzalez de Juana et al. 1972). There are other smaller outcrops of similar gneisses in the Macuro formation west of the Dragon gneiss. In addition there is the El Mango-Dona Juana Igneous Complex composed of granites, gneisses, hornfelses and migmatites. Near the northern coast is a line of small outcrops of serpentinites, which the writer has observed to be intruded by at least two generations of basic dykes. There are also greenschists in the Macuro formation which may be metavolcanic like those in the Northern Range.

So far no igneous intrusions or gneisses have been found in the Northern Range. Although new small exposures may contradict this statement, they could only be very small exposures indeed. It is felt that the lack of igneous and metasomatic rocks in the Northern Range reflects its greater height above the orogenic magma chamber, if indeed any magmatic activity occurred here even at depth.

However, metamorphism throughout the Araya-Paria area is described generally (Gonzalez de Juana et al. 1971, Rodriguez 1968) as regional metamorphism in the greenschist facies. This suggests that although the grade of metamorphism may be higher the process may be the same. Gonzalez de Juana et al. (1972) consider that the Guinimita formation (Upper Limestones member of the Chancellor formation) is less metamorphosed than the underlying formations. One notices that when describing an area of the Coastal Ranges further to the west Oxburgh (1968) recognised the difficulty of supposing burial and elevation as agents for regional metamorphism along a narrow strip, and suggested geothermal activity along a narrow belt as possibly the explanation.

Geological History

The earliest episode that can be described in this area is the deposition of the Maraval formation. This must be dated as pre-Tithonian and in view of the general picture of rapid sedimentation it was probably Jurassic, although it could be somewhat earlier. The Maraval formation consists of relatively pure limestones and marbles with reef development common especially in the lower part of the formation. There is no clear change in facies from one part of the area to another - in fact there is no change eastwards over some 60 kms. It seems therefore that the Maraval formation was laid down in shallow clear water on a gently subsiding floor. This may fit with the idea of a Jurassic date for the opening of the Caribbean Sea (Freeland & Dietz 1971, 1972). Whatever the shape and extent of the new sea formed here, it does seem to have been relatively shallow, quiet and without major sources of sediment. The Maraval formation appears to have been deposited at the same time as the other Jurassic sediments along the northern edge of South America - the first post-Palaeocene marine sediments in the area (the Permo-Triassic rocks are continental in origin) laid down in the new Caribbean Sea.

A change took place late in Jurassic time. In the sea floor a sag developed along the northern edge of South America, and in this trough some 1.5 to 2 kms of flysch were deposited largely as turbidites from a northern source. Contemporary volcanic activity occurred north of the flysch trough. There is no clear evidence for contemporaceous deformation of these sediments, the Maracas formation, although possible exotic blocks suggest some movement. The development of this trough does not seem to be evidence for any closing of the Caribbean such as the presence of a subduction zone would suggest. The question of the northern source material is interesting. It can hardly have been either a bulge in the new Caribbean marine crust, nor yet an igneous or purely volcanic upwelling. It must have been part of a continental mass, and the candidates are either the Blake plateau-Bahamas area, or the perambulating Yucatan and Nicaraguan blocks if we accept the reconstruction of Freeland and Dietz (1971). In passing one notices that these writers have assumed that the Nicaraguan block had already drifted west into the middle American position by late Jurassic time. If this drift were postponed until the end of the Lower Cretaceous, the Northern Range could be provided with a possible source area for the Maracas and Chancellor formations. Indeed one wonders whether it is necessary to consider the Nicaraguan block as having moved any further than from a position due north of Venezuela and Trinidad. No rotation would be required and the Yucatan block could have occupied the Gulf of Mexico to the north of the Nicaraguan block. Could the flysch trough be connected with the moving source block rather than with a subduction zone? It would then be a feature of lateral movement, not compressional.

With the end of deposition of the Maracas formation a change took place, presumably early in the Cretaceous. The succeeding Chancellor formation consists of bedded limestones and shales with relatively few coarse clastics. This suggests that the source material of the Maracas formation had been largely worn down or had moved away. Some of the Chancellor formation may be turbidites deposited as limy flysch. The environment of the mixed conglomerate and carbonate facies of the Chancellor formation and neighbouring rocks in Venezuela may be that of channels cut through the shelf carbonate beds and now filled with rounded cobbles. The cobbles of quartzite may be due to silicification of carbonate blocks, but from thin sections seems more likely to be derived from the older Maracas formation quartzites.

The development of Lower Cretaceous reef carbonates only occurs in one part of the mapped area in the Chancellor formation (Lady Chancellor

Road) but rather more widely in the Laventille formation. In the central part of the Northern Range similar reefing seems to occur, and the Zagaya limestone reef in the Toco formation (Barr 1963) seems to be an equivalent. In eastern Venezuela Patos Island has been described as a reef in the Guinamita formation (Gonzalez de Juana et al. 1968). A large area of the Serrania del Interior of eastern Venezuela is underlain by Lower Cretaceous El Cantil limestone which includes reefal developments - the Borracha formation limestones in the north and the Guacharo limestones in the east (Guillaume et al. 1972). In Trinidad the isolated Stack Road limestone is another piece of reef. Altogether there are so many scattered reefs in the Lower Cretaceous of northeastern Venezuela and Trinidad that one cannot discern any simple trends. It is an interesting extension of the Urgonian facies of Europe and North Africa.

The deposition of the Maracas formation flysch was described as occurring in a sag that developed after the deposition of the Maraval formation. Although a flysch trough some 2 kms thick was produced, there is no clear evidence that it was part of the orogenic phase that followed. While the upper part of the Maracas formation and the Chancellor formation were being laid down shelf sediments were being deposited to the south in Venezuela and Trinidad, with roughly comparable thicknesses. There are carbonate sequences in Venezuela as well as deltaic associations, and under the Gulf of Paria an evaporite and carbonate succession accumulated. This suggests that the flysch may simply have been laid down off the continental edge of South America and off the edge of adjacent parts of North and Central America, possibly along the boundary between the moving blocks. As suggested above such a trough might owe its existence to this relative movement, and the character of sedimentation in the trough may also have been dictated by the movement of the blocks.

The pattern of Jurassic and Lower Cretaceous sedimentation may be tied to ideas about the general nature of the Caribbean Sea. Geophysical evidence suggests that it does not have the character of either an oceanic or a crustal plate, but that sedimentary thicknesses are clearly in excess of those in oceanic areas (Edgar et al. 1971). The Deep Sea Drilling Project, Leg 15 (Edgar & Saunders 1971) examined the sedimentary section at 9 boreholes in the Caribbean Sea. Widespread volcanic rocks appear to underlie sediments ranging in age from Pleistocene to Coniacian. The question remains what lies below the volcanics. It may be that a Jurassic-Lower Cretaceous sedimentary section has been covered by Cretaceous volcanics throughout the Caribbean area. In this case the combination of Mesozoic sediments and volcanics may explain the geophysical differences between the Caribbean floor and the normal oceanic plate. The Caribbean plate could then be considered to have originated with the separation of North and South America although no centre of sea-floor spreading seems apparent, or it could even be a piece of old eastern Pacific plate as Edgar et al. (1971) suggested .

Some time after the deposition of the Chancellor formation and before the deposition of the Morvant beds (Galera formation)i.e. between Aptian-Albian and Campanian-Maestrichtian the first major orogenic movements began. Folding on E-W axes occurred and this appears to have been in at least two phases, because earlier folds have been refolded on approximately the same axes. The style of folding is that of a steep root zone in the south turning into a recumbent overturned structure in the north. In places outside the mapped area the axial surface of the main anticline has been rotated more than 180°. Associated with these folds, and presumably contemporaneous with them, are south dipping thrusts or slides, Low grade metamorphism appears to have been induced by the folding.

The palaeogeographical conditions which prevailed at the time of this folding may be somewhat speculative. Probably the conventional picture would be that the Caribbean Sea developed by spreading in the Jurassic during the separation of North and South America and the movement of those plates away from Africa with the opening of the Atlantic Ocean. The orogenic belts along the northern and southern edges of the new Caribbean plate would be seen as evidence for Lower Cretaceous to Eocene compression caused by North and South America moving together with the formation of subduction zones at the northern and southern edges of the Caribbean.

A subduction zone caused by the northern edge of the South American plate riding over the southern edge of the new Caribbean plate may well explain the geology of the Northern Range and that of the Coastal Ranges of Venezuela. However there are a number of possible differences from what seems to have become the accepted picture. These have been touched on already. It is not clear that there was any compression as early as Upper Jurassic when the trench, if any, was formed along the northern margin of South America. The sediment filling the trench, if any, came from the north not from the present South American plate. It is not clear that sediments in the possible trench had accumulated to a noticeably greater thickness than the equivalent sediments being laid down under what are presumed to be shelf conditions. These problems concern the early stages of the orogeny but extend to questions about the main folding phase.

The idea of a subduction zone answers the questions that arise with regard to these recumbent folds and associated slides. If this amount of crustal shortening (say 15 to 30 kms) had to be accounted for it was necessary to consider lateral compression at depth. This may be the case and the folding may represent squeezing of the new Caribbean plate between the continents of North and South America. But the sequence becomes a little bewildering. First the Caribbean opens in Jurassic times , then closes slightly in Lower Cretaceous and opens up again through Upper Cretaceous and Tertiary times. This recumbent folding could be explained as major gravity sliding and folding and could be seen as a continuation of general tension along the flanks of the Caribbean which culminated in the linear faulting, which seems to characterise the blocklike shape of the southern Caribbean mountain ranges.

However this does not seem to provide a satisfactory explanation for the folded mountains north and south of the Caribbean Sea. Perhaps the Caribbean plate did not ride passively on the expanding Atlantic plate like the continents to north and south. An episode of active pressure from the east by the Atlantic plate might produce a reaction at the northern and southern rims of the Caribbean.

Orogenic activity continued through the Upper Cretaceous with the Morvant beds (Galera formation) being laid down in wildflysch facies. The source area for these sediments appears to have been the Northern Range itself. There were intervals of inactivity at different times during the Tertiary; however the presence of sericite and quartzite in the Upper Miocene and Pliocene of northern and central Trinidad suggests that periodic activity continued until then.

The character of movement changes with time. The large-scale recumbent folds that occurred at the end of the Lower Cretaceous were succeeded by tighter upright folding at the end of the Upper Cretaceous. Finally Tertiary movements seems to have consisted largely of faulting. It is suggested that during the Tertiary the area acquired its predominantly horst-like shape with the development as the El Pilar Fault along the southern boundary. Whether left lateral movement occurred is not clear, but it may have done so in association with the development of a subduction zone along the island arc of the Lesser Antilles. Suggestions that this arc developed on a different site now obscured, as early as Lower Cretaceous, seem difficult to prove.

Finally in Plio-Pleistocene time the final carving of the river valleys occurred, probably in existing Tertiary valleys. Sea level changes together with increased precipitation gave rise to terrace deposits and thick gravels on the floors of the valleys. Tilting continued down to the west, at least to the Dragon's mouths and up to the north in the Northern Range itself.

Economic Geology

The dearth of mineral resources in the Northern Range is rather striking. The small occurrences of iron will be discussed below. To the population of Trinidad however these mountains represent the most important water supply, and an important source of limestone.

Iron

In the Maracas River (723854) a 250 mm band of magnetite appears to dip 55^{o} south, conformably with the quartzites of the Maracas formation. In the river are numerous boulders of haematite which are assumed to have been formed by weathering of the magnetite. The presence of iron in the Maracas valley has been known for many years - Wall & Sawkins (1860) report on the assay of a sample from this area, without giving further details. The most careful examination of this occurrence was that carried out by Thatcher (1960). General comments on Thatcher's survey were made by Joubin (1965) who revisited the localities. The writer visited the area with Thatcher at the time of his survey.

In the field today the magnetite band can be followed westward from the river at 723854, as a zone perhaps 1.5 m wide to a point on the hill-side at 717856 and much float occurs in minor streams. Thatcher investigated this occurrence and also others in the valley to the north (719857) which are now covered by vegetation. In addition he found magnetite in place at localities on the ridge near the peak of La Vigie (705868). Thatcher also found one locality showing iron impregnation east of the river. He concluded that the magnetite had been emplaced in fractures and bedding planes, with some limited spreading through quartzites, and saw the whole occurrence as a zone of shearing. He estimated that 250,000 tons of ore were present with iron content 30%. An airborne magnetometer survey was carried out by Cyprus Mines Company in an attempt to extend the prospective area, but no further action has followed.

The occurrence of haematite and fluorite on Gaspar Grande island has already been mentioned. Thatcher estimated that there are 80,000 cubic yards of ore with 40% iron content. Joubin (1965) shows a sketch of an aeromagnetic map of Gaspar Grande, in which an E-W anomaly across the island is assumed to indicate a pyrrhotite body. Subsidiary anomalies are indicated at the western point (457791) and the southeastern point (474786). Neither of these last two anomalies coincides with good exposures of iron ore. Unfortunately Joubin does not mention the best exposures of haematite at 478795 and 479793. In the general Gaspar Grande, Pointe Gourde area there is widespread iron staining associated with the collapse breccias in the Laventille Limestone.

It does not seem likely that new surveys or changed economic factors can make either the Maracas valley of Gaspar Grande into attractive iron prospects.

Fluorite

On Gaspar Grande at 468788 to 469789 W. Brown first noted fluorite and F.R. Joubin had the area investigated by test pits to such good effect that the writer could find no exposures of fluorite visible. This was partly due to vegetation cover. The fluorite as described seems to occur as pockets in the phyllites of the Laventille formation immediately underlying the Laventille Limestone. This seems close to the horizon where gypsum occurs in the Laventille and St. Joseph areas. Possibly closer examination of this particular horizon might reveal other fluorite occurrences, but probably not of economic significance.

Gypsum

The evaporites in the Laventille formation have been described above. The gypsum at Cristobal Colon in Paria, Venezuela, is worked for the cement industry, and the gypsum at St. Joseph was worked for the same purpose until a few years ago. Now the main quarry has been worked out and test-pitting along strike has failed to extend the occurrence. A new exposure near Port of Spain does not appear likely to be economic. It lies in a school yard (654775) and may extend under nearby housing.

This is one of the problems about the Port of Spain-St. Joseph zone - much of the land under which gypsum may occur is already covered by established urban housing. Although the Gulf of Paria may be underlain by a Lower Cretaceous evaporite basin there does not seem any possibility of commercial development there. The occurrence of evaporites and fluorite along the south side of the Northern Range and along the south side of the Coastal Ranges seems to represent the northern rims of a Lower Cretaceous evaporite basin but it may also be significant that these occurrences lie along the El Pilar Fault system. Further exploration along that fault system in eastern Trinidad may be justified.

Limestone

The Northern Range contains the most important limestone quarries in the island. The Maraval limestone is quarried at two sites near Diego Martin and at a number of quarries in the Santa Cruz area. There are many old abandoned quarries throughout the outcrop. In the Chancellor formation no quarries are now being worked, although formerly the bedded limestones were used as freestone and as random rubble cladding and as random paving. The Laventille Limestone outcrop is riddled with quarries but only two are now working; however one of these is the government quarry at Laventille, probably the biggest quarry on the island. Reserves of good limestone are large both in the Maraval formation and in the Laventille Limestone of the western islands. Here the most useful reserves are those on Pointe Gourde where there is no settlement on the land formerly included in the U.S. naval base.

Water Supply

Surface water supply is more important than groundwater in Trinidad, but the intensely settled valleys prevent the development of reservoirs. Water was taken from the Maraval River just below the village of that name for many years, but fortunately that practice has now ceased. Along the North Coast small hotel and tourist development may use surface supplies and the writer advised the government on one such scheme involving the waterfalls in the Tyrico River in the eastern part of Maracas Bay.

Although the main valleys are not suitable for reservoirs they contain considerable gravels which extend south to fan conglomerates beneath the alluvium at the southern boundary of the Northern Range, as mentioned above. These gravels and fan conglomerates are important sources of groundwater supply for Port of Spain. Many of the wells are located along the coast - if overpumping is attempted salinity rises. South of San Juan the results of structure drilling during petroleum exploration led the writer to suggest the presence of a fan conglomerate not visible at surface. This conglomerate now produces about 5 million gallons per day which may well be above the safe yield.

A later stage of groundwater production has been the planning of water wells higher in the valleys themselves. This has generally been successful although one location suggested by the writer was a spectacular failure because of a high calcium sulphate content. This well lay in the Maraval valley in the broad plain of the Maraval formation and the gypsiferous water suggests the presence of evaporites in the subsurface.

In view of the generally high level of settlement and the intensive use of groundwater it is now unlikely that any further large water supplies can be provided in the area except possibly from the gravels in the Tucker valley. The next step in providing for the increasing water demand will be the damming of the Oropache River to the east - the writer's detailed observations were used by the consultants preparing this project which now only awaits financial support.

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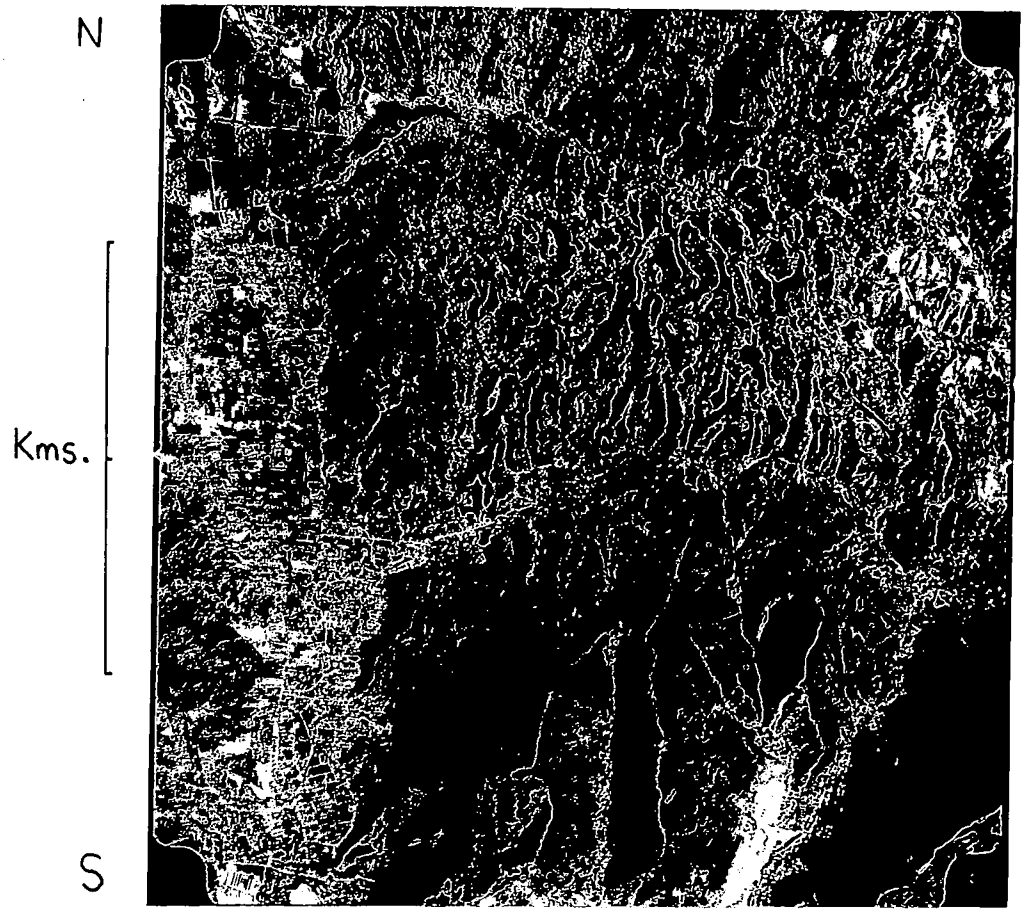
Plate 1. Reduced vertical airphoto Diego Martin area showing karst topography of Maraval formation flanked by Maracas formation to north and south and by alluvium to the west. There is also minor faulting. The photograph includes proposed type sections of Maraval and Maracas formations. The Chancellor formation lies on the southern margin.

Plate 2. View SW from a point on the ridge at 647835 near St. Ann's Peak. This is a typical scene on the south flank of the Northern Range. Lady Young trail can be seen in the trees. The main part of the slope is Maracas formation, but the hollow in the foreground is Chancellor formation as is the cleared hillside on the extreme left of the photograph.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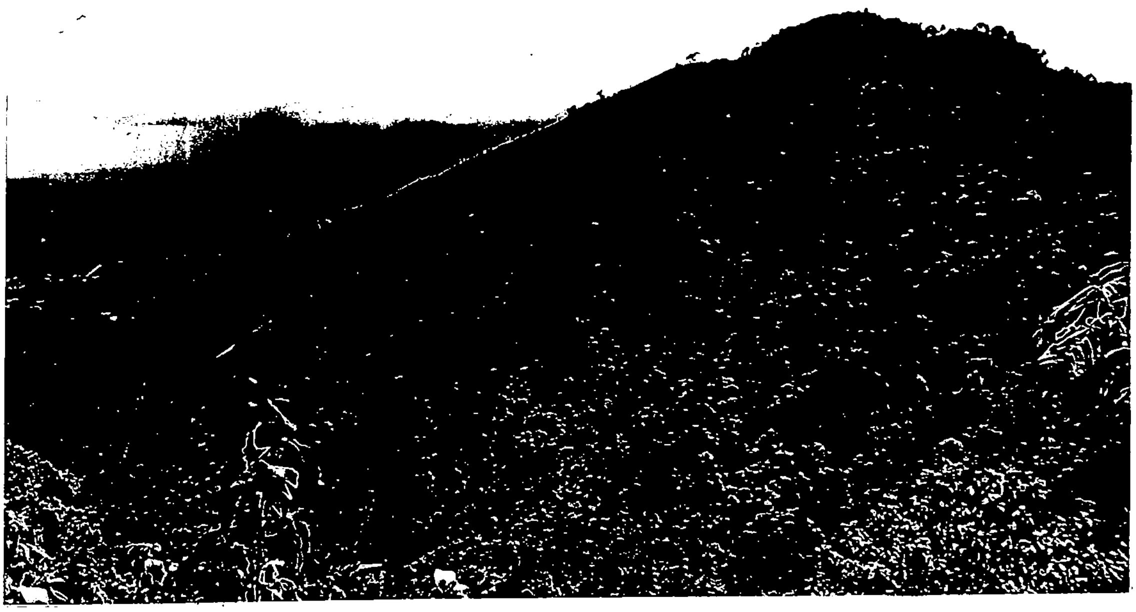

Plate 3. Cumberland Hill (1781 ft.) and Fort George on southern slopes of Northern Range. View E from 563811. Higher part of Cumberland Hill and all housing in foreground are in Maracas formation. Southern, right-hand hill slopes, largely light green cleared land, is underlain by Chancellor formation including subsidiary hillock on the skyline, which is Fort George.

Plate 4. Cerro El Tucuche (3075 ft.). View W from Las Cuevas outside and E of mapped area. All rocks are in inverted Maracas formation of overturned northern limb. Dip slopes can be seen as well as the marked northern scarp.

Plate 5. Monos Island on a calm morning. View SW from Entrada Point area (453843). The northeastern corner of Monos is all in overturned Maracas formation. The island schooner is typical of the vessels that still carry much of the Caribbean local trade.

Plate 6. North Coast. View WNW from 673900. Saut d'Eau Island and Les Boqets (or Boquets) at the point are in overturned Chancellor formation. The rest of the area is in overturned Maracas formation.

Plate 7. North Coast. View ENE from 673900. Balata Bay in foreground with Maracas Bay behind, all in overturned Maracas formation. Slide is mapped across ridge in foreground, then joining a slide in right background which lies in hollow shown by yellow earth slopes where landslips have occurred along a new road near 728901.

Plate 8. North Coast Road (3½ milepost) 660885. Overturned Maracas quartzites, greenschists and calcareous chlorite-mica-schists.

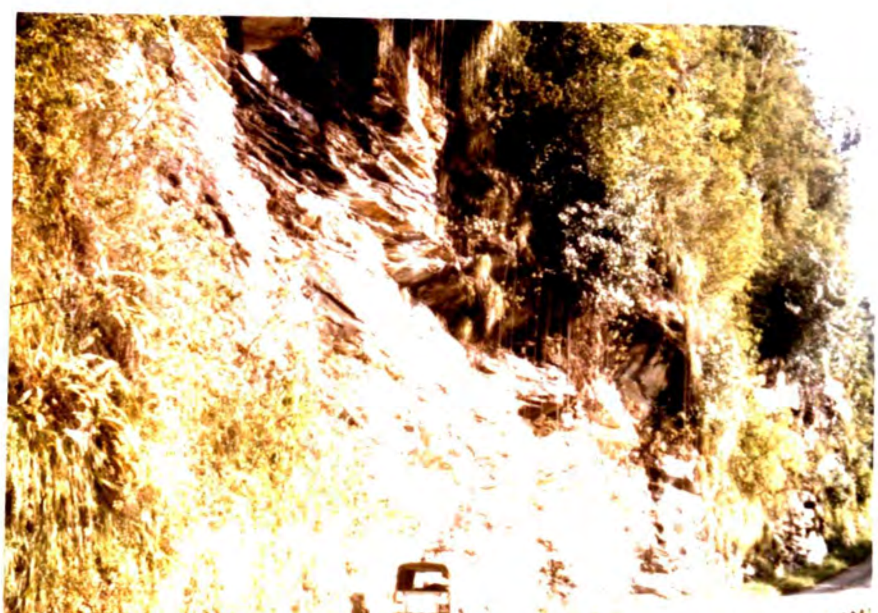

Plate 9. General view from 716884. View WSW. Watershed and northern scarp of overturned Maracas formation dipping south. Lower montane forest and montane forest vegetation.

Plate 10. Maracas Bay. Camera at 701897 view ENE. Sand beach with coastal swamp (now filled) in foreground and overturned Maracas formation in hills.

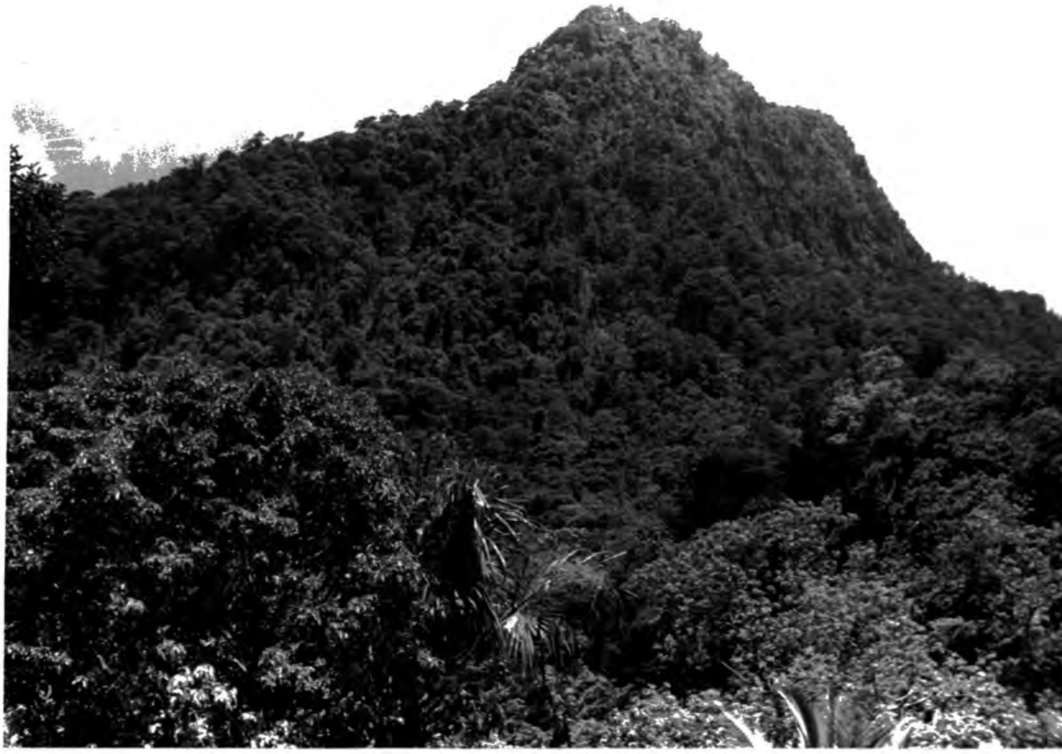

Plate 11. General view western islands, camera at 470806, view W. Monos island in foreground with left hill in Upper Limestones of Chancellor formation then hollow in Lower Phyllites, right hill in Lower Limestones and contact with Maracas formation in nick on skyline. South end of Chacachacare to left of Monos and Paria, Venezuela in distance. Patos Island, Venezuela in Guinimita formation - Laventille Limestone is on the horizon to the left.

Plate 12. La Ceiba River 612842, view N. Tufa delta; river flows across Maracas formation here but has left Maraval formation outcrop only half a kilometre north of this point. A second, smaller, delta can be seen above this, and in shadowed valley 50 m upstream a third tufa delta approximately 5 m high occurs.

Plate 13. La Fontaine Quarry, Diego Martin (587849), view W. Height of quarry face approximately 8 m. Maraval formation. Bedded limestones and marbles with upright minor folds in roof of cave.

Plate 14. La Fontaine Quarry, Diego Martin (588846), view W. Maraval formation. Bedded limestones to marbles with a minor fold below hammer and what appears to be reef patch at left of photograph.

Plate 15. North Coast Road, 647868. Overturned base of meta-volcanic ash bed (epidote greenschist) showing convolute fold; weathered phyllites lie above it now.

Plate 16. Maracas Bay, 699901, view W. Weathered Maracas formation quartzites. The folds face south down-dip and axial plane cleavage is developed. There are also graded beds, confirming the overturning.

Plate 17. North Coast Road, 641853, near The Saddle. Weathered calc phyllites near the top of the Maraval formation. The contorted-bedding lies under competent south dipping limestones and is throught to represent relatively young near-surface sliding.

Plate 18. Monos Island east coast, 444820, view W, height of face seen approximately 5 m. Maracas formation, bedded quartzites with some interbedded phyllites, upright minor folds on south flank of main anticline.

Plate 19. The Dragon's Mouth, bay south of Entrada Point, 452840, view SE. Maracas formation, bedded quartzites overlain by graphitic quartz-schist. Minor folds indicate overturning, as does graded bedding, axial surfaces and incipient cleavage approximately horizontal.

Plate 20. Chacachacare Island east side 376821, view SW, height of exposure seen approximately 8 m. Maracas formation, bedded quartzites, jointed, minor folds, axial surfaces south dipping indicate that this exposure is on the upper normal limb of a major recumbent anticline.

Plate 21. Dumas Bay, Monos (423812), view E. Height of face seen approximately 3 m. Chancellor formation, Upper Limestones, quartzitic conglomerate interbedded with limestones, quartzite cobbles embedded in limestones.

Plate 22. Dumas Bay, Monos (423811) view E. Height of face seen approximately 1 m. Chancellor formation, Upper Limestones. Quartzitic conglomerate channel (?) in bedded limestones, underlying bedded limestones with slump folds.

Plate 23. Dumas Bay, Monos (424810) view E. Height of face seen approximately 3.5 m. Chancellor formation, Upper Limestones. Quartzitic conglomerates underlying bedded limestones with subsidiary conglomerate layers. In centre of exposure a channel in the conglomerates has been filled with limestone.

Plate 24. Delgado Point (458810) view S. Chancellor formation, calcareous phyllites with thin limestones, minor folds.

Plate 25. Delgado Point (458810) view E. Exposure approximately 2 m high. Chancellor formation, bedded quartzites with upright minor folds. This exposure is stratigraphically higher than that in plate 15.

Plate 26. Delgado Point (460810) view S. Chancellor formation weathered phyllites with contorted quartz lenses.

Plate 27. Staubles Bay (469807) view NE. Chancellor formation, Upper Phyllites. Interbedded phyllites and quartzites, folded with crenulations.

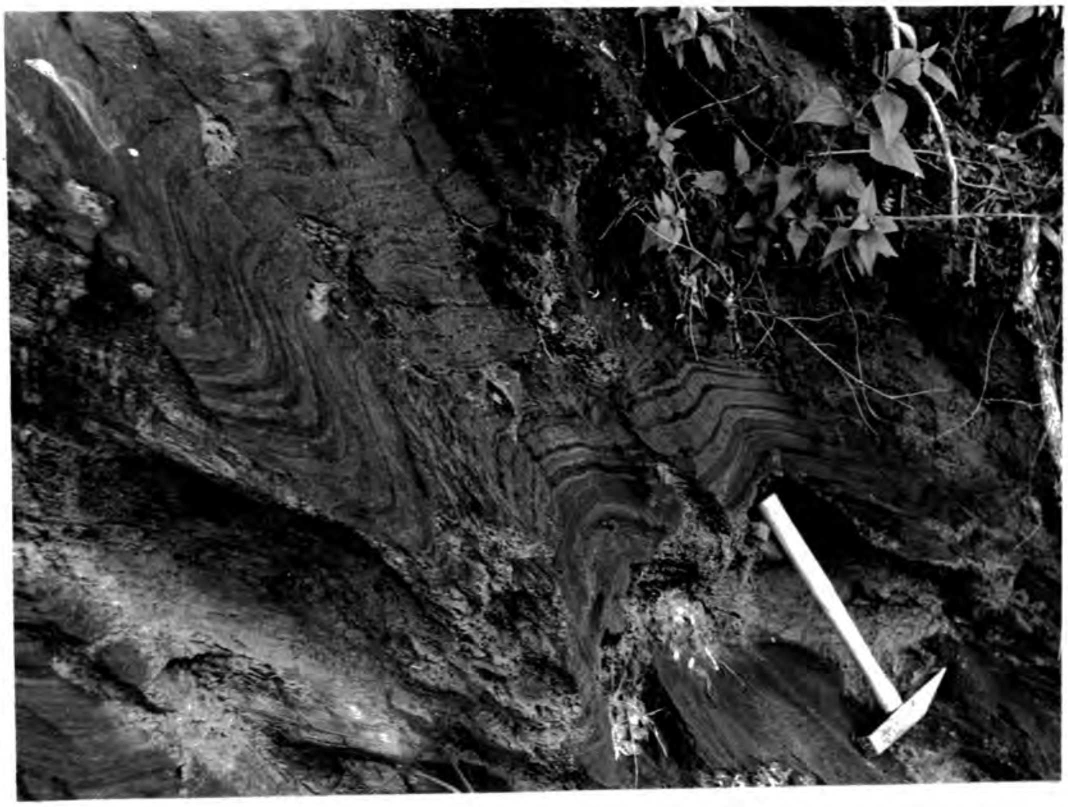

Plate 28. Staubles Bay (467809) view NE. Chancellor formation. Bedded limestones folded in what appears to be young structure probably a collapse fold. These beds have been partly decalcified during weathering.

Plate 29. Gaspar Grande east point (Reina Point) 480794, view W. Laventille Limestone, breccia with iron staining between larger blocks. Height of exposure shown approximately 4 m.

Plate 30. Gaspar Grande east end (479793), view WNW. Haematite in Laventille Limestone as dyke-like body with inclusions of limestone. There are also irregular inclusions of haematite in the limestone at the side of this. Total width of haematite is approximately 10 m.

Plate 31. Government Quarry, Laventille, with Picton Tower (643777). Camera at 645776, view NW. Laventille Limestone - Upper (Picton) Limestone gentle folding, brecciation. Lorries show scale.

Plate 32. Furness Quarry, Laventille (648776) view SW. Locality A in text. Laventille Limestone. Block of massive limestone 6-7 m high lies in phyllitic shales draped over the block. The shales are overlain by the Upper Limestones at top of quarry face. Workman shows scale.

Plate 33. Disused quarry Laventille (646780), view W. Laventille Limestone. Locality C in text. North dipping, faulted lower limestones are unconformably covered by draped phyllitic shales with Upper Limestones at top of quarry face. Goalposts show scale.

Plate 34. Closer photograph of Plate 33, locality C, showing faulting in lower limestones more clearly and irregular contact between phyllitic shales and upper limestones.

Plate 35. Northern wall of disused quarry at Laventille in Plates 33 and 34. Locality C (646781) view W showing another faulted limestone mass lying under phyllitic shales with upper limestone at top of quarry face. Upper limestone below isolated tree may be recognised from Plate 33. Scale may be estimated from telephone pole top centre.

Plate 36. Disused quarry Laventille (649780), view E. Locality B in text. Laventille Limestone. Block of limestone approximately 5 m thick lies in unfaulted phyllitic shales which are draped over it. In this photograph the block could possibly be a lens but it is believed to be a faulted block. Height of exposure approximately 7 m.

Plate 37. Disused quarry Laventille (648786). View SW. Locality E. Laventille Limestone. Bedded Lower Limestone overlain unconformably by disturbed phyllitic shales.

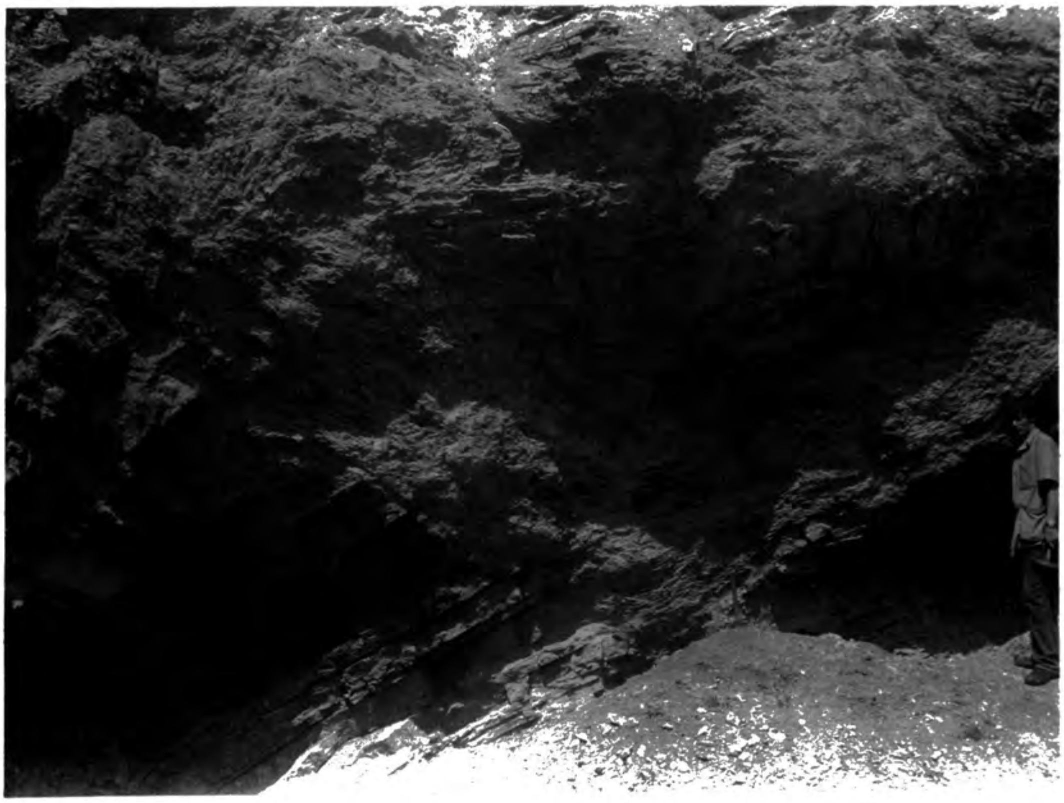

Plate 38. Trotman Street schoolyard (654775). Laventille formation. Contorted gypsum and anhydrite with limestone layers. General attitude vertical.

Plate 39. Lady Young Road (651796) view ENE. Unconformity surface undulating across photograph approximately 15 m wide and 6 m high, slope approximately 40°. In foreground Chancellor formation, Upper Phyllites are folded on nearly vertical axes.

Plate 40. Lady Young Road (651796) view NW. Unconformity surface shown in Plate 30, with Chancellor formation, Upper Phyllites in foreground. At top left-hand corner of photograph Morvant beds rest on the unconformity with some disturbance.

Plate 41. Lady Young Road (651796). Closer view of unconformity surface illustrated in Plates 30 and 31, showing limonitic surface, rolled pebbles and limonitic nodules.

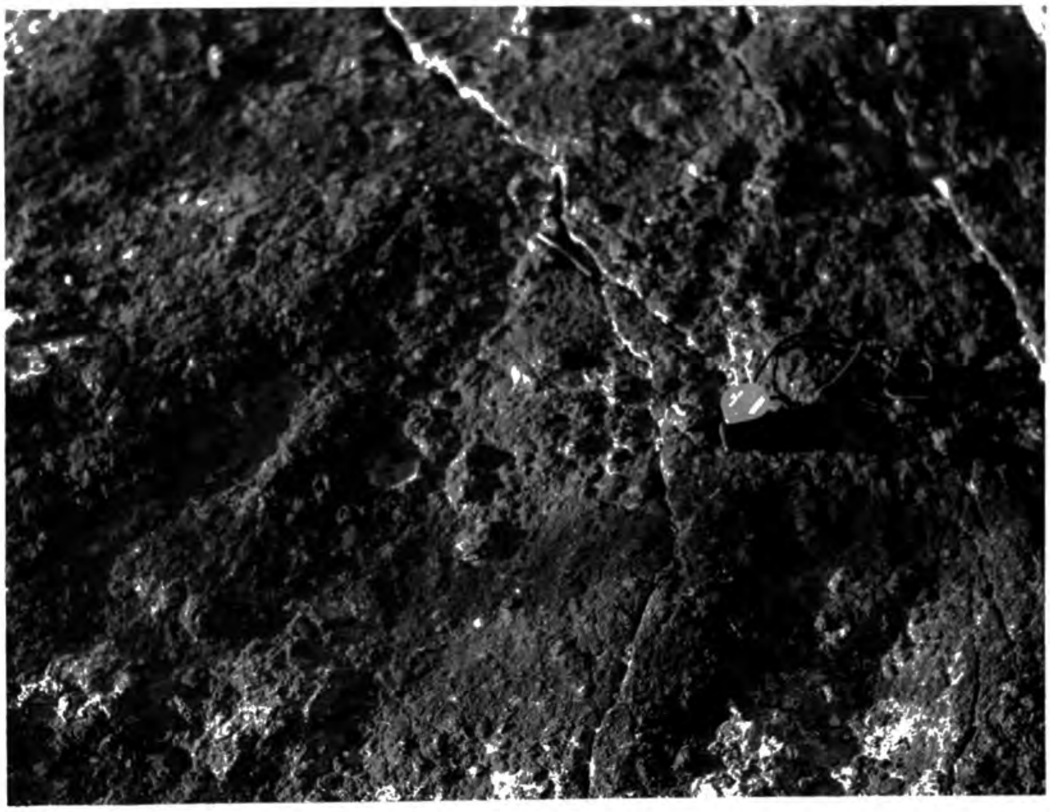

Plate 42. Road cutting east of Maracas Bay (728902) view E. Overturned weathered Maracas formation. The cutting lies along a major slide. This part of the road suffers landslips after every heavy rainstorm. The workmen are cleaning up the latest fall of rock. At one time the road was closed for some weeks, then a bulldozer was kept at the near corner for the whole of the wet season. Now most of the shattered country rock has fallen.

Plate 43. North Coast (694894) view E. Maracas formation, bedded quartzites with interbedded phyllites, slump fold. There are two graded beds in this exposure confirming that the beds are overturned.

Plate 44. Carenage (544813) view W, height of exposure approximately 2 m. Maracas formation. Weathered phyllites with south dipping slide exposed.

Plate 45. Closer photograph of Plate 44 showing angular folds facing down the slide in broken phyllites above the plane, and brecciation below it. It is suggested that the broken beds indicate that the slide is a relatively young structure.

The overturned anticline of the Northern Range of Trinidad near Port of Spain

HENRY C. POTTER

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The overturned anticline of the Northern Range of Trinidad near Port of Spain

HENRY C. POTTER

FORMERLY the Northern Range of Trinidad was assumed to be the south flank of an anticline, with the north flank either out to sea or displaced by faulting. Mapping has shown that the structure is that of an anticline overturned to the north.

The steep southern limb begins with nearly vertical dips in the Chancellor formation and the Morvant beds along the Lady Young Road, and between Port of Spain and Maraval. In this upright limb are local folds 100 m to 500 m in wavelength, parallel with both the main structure and minor folds. Folds of this size have not been recognised in the overturned northern limb. West of Maraval step-like folds with alternating horizontal and vertical limbs occur on east–west axes 10 m to 100 m apart. Axial surfaces dip about 35°N, but all other minor folds in the area have axial surfaces dipping steeply southwards.

Along the axis of the main fold, which occurs in the outcrop of the Maraval limestones, dips are 40°–60°S and the flanks are isoclinal. In the whole of the overturned northern limb dips are much flatter, commonly less than 25°, and appear to become even flatter to the north. The size of this recumbent limb suggests that it is a nappe. The underlying autochthonous beds are not seen.

A number of phases of folding are recognisable. The first folds on east–west axes were refolded on more or less parallel axes. The step-like folding west of Maraval may belong to this second episode. Later folding occurred on north–south axes, but this may not be all contemporaneous, because in the Port of Spain area it is a gentle warping but on the north coast and to the northwest it is much tighter recumbent folding.

There is some southward sliding, but it does not reach the scale described by Metz (1968) in the Paria peninsula, Venezuela. Collapse folds are common in the thinly bedded limestones of the Maraval and Chancellor formations. It is uncertain whether they are due to decalcification, which is common in the Northern Range, or to the solution of an evaporite that may have been present near the top of the Maraval formation.

Superficially faulting may not appear to be important but the Northern Range is bounded by faults. The El Pilar fault to the south has been interpreted as a regional wrench or transform fault (Alberding 1957, Rod 1956). However, only limited lateral movement can be observed and the main effect is 2000 m upthrow of the Northern Range against the Northern Basin to the south. (Metz 1968, Potter 1968). The high cliffs along the north coast suggest east–west faulting, but the only fault mapped in the area has 200 m downthrow to the north, between the mainland and Saut d'Eau Island. The general picture is that of an upthrown east–west block (Bassinger *et al.* 1971).

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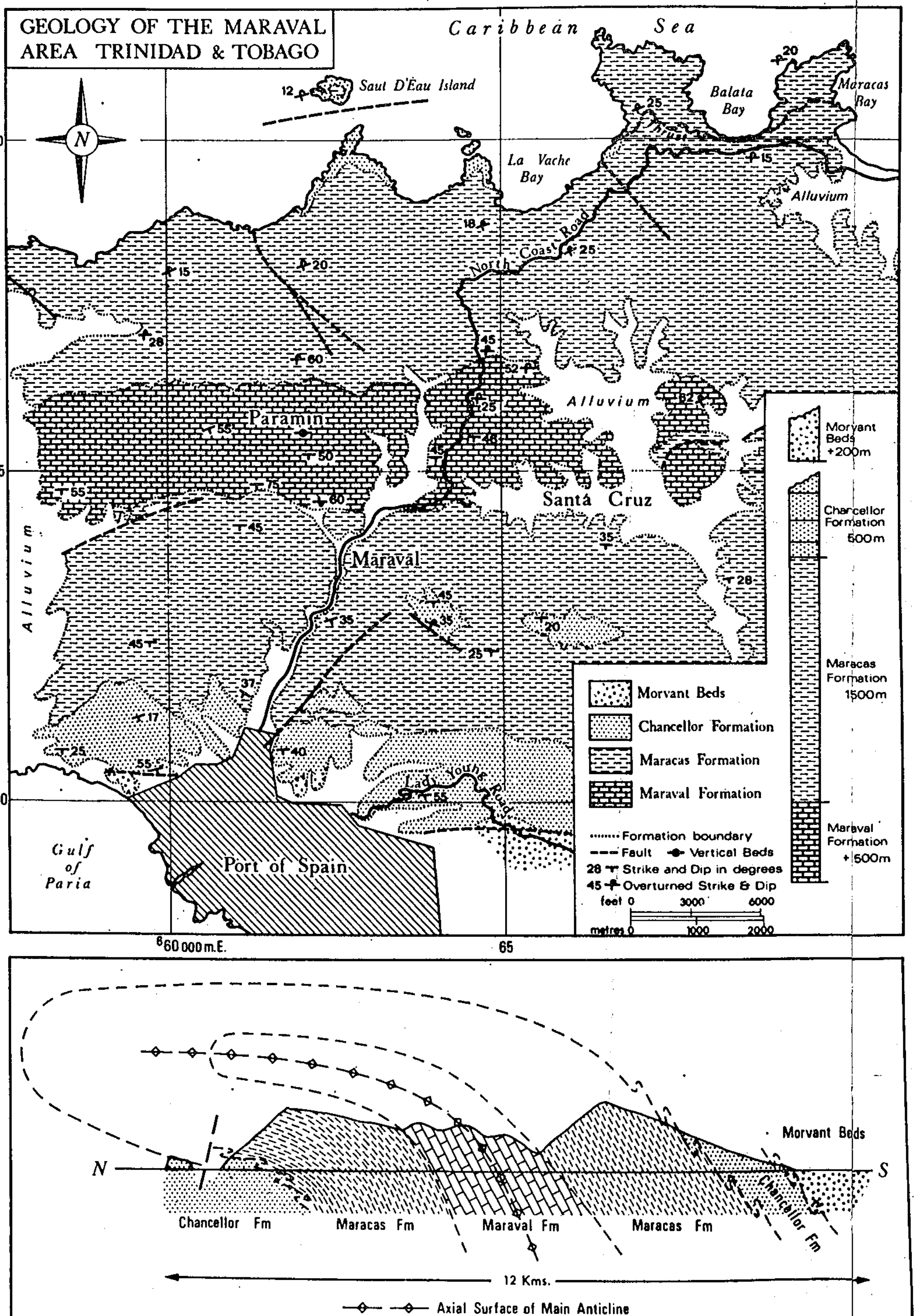

FIG. 1. Geological map of, and cross-section through, the Northern Range of Trinidad near Port of Spain.

In the Northern Range itself northward thrusting occurred in the Maraval, Port of Spain, and North Coast areas, and these thrusts were presumably contemporaneous with the main folding. Only a few minor faults appear parallel to the northwest–southeast wrenches like the Grande Riviere fault (Barr 1963) and the Los Bajos fault (Wilson 1958).

Stratigraphy

This structural picture has led to revision of the stratigraphy of the Caribbean Group (Wall & Sawkins 1860) in this area. The oldest formation is now seen to be the Maraval limestone, which is overlain by the Maracas formation, and this in turn by the newly described Chancellor formation that is itself unconformably overlain by the Morvant beds. The total thickness, excluding the Morvant beds, appears to be 2500 m, rather than the 8800 m previously suggested (Suter 1951, Higgins 1960) or 5200 m (Kugler 1956).

The Maraval formation of Suter (1951) and Kugler (1956) was thought to lie above the Maracas formation, but now it becomes the oldest formation in this area. A maximum thickness of 500 m has been measured near Paramin and the base is nowhere seen. The formation is largely made of three horizons of massive recrystallised limestone and what appears to be a reef knoll at Paramin village. Calc-schists are interbedded with the limestones that are nearly pure marbles with granoblastic-elongate texture and rare ooliths and bioclasts.

The Maracas formation of Suter (1951) and Kugler (1956) was regarded as the oldest formation in the Northern Range, but it is now seen to lie conformably on the Maraval formation. The originally described outcrop is the overturned northern limb of the Northern Range anticline; the upright southern limb was shown as the Grande Riviere formation by Kugler (1961). The succession, about 1500 m thick, is flysch, made of interbedded quartzites and phyllites with rare massive quartzites and slates. A few thin limestones occur near the base and near the top, suggesting transition from the Maraval formation, and to the Chancellor formation. Volcanic ashes were first observed on the North Coast road by Barr (pers. comm.) and have now been mapped further afield. Sedimentary structures indicate turbidites, as suggested by Kugler (1953), and the palaeocurrents were from north to south, as shown for instance by convolute structure on the now-overturned base of the volcanic ash.

The Chancellor formation was introduced as a member by Kugler (1961) and is now raised to formation status. It lies apparently conformably on the Maracas formation and is overlain unconformably by the Morvant beds. The thickness is about 500 m and the formation consists of the following members:

Upper Phyllites	20 m–100 m
Upper Limestones	170 m
Lower Phyllites	40 m–180 m
Lower Limestones	100 m

The recrystallised limestones are less pure than the Maraval limestones and are more interbedded with phyllites and quartzites. Sedimentary features occur in the lower part of the formation, like those in the underlying Maracas formation. A reefal mound 10 m in height and diameter occurs in the Upper Limestones. Some partially recrystallised samples contain ooliths and probable algal fragments.

The Morvant beds of sandstones and shales lie unconformably on the Chancellor formation along the southern edge of the Northern Range where 220 m of strata is seen, but this is only a small part of the whole formation. Black pyritic gypsum bearing shales and coarse graded calcareous sandstones contain wildflysch blocks and boulders, probably from the Chancellor formation and from the Morvant beds themselves.

Regional correlations. The most important correlation is with the beds at Hollis reservoir in the eastern part of the Northern Range in which Tithonian ammonites were discovered (Hutchison 1939, Spath 1939). The phyllites and bedded limestones in which the ammonites were found do not resemble the Maraval limestones and massive Maraval limestones outcrop about 1·5 km north of the Hollis dam. Lithologically the ammonite bearing beds seem more like the Chancellor or the Maracas formations and so they may occur in a limey development in the Maracas formation. If this is so, the Maraval limestones appear older than any other formations described, and would be Upper Jurassic or older. The Maracas formation would appear to be Upper Jurassic; the Chancellor formation may be equivalent to the Lower Cretaceous Toco formation; and the Morvant beds to the Galera formation, Upper Cretaceous (Barr 1963, Saunders 1972) although palaeontological evidence is still lacking.

Summary and conclusions

The earliest discernible event was the deposition of the Maraval limestones, probably during the Upper Jurassic, as a shelf deposit or as part of a miogeosyncline off the northern edge of the Guayana Shield. Next a flysch trough developed, probably from the upper Jurassic to Lower Cretaceous with volcanic episodes and sediments and volcanics derived from an unknown source area to the north. The orientation of this eugeosyncline is not clear but it appears to have been filled by the end of deposition of the Chancellor formation (? Lower Cretaceous) and some of the Chancellor limestones were laid down in shallow water. During the last stages of this basin, fossiliferous shallow water deposits were being laid down to the east (Toco formation) and to the south (Cuche formation).

After this the northward folding and thrusting, and the associated regional metamorphism, took place and was ended by the Upper Cretaceous, and general elevation and erosion followed, leading to the deposition of the wildflysch Morvant beds, perhaps continuing to the Palaeocene.

The regional metamorphism is everywhere low grade. Epidote and chlorite are only found in the overturned Maracas formation in the north. However, mortar structure is widespread in the quartzites and recrystallisation of the limestones is almost complete. The Morvant beds are significantly less metamorphosed than the underlying older rocks.

Last was large scale faulting during the Tertiary, associated with development of the Antillean Arc, but there is little evidence for this faulting within the Northern Range, although both its north and south boundaries are major faults.

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DISCUSSION

DR K. W. BARR complimented Mr Potter on the progress of his programme regarding the elucidation of the structure and stratigraphy of the Northern Range of Trinidad, and made the following points.

Firstly, in respect of the thicknesses of the formations quoted, earlier authors had postulated a variety of thicknesses ranging from a few thousand to perhaps some 30 000 feet. It was appreciated that the higher figures were based on a simpler and almost certainly erroneous structural interpretation. However, in a geosynclinal flysch series such as described, great thicknesses were quite acceptable, and it was questioned whether the thicknesses proposed by the author might perhaps err on the low side, in view of the great regional extent of this Jurassic to Cretaceous geosynclinal fore-deep. Secondly, the author had suggested that the basal Maraval limestone formation might be associated with an evaporitic series; the existence of gypsum deposits to the east of Port of Spain within the Morvant formation was well known. In their present position these are evidently a tectonic emplacement, and one wondered whether there might be some relationship at depth between the two. Thirdly, the commentator agreed that a correlation between the Morvant formation and the Galera Formation at the eastern end of the range was logical. Fourthly, regarding the contact of the Morvant formation and the Chancellor formation of the Caribbean Series, it was questioned whether this contact might be a fault plane. There are many strike faults along the southern margin of the North Range associated with the major El Pilar fault system, and it would not be surprising if the contact in question was in fact a fault. This of course, does not invalidate the probability that there is an unconformable relationship between the Morvant and Chancellor formations, which is suggested by the occurrence of extensive wild-flysch deposits in the former.

The Author agreed with Dr Barr about the difficulty in measuring thicknesses of strata in folded mountains like the Northern Range. Earlier estimates of the thickness of the Caribbean Group had varied between 10 000 to 12 000 feet by Wall & Sawkins, to 1000 to 2000 feet by Cunningham-Craig and then to very much greater thicknesses by later writers. The reason for the reduced measurement lay in (1) the recognition of the overturned anticline which halves former estimates, (2) the use of the new contoured 1:10 000 preliminary map sheets which made measurement easier, (3) the allowance for local folding, minor folds and collapse structures. It was agreed that an element of interpretation was involved in allowing for the smaller folds, but thicknesses were checked with nearby similar sections where folding occurred at different levels. It was interesting that the thickness of a flysch sequence like the Maracas formation should be so close to 1500 m at several localities.

The gypsum of St. Joseph and a newly discovered gypsum exposure at Laventille just east of Port of Spain could occur either in the Chancellor formation or as faulted blocks of Maraval formation. The former seemed more likely both by correlation with Venezuela and because of a reported Lower Cretaceous evaporite section in a well in the Gulf of Paria. There was as yet no clear proof of the author's postulated evaporites in the Maraval formation.

Dr Barr's comments on the Lady Young Road exposure of the postulated basal Morvant unconformity were quite true. This was an area through which a major fault in the El Pilar system passed. The author agreed that the surface shown in photographs looked somewhat like a slide. But closer examination showed corrugations and folding on this surface, limonitic layering and what appeared to be limonite and phosphatic nodules. Moreover by climbing up the hillside to the north it was possible to find the Morvant beds resting normally on the surface, underlain by folded Chancellor formation. It was concluded therefore that this appeared to be the unconformity at the base of the Morvant Beds.

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A PRELIMINARY ACCOUNT OF THE STRATIGRAPHY AND STRUCTURE OF THE EASTERN PART OF THE NORTHERN RANGE, TRINIDAD

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ABSTRACT

The results of field mapping in the area bounded by Arima, Chupara Point, Grande Rivière, Salibea, are presented. The stratigraphic succession is Maracas Formation, Rio Seco Formation, Grande Rivière Formation and on the north coast, Galera Formation. The stratigraphic thicknesses of all formations appear to be less than former estimates because of the recognition of isoclinal folding. It is suggested that the Grande Rivière Formation may be the unfossiliferous metamorphosed equivalent of the Galera Formation. In the Galera Formation a succession of siliceous cherty beds occurs at Grande Matelot. In the Blanchisseuse-Chupara Point area the Galera Formation becomes metamorphosed like the Grande Rivière Formation.

The general structure is anticlinal with the Maracas Formation occupying the core of the Range. A second anticlinal trend lies north of this with Rio Seco Formation in that core. There are two markedly different tectonic styles. The Maracas Formation is gently dipping with many minor recumbent folds all indicating movement of the upper beds southward, downdip. The lower Rio Seco limestones are also folded like this, but the upper limestones and younger formations show isoclinal folding with steeply south dipping axial planes. A plane of décollement appears to lie in the Rio Seco Formation. Faults on both E-W and WNW-ESE trends are mapped, but except for the Brasso Seco and Grande Rivière Faults none are major ones.

INTRODUCTION

The results of field work carried out during the dry seasons of 1963 and 1964 are presented here. Additional field work was done after the verbal presentation of this paper in 1965, and the results are included. This is presented in preliminary form because petrographic work and systematic plotting of tectonic data have not yet been carried out.

The area covered by the survey is the quadrilateral approximately 20 miles E-W, 10 miles N-S, bounded by the town of Arima, the villages of Grande Rivière and Salibea, and by Chupara Point. The topography of the enclosed map is largely based on that of the Geological Map of Trinidad 1959 by H. G. Kugler. The working results and the final map are kept on 1:25,000 sheets prepared by the writer from air photographs

Part of the work was carried out with a grant from H.M. Department of Scientific and Industrial Research. Dominion Oil Ltd. helped the writer greatly with air photographs, maps and transport. Dr. M. Furrer examined many limestone samples and has presented the palaeontological results in his paper at this Caribbean Geological Conference. Mr. J. B. Saunders has examined palaeontological samples from various parts of the area. Through the kindness of Mr. M. H. S. Barker, selected samples were examined at the palynology laboratory of Shell Trinidad Ltd.

GEOGRAPHY

Topographically the Northern Range appears as an east-west trending watershed. The northern slope is steeper than the southern one due to the general south dip. The cliffs of the north coast are undergoing erosion by the Caribbean Sea. The south flank of the Northern Range descends to Quaternary terraces and alluvial fans.

In the area covered here the range can be divided in two. In the west the watershed lies along the middle of the range on a high spine through Morne Bleu (2,781 ft.) and Cerro del Aripo (3,085 ft.). But this ridge only extends eastwards as far as the Oropouche River. Beyond, the watershed is displaced about three miles north on to a different ridge which rises east of the Madamas River, passes through Cerro del Oropuche (2,159 ft.) and continues eastward to the coastal shelf.

The area is thickly forested except for cocoa plantations in the accessible valleys, and coconut plantations on the north coast.

Communications are not well developed. Only the Blanchisseuse Road crosses the Range from north to south in this area. Roads run part way up some of the southern valleys. A main E-W road lies outside the area to the south. On the north coast the eastern and western ends are served by roads, but the central part has only footpaths.

Outcrops are largely confined to stream bottoms, road cuts and coastal sections. Tropical weathering is severe and rapid. New road cuts in argillaceous rocks have been observed to become unuseable in less than a year. New vegetation also covers road outcrops rapidly.

Much of the area has a rainfall of over 100 inches per annum which falls chiefly between May and December. Field mapping is best carried out between early January and late April. In 1964, however, work was stopped by heavy rains in mid-April. In that same year a hurricane in Tobago had brought heavy rains to the north coast, and many hunting trails and narrow valleys were blocked by fallen trees.

PREVIOUS WORK

A full historical account of geological work in the Northern Range is not intended in this preliminary paper. This part of the Range has had less attention than either the western or extreme eastern parts because of the difficulty of access.

The rocks of the Northern Range were described by Wall and Sawkins (1860), and by later writers.

An important ammonite locality was discovered by Hutchison (1938) and the fossils identified by Spath (1939). The stratigraphy of the Northern Range was discussed by Suter (1951) and by Kugler (1953) and the Geological Map of Trinidad compiled by Kugler (1959) showed this area on a scale of 1:100,000.

The geology of the Toco district has been described by Barr (1963). The Toco district lies at the eastern end of the Northern Range, immediately east of the area here described. The same author (1962) presented a cross-section through the Northern Range along the Blanchisseuse Road.

STRATIGRAPHY

The rocks of this part of the Northern Range are sediments at a low grade of metamorphism. The commonest rock is a dark grey sericitic phyllite; quartzitic sandstones and quartzites occur throughout the series; a sequence of recrystallized limestones and calcareous phyllites outcrops in several parts of the area. The oldest known age in the Northern Range is Upper Jurassic and the youngest uppermost Cretaceous to Paleocene.

Wall and Sawkins (1860) included all these rocks in the "Caribbian Group" and subsequent writers retained the convenient term "Caribbean Series". The subdivision of the metamorphic rocks was based on observations at the western part of the Range by Suter (1951) and Kugler (1953). At the extreme eastern end of the Range Barr (1963) made a definitive subdivision based on fossil occurrences east of the Grande Rivière Fault in the Toco area and provisionally extended this subdivision to the Blanchisseuse Road (1962).

One of the problems to be examined in this area was this relationship between the metamorphic rocks to the west and those of the eastern tip of the Range where fossiliferous horizons had been identified. Unfortunately no new macro-fossil localities were found in the lower part of the succession in the area mapped, and examination of the limestones, (Furrer, 1965), while confirming the general Lower Cretaceous to Upper Jurassic age of all the samples, could not allow detailed zoning. Samples of phyllites, calcareous phyllites and limestone were examined by Shell Trinidad Palynology Laboratory, but proved to be barren of identifiable flora. J. B. Saunders identified Upper Cretaceous faunas in samples from the upper part of the succession. Other techniques for correlating these formations will be tried.

The identification of numerous isoclinal folds has caused the writer's estimates of stratigraphic thickness to be much less than former published figures. In addition the mapping on some structures has revealed unexpected stratigraphic relationships.

Microscopic examination of samples has not yet been carried out, therefore the petrography of the succession cannot be described here. In this preliminary paper full lithological descriptions are not attempted.

Maracas Formation

These beds were first described by Suter (1951) and the type section lies along the north coast road to Maracas Bay. Kugler (1953) discussed the relationship of these beds with similar rocks in the Paria Peninsula, raised them to formation status (1955), and showed them extending eastwards along the crest of the Northern Range (1959). Barr (1962) identified this formation on the Blanchisseuse Road.

In the eastern part of the Northern Range the Maracas Formation appears as a succession of fine grained sericitic sandstones interbedded with hard dark grey sericitic phyllites. There are beds of coarser quartzitic sandstones and grits at different horizons.

The bottom of the formation is not seen. Allowing for the contortions that can be seen, the apparent thickness of 6,000 feet exposed has been reduced to 5,000 feet of Maracas Formation in the Blanchisseuse Road area—the best and thickest section in the eastern part of the Range. The base of this section cannot be seen because of the Brasso Seco Fault.

Originally the section must have been a thick sequence of interbedded silts and mudstones with some thicker beds of fine sandstone and several beds of purer mudstone. The character of this section as 'flysch' has been noted by Kugler (1953) and the occurrence of turbidites discussed. Good outcrops showing what appears to be slumping towards the south have been observed and photographed by the writer. Unfortunately the rapid weathering of these beds has already made these outcrops unreadable.

The outcrop of the Maracas Formation narrows eastwards from the Blanchisseuse Road area but the lithological character remains the same. On the Matura River one outcrop of siliceous phyllites in the core of a tight fold has been mapped as Maracas Formation on the grounds of lithology and tectonic style.

North of the Brasso Seco Fault there is an area of just over one square mile on the Blanchisseuse Road and Machapure River (a tributary of the Marianne River) where lithology and tectonic style (see below) resemble the Maracas Formation and are different from the outcrops on the Yarra River to the west and Marianne River to the east. At this time this area is mapped as Grande Rivière Formation but the possibility that it is Maracas Formation overlying the surrounding Grande Rivière Formation in tectonic contact should be borne in mind.

The Maracas Formation underlies the Rio Seco Formation for which an Upper Jurassic (Tithonian) age has been established (Hutchison 1938, Spath 1939).

Rio Seco Formation

This Formation was described by Barr (1963), having been established by that author in a thesis submitted in 1953 and used by other authors since that date. The type locality is on the Rio Seco itself; it lies on the eastern boundary of the area now described. Kugler (1959) and Barr (1962) correlated many of the limestones of the Northern Range with that Formation.

Previously individual massive limestones had been named after areas of good outcrop, e.g. Aripo, Cuare, Hollis. Mapping has now indicated that these limestones lie in the Rio Seco Formation. At this time no attempt is made to extend the correlation to the Maraval Beds of the western end of the Northern Range.

On the Rio Seco this formation consists of dark grey to black calcareous phyllites interbedded with thin dark grey, often recrystallized limestones. Over much of the Northern Range however, the limestones become massive and are separated by only thin bands of phyllites (both calcareous and non-calcareous).

The relationship between these two types of lithology does not seem to be purely one of succession. They appear to be two facies of the same formation with massive limestone lying along the central part of the present Northern Range and calcareous phyllites lying on the flanks.

At one time the writer thought that this formation could be divided into an upper member characterized by calcareous phyllites with thin limestone bands, and a lower member of massive limestones. This differentiation is not valid everywhere; massive limestones appear high in the section near the core of the range. While it is proposed to treat the boundary between massive lime stone and calcareous phyllite as a facies one, the possibility must be borne in mind that the Grande Rivière Formation may lie unconformably on the Rio Seco Formation, and that the upper part of the latter may have been removed by erosion in the centre of the range.

Conglomeratic limestone has been found at several localities: Hollis Reservoir, Cumaca River, Madamas River, Matura River. At various localities dolomite appears to occur. Furrer (1965) has suggested the presence of volcanic material at Brasso Seco in one of the writer's samples.

The only dated fossil locality is the Hollis Damsite where Hutchison (1938) found the Tithonian ammonite, *Virgatosphinctes* cf. *V. transitorius* (Oppel) (Spath 1939). The fossils were in phyllites associated with limestones. Kugler (1959) and Barr (1963) assume that this fossil horizon lies at the top of the Rio Seco Formation. Although the writer has mapped a completely different structural situation in which the Cuare locality appears to be an isolated anticlinal feature surrounded by Grande Rivière Formation, the stratigraphic position of the ammonite bearing horizon appears to be the same, i.e. at the top of the Rio Seco Formation.

Furrer (1965) has examined thin sections of limestones in the Northern Range including many from the writer. He concludes that, apart from the dolomites, they are all echinoid limestones and suggests a general Upper Jurassic to Lower Cretaceous age. One of the most interesting points is that these samples came not only from the Aripo, Oropouche, Rio Seco main outcrop area, but also from Brasso Seco and Madamas River, and most importantly from the northern outcrop extending from Grande Rivière to Paria River.

This northern outcrop area was shown as Toco Formation on Kugler's 1959 map. The writer found these rocks indistinguishable from the Rio Seco Formation outcrops in the type area, found them lying below Galera Formation and apparently below Grande Rivière Formation, and has therefore mapped them as Rio Seco Formation. Furrer's findings confirm this identification, but as yet no definite fossil locality has been found in this outcrop area.

Observations of stratigraphic contact between Rio Seco Formation and Maracas Formation are difficult to find. However, in the Arima, Guanapo, Platanal and Matura Valleys this relationship appears to be approximately concordant.

Thicknesses are difficult to measure because of tight folding. On the Arima River a thickness of 1,220 feet of Rio Seco Formation can be measured and allowing for faulting the outcrop pattern suggests a thickness of about 1,500 feet, but this appears to increase to about 2,500 feet on the Oropouche River.

Grande Rivière Formation

This Formation was described by Barr in a thesis (1953) and published (1963). The type section is on the Grande Rivière, but access to this stream is difficult. The formation consists chiefly of unfossiliferous monotonous non-calcareous slates and phyllites. There are occasional spotted phyllites. Interbedded schistose grits and quartzites both bedded and massive form prominent topographic features. These beds are characterised by complex isoclinal folding and thickness is difficult to estimate. At this time the writer is unable to measure a stratigraphic thickness greater than approximately 3,000 feet.

The Balandra Grit has been described by Barr as the basal member of the formation. These schistose grits can be recognised in the eastern part of the area, but grain size appears to decrease towards the west, and the member appears to be missing in a number of places.

Although a regional unconformity may well separate the underlying Rio Seco Formation and the Grande Rivière Formation, the junction between the two appears to be approximately conformable at a number of scattered localities.

Galera Formation

This formation was described by Barr (1963) with the type locality at Galera Point, the north eastern tip of Trinidad. Intense folding makes measurement of thickness difficult; in the area now discussed only about 1,500 feet of section can be clearly recognised. The formation consists of non-calcareous dark grey shales, occasionally silty and quartzitic sandstones ranging in grain size from coarse to very fine. In the lower part of the section sandstones predominate while the upper part is almost wholly shale.

Bolli (unpublished) recognised microfaunas of Senonian to Maestrichtian age in the Toco area. Saunders has identified the same faunas from the writer's samples along the north coast between Grande Rivière and Blanchisseuse.

A change in lithology occurs in the Grand Matelot area. Here the bedded quartzitic sandstones of the lower to middle part of the formation are replaced by a rhythmically banded (2 inches) sequence of quartzites, cherts and phyllites. Between 300 feet and 500 feet of this succession appears to be present. Nearby on the Petite Rivière is a section of massive uniform light grey micaceous mudstone. Tentatively this rock appears to have been leached mudstone. The cherty beds of Grand Matelot resemble the bedded cherts of the San Antonio Formation of Eastern Venezuela.

The metamorphism of the Galera Formation appears incipient only, except in the north western part of the area where schistose grits and spotted phyllites occur, very similar to the lithology of the Grande Rivière Formation.

The base of the Galera Formation appears to lie more or less conformably on the top of the Rio Seco Formation. However, the situation is complicated by the fact that the basal part of the Galera Formation is usually a sandstone, while the upper part of the Rio Seco Formation is calcareous phyllite with many minor structures which do not effect the thick overlying Galera sandstones. The top of the Galera Formation is not seen.

The field relations between the Galera and Grande Rivière Formations require elaboration. South of Grande Rivière Barr suggested that the Galera Formation on the north might lie unconformably on the Grande Rivière Formation to the south. Mapping indicates that the quartzites mapped by Barr as Grande Rivière Formation can be traced into the Galera Formation further west, on the Homard and Shark Rivers. The whole outcrop area appears to be Galera Formation lying on the north side of an outcrop of Rio Seco Formation. On the south side of the anticlinal outcrop of Rio Seco Formation the main outcrop of Grande Rivière Formation occurs.

Based therefore on field relationships and lithological similarity the writer suggests that the Grande Rivière Formation may be the equivalent of the Galera Formation at a higher grade of metamorphism. In fact at Chupara Point part of the Galera Formation outcrop reaches as high a metamorphic grade as the Grande Rivière Formation to the south. Whether the lack of microfossil evidence in the Grande Rivière Formation is due to destruction by metamorphism or to unfavourable environment is not yet clear. At this preliminary stage the outcrop areas of the Galera and Grande Rivière Formations have been lettered separately on the enclosed map.

STRUCTURE

The general structure of the eastern part of the Northern Range is anticlinal with the Maracas Formation occupying the core of the Range and Rio Seco and Grande Rivière Formations distributed to north and south. The axis of the structure lies east-west and the gentle eastward plunge of about 3° appears to continue over the whole twenty miles of the mapped area. The whole Maracas Formation outcrop is one south dipping limb with dip probably steepening southward. There is no north flank; the Brasso Seco Fault has downthrown the rocks to the north bringing Rio Seco and Grande Rivière Formations in fault contact against the Maracas Formation.

A second anticlinal feature lies about 4 miles north of the main structure and parallel to it. Presumed Rio Seco Formation is exposed in the core of this structure between the Grande Rivière and Paria Rivers.

One of the most interesting results of this mapping has been the delineation of universal isoclinal folding in the Rio Seco, Grande Rivière and Galera Formations. This has emphasised the marked difference in structural style between the Maracas Formation and the lower part of the Rio Seco Formation on the one hand, and on the other, the upper part of the Rio Seco Formation, the Grande Rivière Formation and the Galera Formation.

The Maracas and lower Rio Seco outcrops dip southward at low angles, rarely more than 30°. There is some tendency for the dip to increase southwards. Minor recumbent folds are widespread and all show movement of the upper beds southwards, i.e. down the regional dip. Slumping southwards can also be seen in these beds.

At first these minor folds were assumed to be drag

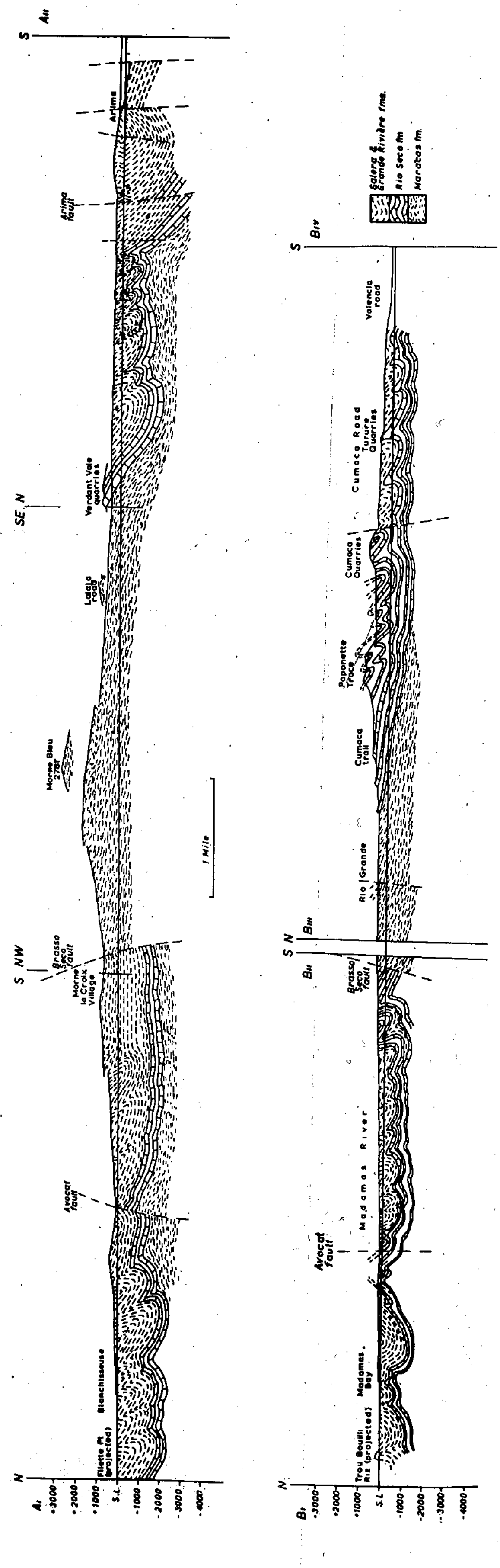

Fig. 1: Cross-Sections of the Northern Range of Trinidad.

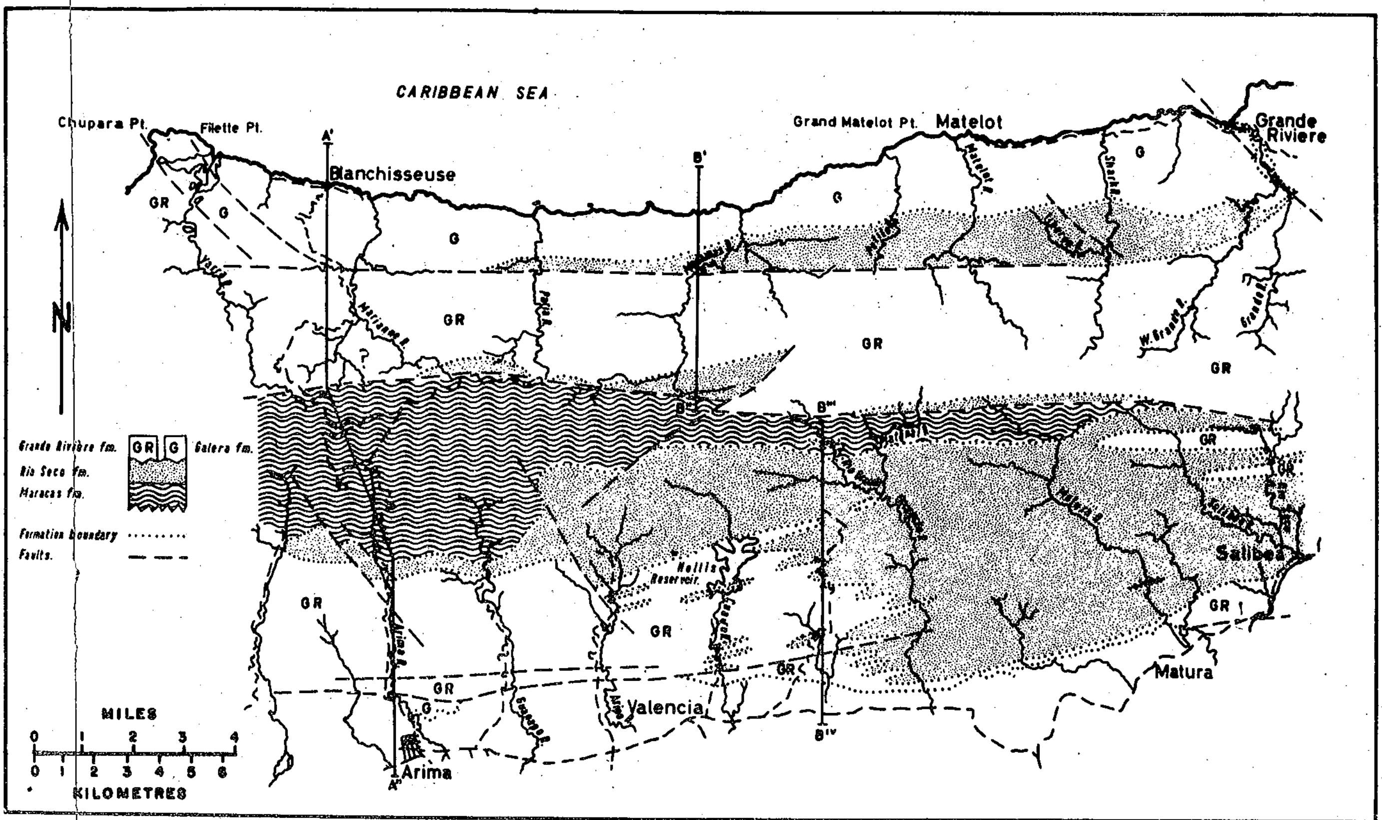

Fig. 2: Geological Map of the Eastern Part of the Northern Range of Trinidad.

folds, and various tectonic hypotheses were examined to explain the apparent inverted position of the beds. But in any case the few sedimentary indications of succession contradicted this overturning. Now the writer suggests that these folds, together with associated flat cleavages reflect an episode when younger beds in and over the Maracas Formation moved southwards, possibly sliding under gravity.

South of the flat lying Maracas core is a zone where the Rio Seco limestones in the Matura-Platanal-Aripo area are folded in a series of steep to overturned, often isoclinal, folds. Axial planes dip steeply south southeast. But the northernmost (lowest) limestones of the Rio Seco Formation in the Aripo and Platanal areas do not appear to be folded like this; they dip gently southwards like the underlying Maracas Formation. It is suggested, therefore, that there may be a plane of décollement within the Rio Seco Formation. At this time the identity of the different limestone bands has not been established. It is possible that in Platanal, etc., we are seeing both limestones in place, and the same beds which have slid southwards off the core of the Range. The gypsum horizon occurring in northwest Trinidad and the Paria Peninsula in beds more or less equivalent to the Rio Seco Formation, has not been observed in the eastern part of the Northern Range. But if it had been present it might well have provided a sliding plane.

South of the Platanal trend folding becomes isoclinal especially in the Grande Rivière Formation. Axial planes dip steeply south southeast. There seems to be some tendency for axial planes to dip more steeply in the southern part of the area.

On the accompanying sections it has been assumed that the isoclinal folds in the Grande Rivière Formation become more open downwards in the Rio Seco Formation, and that the uppermost limestones in the Oropouche-Platanal area have been folded on the unfolded lower limestones of the same formation. Both these assumptions may be revised.

North of the core of the Range, the Grande Rivière Formation is also isoclinally folded together with the Rio Seco Formation. Axial planes dip steeply south southeast here also. Mention has been made above of the relatively flat dipping area between the Marianne and Yarra Rivers, at Morne la Croix on the Blanchisseuse Road, where Maracas Formation may be present.

A change takes place in the Galera Formation in the north of the area. In the eastern part of this outcrop isoclinal folding on nearly vertical axial planes is dominant. In the western part of the Galera outcrop we see larger overturned folds with axial planes dipping steeply south southeast. This change in structural style may reflect the increase of metamorphism in the Galera Formation towards the west.

A number of faults can be recognized. The Brasso Seco Fault is the most important, bounding the Maracas Formation outcrop on the north and running across the whole mapped area from east to west. This fault was described as the Brasso Seco Thrust by Kugler (1959) and Barr (1962). However, it has been observed in various headwaters of the Marianne, Paria and Madamas Rivers and appears to be nearly vertical. Comparison must clearly be made with the El Pilar Fault, but there is no evidence for lateral movement of the Brasso Seco Fault. The vertical throw must be in the order of 5,000 feet at the western end of the mapped area, decreasing to the east and appearing as only a minor fault east of the Rio Seco.

The Avocat Fault appears as a marked E-W topographical feature between the Yarra and Matelot Rivers. However, on the Yarra River, although minor faulting can be mapped, alluvium hides the main fault. East of the Matelot River the fault appears to die out, and on the Shark River a normal contact between Rio Seco and Grande Rivière Formation can be seen. On the Madamas River the fault appears to be nearly vertical. This fault is downthrown to the south by an unknown amount at the east end, has very little throw on the Madamas River, and may be downthrown to the north on the Marianne River. It must be borne in mind that despite the topographic prominence of this feature, the fault, some 12 miles long, may be relatively minor, and it may have been emphasised by differential erosion of the calcareous phyllites of the Rio Seco Formation and the quartzitic sandstones of the Grande Rivière Formation.

The Arima Fault can be followed from the Arima Valley eastwards to the Oropuche River. On the Oropuche River, 1½ miles south of this, there are fault indications which may line up with faulting at Matura Point. Here at Matura Point there are good indications of wrench faulting on a trend of 080°. In steeply dipping shales and sandstones of the Grande Rivière Formation, the northern beds appear to have moved eastwards with reference to the southern beds. Similar evidence for lateral movement has been noted on small E-W faults in the Matelot area, not shown on the accompanying reduced map.

The Grande Rivière Fault (Barr 1963) separates relatively unmetamorphosed fossiliferous sediments from the metamorphic sequence described above. In the Grande Rivière Valley the writer maps the fault some 500 yds. south of the position shown on Barr's map. This is based on excellent outcrops near the junction of the West Grande Rivière with the main river, where bedded quartzitic sandstones of the Galera Formation are faulted against massive Zagaya limestone of the Toco Formation. A second parallel fault may lie along the east side of the Grande Rivière Valley.

Faulting has been observed at Chupara Point and at Verdant Vale in the Arima Valley, but these occurrences do not appear to line up as the Chupara Fault mapped by Kugler (1959). At Chupara Point the faults can be seen to dip southwest at 50° and the throws appear to be normal.

At least two small wrench faults can be seen at Verdant Vale, and one spectacular faulted cliff appears above the western side of the Arima Valley. The outcrop west of the valley is much broader than that east of the Arima River, but this is not entirely caused by wrench faulting. Lithological comparison of the limestones across the valley suggest that the upper dark coloured bedded limestone is continuous across the valley, while the lower white recrystallised limestone has disappeared to the east, presumably by some type of bedding plane slip not easily recognised.

Cutting across the highest and least accessible part of the Northern Range from the headwaters of the Aripo River to the headwaters of the Madamas River there is a NE-SW topographic feature that appears to fault the outcrops of Rio Seco Formation. This has been shown on the attached map as a wrench fault complimentary to the usual Los Bajos trending faults. But exposures of this fault have not been found in this high rain forest, and one should perhaps keep in mind the possibility of a northwest dipping thrust cutting across the Range from the Madamas River, through the Aripo area, to the Arima Valley at Verdant Vale, which would explain detailed changes in limestone sections on a tectonic basis. The possibility of a sliding hypothesis has already been mentioned.

A general comment on the structure of the area is one of surprise that folding appears to be more important than faulting in drawing the outlines of the Northern Range here. A vertical throw of 5,000 feet on the Brasso Seco Fault, without any evidence of lateral movement, is in line with evidence for similar movement in the southern boundary fault of the Northern Range in the Port-of-Spain area. The dating of lateral movement on E-W faults at Matura and Matelot is unsure, because it lies within the Caribbean Series itself. Certainly the Pliocene-Pleistocene gravel fans at the mouths of the rivers in the Northern Range show no evidence for lateral movements since, say, late Pliocene time.

The metamorphism of the Northern Range is not discussed now. The relative age of folding in the Maracas Formation and in the younger beds will be investigated, together with other questions in this fascinating and complicated area.

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VI CONFERENCIA GEOLOGICA DEL CARIBE – MARGARITA, VENEZUELA
MEMORIAS 1972

COMMENTS ON THE GEOLOGY OF NORTHWESTERN TRINIDAD IN RELATION TO THE GEOLOGY OF PARIA, VENEZUELA

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ABSTRACT

Field mapping in the northwestern peninsula of Trinidad has led to the preparation of a revised stratigraphic column and to the recognition of alpine style recumbent fold nappes. Diagrammatic cross sections are presented showing variations in this structural style. Palaeocurrent evidence suggests that sediments forming the Caribbean Group came from the north. The paleo-geographical implications of this are discussed in relation to the geology of northeastern Venezuela. Polyphase folding is briefly described and it is hoped to correlate the phases with similar folding in Venezuela.

INTRODUCTION

As field mapping in the Northern Range of Trinidad has now reached the western end of the range, it is believed that some of the features mapped, and general conclusions reached, may have interest for those geologists working in northeastern Venezuela, and to those members of A.V.G.M.P. who visited the Northern Range in 1969.

Briefly, the mapping has led to a revised stratigraphic column for the Caribbean Group, as measured in the Port of Spain, Maraval, Maracas Bay areas. It has also led to the recognition of Alpine style recumbent folding on a large scale. Nappes are hypothesised, although the boundaries of such nappes cannot be recognised. The larger scale significance of some palaeocurrent observations involves ideas about the origins of the Caribbean area.

STRATIGRAPHY

The revised stratigraphic column for the Port of Spain area is shown in Fig. 1. The Maraval Formation is now seen to be the oldest formation in the area. It consists of recrystallised limestones and marbles at least 400 m thick; the base of the Maraval Formation is not seen in the northwest of Trinidad.

The Maracas Formation overlies the Maraval limestones without any apparent unconformity and with some evidence of a transitional boundary. It consists of approximately 1500 m. of interbedded slates, schists and quartzites, together with more massive quartzite beds. In character the Maracas Formation appears to be flysch and the major part of the formation seems to consist of turbidites. A bed of volcanic ash occurs in this formation and other horizons seem to include ash components.

The Chancellor Formation overlies the Maracas quartzites without any apparent unconformity and with some evidence of a transitional boundary. It consists of approximately 500 m. of thin recrystallised limestones interbedded with non-calcareous and calcareous phyllites, slates, and quartzites. At some horizons bedded limestones become predominant. It is supposed that the Chancellor Formation consists partly of calcareous flysch, probably proximal turbidites and partly of near-shelf carbonates.

Unconformably on the Chancellor Formation are beds of shales, wildflysch and sandstones which are thought to be equivalent to

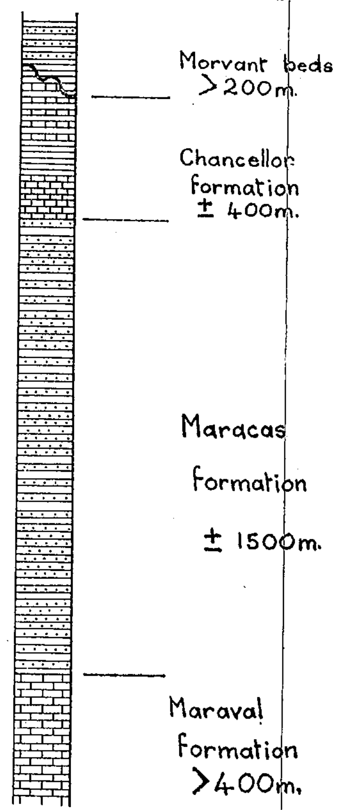

Figure 1.–Generalized Stratigraphic column of the Caribbean Group in the Port of Spain area.

(1) University of London, King's College, England.

the Galera Formation, described in the Toco area (BARR, 1963). These beds have been described provisionally as Morvant beds.

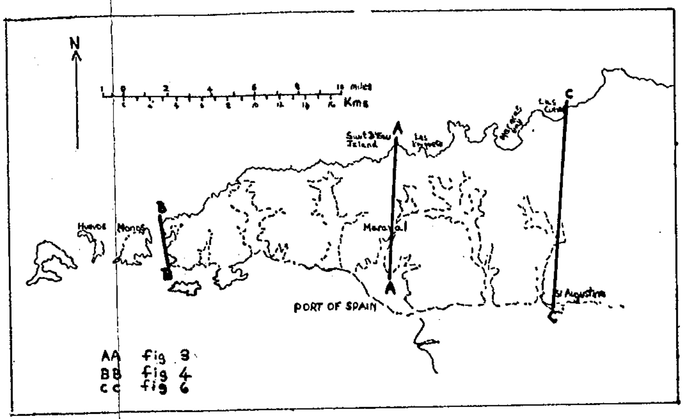

Figure 2.—Location Map of diagramatic Cross-Sections.

STRUCTURE

The structure of the western part of the Northern Range is that of an anticline overturned to the north. The south flank is relatively steep and has a number of subsidiary folds. The north flank is overturned to the north, and is essentially recumbent. Generally the dip becomes more recumbent northwards. This leads to the supposition that in the northern part of the mountains the exposed rocks must be allochthonous and must have moved as a nappe. Unfortunately the autochthon cannot be seen in the northwestern part of Trinidad.

A diagrammatic cross section from north to south across the Northern Range in the Saut D'Eau Island, Maraval, Port of Spain area is shown in Fig. 3, which illustrates the general description in the preceding paragraph.

thrown to the south cuts the structure in Teteron Bay and it is believed that this fault has been traced northwestwards across the Boca de Monos into the island of Monos. The effect of the fault is to reduce the width of outcrop of the Maracas Formation in the upright limb. On the south coast the limestones, phyllites and quartzites of the Chancellor Formation are well exposed at Delgada Point.

At the north coast, in the base of the vertical cliffs at Entrada Point, a number of thin limestones appear. They also occur in the next, un-named, point. It is suggested that these beds represent the basal part of the Chancellor Formation in the overturned limb of the structure.

An interesting and unexpected development in structural style occurs in Las Cuevas area where a large exposure by the North Road (map reference 758922) contains the features diagrammatically illustrated in Fig. 5. The section consists of interbedded quartzites and graphitic schists of the Maracas Formation. The relationship between graded bedding, minor structures, and axial plane cleavage (not shown on the diagram) indicates that the exposure is that of the inverted limb of a fold system with south dipping axial surfaces overturned to the south as in Fig. 6. Further examination of the Abercromby Point area and the exposures south of Las Cuevas revealed that in fact the overturning to the north prevailed, but at Las Cuevas the toe of the overturned recumbent fold had been downbent above a thrust as shown in Fig. 6.

North of the thrust the overturned beds of the Maracas Formation continue under the axis of the fold, therefore the downbent anticlinal closure at Las Cuevas is a feature of somewhat restricted size. However it does illustrate the kind of folding that occurs in the Caribbean Group of the Northern Range of Trinidad. If the south end of the diagrammatic cross section shown in Fig. 6 can be diverted slightly to run through St Augustine we see an interesting variation. Here the beds of the Chancellor Formation dip steeply northwards but "young" to the south i.e. they are overturned to

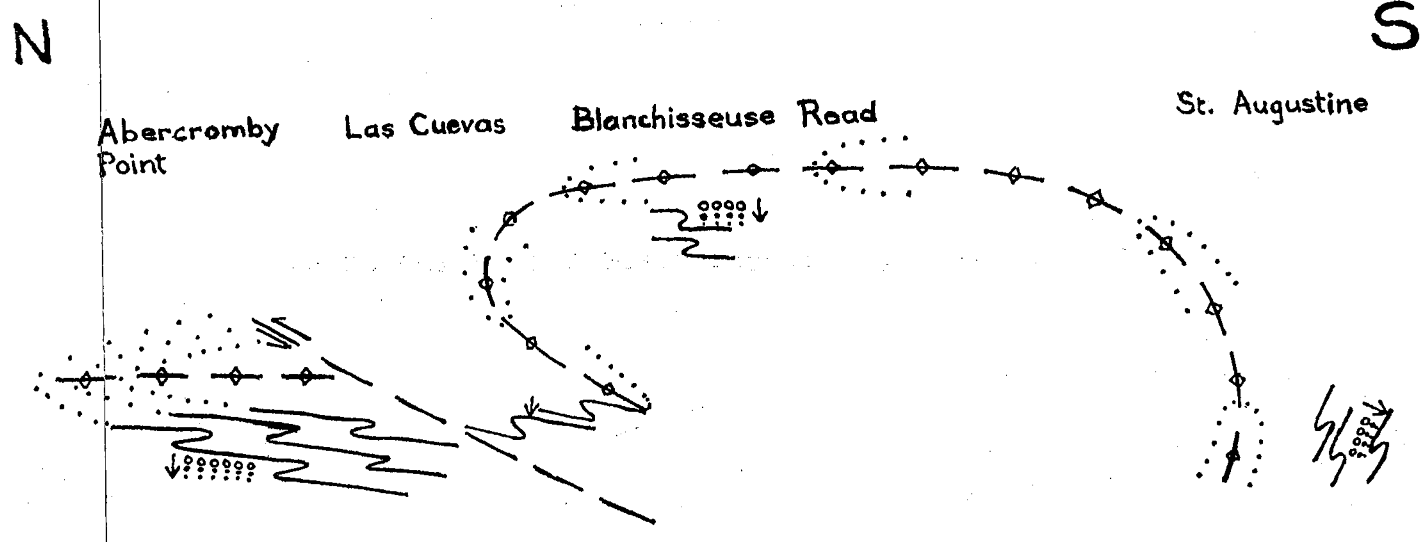

Figure 3.—Diagrammatic cross section AA.

The structure at the western end of the northwestern peninsula is somewhat different. This is shown in Fig. 4. The core of Maraval marbles has now disappeared, either because of a general plunge to the west, or because of increased thrusting from the south. In view of the broad outcrop of recumbent overturned north flank from Teteron Bay through Scotland Bay to Entrada Point the thrusting hypothesis does not seem very likely, and it is believed that the plunge of the main anticline has been mapped successfully. A fault down-

the south. However as we go northwards we find that they become vertical and then turn over to a normal south dipping section. It is suggested that this change in overturning is part of the evidence that these great recumbent folds formed under gravity gliding conditions following either uplift along a line more or less where the southern edge of the Northern Range is now, or underthrusting of oceanic crust from the north at the edge of the continental crust in the same place.

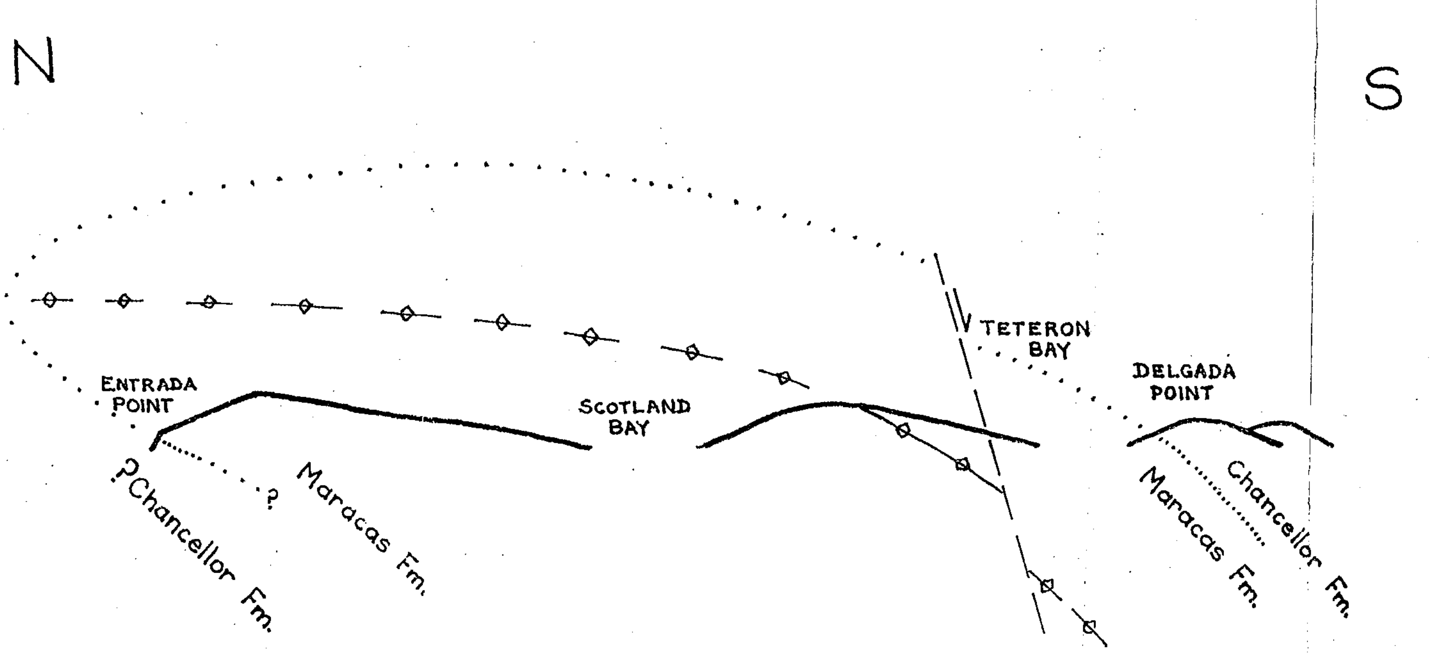

Figure 4.—Diagrammatic cross section BB

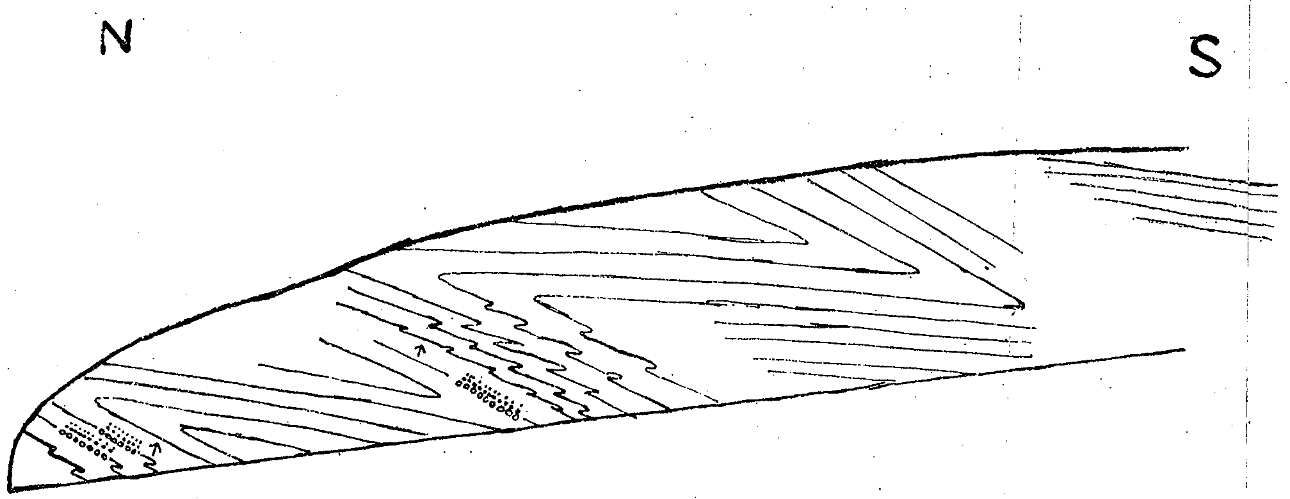

Figure 5.—Sketch of Maracas Formation exposure in North Coast Road near Las Cuevas.

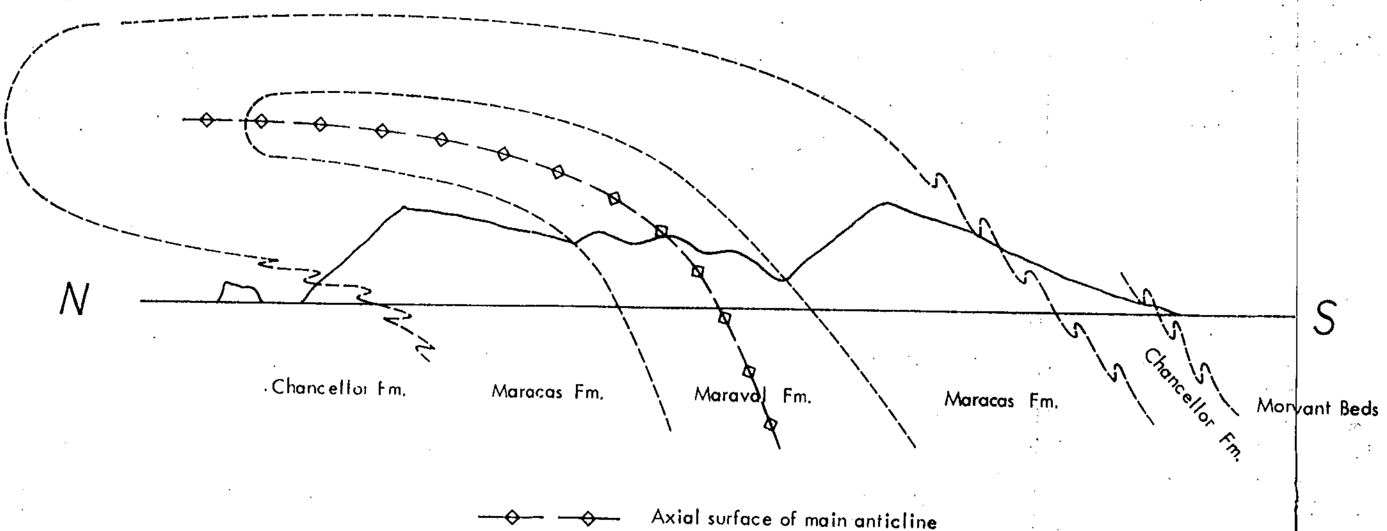

Figure 6.—Diagrammatic cross section CC.

HISTORY OF FOLDING

Different phases of folding have been recognised in northwestern Trinidad. The first folds are associated with the major recumbent fold nappes, axes are more or less E–W. However many of these folds are seen to be refolded on more or less parallel axes in a second phase. Following this there are a number of later folds on N–S axes. Finally the calcareous sediments of the Chancellor Formation, and the more argillaceous portions of the Maraval Formation, display near-surface gravity collapse structures that may be associated with decalcification of the calc-schists.

PALAEOGEOGRAPHY

A eugeosyncline developed on the site of the present Northern Range in Upper Jurassic to Lower Cretaceous times, together with a miogeosyncline in Lower Cretaceous times in central Trinidad. Both these basins may have started earlier, because we cannot see the bottom of either the Caribbean Group or the Cuche Formation. The trend of the eugeosyncline is not clear, although it might be expected to parallel the northern edge of the Guayana Shield, i.e. to be E-W or NW-SE. Some 2500 m. of sediments, largely flysch, were deposited in this trough.

The sediments might have been expected to have come from the Guayana Shield to the south, but in fact palaeocurrent evidence indicates that the sediments of the Maracas and Chancellor formations, including the ash bed, came from the north. It is possible that this material had originally been derived from the Guayana Shield and had been deposited to the north of the present Northern Range and then eroded and laid down in the developing trough, but it seems more likely that the source area itself lay to the north. It may have been part of the North American crust, or possibly a piece of Caribbean, continental crust which has been broken up and moved since Mesozoic times.

Following the filling up of the eugeosyncline with the deposition of the Chancellor Formation, there must have been relative elevation of the south flank of the basin, because large scale recumbent folding occurred, overturned to the north. This could also be explained by thrusting of the Caribbean oceanic plate under the edge of the Guayana continental plate. Following this elevation occurred and the Morvant beds, including wildflysch, were laid down unconformably on the older part of the Caribbean Group.

All this activity preceded the formation of the Antillean arc. Possibly the next phase of tight folding may have been contemporaneous with the beginning of the island arc and the development of the major faults which bound the uplifted block of the Northern Range. But the mountain structures as we see them today had already been formed.

CONCLUSION

The presence of Alpine-type recumbent folds and nappes in the Northern Range suggests that similar structures may be present in the Peninsula of Paria. The general plunge to the west in northwestern Trinidad indicates that major faulting must occur in the Dragon's Mouth. The presence of several phases of folding in Trinidad leads to the hope that similar phases can be recognised in Paria and correlated with Trinidad.

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Abstracts

ACADEMIA

PRAGUE 1968

X

Carpathians and perhaps longitudinally replaced. At the same time the sea transgressed farther into the Bohemian Massif, where the Carpathian Foredeep began to form. It was filled by molasse beds showing especially in the marginal parts some platform signs. During the Miocene the foredeep was gradually displaced towards the Bohemian Massif.

Tectonic Denudation as Exemplified by the Heart Mountain Fault, Wyoming

William G. Pierce

U.S.A.

Tectonic denudation, sometimes improperly called a pull-apart, is used here for the process of laying bare a segment of the earth by tectonic movement. It is rare, but where found determines important principles for the mechanics of the associated faulting; for example, tectonic denudation is not compatible with a thrust produced primarily by a push from the rear.

The Heart Mountain fault, on the east side of the Rocky Mountain front in northwest Wyoming, produced a surface of tectonic denudation over 50 km in length, measured in the direction of upper plate movement, with many scattered blocks of the upper plate resting upon it. That fault, which extends for 100 km in the direction of movement, had horizontal movement of the frontal beds of about 50 km. Although the slope on which movement took place is very low, probably less than 3 degrees, movement of the upper plate and the tectonic denudation accompanying it must have been extremely rapid. Near the close of the early Eocene, 450 to 750 m of strata, mostly Paleozoic carbonates, were tectonically removed. Immediately after denudation, volcanic rocks blanketed the area and entombed the denuded surfaces.

Tectonic denudation by the Heart Mountain fault occurred at a single stratigraphic horizon, about 2 m above the base of the Ordovician Bighorn Dolomite. The surface of tectonic denudation has been preserved by a widespread blanket of lower Tertiary andesitic volcanic rock, mostly breccia, which is only now being removed by erosion. The contact between volcanics and the tectonic surface is sharp, the strata below are not brecciated, and locally a thin veneer of carbonate fault breccia remains on the tectonic surface on which the volcanics were deposited. In a number of places some of this comminuted limestone breccia and rock flour has been injected as limestone dikes in the basal part of the volcanic rocks.

Faulting in the Northern Range of Trinidad

H. C. Potter

United Kingdom

Geophysical work at sea led to the formulation of theories on the formation of Island Arcs. One of the factors in discussion of the West Indian Island Arc has been the possibility of wrench faults with large displacement on both the North and South flanks of this Arc. Much of the literature has been theoretical, and very little field mapping has been done. Recent mapping in the Northern Range of Trinidad has provided data for examining possible movement on El Pilar Fault. There is good evidence for vertical movement of up to 6000 feet on this fault and on the Brasso Seco Fault; but no evidence for lateral movement. In addition lateral movement since late Pliocene time is not suggested by the positions of buried Plio-Pleistocene alluvial fans. Evidence for lateral movement has been found in the Matura and Matelot areas.

Observations on the Laventille Formation, Trinidad

by

Henry Clifford Potter, London

With 2 Figures

ABSTRACT

Based on field mapping it is suggested that the Laventille limestones outcrops represent discrete carbonate platforms or reefs lying within the upper part of the predominantly shale Laventille formation. A zone of penecontemporaneous disturbance is described in the eastern part of the Laventille Limestone outcrop. Correlation of the Laventille formation with the metamorphic Chancellor formation is suggested.

Introduction

Since Wall and Sawkins (1860) noted the difference between the 'crystalline limestones contained in the slates' of the Northern Range, and the 'compact limestones, either quite unconnected with the schistose group, or only associated with its upper strata' in the Laventille Hills, there has been considerable interest in these rocks. A detailed bibliography is not attempted, Liddle (1928) raised them to formation status. Kugler (1953) included the Patos conglomerate in the Laventille formation, and also (1959) included some of the phyllitic shales along the southern margin of the Northern Range between Port of Spain and Arima.

Field mapping has recently been carried out in northwestern Trinidad and an account of some of the exposures of the Laventille formation may be of interest especially since most observers have concentrated particularly on the palaeontology of these rocks.

The map, Figure 1 is based on the Trinidad 1:25,000 topographic sheet 13, of 1970. Map references are given on the international metric grid.

Lithofacies Distribution

The Laventille formation as mapped by Kugler (1959) consists of two different lithofacies. The Laventille limestone is a succession of bedded to massive limestones with subsidiary interbedded phyllitic shales, while the rest of the Laventille formation consists of phyllitic shales with a few thin bands of limestone and a few thin quartzites. The boundary between the two is clear and sharp and can be mapped around the Laventille Hills (Fig. 1).

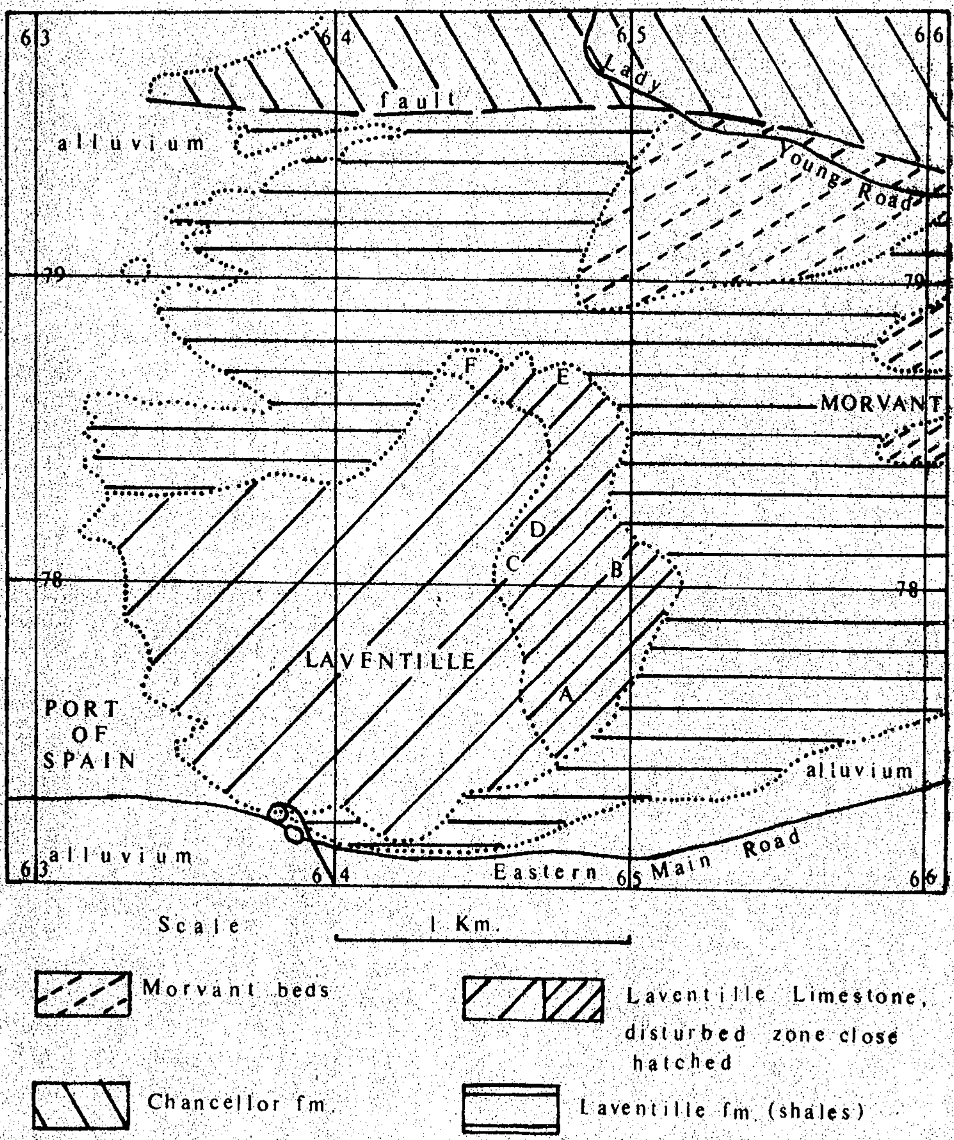

Fig. 1. Geological map of Laventille area showing disturbed zone in Laventille limestone and quarries A–F described in text.

From Laventille eastwards the formation is predominantly shale, although at a few localities limestones up to a few metres thick occur, as well as occasional beds of quartzites and a few small exposures of gypsum and anhydrite. Westward from Laventille the only exposures are on the islands of Gaspar Grande, Gasparillo, Carrera, Cronstadt, the Five Islands, Patos in Venezuela, and on the peninsula of Pointe Gourde. These western exposures are massive limestones with only subsidiary shales.

It may have been assumed that the islands to the west represent only the exposed peaks of an overall limestone development that stretches all the way from Laventille to Patos. But the sharp boundary between the limestones and shales in the Laventille area can be used as a model, and the flat sea floor around the islands suggests that most of that sea floor covers shales. The vertical edges of all the limestone islands suggests that some erosion has taken place, but it may not have been great, limestone debris seems rather limited in area. This may not have been true of the present sea floor between Gaspar Grande and Pointe Gourde. But it is suggested that in general the extent of the present islands represents the extent of the original limestones, allowing for some erosion.

The isolated plates or blocks of limestone at Laventille and in the islands' area could have had either a stratigraphic or a tectonic origin. They could be reefs or platform carbonates developed locally within the Laventille formation, they could be in unconformable contact with that formation, they could be klippen or they could be wildflysch blocks. A suggested origin will be discussed below.

Structure

Most of the previous work on the Laventille formation has been palaeontological in nature, concerned with the age and correlation of the beds, however one structural study was carried out by I. RUMSEY and P. VERRALL. Although the work is unpublished the results were shown by KUGLER (1959) in the Geological Map of Trinidad. The structure of the Laventille quarries area was interpreted as a NNE plunging syncline with parallel subsidiary folds. The limestone was shown as faulted against shales to the north and to the east. Other minor faults and subsidiary folds on other axes were also mapped by these workers.

The general synclinal nature of the limestone outcrop and the subsidiary folding are confirmed by recent mapping in the area. However although there is abundant evidence for minor faulting, the writer has not been able to confirm the presence of major faulting bounding the limestones to the north and east. To the south and east the limestones form an inward dipping scarp overlying the thick shales of the formation. To the west there appears to be an erosional edge and the limestones are bounded by alluvium. However to the north although faulting is involved, the edge of the limestones is much more complicated than that to be expected by simple bounding fault. There is a zone of interdigitation of carbonate and shale which will be discussed below.

On the whole the Laventille quarries area seems to represent, at least in the upper limestones, a crumpled saucer-like synclinal feature, with the major axes trending NE.

On the Western Islands and Pointe Gourde the structures in the limestones appear to be rather open folds on axes trending approximately ENE. As might by expected folding in the interbedded (and underlying) shales is more intense than in the limestones. In general folding on the islands and Pointe Gourde seems similar to the folding seen in the Laventille area.

To the east of Laventille folding is intense in the predominantly shale part of the formation. Overturning to the north can be seen in the folded exposures along Riverside Road, east of St. Joseph. It is assumed that the difference in folding between the limestone areas and the shale areas is due simply to the competent nature of the limestones.

On Figure 1 Morvant beds are shown as a number of synclines lying on the Laventille formation. This series of shales and sandstones is thought to be equivalent to the Galera formation. It appears to lie unconformably on the Chancellor formation (POTTER 1973) and also appears to lie unconformably on the Laventille formation.

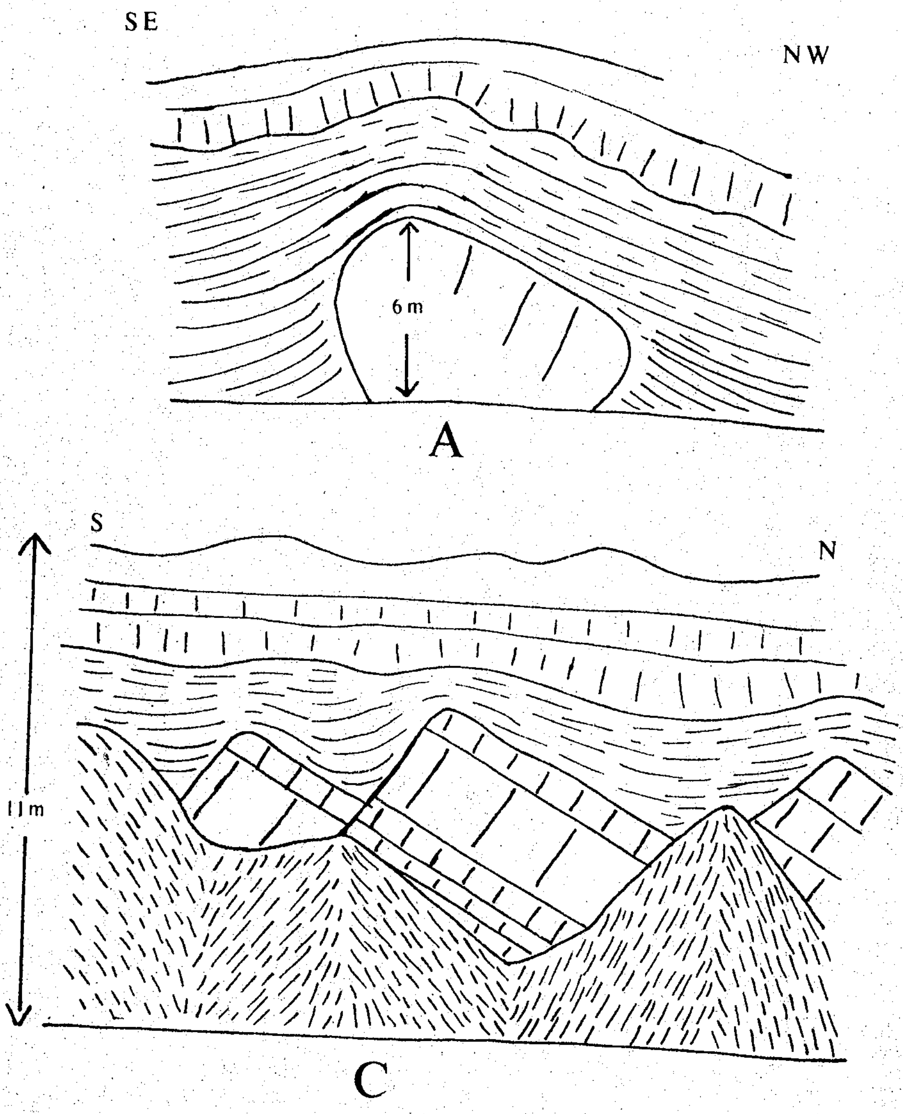

Fig. 2. Sketches of quarries in the Laventille area.
A Isolated limestone block lying in draped shale under an upper limestone.
C Faulted limestones under draped shales covered by unfaulted upper limestones.
Locations shown in Figure 1.

In the northern and eastern exposures of the Laventille limestone in the Laventille area the phenomena illustrated in Figure 2 are seen in six separated quarries.

In Quarry A at 648776 a block of massive recrystallised limestone without any obvious internal features except joints, lies in a section of weathered phyllitic shales. The block is some 6 m high and the shales 8 to 9 m thick. Overlying the shales is some 2 m of bedded limestone, thickening irregularly to the northeast. The shales are draped over the block, and to the North contain an increasing proportion of thin limestones. This is not a single block; several of the surrounding quarries show similar ones.

At B (649780) approximately 5 m of bedded limestones, jointed and partly boudinised lie in a fossiliferous shale succession. This appears to be a faulted block with unfaulted shales draped over it. Some 100 m to the East there is a similar exposure in which shales are draped over disturbed and tilted limestones, however here some of the phenomena could be due to hill creep, which is not so at B.

C is a large exposure at 646781 and contains a series of bedded limestones repeatedly faulted down to the southwest and tilted to the northeast, with unfaulted shales lying draped over them. The shales are overlain by 1.5 to 3 m relatively flat cavernous rubbly chalky limestone which also caps surrounding quarries.

Some 150 m to the northeast, at D (647782) the lower limestones appear to be faulted in the same way as in C, but the overlying shales have given way to thinly bedded limestones and shales which lie irregularly, and apparently draped over the lower limestones. The upper part of this exposure was inaccessible.

In the northeastern corner of the Laventille limestone outcrop at E (648787) approximately 8 m of bedded limestones lie conformably on phyllitic shales, and are overlain apparently unconformably by 3 m contorted purple shales which are themselves overlain with apparent conformity by approximately 6 m cavernous chalky rubbly limestone. The 'unconformity' here could be interpreted as a flat fault.

Finally at F, the northernmost limestone exposure in the Gonzalez quarries (644787) lilac to purple shales and white to red rubbly chalky limestones are faulted twice against two 12 m blocks of bedded to massive limestone. The dip here is southeast and the faults appear to be downthrown to the northwest, i.e. at right angles to the throw in quarry C.

Finally having described these six disturbed quarries it must be remembered that a few hundred metres west of them there are a number of large quarries in thick limestone sections without appreciable shales, in which only conformable bedding can be seen. These thick massive limestones form the core of the Laventille Hills.

These disturbed exposures cannot be explained by hill creep, because the faulted blocks are capped not only by draped shales, but also by bedded limestones. At first it was thought that there might be a thrust or flat slide and indeed there is evidence for some tectonic movement in the shales. However the spatial relationships between the quarries does not seem to fit such a feature.

The 'unconformity' cannot be of a regional character because it seems to be confined to a narrow zone. Moreover SAUNDERS (1971) reports that the same Lower Cretaceous microfauna occurs in the shales associated with the quarry limestones as in the phyllitic shales north of the limestone mass.

Taking into account the shape of the limestone area, and the position of the disturbed zone along the edge of the limestones we can look for a stratigraphic explanation.

It is noticeable that the disturbed zone coincides with a zone of remarkable increase in limestone content in the Laventille formation, from east to west. It is suggested that this was the edge of a platform or reef which stood above the muddy sea floor to the east, and that frontal blocks cambered and slid forward, along a zone akin to a fore-reef debris zone.

The platform continued to control carbonate deposition for some time as shown by variations in the upper shales, but finally shallow seas prevailed overall, with the deposition of the upper limestone. Thus a stratigraphic origin is suggested for the Laventille Hills limestone mass, and by inference for the western limestones too. But it may be that the smaller islands are either slip masses or faulted blocks, especially an island like Gasparillo near the major fault zone. There is still a possibility that the lower limestones are considerably older than the rest of the Laventille formation. They are more recrystallised than the upper limestones, and they could lie under younger shales. But this is not too likely – in the southernmost quarries, phyllitic shales like those in the rest of the Laventille formation underlie what appears to be the lowest limestone.

Correlation

Mapping in the area has not provided any clear insight into the age of the Laventille formation or the correlation with neighbouring rocks. However it is noticeable that north of the Laventille Hills it is not possible to distinguish between the phyllitic shales of the Laventille formation and the phyllites of the Chancellor formation (Potter 1973). In fact one of Saunders' (1971) Lower Cretaceous samples appears to lie north of the major fault, in the Chancellor formation.

It may be reasonable therefore to accept Saunders' (1971) suggestion that the Laventille formation is the age equivalent of the Toco formation and of the Guinimita formation of Paria (Gonzalez de Juana 1968) and to extend this correlation to the somewhat more metamorphosed Chancellor formation of the Northern Range, which occupies a similar structural position to the Guinimita formation. In passing one notes that Gonzalez de Juana (1968) considers the Patos limestone to be a reefal development within the Guinimita formation and the Patos conglomerate, a reef talus. The limestones of the Chancellor formation are usually thinly bedded, but at one locality on the Lady Chancellor Road near Port of Spain a reefal mound is exposed. In the southern bays of Monos Island polygenetic conglomerates with quartzite and limestone components are developed in the Chancellor formation, interbedded with and penetrated by limestones. These conglomerates resemble those of the Guinimita formation and the Patos conglomerate and support the correlation suggested above

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LEGEND

a Alluvium

t Terraces(Quaternary?)

5 Morvant beds

3 Chancellor formation

3-4 Laventille, 4 Limestone } Laventille formation

2 Maracas formation

Dragon Gneiss

1 Maraval formation

20 Attitude of bedding without evidence of sequence

20 Attitude of upward facing bedding

20 Attitude of overturned bedding

Axial surface of major anticline on sections

20 Axis and plunge of minor fold with direction of facing

THE PLUNGE OF MINOR FOLDS IN THE WESTERN PART OF THE NORTHERN RANGE OF TRINIDAD

Minor folds have been recorded and a selection of these have been plotted on the accompanying 1 : 25,000 geological maps. It is difficult to comprehend the overall pattern of the minor folds from the maps themselves, and therefore all the fold axes have been plotted on seven equal-area projections corresponding to the seven areas shown on the location map, fig. 1.

The areas are as follows:

1. The western islands and the western end of the Peninsula including Scotland and Teteron Bay.
2. The Northwestern Peninsula from area 1 to the Diego Martin valley.
3. The overturned northern flank of the Santa Cruz Anticline from the Diego Martin valley to La Vache Bay and the Santa Cruz valley.
4. The overturned northern flank of the Santa Cruz Anticline East of the Santa Cruz valley.
5. The south flank of the Santa Cruz Anticline between the Diego Martin valley and the Santa Cruz valley.
6. The south flank of the Santa Cruz Anticline to East of the Santa Cruz valley.
7. The outcrop of the Laventille formation from the Laventille Hills to St. Joseph.

The projections have not been contoured because the numbers of folds vary greatly between different areas and it seems preferable to present the data unvarnished.

AREA 1

A western plunge has been proposed because the axis of the recumbent Monos Anticline occurs high in the cliffs at Monos but lies out to sea north of Chacachacare and Huevos. But this is not evidence of a true plunge and could be explained by a northwestern trend of the axis.

In fig. 2 65 minor fold axes have been plotted. The overturned data from the northeastern corner of Monos and Scotland Bay are shown separately. There is no evidence for a northwestern trend - in fact there appears to be a clear ENE - WSW trend. Although the axes are distributed on opposite sides of the projection, there does seem to be an overall plunge of perhaps 10° to the WSW.

There is a difference between the normal limb which shows WSW plunge fairly clearly, and the overturned limb in which there is a suggestion of a plunge to the East. Of course all the overturned data come from the eastern boundary of the area and may have been affected by the Morris Bay Fault.

A few folds plunge gently to the south and south east, and may represent the later warping noted elsewhere.

AREA 2

In the Northwestern Peninsula itself a western plunge had been indicated by the outcrop of the Maraval formation on the Green Hill Anticline, as well as by the disappearance of the Maraval formation at the Diego Martin valley on the tentative prolongation of the Monos Anticline.

The distribution of the fold axes in fig. 3 appears to confirm this picture, and suggests an overall plunge of perhaps 15° to the southwest. There is, however, a suggestion of a separate group of folds plunging gently to the ESE.

AREA 3

Along the north coast there appeared to be a change of trend associated with the thrusting in the northern capes, but not visible in this area. The mapping did not suggest any plunge in this area.

The projection, fig. 4 is based on only a few folds, but it shows a main E - W trend with possibly a subsidiary trend WNW - ESE. There does not appear to be any plunge. Both the new trend(s) and the lack of plunge indicate differences with areas 1 and 2 to the West.

AREA 4

The thrusting in the northern capes has already been mentioned. In addition there may be changes in trend across the thrusts in the Santa Cruz area. There seemed a possibility of eastern plunge at least on the Santa Cruz Anticline where the Maraval formation disappeared south of La Vigie, under a thrust.

In fig. 5 this is confirmed by clear evidence of a plunge of about 10° to the East or ESE. This suggest that the culmination of the Green Hill - Santa Cruz Anticline occurs in Area 3.

AREA 5

This is a large area and yielded more data than the other areas. There appears to be a dominant NE - SW trend like that in Area 2. There is probably a SW plunge on this trend but it is quite small, say approximately 5°.

In addition there appears to be a secondary E - W trend and this may actually plunge very gently (less than 5°) to the East.

The south plunging gentle folds which warp the older folds are suggested but the lack of clarity is due to the insufficient data (which could be remedied.)

AREA 6

This is the eastern continuation of Area 5 and might have been expected to show the same features. However, on the basis of the scanty data shown in fig. 7 a WSW plunge of 5° - 10° may be suggested rather than a SW plunge and no evidence for an E - W trend is seen.

AREA 7

The main interest in the minor folds of this area was to see whether they were different from those in the other areas because of lateral movement on the Santa Cruz fault and other faults of the El Pilar system.

On the basis of 30 folds in this rather small area there appears to be a NE - SW trend with a suggestion of gentle plunge to the NE i.e. the fold trends are not markedly different from those in the main range.

The study of the plunge of the minor folds in the western part of the Northern Range seems to confirm the idea of a westerly plunge in the Northwestern Peninsula with a culmination in the Santa Cruz area, and an Eastern plunge in the northeast of the mapped area. In addition, evidence of a secondary E - W trend of folds has come to light in addition to the principal NE - SW or ENE - WSW fold trend. Inspection of the E - W data makes it difficult to generalise about the two trends because both the oldest and the youngest folds seem to be included in this trend, as well as some features which may be near surface collapse structures.

It is intriguing that in areas where mapping has established an E - W outcrop pattern, both mapped dips and minor fold axes should show ENE - WSW or NE - SW trends. No clear answer can be given but movement on the El Pilar Fault system may be one reason.

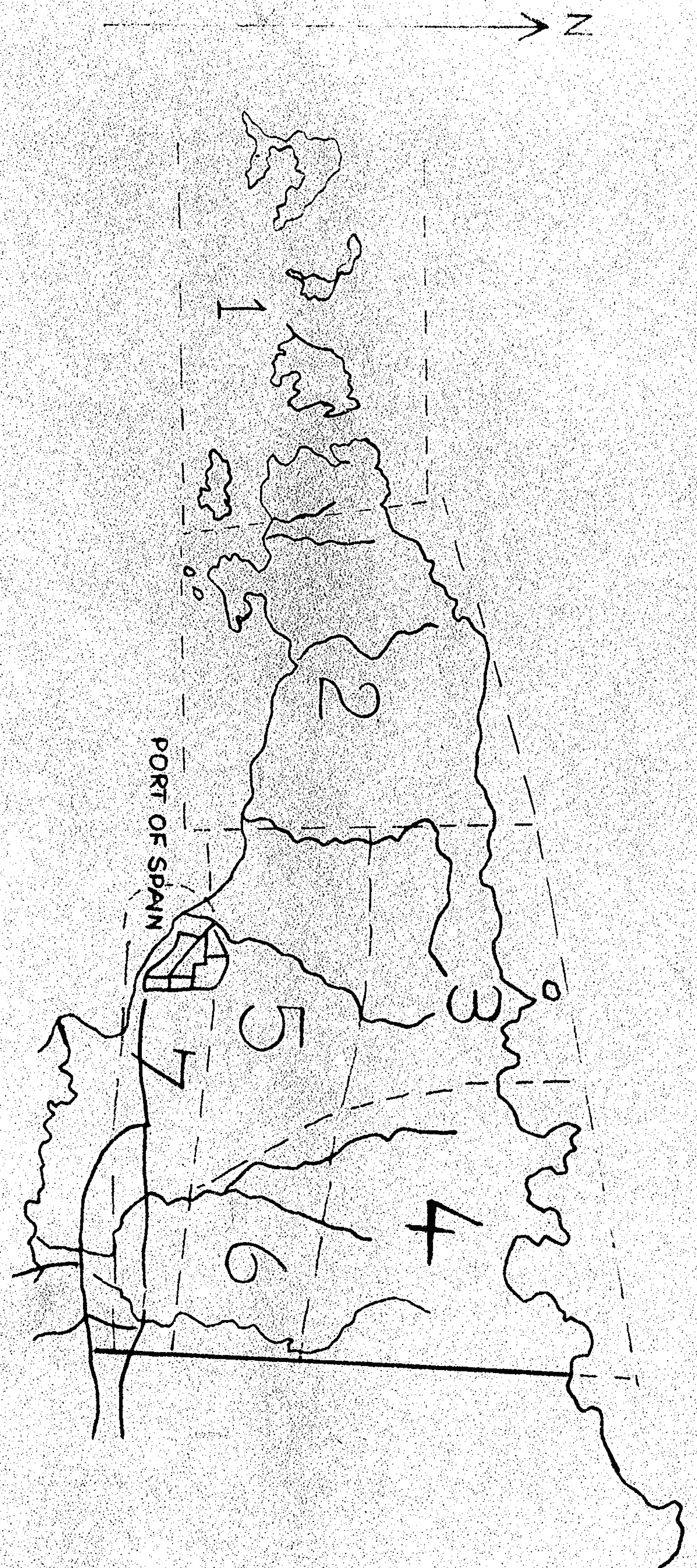


Fig. 1 Location map showing boundaries of areas covered by each projection in figs. 2 - 8.

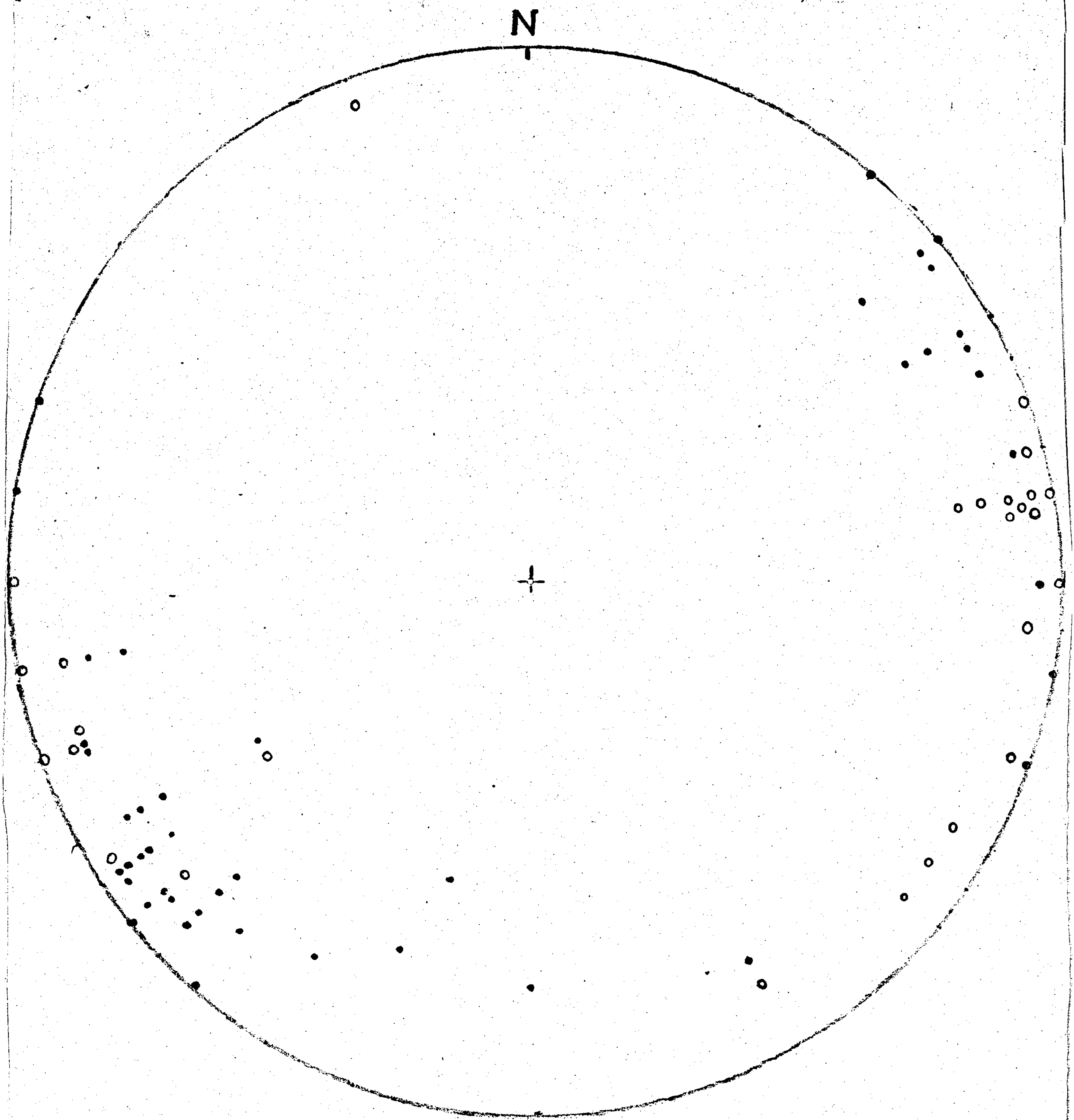


Fig. 2 Equal-area projection of the axes of 65 minor folds in Area 1.
Dots represent folds in the normal limb; circles represent folds in the overturned limb of the Monos Anticline.

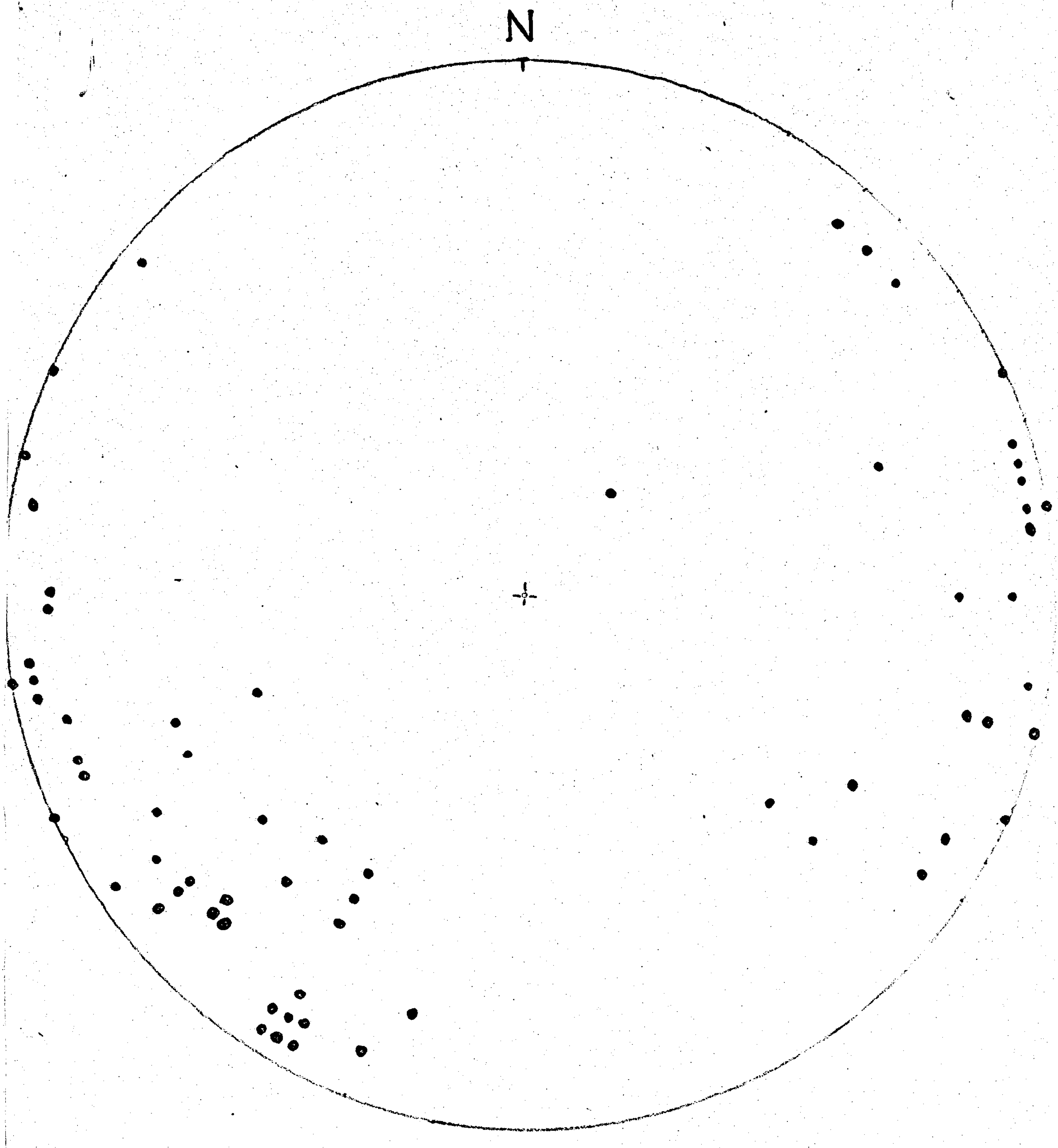


Fig. 3 Equal-area projection of the axes of 62 minor folds in Area 2.

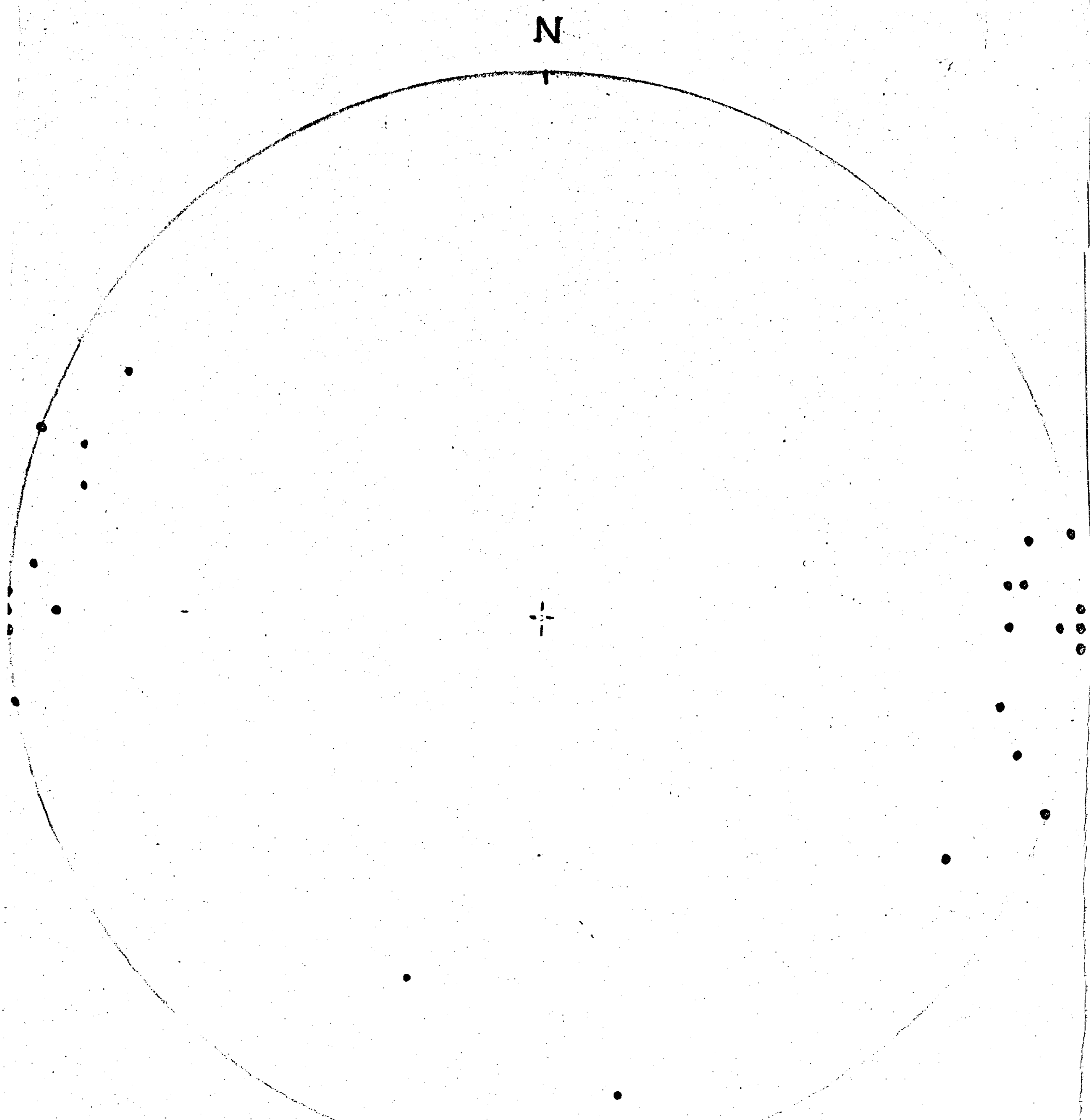


Fig 4 Equal-area projection of the axes of 22 minor folds in Area 3.

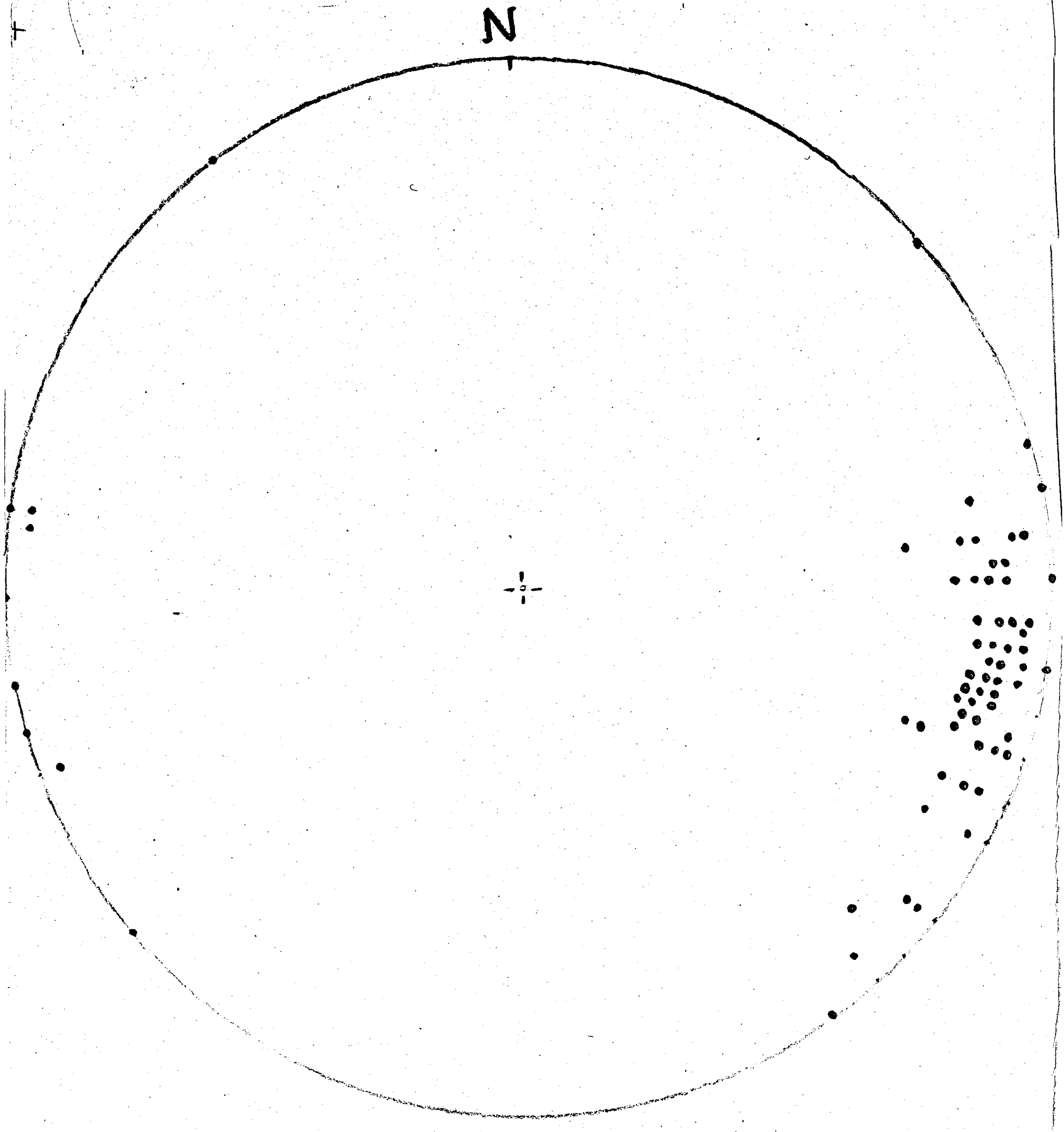


Fig. 5 Equal-area projection of axes of 63 minor folds in Area 4.

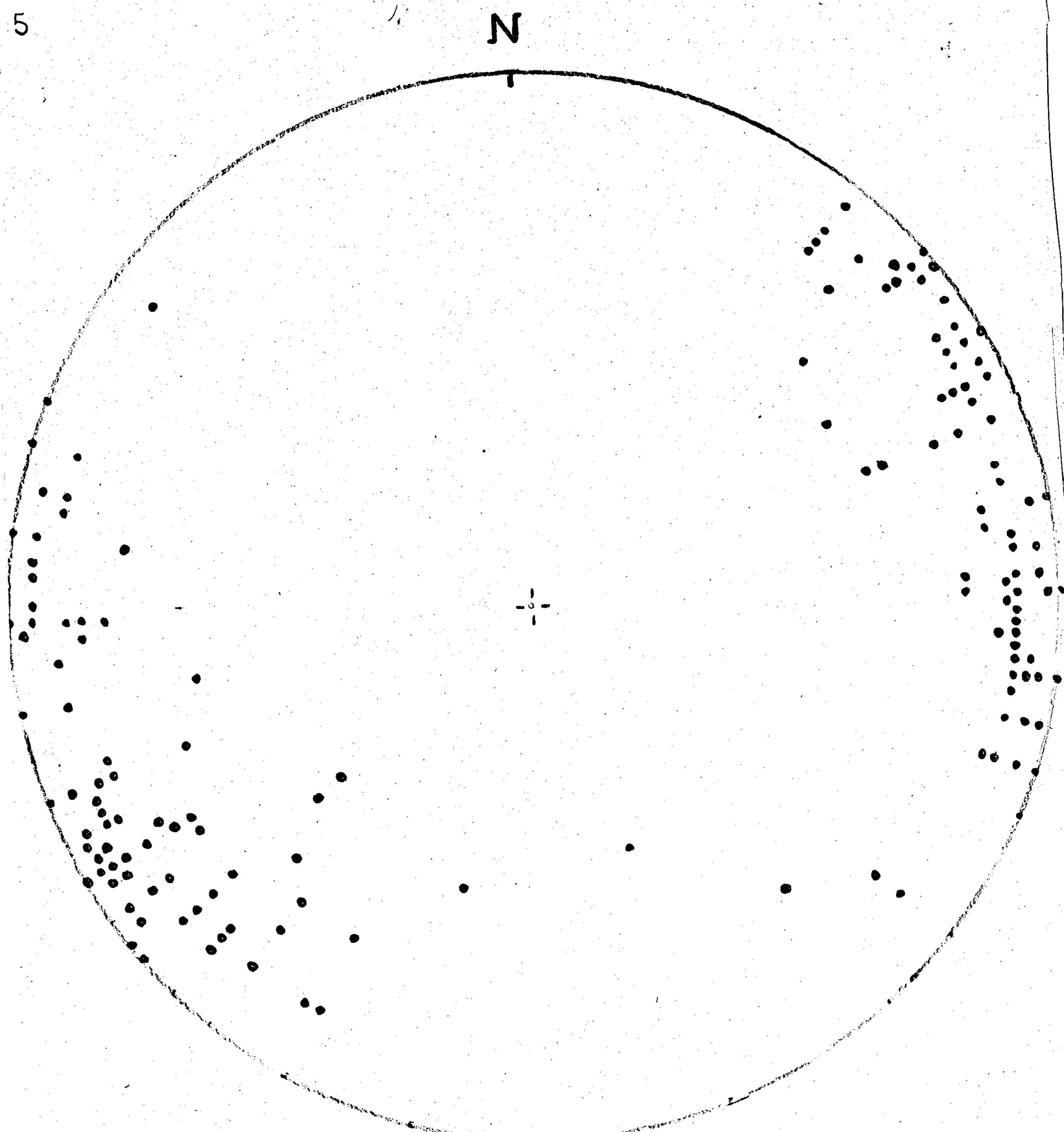


Fig. 6 Equal-area projection of axes of 144 minor folds in Area 5.

6

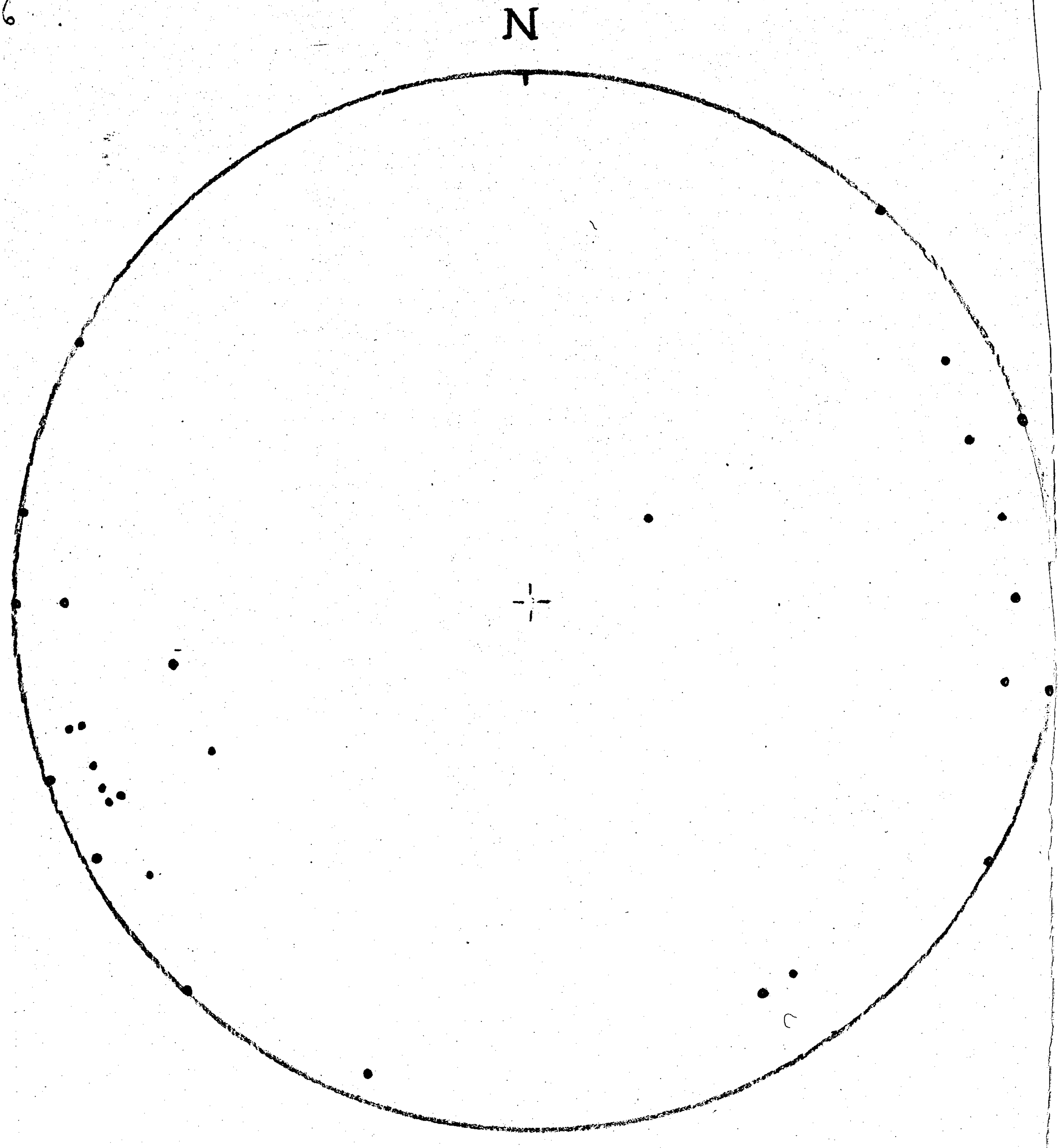


Fig. 7 Equal-area projection of axes of 25 minor folds in Area 6.

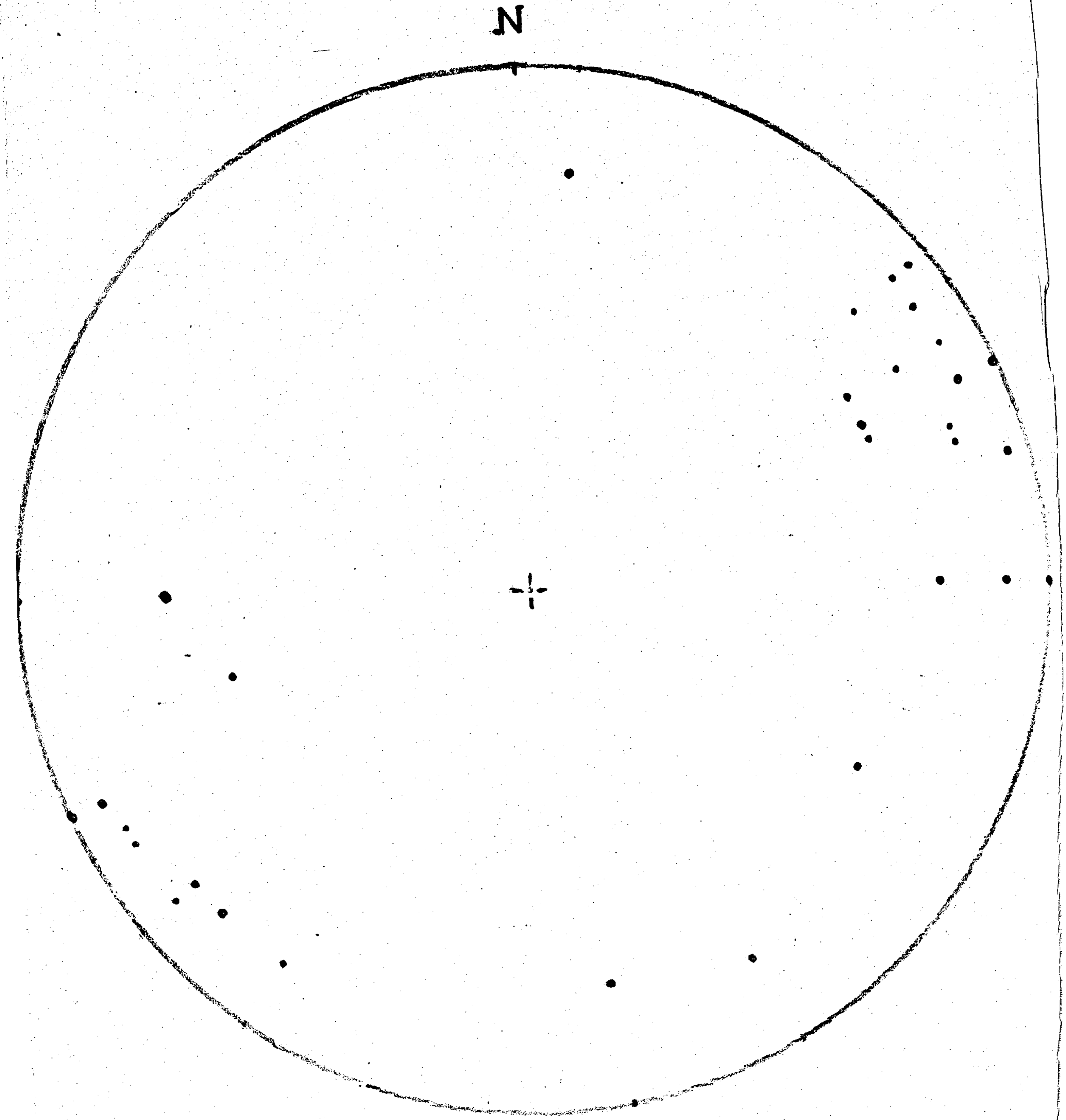
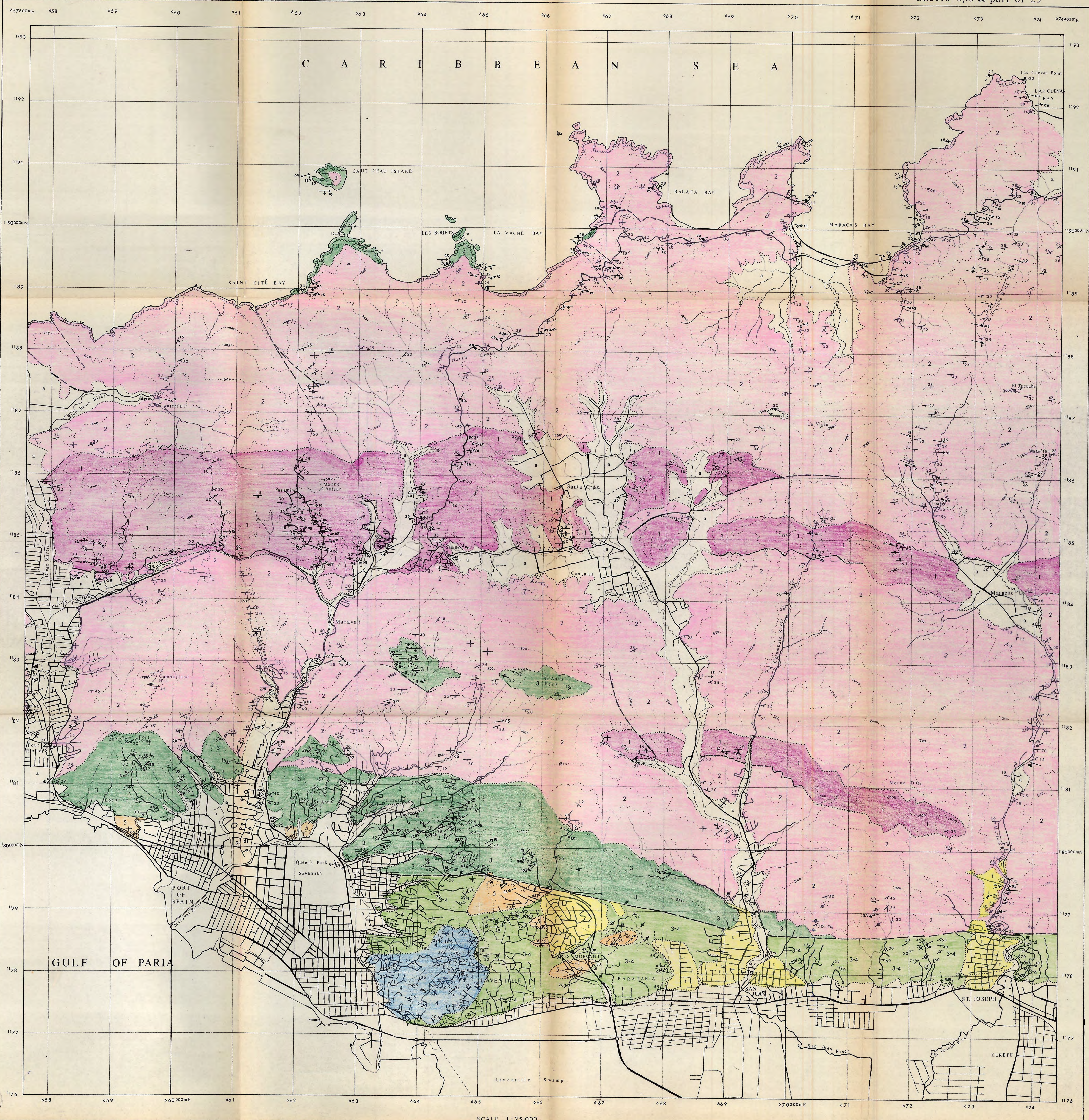
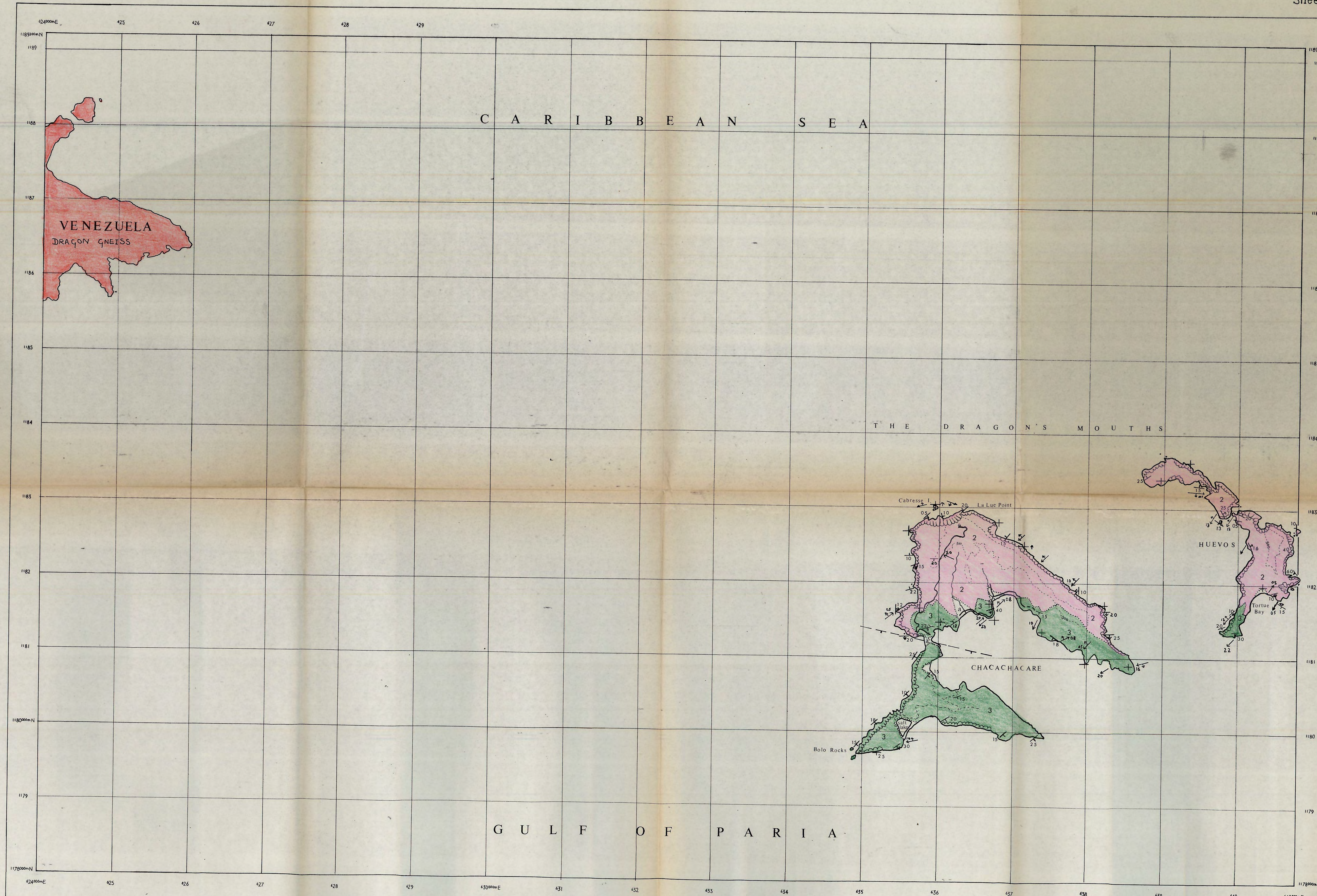


Fig. 8 Equal-area projection of axes of 30 minor folds in Area 7.

Sheets 3,13 & part of 23



SCALE 1:25.000



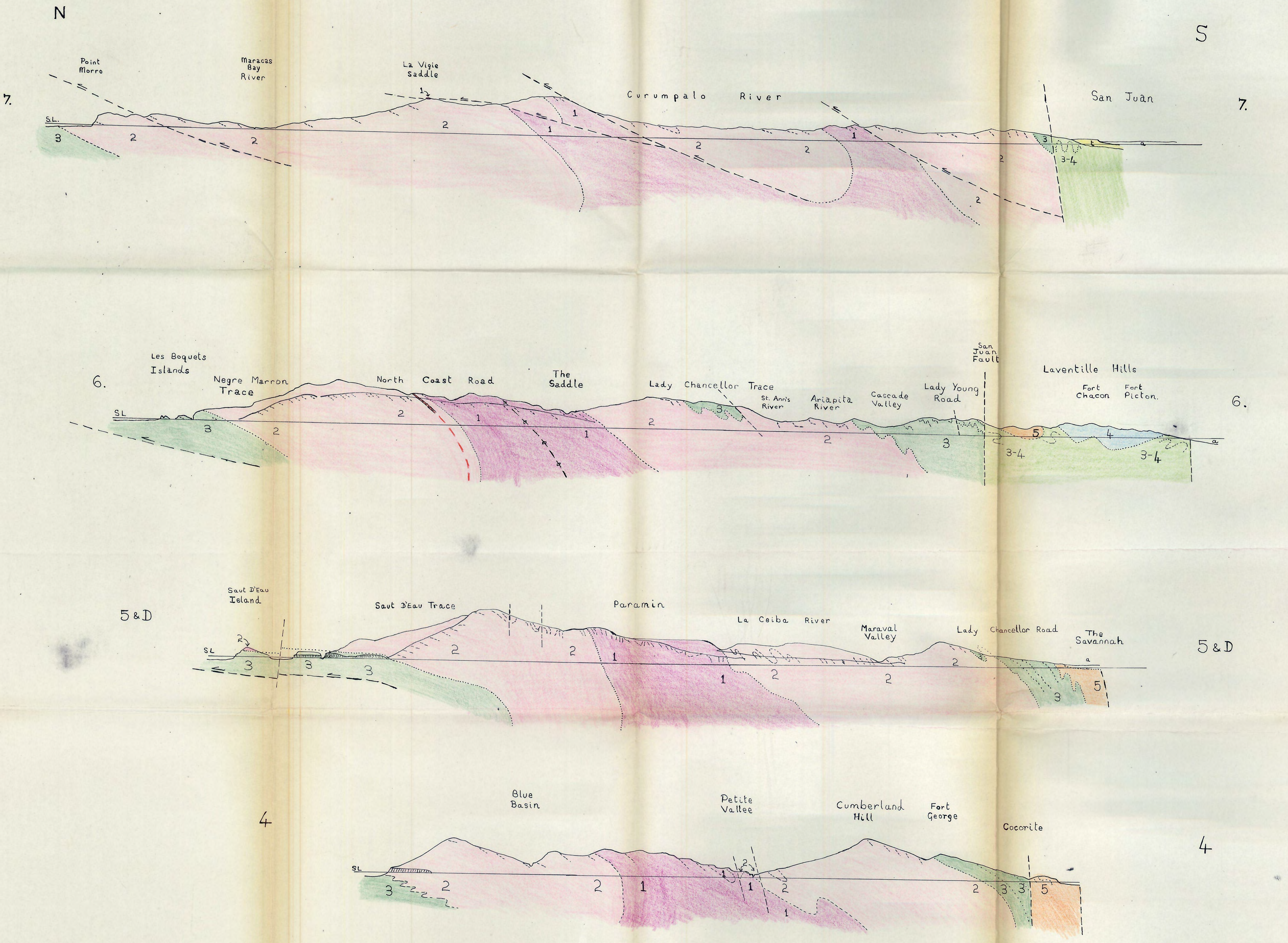
SCALE 1 : 25,000

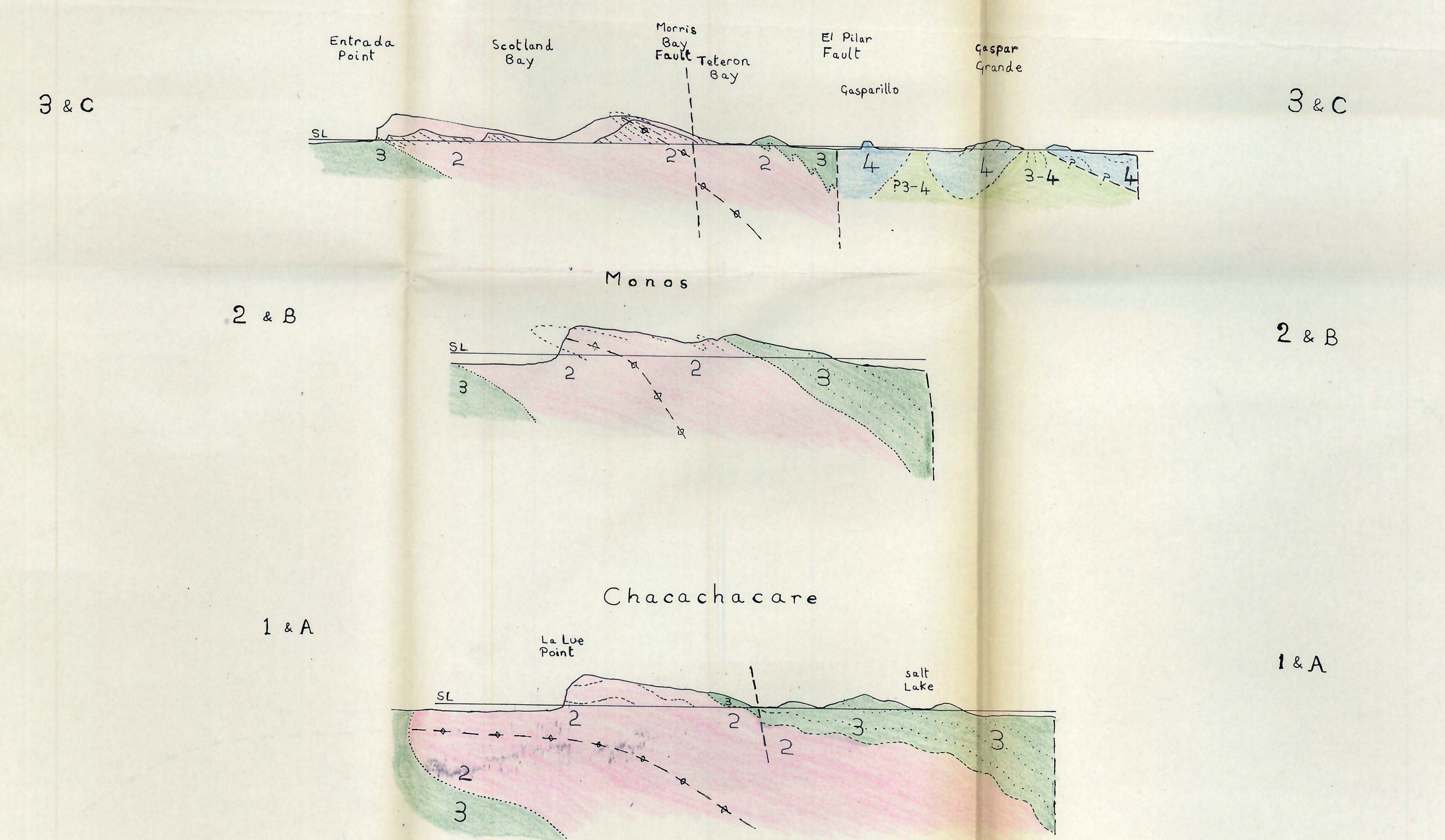
miles

kilometres

Grid North


CARIBBEAN SEA
THE DRAGON'S MOUTHS
GULF OF PARIA
MONOS
HUEVOS
Cape Cola
Dumas Bay
Grand Fond Bay
MORRIS BAY
Biscayne Bay
Le Chapeau
Point au Diable
Entrada Point
?3 transition
SCOTLAND BAY
Teteron Bay
Chaguaramas
GASPARILLO
GASPAR GRANDE
CRONSTADT
CARRERA
POINT GOURDE
FIVE ISLANDS
Carenage
TUCKER VALLEY
Macqueripe Bay
Green Hill
Diego Martin Village
Four Roads
SCALE 1:25,000
miles
kilometres
Grid North





GEOLOGICAL SECTIONS

ACROSS

THE NORTHERN RANGE

TRINIDAD

SCALE 1:25,000