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STUDIES IN WEST INDIAN SOILS

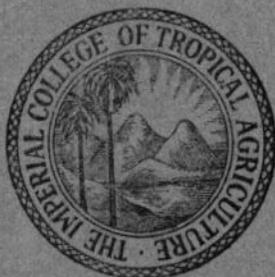
(XI) — THE AGRICULTURAL SOILS  
OF MONTSERRAT

BY

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WITH

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*Via colendi haud facilis*

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## CONTENTS

### Introductory

#### PART I

#### CLIMATE, AGRICULTURE, GEOLOGY AND SOILS

##### GENERAL

(1)	CLIMATE — RAINFALL : TEMPERATURE : HUMIDITY : PREVAILING WINDS : SUNSHINE : EXPOSURE .....	1
(2)	AGRICULTURE — NATURAL VEGETATION : CHIEF CROPS, COTTON, LIMES, TOMATOES AND VEGETABLES .....	3
(3)	GEOLOGY — GEOLOGICAL HISTORY : STRUCTURE OF THE VOLCANOES .....	4
(4)	LITHOLOGY .....	5
(5)	SOIL FORMATION — SOIL-FORMING FACTORS : ROCK WEATHERING AND SOIL PARENT MATERIALS .....	5
(6)	CHIEF SOIL-TYPES — CLASSIFICATION : DISTRIBUTION .....	7
(7)	DESCRIPTION OF THE SOIL-TYPES (A) AZONAL SOILS : (1) LITHOSOL (2) ALLUVIAL-COLLUVIAL SOILS .....	8
	(B) INTRAZONAL SOILS CALCIMORPHIC SOILS : (3) BROWN EARTH SOIL (4) RENDZINA SOIL .....	8
	(5) YELLOW EARTH SOIL .....	8
(8)	HYDROMORPHIC SOILS : (6) TERRAS SOIL (7) SHOAL SOIL .....	9
	LABORATORY DATA FOR SOIL PROFILE SAMPLES DISCUSSION OF THE LABORATORY DATA .....	10
(9)	CHEMICAL AND MINERALOGICAL TRANSFORMATIONS INVOLVED IN SOIL FORMATION FROM FRAGMENTAL VOLCANIC MATERIALS	
	(A) TERRAS .....	14
	(B) SHOAL .....	15
(10)	PEDOLOGICAL RELATIONSHIPS .....	16
(11)	SOIL EROSION — CLASSIFICATION .....	17
	(A) LAND MOVEMENTS AFFECTING FREE-DRAINING SOILS GHAUT FORMATION : DEBRIS AVALANCHE, MUDFLOW, EARTHFLOW : SOIL-CREEP, TALUS-CREEP, ROCK-CREEP : LANDSLIDE : "HOE-ROSION" .....	17
	(B) LAND MOVEMENTS AFFECTING IMPEDED-DRAINING SOILS .....	19
	(C) SOIL CONSERVATION AND ANTI-EROSION MEASURES .....	19
	(D) SOIL RENOVATION .....	20

#### PART II

	THE ECOLOGY OF COTTON AND OF LIMES .....	21
(A)	COTTON : CHOICE OF PLANTING DATE .....	21
	INTRODUCTION	
	CLIMATE : WATER RELATIONS .....	21
	COTTON YIELDS AND RAINFALL .....	22
	DATE-OF-PLANTING EXPERIMENTS .....	23
	NUTRIENT RELATIONS .....	24
	INTERPRETATION OF RESULTS OF MANURIAL EXPERIMENTS	
	EXPERIMENTS OF 1940 .....	27
	EXPERIMENTS OF 1941 .....	27
	EXPERIMENTS OF 1942 .....	27
	GENERAL CONCLUSIONS : NITROGEN RELATIONS OF COTTON .....	29
	RECOMMENDATIONS .....	29
(B)	LIMES : THE "DYING-OUT" PROBLEM .....	29
	INTRODUCTION	
	NUTRIENT RELATIONS OF THE LIME TREE .....	30
	MANURIAL EXPERIMENT ON LIMES .....	31
	THE SPECIAL ROLE OF CALCIUM .....	31
	RELATIONSHIPS BETWEEN DYING-OUT OF LIMES AND CHEMICAL COMPOSITION OF LIME- LEAVES AND SOILS GROWING LIMES .....	31
	DISCUSSION : SOIL DATA : .....	32
	LEAF DATA : .....	32
	THE INTERMEDIATE SAMPLES .....	33
	CALCIUM-DEFICIENCY SYMPTOMS IN CITRUS .....	33
	SPECTROGRAPHIC DATA .....	34
	CONCLUSIONS .....	34
	ROOT RELATIONS OF THE LIME TREE .....	35
	RECOMMENDATIONS .....	35
	SUMMARY .....	36
	REFERENCES .....	37
	LABORATORY METHODS OF SOIL ANALYSIS .....	38
	APPENDIX :- TABLES OF LABORATORY DATA .....	41
	FIGURES 1-3 (Reproductions of photographs) .....	41
	ROUGH SOIL MAP OF MONTSERRAT	
	RAINFALL MAP	

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## INTRODUCTORY

THIS report forms a continuation of an earlier paper by the senior author (1) that comprised Part II of the series of Studies in West Indian Soils, issued January, 1922, in Vol. XIX of the *West Indian Bulletin*, an official publication of the now defunct Imperial Department of Agriculture. The present report describes a fuller field reconnaissance carried out within a period of 11 working days during March and April, 1940. It presents the results of the subsequent laboratory examination at the College of some 576 soil profile samples then collected.

The report is divided into two parts; *Part I* deals with the climate, agriculture, geology, soil formation and soils of Montserrat and is mainly descriptive and factual. Much of the geological information is taken from the report of the 1936 Royal Society Expedition to Montserrat, written by A. G. MacGregor, Geologist. That report contains the fullest and most up-to-date account yet presented of the rocks of a typical West Indian volcanic island and discusses the developmental sequence of its component volcanoes. For this reason the report affords a unique basis for a detailed study of soil formation from volcanic rocks under a humid tropical climate. The relative simplicity of the Montserrat vulcanology clarifies the inter-relationships of the main soil-types that occur widespread in the Caribbean volcanic arc comprising the Lesser Antilles islands, namely, Grenada, Grenadines, St. Vincent, St. Lucia, Martinique, Dominica, Western Guadeloupe, Montserrat, Redonda, Nevis, St. Kitts, St. Eustatius and Saba.

*Part II* consists of a discussion of the ecology of the cotton crop and the lime crop in Montserrat which has claimed the attention of a number of investigators, including agricultural officers and specialist mycologists and entomologists. The apparent close bearing of climate and soils on the growth and reproduction of

cotton and limes presents problems of fundamental importance in tropical agriculture that are well worthy of continued study, since they are not yet fully solved.

## PART I

CLIMATE, AGRICULTURE, GEOLOGY  
AND SOILS

*General:* Montserrat is a small island forming part of the Leeward Islands Colony, latitude 17° N. It lies 27 miles south-west of Antigua, 30 miles south-east of Nevis and 35 miles north-west of Guadeloupe. Its area is about 32 square miles, its length 10½ miles, and its width 6 miles. Its outline is roughly pear-shaped. The land comprises three main hill masses, namely, Silver Hill in the north (1,285 ft.), Central Hills (2,450 ft.) and Soufriere Hills (3,003 ft.) in the south, together with three smaller hills, Garibaldi Hill (840 ft.) and St. George's Hill (1,200 ft.) lying between and to the west of the two last-named masses, and South Soufriere Hill (2,505 ft.), rising out of the southern slopes of the Soufriere Hills. These uplands represent the remnants of six extinct volcanoes of differing geological age (2), (2A). Their relative positions and contours are indicated in the accompanying topographical and soil maps. The volcanoes are separated from each other by well-marked valleys or depressions and their sides are radially scored by deep gorges, locally termed "ghauts" or "guts", which carry water only in the wet season. The ghauts are steep-sided in the southern uplands but shallow with gently-sloping sides in the Silver Hill district.

## (1) CLIMATE

*Rainfall:* The distribution of the rainfall in Montserrat in especial relation to soil humidity is indicated in the accompanying rainfall map. Apart from the regions of highest elevation, the magnitude of the total annual rainfall

is not very great, being on the average about 55 inches. The leeward slopes receive more rain than the windward which is opposite to the case of the more mountainous West Indian islands such as Dominica whose windward slopes are the wettest. The rainfall over the agricultural lands ranges from 70 to 40 inches. The rainiest months are September, October and November, but the incidence of rainfall is extremely variable, the dry season (December to June) usually being ill-defined.

The actual distribution of the rainfall is of the greatest importance in Montserrat, in-so-far as it largely influences the growth and maturation of the cotton crop. In Table I is set out the number of dry months, medium-dry months

and wet months for 28 stations where rainfall records have been kept for periods varying between 4 and 36 years but mostly above 10 years. The definition of a dry month is that due to Mohr (3) who found that, in Java, for mean monthly rainfalls less than 2.4 inches, all the rain that falls evaporates without penetrating into the soil. He also found that, for mean monthly rainfalls greater than 4.0 inches (wet months) a large proportion of the rain penetrates into the ground without evaporating (provided the soil surface is infiltrable) and percolates deeply. Mean monthly rainfalls lying between 2.4 and 4.0 inches (intermediate months) may either evaporate or penetrate, depending on the previous condition of the soil.

TABLE I: Rainfall Regimes in Montserrat

(Based on Mohr's classification of rainfall)

GROUP I				GROUP II				GROUP III			
CONTINUOUSLY MOIST				WEAK DRY SEASON				MARKED DRY SEASON			
Mean annual rainfall 70-55 ins.				Mean annual rainfall 60-50 ins.				Mean annual rainfall 50-40 ins.			
Leeward; Central				Leeward; Windward				Windward; North; South			
<i>Dry Med. Wet</i>				<i>Dry Med. Wet</i>				<i>Dry Med. Wet</i>			
Rileys	(70)	0	- 1 - 11	Harris	(58)	1	- 1 - 10	Brades	(50)	2	- 4 - 6
Woodlands	(67)	0	- 2 - 10	Ile's Bay	(54)	1	- 3 - 8	Whites	(50)	2	- 4 - 6
Amersham	(65)	0	- 2 - 10	Paradise	(60)	1	- 4 - 7	Trants	(48)	2	- 5 - 5
Parsons	(68)	0	- 3 - 9	Kinsale	(50)	1	- 4 - 7	Farm	(43)	2	- 6 - 4
Gages	(67)	0	- 3 - 9	Blakes	(50)	1	- 5 - 6	(Elberton	(46)	3	- 3 - 6)
Oveston G.	(67)	0	- 3 - 9					O'Garas	(43)	3	- 4 - 5
Oveston	(61)	0	- 3 - 9					Sweeney's Well	(43)	3	- 5 - 4
Waterworks	(61)	0	- 4 - 8					Bethel	(43)	3	- 5 - 4
Richmond	(61)	0	- 4 - 8					Tar River	(42)	3	- 5 - 4
Grove	(61)	0	- 4 - 8					Roches	(40)	3	- 7 - 2
Farrells	(57)	0	- 4 - 8								
Cugoe head	(56)	0	- 5 - 7								
Dagenham	(55)	0	- 5 - 7								
MEANS	(63)	0	- 3 - 9	MEANS	(55)	1	- 4 - 7	MEANS	(45)	3	- 5 - 4

Reference to Table I and to the map indicates that the rainfall over most of the relatively wet leeward and central parts of Montserrat lies between 70 and 55 ins. Here no month is dry and the climate may thus be described as continuously moist. A large proportion of the rain water penetrates into the soil and downward water movement prevails the whole year round. At the other extreme, the rainfall over the drier windward, northern and southern parts of Montserrat varies between 50 and 40 ins. and 2 or 3 months or more are dry. The climate here thus shows a marked dry season during which evaporation exceeds penetration and the movement of water is upward so that the soil frequently suffers desiccation. Some parts of the island are intermediate, showing a weak dry season with only one month really dry.

In general, the more elevated stations receive most rain. Rainfalls over 70 inches a year probably occur in the Central Hills, the Soufriere Hills and South Soufriere Hill at alti-

tudes above 800 feet. The average increase of rainfall with altitude in Montserrat is about 4.5 inches for every 100 feet rise in height.

*Temperature:* Records at the Grove Experiment Station near Plymouth show that the mean maximum temperature is about 86.5° F., and the mean minimum, 73.5° F., though these limits may be exceeded at other places.

*Humidity:* The mean relative humidity at the Grove Station is about 71 per cent at 9.00 a.m. and 65 per cent at 3.00 p.m.; it doubtless reaches 100 per cent during the night at most places throughout the year, especially in elevated regions, and may fall below 50 per cent in the afternoon during the driest days.

*Prevailing Winds:* Montserrat is wind-swept for the greater part of the year. During the early months, the north-east trade winds blow with great persistence and often with violence and exert great drying effects over land

unprotected by wind-breaks. The average wind velocity at the Grove Station is about 8.3 miles per hour. Montserrat lies in the hurricane zone.

*Sunshine*: The duration of the daily sunshine on the average is about 8 hours at the Grove Station and varies little for the different months of the year. Thus for the first nine months of 1943 the recorded values were: 8.1, 8.4, 8.2, 9.2, 5.5, 7.7, 8.4, 7.6 and 7.3; mean 7.8 hours of sunshine per day. Other places show a greater or lesser mean value for daily sunshine depending mainly on their nearness to the hills which cut off the sun's rays for varying periods of time in the early morning or late afternoon.

*Exposure*: The general meteorological conditions in the different parts of Montserrat, as detailed in the foregoing paragraphs, suggest the following territorial sub-divisions with regard to general exposure.\*

- (i) *Extreme north*: Cool, dry, exposed to Atlantic winds; no forest protection.
- (ii) *Windward coast*: Cool, moderately dry, reduced sunshine, windy.
- (iii) *North leeward coast and north-west slopes of Central Hills and Soufriere Hills*: Hot, wet, humid; limited air movement, generally still.
- (iv) *Central leeward coast*: Hot, moderately wet; sheltered from wind; continual sunshine.
- (v) *Central divide and north-east high slopes of Soufriere Hill above the 1,200 ft. contour*: Cool, wet, misty, cloudy, humid; reduced sunshine.
- (vi) *Extreme south*: Hot, moderately dry, clouds mostly blown out to sea; exposed to south-east winds, continual sunshine; sunny afternoons.

## (2) AGRICULTURE

*Natural vegetation*: The higher slopes of Centre Hills, Soufriere Hills and South Soufriere Hill are covered with forest above the 1,000 or 1,500 ft. contours. The vegetation has been damaged by hurricanes, particularly by the hurricane of 1928, so that its original features have been greatly modified. For the most part, the high land is now covered by a plant association consisting mostly of palm trees and shrubby undergrowths. This is well developed, for example, on Chance's Mountain in the Soufriere Hills, although in the higher parts of the Centre

Hills remnants of evergreen rain-forest still exist. The lower mountain slopes, at present under extensive cultivation, contain few traces of the original vegetation, but patches of secondary dry woodland, thorn-bush and scrub occur on Garibaldi Hill and St. George's Hill and on South Soufriere Hill, and above Trants on the windward side.

*Chief crops*: The chief crops of Montserrat in order of importance, are, cotton, limes, tomatoes (together with certain vegetables grown for export) and sugar-cane (4). The total area of cultivated land is about 7,000 acres, or nearly one-third of the island's surface. There are about 40 privately-owned estates. The rest of the land comprises peasants' properties. In recent years, several estates have been cut up into small holdings, rented to peasants or worked on a share basis. Cotton nowadays occupies about 4,600 acres of land, limes about 100 acres, tomatoes and vegetables, 300 acres, sugar-cane, 200 acres and ground provisions (mainly consumed locally), 2,000 acres.

*Cotton*: The type of cotton grown in Montserrat is Sea Island which is cultivated both by estate owners and by peasants. In 1938, 1,050 acres of cotton were cultivated by the estates and 3,403 acres by peasants. Seed supply is controlled by the Department of Agriculture. There is a cotton-breeding station in Montserrat where a special strain of cotton (MSI) has been evolved, having a 1 $\frac{3}{4}$ -inch staple and a high (over 30 per cent) ginning out-turn. Yields of lint varied during 1934 to 1938 from 101 to 283 pounds per acre; they have averaged 185 lbs. ac. between 1939 and 1943.† The mean yield of the Leeward Islands Colony for the 4-year period 1934-1938 was 153 lb. per acre. Seasonal fluctuation in yield is great because of the variable climate. Besides all of the lint, some cotton seed, seed oil and seed cake are exported.

*Limes*: The lime industry of Montserrat was formerly of much greater importance than it is at the present day. The decline in recent years is partly owing to a decreasing demand for lime products and partly to natural causes, including hurricane damage and the ravages of pests and diseases. There are at present only about 100 acres of estates limes with an additional unknown area in small holdings. Climatic conditions in Montserrat are believed to be marginal for limes and soil conditions seem to have gradually deteriorated so as adversely to affect the water relations of the crop and thus to render the trees more susceptible to insect and fungus attack. These and other factors are

\* S. A. Schouten, Agricultural Assistant, private communication, March, 1940.

† These are average figures; it should be noted that yields of 400 lb. of lint per acre are common and even yields of 600 lb. per acre have been attained.

more fully considered in the second part of this Report.

Limes have been chiefly grown on the estates of the Montserrat Company which are mostly situated in the leeward part of the island near the capital, Plymouth. The history and behaviour of the lime trees growing in different soil-types have been variable, particularly with regard to the problem of the "dying-out" of limes which is the general name given to the failure of the crop and the effects of pests and diseases that have accompanied its decline.

*Tomatoes and vegetables:* The cultivation of tomatoes and vegetables was carried on in Montserrat for several years prior to the last war. The industry was mainly in the hands of peasants and the exports were all made to Canada. A packing depot with cold storage was provided by Government and packing was also undertaken in privately-owned buildings. Tomato plants grow well in most parts of the island, but the industry is chiefly confined to the windward and northern slopes of the Soufriere Hills, which have proved to be the most successful tomato-growing district. The crop is liable to suffer when the rainfall is too high or too low and is thus a very uncertain crop in Montserrat.

### (3) GEOLOGY

The latest account of the geology of Montserrat is that published in 1938 (2) by A. G. MacGregor, who, along with C. F. Powell, Physicist, comprised the personnel of the expedition sent out to Montserrat by the Royal Society of London early in 1936 to investigate the earthquakes and soufriere activity that had caused much alarm in 1934 and 1935. The following notes are taken mainly from MacGregor's publication.

*Geological History:* Montserrat is one of the islands of the Caribbean Volcanic Arc built up on a submarine ridge that was initiated during Cretaceous times. This ridge runs north to south along the eastern margin of the Caribbean Basin. Earth movements in Post-Miocene times (say 10 million years ago) caused much folding and faulting. Six main volcanic centres have been identified by MacGregor within the island. Each centre was active at a different period since the middle of the Miocene era. The first volcano to erupt was Silver Hill, the next to erupt much later during the Pleistocene era was Centre Hills, followed in order by Garibaldi Hill, South Soufriere Hill, St. George's Hill, and lastly, Soufriere Hills. All except Silver Hill erupted last between 500 and 25 thousand years ago; none has been active within the span of human history.

Very little of the present-day dry land seems to have been submerged beneath the

ocean since late Miocene times. The occurrence of embayed valleys (for example, Old Road Bay) and of sea cliffs all around the coast suggests, however, that peripheral submergence, accompanied by marine erosion, took place in recent geological times. This may be accounted for by the return of water to the ocean by the melting of the great continental ice-sheets in Post Glacial times, twenty thousand years ago. The eruption of the Soufriere Hills volcano was probably contemporaneous with, or later than, this final submergence.

At Roches Bluff in the south-east of the island, occurs a fossiliferous limestone of undoubted early Pleistocene age associated with volcanic ejecta. The outcrop has been elevated by local faulting above sea level. The limestone was therefore probably formed at about the same time as the Centre Hills volcano was erupting, half-a-million years ago. Its occurrence cannot therefore be regarded as proving any significant wide-spread submergence likely to have involved the main masses of the Montserrat volcanoes. There are no raised beaches nor other evidences of large scale emergence in the island, hence it may be concluded that, with the exception of Silver Hill, the volcanic ejecta which comprise the five main volcanic cones are all subaerial and have never been subjected to the profound action of salt-water through their never having been submerged below sea-level. This fact has considerable bearing on the nature and composition of the parent materials from which the soils of Montserrat have been formed.

#### *Structure of the volcanoes:*

- (i) *Silver Hill* consists mainly of solid igneous rock, probably representing the remnants of a large intrusive mass or the deep-seated nucleus of a very old volcano. Practically all the ejecta that have been erupted by this volcano have since been removed by denudation.
- (ii) *Centre Hills* comprise a large maturely-dissected volcano consisting of a central core of igneous rock surrounded by irregularly bedded massive agglomerates, for the most part consolidated, forming the lower grounds and ending in precipitous cliffs along the leeward and windward coasts. The component rocks vary in size from boulders, 6 to 20 feet across, to fine sand forming a matrix, sometimes abundant sometimes absent.
- (iii) *Garibaldi Hill:* This is a separate small volcano of about the same age as the last. It is composed partly of well-consolidated agglomerate, partly of semi-consolidated sand, usually pale-coloured and pumiceous. A horizontal bed of coarse

agglomerate forming Bransby Point and the ridge to the east of it shows many of the boulders to be encrusted with pure white calcareous tufaceous material, probably solfataric in origin.\* Several hot springs abound in this area and a hot water pond occurs on the beach below.

- (iv) *South Soufriere Hill*: This consists of interbedded lavas and fragmental rocks comprising loose, slaggy, black cinders. The most westerly of the lava-flows forms the coastal cliff behind O'Garas.
- (v) *St. George's Hill*: This is a purely explosive small volcano quite separate from Centre Hills. It consists chiefly of fine ash and dust with layers of stones and boulders dipping steeply away from the centre.
- (vi) *Soufriere Hills* comprise the largest though youngest volcano of all. This volcano dominates the southern part of the island and contains all the present-day active soufrieres. Its ashy materials envelop South Soufriere Hill. The lower slopes of Soufriere Hills up to the 800-1,000 feet contour are inclined at an angle of about 10° but at higher altitudes the inclination increases rather suddenly to 20° or 30°. This is accounted for by the fact that the volcanic plug, consisting of consolidated rock or solidified lava, has resisted weathering, whereas the loose material ejected by explosive volcanic action has gravitated downwards, aided by the action of running water, so as to form detrital taluses, fans or glacis. Narrow steep-sided ghauts cut deeply into the central core as well as into the loose ejecta. Most of the best cultivations are situated on the lower parts of the western glacis of the Soufriere Hills above Plymouth, and on the eastern glacis near Bethel.

#### (4) LITHOLOGY

The main kinds of rock of which the eruptive fragmental volcanic rocks and lavas of Montserrat are composed are *bandaite* (or labradorite-dacite, that is quartz-bearing andesite rich in labradorite feldspar) and *olivine basalt* (a finely-crystalline equivalent of andesite, rich in olivine). The range of rock types is said to represent nearly the full series of igneous rocks known to occur in the Caribbean Volcanic Arc (2).

*Bandaite* is a blue-grey, grey-green or whitish-grey, hard, finely-crystalline, sub-basic igneous rock resembling andesite, having a total silica content between 56 and 64 percent. Its characteristic minerals are labradorite (soda-

lime feldspar), dark green hornblende and some brown augite. Magnetite is fairly abundant but olivine is rarely present. Quartz frequently occurs as porphyritic crystals, and tridymite is often plentiful. Apatite is present as delicate needles in the groundmass.

*Olivine-basalt* is a black, dense, finely-crystalline rock, consisting of labradorite, ferromagnesian minerals and magnetite.

Fine volcanic ash, sand and dust, having particle size less than about 0.5 m.m., occur plentifully in the fragmental deposits erupted from each of the volcanic cones except South Soufriere Hill. They are composed mainly of single-grain crystals of feldspar, hornblende, augite, and other minerals, or of particles or shreds of volcanic glass. The coarser ash is usually markedly porous (pumiceous) and whitish-grey in colour, though sometimes dark-coloured. The coarse, porous, cindery ash of the South Soufriere Hill volcano is different in that it is nearly black in colour and more basic in composition. The finer materials last erupted from the Soufriere Hills volcano are distinctly stratified; they were probably deposited from "black clouds" (*nuées ardentes*) consisting of dense mixtures of dust and steam, similar to those that characterised the recent (1902-03) eruptions of Mt. Pelée in Martinique and Mt. Soufriere in St. Vincent. "Black cloud" deposits are apparently not represented among the fragmental materials erupted from the other older Montserrat volcanoes (Centre Hills, Garibaldi Hill and St. George's Hill), which are generally more bouldery, less stratified, and arranged in tumultuous fashion, or piled up as irregular cones around their craters.

According to the mineralogical composition of the volcanic rocks of Montserrat, we should expect a general shortage in them, and in their derived soils, of potash and it is noteworthy that the rock-types represented in Montserrat contain even less potash than those represented in other islands of the Lesser Antilles, that is, they are below the normal for the Caribbean region.

#### (5) SOIL FORMATION

It has been shown in a previous section that very little of the present-day land-mass comprising Montserrat has been submerged beneath the sea since the end of the Miocene era, about 10 million years ago. Thus the oldest land has been exposed to subaerial weathering and denudation for a very great length of time. The old Miocene basement is still exposed in the northern Silver Hill district. The longest time of exposure in the central district is probably less than half-a-million years, and in the southern district, less than twenty thousand years.

\* This lime-encrusted boulder-bed is not mentioned in MacGregor's report.

To what extent the newer volcanic deposits formerly covered over parts of the older ejecta, having since been removed by denudation, cannot accurately be determined, but it is evident, geologically speaking, that the weathering of the last-formed deposits has gone on for only a relatively short period of time.

*Soil forming factors:* Soil formation from any given kind of parent rock depends upon the operation of the factors, climate, vegetation, topography and time. In order to trace the transformations that have occurred during soil formation, it is therefore necessary to assess the effect of each of these factors separately. We have already seen that, in Montserrat, the *parent rock* is mainly a fragmental type, having great porosity and depth, so that the chief climatic agent of soil formation, namely rain-water, could readily gain access to a great mass of mineral material presenting a large surface area to its weathering action. The other climatic weathering agent namely, temperature, has been throughout relatively intense, so that the chemical processes of mineral decomposition, namely, hydrolysis, hydration and oxidation, have proceeded very rapidly.

The nature and identity of the minerals comprising the parent rocks of Montserrat\* are nearly the same for the whole island, but their susceptibility to decomposition varies greatly, not only between one mineral entity and another, but between the different states of the particles.† Thus, in some cases, the mineral grains comprise whole crystals or parts of crystals, whereas in other cases, they are made up of glassy material that has cooled too rapidly to crystallise. Such fused glassy particles resist decomposition much more effectively than crystalline matter; their rate of weathering may therefore be very slow. Similarly coarse-grained crystalline masses of hard rock (boulders and stones) having rough surfaces, are more susceptible to weathering than fine-grained semi-vitreous or glassy rocks (bombs, lapilli, sand) having smooth exteriors. Porous, vesicular, pumiceous or cindery rocks occupy an intermediate position between these extremes, presenting a large surface area to weathering, but offering considerable resistance to chemical alteration.

*Rock weathering and soil parent materials:* The progress and results of weathering of loose fragmental volcanic rocks under the particular climatic conditions that prevail in Montserrat thus vary greatly depending on particle size and

assortment of particles having different dimensions. At one extremity lie coarse agglomerates (boulder beds, cinder heaps, stony screes), at the other, volcanic ash, sand and dust (mudflows, glacia, talus-fans) and partly-cemented tuffs.

- (i) During weathering, the first group alters superficially, the individual rounded fragments decomposing slowly to the core forming shells of differentially-weathered material, or the stones may decompose along radial cracks that become lined with the products of decay. These products chiefly consist of kaolinic clay, stained reddish-brown by hydrated ferric oxide. Steely-blue films of manganese oxide may also be produced over the decomposing rock surfaces or along the cracks. The less altered material may have a creamy-yellow colour. For convenience, the clayey residuum that gradually develops will be termed *Brown Earth*. It gives rise to a soil-type sufficiently distinctive to be classified and mapped separately. This soil-type is characterised by an alkaline or only slightly acid reaction and a high degree of saturation by calcium which dominates the exchange-base system and confers desirable physical features on the clay, such as a crumbly, friable structure. The soil would consequently be described as *calcimorphic*, according to modern American nomenclature.
- (ii) Mention has already been made of the unique occurrence on the Bransby Ridge of an extensive bed of lime-encrusted boulders forming a special sort of agglomerate that has given rise to a peculiar kind of *Brown Earth* whose colour is dark sepia-brown to black. Here too, calcium dominates the system and the resulting soil-type conforms closely to *Rendzina* or "humus-carbonate" soil, such as develops over soft limestones and marls.
- (iii) The *fine* grained fragmental rocks decompose differently. The individual mineral particles give rise to various products depending on their mineralogical identity. Thus augite, hornblende and hypersthene give iron oxide

\* These were first identified in the derived soils as far back as 1905 by Dr. Francis Watts (*W.I.B.* 1905, VI, p. 282) as mainly comprising plagioclase feldspars (labradorite and anorthite), brown hornblende, green augite, hypersthene and some quartz; in addition, orthoclase (potash feldspar) was recorded in some windward soils. Magnetite is also common. This assemblage agrees with the mineralogical composition of the prevailing rock-types discussed by MacGregor.

† The order of diminishing susceptibility to decomposition of these minerals is:— augite, hypersthene, hornblende, anorthite, labradorite, orthoclase, quartz and magnetite (the most resistant).

residues, together with chlorite, serpentine and carbonates of calcium and magnesium, having brown, ochre-yellow or olive-green colours, whereas the felspars give kaolinic residues which are white in colour. Magnetite remains relatively unchanged, producing a "pepper-and-salt" appearance in the mass. The clayey residuum in this case may be termed *Yellow Earth* in contradistinction to *Brown Earth* into which it merges. *Yellow Earth* is similar to *Brown Earth* in its main chemical features; it also is dominated by calcium and would accordingly be described as calcimorphic.

- (iv) During the weathering of loose masses of both coarse and fine-grained fragmental volcanic rocks, certain products are liberated and move downwards in solution or colloidal suspension, penetrating to various depths into the substrata, depending on rainfall intensity and distribution. Among the soluble or colloidal products are calcium and magnesium bicarbonates, hydrous iron oxides, hydrous silica and secondary clay minerals containing a high proportion of silica. These may be variously deposited so as to cement together the component particles of the parent rock, giving rise to a more-or-less impervious layer that impedes downward drainage. At first the cementation is only light, the substratum still being friable though harsh and gritty. In the Lesser Antilles, this material is commonly known as *Terras*. Its development in the soil profile gradually deflects soil formation from that characterised by free-draining, highly-oxidising conditions to a modified process taking place under excessive wetness, with sluggish drainage or water-logging, and markedly reducing conditions. The resulting kind of soil is consequently described as *hydromorphic* according to modern American nomenclature.

- (v) A late stage in this process where the substratum is almost completely sealed up and cemented into a hard, coherent, compact mass may be recognised; it is especially prominent in the Centre Hills district of Montserrat. The hard substratum here is known as *Shoal* since it is frequently exposed through the removal by surface erosion of the overlying soil material, leaving a hard pavement-like mass resembling a bed of concrete.

The four developmental stages affecting fragmental volcanic ejecta as described above

are clearly recognisable in Montserrat, namely, *Brown Earth* (with *Rendzina*), *Yellow Earth*, *Terras* and *Shoal*. In addition, the weathering of certain non-fragmental, hard, compact rocks must briefly be considered although such rocks are not abundant within the agricultural regions of Montserrat. They chiefly comprise the Miocene basement igneous rocks exposed in the Silver Hill district, the consolidated crystalline rocks comprising the core of the Centre Hills volcano and the small lava flows from the South Soufriere crater. The Silver Hill rocks have weathered into a hard, pavement-like material closely resembling *Shoal*. The Centre Hills igneous rocks have weathered under the wet climate that prevails at high altitudes into *Red Earth*, but the South Soufriere lava-flows have not weathered greatly where exposed in the southern sea-cliffs.

The chief soil-types derived from each of these weathered parent materials may conveniently be referred to under the same names. It must be understood that these lithological soil-type names are provisional and tentative and are intended to be merely descriptive.

#### (6) THE CHIEF SOIL-TYPES OF MONTSERRAT

*Classification*: In accordance with the principles formulated in the last section, the chief soil-types developed in Montserrat may provisionally be named and classified thus (5) :—

- (a) *Fresh, Unaltered, Loose Parent Fragmental Volcanic Materials*
- (1) *Lithosol* *Azonal*
  - (2) *Alluvial* (River: Estuarine) and *Colluvial* Soils
- (b) *Partly-Weathered, Loose Parent Materials*
- (3) *Brown Earth* — from coarse materials *Calcimorphic*
  - (4) *Rendzina* — from lime-encrusted materials *Intrazonal*
  - (5) *Yellow Earth* — from fine-grained materials
- (c) *Well Weathered, Cemented Parent Materials*
- (6) *Terras Soil* — partly cemented below *Hydromorphic*
  - (7) *Shoal Soil* — well-cemented below *Intrazonal*
- (d) *Well Weathered Residual Parent Materials*
- (8) *Red Earth* — from volcanic core igneous rocks *Zonal*

*Distribution:* The distribution of these soil-types within the area under consideration is shown in the accompanying reconnaissance soil map, in which the sites of the pits that were dug for soil profile examination and sampling are indicated by numbers in circles. In addition to those shown on the map, seven other Lithosol profiles were sampled at Richmond\* and two forest soil profiles, one near the summit of Centre Hills (Red Earth) and one at Chances Mountain in the Soufriere Hills (Brown Earth).†

It will be noted in the map that the *Lithosol* forms a coastal strip along the south-western part of the island, and that it occurs over the fringes of the volcanic deposits of St. George's, Soufriere and South Soufriere Hills, where the rainfall is relatively small (below 50 inches), and weathering consequently slight.

*Yellow Earth* forms a strip roughly parallel to the *Lithosol* strip though having higher elevation, lying approximately between the 250 and 600-foot contours on the leeward slopes of Soufriere Hills, and between the 600-foot contour and the summit of St. George's Hill. Here the rainfall is higher (50 to 60 inches a year).

*Brown Earth* forms another concentric strip running along the contours of the Soufriere Hills at a higher elevation than the last (*i.e.*, above 600 feet) where the rainfall is still greater (above 60 inches a year). The main feature of the Brown Earth belt is the bouldery nature of the parent fragmental rocks (since a tendency exists for the coarser particles to be ejected nearer to the volcanic crater) and also for the finer component particles to be gradually washed out and carried downhill. The ejecta comprising St. George's Hill are notable for their fineness of grain which has doubtless mainly decided the development there of Yellow Earth rather than Brown Earth.

*Terras Soil* and *Shoal Soil*, displaying impeded drainage features in the profile, although sometimes difficult to differentiate in the field since they merge imperceptibly one into the other, have developed solely from the older fragmental materials comprising Garibaldi Hill and Centre Hills. This implies that they are older types of soil than either the *Lithosols*, the *Yellow Earth* or the *Brown Earth*, and have taken longer to evolve; they are more mature though their development into Zonal Soils has been deflected because of the effects of the special sub-soil conditions which impeded drainage has induced through the cementation and gradual sealing-up of the substratum. These two hydromorphic soil-types have evidently developed under annual rainfalls below 60 inches. In the soil map, Shoal soil is shown occurring above

the 400-foot contour on Centre Hills. Its presence there was conjectured; no exploration of this part of the island was made in the limited time at our disposal. Similarly, Shoal is shown over the Silver Hill district. This also was conjectured from verbal reports; no soil investigations were made in this area either.

## (7) DESCRIPTION OF THE SOIL-TYPES

### (A) Azonal Soils

(1) *Lithosol*: Soils of this class are derived from fresh unweathered, loose, uncemented or only partially-cemented volcanic ejecta consisting of all sizes and kinds of rock fragments, pumice, glass and separate mineral grains. The soil profile displays a black humic sand about 6 ins. deep, merging into unaltered fragmental materials. Slight eluviation may have produced an incipient clay-pan; the parent material usually shows stratification and old buried humic soils may be discerned at various depths. Numerous phases of *Lithosol* may be distinguished according to particle size, angle of slope, kind of deposit and humus status.

Productivity depends mainly on the degree of organic incorporation, which in turn depends on age. The soil is liable to dry out in droughts. Erodibility is low except under torrential rains. Stones help to protect the surface from loss of water and from erosion.

(2) *Alluvial and Colluvial Soils*: These are derived from loose sediments occurring in river valleys, estuaries, narrow coastal plains and the bases of hills. Phases include (a) bouldery, stony, sandy and silty soils, (b) "living" alluvium (receiving replenishment by hill-wash), and (c) "dead" alluvium, undergoing pedological differentiation. Alluvial soils occupy only a limited area in Montserrat. Their greatest development occurs at Trants Estate on the windward coast and at Old Road on the leeward.

### (B) INTRAZONAL SOILS

*Calcimorphic Soils*: These soils owe their features largely to the effects of calcium-ion liberated by the hydrolysis of lime-bearing minerals. The element forms calcium bicarbonate which induces alkalinity around the soil particles, thus fixing iron oxide, as well as precipitating humus.

Among the calcimorphic characters are (a) bright ochre-yellow to red-brown colouration, attributed to limonite, (b) intense dark colouration of the humic layer, (c) sharp division between the humic soil and the parent material immediately below it, (d) high C/N ratio

\* by Mr. R. E. D. Baker, Mycologist, I.C.T.A.

† by Dr. J. S. Beard, Assistant Conservator of Forests, Trinidad.

(above 12.0) and (e) alkaline to slightly acidic reaction, accompanied by a high degree of saturation by exchangeable calcium.

(3) *Brown-Earth Soil*: This soil-type develops over loose coarse agglomerates and gravels, consisting mainly of fragments of rock rather than separate mineral grains. Superficial weathering has produced within a shallow surface zone coatings of clay and a gritty-clay matrix having a "ginger-bread" colour. This gives rise to a dark chocolate to black, slightly acid, humic soil with a granular or nut structure, cloddy below. The clay-loam subsoil is distinctly paler and contains rock fragments showing varying degrees of decomposition and staining by manganese oxide. Its reaction is nearly neutral and its exchangeable calcium status is high. Phases of the type show differing depth of soil, angle of slope and boulderiness.

Brown Earth has developed best in Montserrat at elevations above 1,000 feet on misty slopes with rainfall around 70 inches. It is very productive of provision crops, tomatoes, sugarcane and cotton. The less bouldery phases are prone to erosion on the slopes.

*Relationships*: Brown Earth Soil resembles the original Brown Forest Soil (Braunerde) of Ramann. Incipient podsolisation has taken place in some cases, as shown by reaction gradients in the profile. The less-mature phases merge into Lithosol, the more mature into Red Earth Soil. Subsoil cementation leads to the development of hydromorphic types. Yellow-Earth soil may be a sub-type of Brown-Earth.

(4) *Rendzina*: This soil-type develops over soft limestones and marls under a wide range of climates. The Montserrat (Bransby Ridge) Rendzina has a black humic layer, 18 inches thick, overlying coffee-brown clay becoming paler below. It is alkaline or slightly acid in reaction and contains medium-high amounts of organic matter.

(5) *Yellow Earth Soil*: This soil-type develops over volcanic ash or sand in which the ferromagnesian mineral grains have broken down to ochreous limonite and the lime felspar crystals have changed into pseudomorphs of a clay-mineral resembling beidellite, judging by its physical properties and the relatively high base exchange capacity of the soil. Magnetite has remained unaltered so that the soil parent material displays a "pepper-and-salt" appearance. The humic layer is dark brown to black with depth up to 36 inches. It is alkaline or neutral in reaction and possesses a crumb to small clod structure. It sharply overlies the parent material which is uniform to great depth, though usually showing sepia spotting or staining with manganese peroxide between 3 and 8 feet depth and white speckling and spotting with powdery calcium carbonate at depths between

7 and 50 feet. Yellow Earth is not typically developed in Montserrat, being here difficult to distinguish from Terras. (The best examples of Yellow Earth occur in St. Vincent).

*Relationships*: The type-features resemble those of Rendzina derived from marl and the development of these two calcimorphic soils from deep porous calciferous parent materials is somewhat analogous. The more mature phases of Yellow Earth show incipient cementation and thus merge into Terras. The bouldery phases resemble Brown Earth.

*Hydromorphic Soils*: Hydromorphic soils owe their features to drainage impidence which may appear in loose fragmental volcanic rocks either by the consolidation and induration of the original volcanic materials or by cementation within Yellow Earth and less commonly, Brown Earth, parent materials. Cementation generally occurs by deposition (illuviation) in the subsoil (B-horizon) of silica or a highly siliceous clay mineral formed by the breakdown of felspars. Occasionally the cement may include rusty-brown ferric oxide. The deposit of siliceous cement resembles a clay-pan. The loosely-coherent material is colloquially called "terras", a corruption of "trass", a kind of puzzulana, and is used locally as a binder for road metal. When cementation is firmer, the product is called "shoal" in Montserrat; it sets very hard and resembles concrete.

Induration and cementation of fragmental volcanic materials may take place during different geomorphic cycles. The processes particularly affect volcanic ash and the finer agglomerates that have been *submerged beneath the sea* subsequent to their sub-aerial deposition. (Altered materials of this kind should perhaps be differentiated from true *volcanic tuff* which is a stratified sedimentary rock consisting of volcanic ash or dust deposited directly in the sea or in lakes and consolidated by pressure). Prior to their elevation above sea-level, indurated fragmental volcanic materials usually have become greatly decomposed so that their original mineralogical composition is profoundly modified.

Two kinds of terras and shoal may thus be distinguished; the first may be described as "pedological", the second as "geological". In *pedological* Terras or Shoal Soil, the impervious cemented layer comprises a true B-horizon of accumulation. In *geological* Terras or Shoal Soil, the impervious indurated layer may be regarded as the parent soil material (C-horizon) or as the parent rock (D-horizon). In either case, drainage impidence causes the development of a characteristic *clay type of soil* which is plastic and slippery when wet and hard and horny or waxy when dry. Its colour is either

creamy-brown ("milk-chocolate") or brownish-green (khaki). Its structure is coarsely cloddy and it tends to crack deeply and to break into prismatic columns on drying. The chief clay mineral present appears to be *beidellite* but this conclusion needs to be verified by further investigation.

(6) *Terras Soil*: The profile of this soil-type consists of a uniform stony and sandy humic clay (containing about 25 per cent of clay), variably acid in reaction, sharply overlying loosely cemented, grey terras sometimes rusty-stained in its upper part. The thickness of the terras may vary from a few inches to several feet.

(7) *Shoal Soil*: The soil-profile of both "geological" and "pedological" shoal consists of a heavy humic clay (containing about 70 per cent of clay), often acid in reaction, merging into a more-or-less red or brown-mottled clay having a thin waxy black organic layer or smear at its base, overlying nearly-impervious shoal. Pisoliths rich in manganese peroxide may occur within the humic soil and smears of the same substance may line the cracks of the shoal.

- (i) Shoal soil that has developed by further cementation and induration within the Terras soil profile may be designated "*Primary Shoal Soil*."
- (ii) Numerous cases have been observed, however, where the original soil (A-horizon) has been removed by erosion so as fully to expose the shoal. This has then formed a thin soil (akin to a sandstone lithosol). This may be designated "*Secondary Shoal Soil*".
- (iii) Finally, a few cases have been noted where extraneous soil, transported from land at a higher level, has been superimposed on an eroded shoal forming a composite profile which may be designated "*Tertiary Shoal Soil*".

*Relationships*: The graded series of hydro-morphic soils described above show the effects of increasing maturity. They might be expected finally to end in the formation of *Ground-Water Podsol* or even *Ground-Water Laterite* soils. Cases of such extreme development have not, however, so far been discovered in Montserrat nor in any other island of the Lesser Antilles, probably because of the relative youth of the region. In the Netherlands East Indies, E. C. J. Mohr has described advanced stages of hydro-morphism in fragmental volcanic soils in which water-logging has produced well-marked red-mottled "glei", and drainage-impedence has given rise to fresh-water springs.

(8) *Red Earth*: The profile of this usually very deep, mature, fully-developed, Zonal soil-type shows no differentiation into layers. The dark-brown humic soil grades imperceptibly into the uniform, bright brick-red, crumbly parent material which has a highly acid reaction, having been deprived of soluble bases by leaching. In Montserrat, this soil-type occurs only on the summit of Centre Hills.

#### (8) LABORATORY DATA FOR SOIL PROFILE SAMPLES

The soil samples were subjected to the routine methods of partial physical and chemical analysis customarily applied in the College Chemistry Department. The methods used are described at the end of this report. The full laboratory data for all the profile soil samples examined are set out in the Appendix. Data for surface six inches 10-spot composite samples, collected at the times when the profiles were sampled, are brought together in Tables II, III and IV. The mean results for each soil-type are summarised in Table V which also shows the approximate area of each soil-type at present under cultivation.

*Discussion of the laboratory data for surface six-inch layers*: The values for any one soil constant vary considerably for each soil-type; they indicate general tendencies which serve to differentiate one kind of soil from the other.

- (a) The *degree of clayiness*, measured by silt-and-clay content and by index of texture, is least in the Lithosol and Alluvial soils. The Brown Earth and Yellow Earth soils, however, are a little more clayey, being somewhat decomposed. By contrast, the Rendzina and the Terras and Shoal hydro-morphic soils contain appreciably more clay-and-silt, although, on their index of texture values, they would still be classed as sands or loamy-sands. None of the Montserrat soils would be regarded as really clayey.
- (b) The *degree of acidity* is never very high in any of the surface soils, the average for the whole range being pH 6.5, which would be regarded as only slightly acid. The Shoal Soils are the most acid, as would be expected from their relative maturity, though none has a reaction value below pH 6.0.
- (c) *Organic matter and nitrogen* contents show considerable variation among the soil-types. They are regularly the highest in the Rendzina and Shoal Soils but diminish in the Terras, Brown Earth and Yellow Earth soil-types, being relatively low in the

Lithosol and Alluvial types which contain only about 1.7 per cent of organic matter, 0.09 per cent total nitrogen, with mean C/N ratio 10.7. The Brown and Yellow Earth soils contain about 2.2 per cent organic matter, 0.12 per cent of nitrogen and C/N ratio 10.3. By contrast, the

more clayey types contain on the average 2.9 per cent of organic matter, 0.17 per cent total nitrogen, with C/N ratio about 10.0.

(d) *Electrical conductivity*, determined on soil and water mixtures as a measure of total soluble nutrients, did not

**TABLE II: Azonal Soil-Types**  
(Laboratory data for surface 6-inch layers)

		Grav- el (%)	Crse. sand (%)	Silt and Clay (%)	Index of Text. (I.T.)	React- ion (pH)	Org. matt. (%)	Total nitro- gen (%)	C/N Ratio	Aveil. phosphate P <sub>2</sub> O <sub>5</sub> p.p.m.	Avail. potash K <sub>2</sub> O p.p.m.	
<b>(1) LITHOSOL (Fresh Volcanic Ash and Cinders)</b>												
Richmond Estate: Leeward												
(1)	Richmond	1	18	47	26	3	6.7	1.43	.08	11.1	(353)	221
(2)	"	2	9	36	34	7	6.5	2.26	.12	11.1	57	143
(4)	"	4	20	59	18	0	6.2	1.26	.07	10.0	300	179
(5)	"	5	19	58	19	2	6.4	1.22	.07	10.3	180	113
(10)	"	10	12	39	33	11	6.7	2.86	.15	10.7	154	207
(i)	"	13	48	90	2	0	7.2	0.67	.03	7.8	150	76
(ii)	"	14	37	59	19	2	6.5	1.36	.07	11.1	233	72
(iii)	"	15	34	48	26	6	6.5	2.21	.12	10.9	80	221
(iv)	"	16	38	56	24	5	6.5	1.87	.10	10.5	180	136
(v)	"	17	17	44	33	6	6.6	2.25	.12	11.8	73	123
(vi)	"	18	41	67	17	3	6.4	2.02	.11	10.9	92	118
(vii)	"	19	33	46	29	6	6.4	2.78	.14	12.1	50	89
<b>MEANS</b>			27	54	23	4	6.5	1.85	.10	10.7	141	141
Dagenham Estate; Leeward												
(49)	Dagenham	1	13	36	30	7	6.6	1.55	.09	10.5	388	244
(50)	"	2	14	37	31	7	6.5	2.14	.11	11.1	780	292
(51)	"	3	16	53	21	2	6.4	1.36	.08	10.2	490	231
(52)	"	4	14	46	28	4	6.6	1.45	.08	11.1	312	172
<b>MEANS</b>			14	43	28	5	6.5	1.62	.09	10.7	493	255
O'Gara's Estate: South												
(25)	O'Gara's	1	20	60	15	0	6.8	0.97	.06	10.0	325	207
(26)	"	2	24	39	34	10	7.7	1.91	.10	10.8	(2880)	557
(27)	"	3	39	48	25	13	6.9	(4.86)	(.29)	(9.7)	284	561
(28)	"	4	44	57	16	5	7.2	1.87	.12	9.5	212	358
<b>MEANS</b>			32	21	23	7	7.1	1.58	.09	10.1	274	421
Windward												
(37)	Whites	2	10	27	33	7	6.3	2.36	.11	12.6	44	227
<b>(2) ALLUVIAL and COLLUVIAL SOILS (Mostly Flood Materials, resembling last)</b>												
Richmond and Ile's Bay Estates: Leeward												
(12)	Bath		17	59	16	6	6.5	1.02	.06	9.9	195	153
(19)	Ile's Bay	1	9	41	36	9	6.3	2.52	.14	10.5	84	127
(20)	"	2	3	33	33	12	6.5	2.22	.12	10.7	120	183
<b>MEANS</b>			10	44	28	9	6.4	1.92	.10	10.4	133	154
Trants Estate: Windward												
(29)	Trants	1	9	44	26	3	6.6	1.43	.08	10.8	292	351
(30)	"	2	6	49	25	3	7.2	1.72	.09	11.6	(2920)	389
(31)	"	3	5	46	31	4	6.9	1.72	.09	11.6	364	289
(32)	"	4	4	37	32	4	6.9	1.58	.08	11.9	170	248
(33)	"	5	4	36	27	3	6.8	1.01	.06	9.9	76	268
<b>MEANS</b>			6	42	28	3	6.9	1.49	.08	11.2	225	309
<b>WEIGHTED MEANS</b>			20	44	25	5	6.6	1.75	.09	10.8	219	226

reveal any significant differences between the soil-types. The recorded values on the whole are fairly high in magnitude because of the high base status of the majority of the soils.

- (e) Available phosphate content of the top 6-inch layer is extremely variable. It is very high (over 100 p.p.m.) in the Lithosol, Alluvial-Colluvial and the Yellow Earth soil-types, although, as has previously been stressed, the high Truog values for the first two of these soil-types do not necessarily imply adequate supplies of readily-soluble

phosphate since these soils actually show marked phosphate-shortage in pot-test with indicator plants such as tomato.

Available phosphate content of the other soil-types (Brown Earth, Rendzina, Terras and Shoal) tends to be relatively low (average, 45 p.p.m.), although not in every case necessarily deficient.

- (f) Available potash is also variable and generally rather low. Variability is

TABLE III: Intrazonal Soil-Types

(Laboratory data for surface 6-inch layers)

	Grav- el (%)	Crse. sand (%)	Silt and Clay (%)	Index of Text. (I.T.)	React- ion (pH)	Org. matt. (%)	Total nitro- gen (%)	C/N Ratio	Avail. phosphate P <sub>2</sub> O <sub>5</sub> p.p.m.	Avail. potash K <sub>2</sub> O p.p.m.	
<b>CALCIMORPHIC (Calcium dominant)</b>											
<b>(3) BROWN EARTH</b>											
<b>Windward</b>											
(34) Hermitage	1	27	34	34	9	6.1	2.43	.14	10.3	46	102
(35) "	2	18	28	39	9	6.1	2.47	.12	11.4	128	166
(36) Whites	1	17	35	32	6	6.5	1.86	.09	11.5	(192)	159
(38) Bethel	1	14	25	37	7	6.5	1.85	.11	10.2	31	148
(40) "	3	21	26	38	6	6.5	1.28	.07	10.1	45	198
(41) Tuits	3	11	21	45	17	6.5	3.80	.19	11.3	37	204
(42) Tar River	1	20	41	42	14	6.5	2.55	.17	8.6	71	(276)
(43) "	2	33	42	39	16	6.4	3.21	.18	10.6	72	(415)
(44) Rileys	1	9	17	56	19	6.2	1.77	.11	9.0	9	101
(45) "	2	9	14	57	19	6.1	2.31	.13	9.9	14	196
(46) "	3	9	10	62	33	5.9	3.48	.21	9.6	5	190
(47) Farrells	1	8	28	41	10	6.2	1.79	.10	10.5	12	106
<b>Leeward</b>											
(54) Parsons	1	9	21	47	12	6.5	1.98	.10	11.2	103	169
(55) Amersham	1	37	20	50	15	6.7	1.56	.10	8.7	22	66
(56) "	2	21	26	41	8	6.9	1.79	.10	10.8	(376)	(406)
MEANS		16	26	44	13	6.4	2.28	.13	10.2	46	150
<b>(4) RENDZINA</b>											
<b>Bransby Ridge: Leeward</b>											
(11) Richmond	11	12	18	58	29	6.5	3.40	.21	9.4	23	139
(18) Elberton	5	8	15	61	29	7.2	3.09	.17	10.2	89	243
<b>(5) YELLOW EARTH</b>											
<b>Richmond Estate: Leeward</b>											
(3) Richmond	3	11	41	30	9	6.3	3.39	.18	11.1	57	162
(6) "	6	9	34	33	10	6.5	2.29	.12	11.1	165	152
(7) "	7	19	52	27	6	6.6	2.47	.12	11.5	(323)	147
(8) "	8	18	40	30	7	6.5	1.90	.10	10.6	50	95
(9) "	9	18	54	22	5	6.6	2.38	.13	10.2	135	108
(48) Gages		20	46	28	7	6.6	1.79	.11	9.6	170	(226)
(53) Webbs		10	28	41	9	6.5	1.79	.10	10.8	70	(379)
<b>Windward</b>											
(39) Bethel	2	15	35	31	6	6.4	1.36	.09	8.9	(340)	(676)
MEANS		15	41	30	7	6.5	2.17	.12	10.5	108	131
WEIGHTED MEANS		15	30	41	12	6.5	2.32	.13	10.3	65	152

greatest among the Lithosol and Alluvial-Colluvial soils, excepting the O'Garas soils which are apparently

rich in potash. It tends to be lowest in the Yellow Earth and the Shoal soils.

TABLE IV: Intrazonal Soil-Types (Continued)

(Laboratory data for surface 6-inch layers)

	Grav- el (%)	Crse. sand (%)	Silt and Clay (%)	Index of Text. (I.T.)	React- ion (pH)	Org. matt. (%)	Total nitro- gen (%)	C/N Ratio	Avail. phosphate P O 2 5 p.p.m.	Avail. potash K O 2 p.p.m.	
<b>HYDROMORPHIC</b> (Water dominant; Impeded drainage)											
<b>(6) TERRAS</b>											
(14) Elberton	1	8	21	51	16	6.6	2.88	.17	10.0	94	279
(15) "	2	11	25	50	27	6.7	2.48	.16	9.2	23	120
(16) "	3	6	19	50	14	6.9	1.79	.12	9.0	38	138
(17) "	4	11	19	54	15	6.8	2.17	.13	9.5	113	(401)
<b>MEANS</b>	<b>9</b>	<b>21</b>	<b>51</b>	<b>18</b>	<b>6.7</b>	<b>2.33</b>	<b>.14</b>	<b>9.4</b>	<b>67</b>	<b>179</b>	
<b>(7) SHOAL</b>											
(21) Ile's Bay	3	17	28	42	18	6.4	3.76	.21	10.6	(169)	(482)
(22) Olveston	1	5	17	61	22	6.1	3.88	.22	10.2	21	94
(23) "	2	7	19	45	20	6.3	4.22	.24	10.0	27	99
(24) "	3	13	15	58	34	6.4	3.43	.19	10.3	31	158
(57) Sweeneys	1	25	30	45	13	6.8	2.02	.11	10.5	35	205
(58) "	2	19	29	44	10	6.6	2.07	.11	10.7	55	207
(59) Woodlands	1	11	18	55	16	6.1	2.38	.14	10.2	18	114
(60) "	2	36	19	54	19	6.4	3.84	.20	11.0	44	(366)
(61) Cork Hill		8	38	45	19	6.2	1.55	.10	9.5	17	80
<b>MEANS</b>	<b>16</b>	<b>24</b>	<b>50</b>	<b>19</b>	<b>6.4</b>	<b>3.02</b>	<b>.17</b>	<b>10.3</b>	<b>31</b>	<b>137</b>	
<b>WEIGHTED MEANS</b>	<b>15</b>	<b>23</b>	<b>50</b>	<b>19</b>	<b>6.5</b>	<b>2.81</b>	<b>.16</b>	<b>10.0</b>	<b>43</b>	<b>150</b>	

TABLE V: Summary of Laboratory Data for Chief Soil-Types

(Surface 6-inch layers)

	Total area culti- vable (thou- sand acres)	Grav- el (%)	Crse. sand (%)	Silt and Clay (%)	I.T.	Normal react- ion (pH)	O.M. (%)	Total nitro- gen (%)	C/N Ratio	Avail. phosphate P O 2 5 (p.p.m.)	Avail. potash K O 2 (p.p.m.)
<b>FREE DRAINING</b>											
1. Lithosol	2.1	25	45	25	5	6.5	1.78	.10	10.6	230	210
2. Alluvial- Colluvial	0.2	8	43	28	5	6.7	1.65	.09	10.9	190	250
3. Brown Earth	4.4	16	26	44	13	6.4	2.28	.13	10.2	45	150
4. Yellow Earth	1.7	15	41	30	7	6.5	2.17	.12	10.5	110	130
<b>Weighted means</b>	<b>18</b>	<b>40</b>	<b>32</b>	<b>8</b>	<b>6.5</b>	<b>1.80</b>	<b>.11</b>	<b>10.5</b>	<b>150</b>	<b>190</b>	
<b>IMPEDED DRAINING</b>											
5. Rendzina	—	10	17	60	29	6.9	3.25	.19	9.8	50	190
6. Terras	0.7	9	21	51	18	6.7	2.33	.14	9.4	70	180
7. Shoal	10.5	16	24	50	19	6.4	3.02	.17	10.3	30	140
<b>Weighted means</b>	<b>14</b>	<b>22</b>	<b>51</b>	<b>20</b>	<b>6.5</b>	<b>2.88</b>	<b>.165</b>	<b>10.0</b>	<b>45</b>	<b>155</b>	

(9) CHEMICAL AND MINERALOGICAL TRANSFORMATIONS INVOLVED IN SOIL FORMATION FROM FRAGMENTAL VOLCANIC MATERIALS

(a) *Terras*: The only transformations we have so far studied in detail in Montserrat are those between the parent rock and a *Terras* type of soil exposed in a road-side quarry at the

base of Cork Hill, near Olveston, site No. 61 on the soil map. The laboratory data for this profile are given in the Appendix.

The soil profile has the following features:—

- (1) *A-horizon* (0-24 ins.): Black humic soil, 7 per cent stones, 25 per cent clay. The sand fraction consists chiefly of lime felspar, hornblende, magnetite.

TABLE VI: *Terras* Soil Profile (Cork Hill)

Results of bulk chemical analysis

Depth (ins.)	Percentage Composition										Ratios				
	SiO <sub>2</sub>		Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>		CaO	MgO	K <sub>2</sub> O	Na <sub>2</sub> O	H <sub>2</sub> O	Molecular				
	Quartz	Comb.	Total	Magnetite	Other						SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>			
(A) WHOLE MATERIAL															
(A) Soil															
(1)	0-6	54.3	19.2	1.2	7.6	5.1	2.2	—	—	6.4	4.81	0.53			
(4)	18-24	55.1	19.5	1.0	8.1	4.9	2.4	0.6	2.3	6.4	4.80	0.54			
(B) Cemented layer ( <i>Terras</i> )															
(5)	24-27	56.6	17.0	0.4	7.2	6.8	3.1	1.1	3.0	1.0	5.64	2.98			
(6)	69-72	64.0	16.7	0.2	5.0	4.3	1.9	1.5	3.0	2.4	6.49	1.22			
(C) Parent ash															
(7)	116-	55.0	19.0	0.2	8.7	8.4	3.8	—	—	1.0	4.90	3.40			
(B) CLAY FRACTION															
(A) Soil															
(1)	0-6	4.8	44.6	23.1	11.0	—	0.9	—	—	14.5	3.28	0.28			
(4)	18-24	4.3	44.1	21.7	11.6	—	0.7	—	—	14.6	3.45	0.26			
(B) Cemented layer ( <i>Terras</i> )															
(5)	24-27	47.2	24.3	8.6	—	0.6	1.8	—	—	13.3	3.30	0.32			
(6)	69-72	64.0	18.3	4.7	—	1.6	1.6	—	—	9.0	5.94	0.36			
(C) Parent ash															
(7)	116-	69.1	14.8	3.3	—	2.2	1.6	—	—	4.8	7.92	0.54			
Results recalculated to constant alumina content															
WHOLE MATERIAL															
(C) Parent ash															
(7)	116-	55.0	19.0	0.2	8.7	8.4	3.8	—	—	—	4.90	—			
(B) Cemented layer ( <i>Terras</i> )															
(6)	69-72	72.8	19.0	0.2	5.7	4.9	2.1	1.7	3.4	2.7	—	—			
(5)	24-27	63.4	19.0	0.4	8.1	7.6	3.5	1.2	3.4	1.1	—	—			
(A) Soil															
(4)	18-24	53.7	19.0	0.9	7.9	4.8	2.3	0.5	2.2	6.2	—	—			
(1)	0-6	53.7	19.0	1.2	7.6	5.0	2.2	—	—	6.3	—	—			
Losses and Gains between parent rock (stony ash), cemented layer ( <i>Terras</i> ) and humic soil.															
(B) Cemented layer ( <i>Terras</i> )															
(6)	69-72	17.8	—	0.0	-3.0	-3.5	-1.7	—	—	—	—	—			
(5)	24-27	9.4	—	0.2	-2.4	2.7	1.4	-0.5	-0.0	-1.6	—	—			
(A) Soil															
(4)	18-24	9.7	—	0.5	-0.2	-2.8	-1.2	-0.7	-1.2	5.1	—	—			
(1)	0-6	0.0	—	0.3	-0.3	0.2	-0.1	—	—	0.1	—	—			
											Kaolinite	—	Al <sub>2</sub> O <sub>3</sub> .2SiO <sub>2</sub> .2H <sub>2</sub> O	2.00	0.50
											Halloysite	—	Al <sub>2</sub> O <sub>3</sub> .2SiO <sub>2</sub> .4H <sub>2</sub> O	2.00	0.25
											Beidellite	—	Al <sub>2</sub> O <sub>3</sub> .3SiO <sub>2</sub> .3H <sub>2</sub> O	3.00	0.33

TABLE VIA: Terras Soil Profile (Cork Hill)

Results of Exchangeable Base determinations  
(Values are milligram equivalents per 100 grams)

	Hissink's method (NaCl extract)			Rice Williams' method (Acetic acid extract)		
	CaO	MgO	Sum	CaO	MgO	Sum
Topsoil (0-6 ins.)	11.2	7.5	18.7	9.0	7.0	16.0
Subsoil (18-24 ins.)	8.7	6.4	15.1	7.4	5.8	13.2
Terras (27-72 ins.)	8.3	5.3	13.6	3.3	2.4	5.7
Parent ash (72-116ins.)	1.1	0.4	1.5	3.3	0.9	4.2

NOTE: Extraction with salt solution demonstrates clearly the high base exchange capacity of the terras, as well as of the soil overlying it.

quartz, glass and ferric oxide pisoliths. The reaction is pH 6.3; no colouration was given with Comber's thiocyanate reagent; the soil is therefore presumably highly saturated with bases.

(2) *B-horizon* (24-72 ins.): *Terras*:

This consists of cemented, stony volcanic ash, coherent above, less coherent below, with clay content 5 per cent. The content of stones is 70 per cent; their average diameter is 1 inch and they are mostly pumiceous with internal pore-space 25 per cent. The matrix consists of fresh mineral sand. The reaction is pH 6.9 near the top and pH 7.3 below.

(3) *C-D horizon* (72-116 ins.): This is

the parent ash, consisting of loose, incoherent, white to purple-grey, round pumiceous stones, 1½ inch in diameter, having a gritty-sandy matrix. There is no clay present but the matrix contains 20 per cent of fine sand and silt. The reaction is pH 7.1.

*Results of chemical analysis*: Bulk chemical analyses were carried out on the 2 mm. material and on the 2 μ clay fraction by the fusion method. Unfortunately, quartz could not be determined in all samples because of the failure of tri-acid mixture to decompose all the silicates present. The results obtained are set out in Table VI.

*Discussion*: None of the samples contained free alumina as gibbsite (alizarin test). All the sand fractions contained abundant quartz grains (microscopic examination). Magnetite (separated by means of an electromagnet) occurred only in small amount.

The main transformations (assuming no migration of alumina) were; (i) a marked enrichment of the cemented layer (*B-horizon*; *Terras*) by silica, some of which appears to

have moved upwards from below, (ii) a slight accumulation of ferric oxide near the top of the cemented layer, (iii) only slight removal of bases, (iv) a large fixation of water in the soil, presumably as water of hydration of a newly-formed clay mineral.

The chief result of this investigation therefore is the proof that the restriction of downward leaching through the formation of a cemented layer greatly reduces the loss of bases (particularly lime) and causes the development in the soil of a highly hydrated secondary clay mineral. Judging by the ratios for the clay fractions set out in the last two columns of Table VI, this secondary mineral is probably *beidellite*, a conclusion which needs to be fully confirmed before final acceptance. The marked shrinkage of the topsoil on drying and the relatively high base exchange capacity of the topsoil when compared with that of the terras and of the parent ash, as indicated by the results obtained by measuring the exchangeable lime and magnesia in acetic acid extracts given in Table VIA help to substantiate the claim.

(b) *Shoal*: Confirmation of the results set out above was obtained by bulk chemical analysis of the clay fraction obtained from samples of soil and shoal collected from profile No. 21, Ile's Bay 3. The results are set out in Table VII.

*Discussion*: The analyses recalculated to constant alumina show, (i) that the clay fraction of the *shoal* contains 6.5 per cent more silica than the soil, which may be accounted for by downward leaching, (ii) that it contains the same amount of ferric oxide, (iii) that it contains 1.1 per cent more lime and 0.5 per cent more magnesia than the soil, and (iv) that its degree of hydration is high in both materials. As in the example of *Terras*, impeded drainage in the *shoal* profile has apparently prevented the loss of the lime and magnesia by leaching and has maintained alkaline conditions within the *shoal* layer.

TABLE VII: Shoal Profile (Ile's Bay)  
Results of bulk chemical analysis

Depth (ins.)	Total SiO <sub>2</sub>	Total Al <sub>2</sub> O <sub>3</sub>	Total Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO	K <sub>2</sub> O	Na <sub>2</sub> O	H <sub>2</sub> O	Ratios (molecular)		
									SiO <sub>2</sub> Al <sub>2</sub> O <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub> H <sub>2</sub> O	
CLAY FRACTION											
(1) Soil (12-20)	49.1	22.3	10.0	0.5	1.7	—	—	13.3	3.75	0.29	
(2) Shoal (20-23)	52.6	21.4	9.9	1.8	1.8	—	—	11.1	4.17	0.34	
(3) Shoal (33-36)	54.2	21.2	9.4	1.4	2.4	—	—	10.9	4.34	0.34	
Reaction: (1) pH 7.3, (2) pH 7.2, (3) pH 7.2											
Difference in composition between shoal and soil, assuming constant-alumina content.											
(1) Soil	46.9	21.3	9.6	0.5	1.6	—	—	12.8	3.75	0.29	
(2) (3) Shoal (average)	53.4	21.3	9.6	1.6	2.1	—	—	11.0	4.25	0.34	
Difference (gain by shoal)	6.5	—	0.0	1.1	0.5	—	—	-1.8			

#### (10) PEDOLOGICAL RELATIONSHIPS

The regular occurrence of *Terras* and *Shoal* soil-types within the coastal regions of Montserrat where the climate is comparatively dry (rainfall less than 60 inches a year) and shows a well-marked dry season (one or more "dry" months having rainfall less than 2.4 ins.), and their general absence in higher and wetter regions, suggest that these two soil-types owe their distinctive features to *Climate*, and should therefore be classified as *Zonal* rather than *Intrazonal*. The following arguments are opposed to this view:—

- (1) *Terras* and *Shoal* do not invariably occur in regions of medium-low rainfall; in St. Vincent, for example, they occur in a narrow coastal strip having mean annual rainfall 84 ins., although admittedly this is an exceptional case. In St. Lucia, they occur in the 70 to 50 ins. rain belt.
- (2) Typical representatives of *Terras* and *Shoal* soils are developed in Montserrat and some other volcanic islands over *fine-grained* parent materials which characteristically occur within coastal or peripheral areas because such materials are naturally deposited furthest away from the volcanic craters, being carried partly by winds and frequently by "black clouds"

(*nuées ardentes*). In this sense, they may therefore be regarded as lithological soil-types.

- (3) In some cases *Terras* or *Shoal* consists of much-decomposed ash or agglomerate that has been submerged beneath the sea for long periods of time. Thus, where the old Miocene basement has become exposed because of uplift and denudation, the parent material is already cemented and indurated. The derived soil-type (which has provisionally been designated "Geological Shoal Soil") closely resembles Shoal Soil that has evolved from *Terras* by further cementation in the subsoil ("Pedological Shoal Soil") and has been mapped as such. Its distribution is necessarily coastal since the denudation which has exposed the Miocene basement has been most profound along insular margins.
- (4) Pedological accumulations of calcium carbonate in practically all cases where they have been identified in *Terras* or *Shoal* occur at relatively great depth (for example, below 87 inches in a pit at Elberton; Site No. (13), Appendix tables). In *Zonal Pedocals* which are true climatic soils (for example, Black Earth or Chernozem), calcareous ac-

cumulations occur at shallow depth within the soil profile proper.

- (5) The formation of a clay mineral resembling *beidellite*, whose presence in Terras and Shoal soil has been indicated, implies drainage impedence and conforms with the concomittant increase in alkalinity which has been found to occur within the terras or shoal layer.
- (6) Under high rainfall, volcanic ejecta appear normally to give rise in the volcanic islands to *Red Earth Soil* (for example, Grenada, Dominica, St. Lucia). This is undoubtedly a free-draining true *Zonal* ("lateritic") soil-type, in which cementation in the B-horizon has been prevented by the constant downward movement of water under a continuously wet or continuously moist climate, and by very deep water-penetration, so that conditions favouring the accumulation of cementing substances and lime are here absent.

*Conclusions* : The writers favour the view that Terras and Shoal should provisionally be placed in the Hydromorphic Intrazonal suborder, but reserve final opinion until the two kinds of Terras and Shoal, namely, "geological" and "pedological" shoal, have been clearly distinguished in the field, their occurrences accurately mapped, and their mineralogical composition more fully investigated.

### (11) SOIL EROSION

The main processes of soil erosion are identical with those of geological erosion but their rate of effective operation has been greatly enhanced through the agency of man. The main manifestation of man's interference with the processes of Nature has been the removal or destruction of protecting vegetation by felling, chopping and burning. In consequence, the vastly increased exposure of the surface of the land to the agents of weathering and transportation, chiefly comprising sun, wind and water, results in a series of continuous small abrasions rather than an interrupted sequence of widely-spaced catastrophies such as characterises geological denudation. Soil erosion may thus be regarded simply as accelerated geological erosion.

In order to differentiate between the various sorts of erosion going on in Montserrat, the classification of land movements suggested by C. F. Stewart Sharpe (6) may conveniently be followed. This scheme distinguishes between flowage and slippage and slow and rapid movements. It also stresses the importance of water content and of differences in composition and

structure of the affected materials in deciding the various kinds of land movements.

*Classification* : The following classes of land movement among those listed by Sharpe are recognisable in Montserrat :

#### (A) FLOWING MOVEMENTS :— LAND-FLOW AND LAND-CREEP

(I) SLOW :— (i) Soil-creep, (ii) Talus-creep, (iii) Rock-creep.

(II) RAPID :— (iv) Earth-flow, (v) Mud-flow, (vi) Débris avalanche.

#### (B) SLIDING MOVEMENTS :— LANDSLIDE OR LANDSLIP

(vii) Slump, (viii) Débris slide, (ix) Débris fall, (x) Rock-slide, (xi) Rock-fall.

The kind and degree of soil erosion that occurs under a given climate vary with soil-type. For the purposes of this review, it will be sufficient to subdivide the soils of Montserrat into two main groups in accordance with their degree of drainage, namely :—

(I) *Free-draining soils* : (1) Lithosol, (2) Alluvial-Colluvial, (3) Brown-Earth, (4) Yellow Earth.

(II) *Impeded-draining soils* : (5) Rendzina, (6) Terras, (7) Shoal.

The first group comprises about 43 per cent of the total cultivable area of the island (Table V), and the second group makes up the remaining 57 per cent, that is assuming that most of the Centre Hills area is occupied by Shoal soil which is doubtful. The following notes mainly concern the free-draining soils developed over fragmental volcanic materials since these comprise most of the land under continuous and widespread cultivation, whereas Terras and Shoal soils are mostly given over to the cultivation of short-term peasants' provision crops.

#### (A) LAND MOVEMENTS AFFECTING FREE-DRAINING SOILS

*Ghaut formation* : The rate at which flowage proceeds depends on *water-content* and *angle of slope*. In the extreme case of streams and torrents where the amount of water and the angle of slope are sufficiently high to enable the water to carry sand, stones and even large boulders bodily in suspension, the land surface over the free-draining volcanic deposits has been scored out into a series of "ghauts" or "guts"

whose occurrence in Montserrat forms a conspicuous feature of the landscape. The deepening, widening and backward cutting of the ghauts is doubtless still going on. The early-formed ghauts situated on the oldest volcanoes (for example, Centre Hills) are now the broadest and least ravine-like, whilst those occurring on the youngest cones (for example, Soufriere Hills) are the deepest and narrowest. Undercutting followed by collapse of the vertical walls are still in evidence in the newer ghauts. Terraced agricultural plots have been established by peasants on the high slopes of some of them.

*Débris avalanche, mudflow, earthflow* : Where water content is not great enough to separate the particles and bring them into suspension but is still sufficient in amount to lubricate the mass of incoherent material, and where the angle of slope is high, *débris avalanche*, mudflow and earthflow occur. An *avalanche* usually starts as a landslide on the slopes of a steep hill and ends as a mudflow or earthflow where the slope flattens out. Mudflows usually follow a stream course and generally recur in the same channel but frequently they break away and form new courses, or they may carry off a broad swathe of surface soil as in the case of earthflows.

The formation of "wash-outs" (which is the common name for mudflows and earthflows) during heavy rainstorms is by far the most general and striking feature of soil erosion over the greater part of the agricultural lands of Montserrat comprising free-draining soil-types. Under normal circumstances when the rain showers are of moderate intensity, these highly-porous soils are fully capable of absorbing and draining away large amounts of rain water. Even the most steeply-sloping land usually suffers no damage, so long as the rainfall is gentle. Cultivation is often practised on hill-sides whose high angle of slope (approximating 40 degrees in extreme cases) would completely exclude them from agricultural utilisation if the soil comprised less-pervious material. Such steep cultivations are a common sight in Montserrat, and the general custom of laying out the land in contour banks for cotton planting is generally sufficient to protect the soil from surface erosion under moderate rainfalls. Where free-draining soils occupy wide unbroken stretches of flat land or easy slopes, erosion is almost imperceptible under light rain showers, but where the flats or slopes are adjacent to steep hills, the danger of erosion by *débris avalanche*, mudflow and earthflow is ever prevalent, especially when the rainfall exceeds a certain critical intensity. In this event, the sudden accumulation of storm water on the hillslopes above, and its rapid passage over the flatter lands, initiate numerous channels which are sometimes narrow and deep and at other times shallow and wide.

*Examples* : An extreme example of *débris avalanche*, accompanied by mudflow and earthflow, occurred on the leeward slopes of St. George's Hill on 9th November, 1896. On that day, over 27 inches of rain were measured at Elberton not far away. The rapid accumulation of water on the hillside by the porous soil material caused a large mass of loose volcanic ash to start moving down the slope. The mass gathered speed and flowed for half-a-mile westward, eventually filling a hollow occupied by a pond. On a more recent occasion, in May, 1941, a large mudflow seriously damaged some of the plots of a manurial experiment at Richmond, cutting channels in the land surface and carrying away a large amount of topsoil.

Occurrences of buried soils at various depths within the area of Lithosol occupying the lower south-westerly slopes and adjacent flat lands of St. George's Hill are recorded in the tables of laboratory data in the Appendix [for example, profile Nos. (1), (3), (4), (5), (9) and (10)]. They may be accounted for by mudflows or earthflows that have occurred in recent or historic times.

*Soil-creep, talus-creep, rock-creep* : Apart from the rapid flowing movements described in the last section, slower movements, known as soil-creep, or if they affect rock fragments rather than true soil, talus-creep and rock-creep, doubtless occur more-or-less continuously in the areas of loose freely-drained soil in Montserrat. They are so slow as to be imperceptible; they really comprise a succession of minute movements. They may gradually displace trees, walls, roads and fence-posts or even small houses. The chief cause of soil-creep is the rhythmic expansion and contraction of the upper foot or two of soil through alternate wetting and drying. Saturation by water may convert soil-creep into earthflow or *débris avalanche*. A good example is shown in Figure 1, though here earthflow may have mainly operated.

*Landslide* : This differs from earthflow or soil-creep in that slip-planes develop, separating the moving material from its bed. Sufficient water is needed for lubricating the slip-surface, and the slope of the land must be high. The various subdivisions of landslides differ chiefly in the nature of the material involved and on the rate of movement. Landslides are frequently initiated by earth tremors; they were particularly common during the 1933-1937 earthquakes in Montserrat.

The most conspicuous kinds of landslide movements occurring in Montserrat are *débris-slide*, *débris-fall*, *rock-slide* and *rock-fall*. These

mainly affect the partly-coherent volcanic materials of undercut ghaunt-walls or loose ejecta comprising steeply-sloping hills, especially those occurring in the Soufriere Hills area. The displaced débris or rock slides or falls forward rapidly without backward rotation and forms hummocky morainic deposits on the gully floors or at the bases of cliffs and hills, leaving conspicuous scars on the valley slopes or hillsides. Usually the slides and falls have only small magnitude. The moving material of landslips is relatively dry; when it is water-saturated (which is a common cause of instability in volcanic ejecta) it produces débris avalanche.

"*Hoe-rosion*": An insidious kind of man-made erosion, all too common in Montserrat on the looser, less coherent kinds of soil, is the downhill drag of surface soil caused by the common practice of hoeing continually down the slope. Many peasants' plots, especially those resulting from the fragmentation of former private estates, are rectangular in shape and are laid out in regular pattern on variably sloping ground. The peasant cultivates his holding solely with the hoe. He works from the upper boundary-edge and lays the land in a series of successive parallel banks (not necessarily strictly along the contours) until he reaches the lowest boundary-edge. The process is repeated each time the land is tilled. This kind of man-induced erosion may perhaps be termed for convenience "*hoe-rosion*". In due course a small escarpment is produced along the upper boundary. Sometimes this escarpment is breached during rainy weather by heavy run-off from the adjacent holding above. Occasionally a line of trees, bushes or some other kind of vegetation is planted to prevent this happening, or a rough wall of boulders is built with the object of forming a retaining barrier to prevent the soil from moving onto the next adjacent plot lower down the slope. In most cases, the barrier is inefficient or useless for the purpose intended.

A typical example of a small erosion escarpment is shown in Figure 2, reproduced from a photograph taken in the Parsons-Amersham land settlement area on Brown Earth soil. Soil samples were collected here in an attempt to determine the difference in nutrient status between the soil at the top of the holding and that at the bottom.

The results of their laboratory examination are tabulated in the Appendix, (Site No. 62). They show no regular differences between the upper and lower soils, which implies that, at the time of sampling, the hoeing had affected only the original surface humic soil and had not yet disturbed or displaced any of the soil below about the 6-inch depth.

## (B) LAND MOVEMENTS AFFECTING IMPEDED-DRAINING SOILS

The effect on soil erosion of a layer of cementing substance or of impervious bed-rock, such as imparts drainage-impedence to Terras and Shoal soils, may be very marked. In Terras (and in some phases of Yellow Earth showing incipient cementation) the soil is generally very permeable, at least down as far as the cemented layer, so that the same kinds of erosion that affect free-draining soils (débris-avalanche, mudflow, earthflow, soil-creep) may also affect these other soil-types. The nearness of the impeding layer to the land surface, however, causes the pervious upper soil to fill up more rapidly than if the cemented layer were absent; hence soil movement may take place under less intense rainfalls than would affect loose, deep uncemented fresh ash or agglomerate. Only limited areas of Terras or incipient Terras occur in Montserrat and these are apparently mostly confined to the Elberton area on the slopes of Garibaldi Hill.

Land movements affecting *Shoal* soils, having a characteristic layer of hard impervious cemented material overlain by clay, would be expected to be mainly the sliding or slipping kinds (landslides). The clay absorbs rain water mostly through the abundant cracks which develop in the dry season. When the clay covering is saturated with water, it becomes detached and tends to slip away from the surface of the shoal below. The slide may develop into a débris avalanche where the slope is steep, otherwise it produces small independent slumps, forming parallel terracettes, sometimes called "*cat-steps*" which run in parallel series along the contours of the hill at vertical intervals of a few feet.

## (C) SOIL-CONSERVATION AND ANTI-EROSION MEASURES

The best treatment of flat land occupied by free-draining, loose, incoherent soils liable to débris avalanche, mudflow and earthflow, is the construction of storm-drains having suitable outlets so that torrential run-off from neighbouring hillslopes is carried away safely. In addition to these, protective catchment trenches should also be constructed along the contours of the lower slopes of the hills. The excavated soil should be piled up on the up-slope side of the trench and a line of suitable herbage, possessing a vigorous and abundant root system, should be planted on the bank to prevent run-off water breaching it, and to cause excess of water from behind the bank to overflow quietly into the trench and so to a storm-drain.

Systems of contour catchment barriers have been tested since 1938 by the Agricultural

Department of Montserrat over an experimental area comprising about 3 acres of land occupying the side of a small spur of St. George's Hill at about 250 feet altitude (Site No. 63, Appendix tables). The soil-type is Yellow Earth developed over uniform fine-grained volcanic ash of which this hill is composed. Three kinds of barriers were erected, namely, (a) stone walls, (b) Vetivert Grass with contour drains, and (c) contour banks. Various crops were planted on the 16-foot wide terraces that have gradually formed behind the barriers. The crops included cotton, maize and sugar-cane.

A good test of the efficacy of the barriers for controlling soil erosion was afforded by their exposure to a heavy rainstorm on 3rd May, 1941, when about three inches of rain fell between 9.00 p.m. and 10.30 p.m., over this part of the island. Inspection afterwards\* showed that the stone-wall barriers (See Figure 3) had completely checked soil movement. The dry trash covering the sugar-cane plots had materially helped to protect the soil from rain damage. On the other hand, the clump-grass barriers presented numerous gaps because of the partial growth-failure of the plants, and these were badly scoured by the heavy run-off. Several channels up to 28 feet long, 1 foot wide and 6 inches deep, were cut in the cotton plot, involving one or two terraces but no more. Even larger channels, up to 34 feet long, 1 foot wide and 9 inches deep, involving as many as five terraces, were cut in the sugar-cane plot which here contained no protective trash. In the maize plot, surface soil was moved bodily into the drains alongside the grass barriers which it completely filled. The contour bank barriers proved to be the least protective of the three kinds. Much soil movement occurred and channels up to 300 feet long, 15 inches wide and 10 inches deep were cut in the cotton plots and the maize plots. The surface of the sugar-cane plot was well covered by a thick mulch of cane-trash, which prevented loss of soil.

A large catchment contour drain had been constructed above the experimental area higher up the slope. It served its purpose very well and prevented water from running onto the experimental area. It was quite undamaged by the flood water. The surface of a cotton field on a similar slope situated to the south of the experimental area was badly damaged during the same storm. Several deep channels were cut from the top of the cultivated land to the bottom of the slope and a large amount of soil was removed.

In order to find out whether repeated mass movement of soil through erosion aided by hoeing had impoverished the soil on the upper

parts of the hillslope at this same site, and had thereby created a gradient of fertility from top to bottom, special soil samples were collected and chemically analysed. The results are given in the Appendix tables, (Site No. 63). The values for organic matter show a distinctly, though only slightly, higher content for the soil at the bottom of the slope (2.31 per cent) as compared with that at the top (2.13 per cent), a difference of about 8 per cent in favour of the transported material.

The conclusions drawn from this experiment are, (1) that on slopes of less than 22 degrees (40 per cent), the formation of terraces by the construction of stone-walls or suitable plant barriers permits the safe cultivation of annual crops such as cotton, and (2) that contour cultivation alone does not afford sufficient protection against soil erosion. It must be remembered, however, that whilst these findings may apply to the loose incoherent free-draining soils that occupy so much of the gently-sloping cultivated lands of Montserrat, they may not necessarily apply to land having very high angles of slope nor to other soil-types whose erosion problems still remain to be investigated. That the advocated methods have proved to be satisfactory in practice is indicated by the fact that, up to the end of 1944, nearly 1,000 acres of agricultural land had been treated by the suggested methods, half being estates land and half peasants.

#### (D) SOIL RENOVATION

The treatment of eroded soils has apparently not received detailed consideration in Montserrat. The only kind of plant rotation practised by peasants is a natural ley of weeds and grass following cotton. Otherwise, land not being utilised for crop-growing is "rested" by allowing it to revert to bush for varying lengths of time. This custom simulates the well-known practice of shifting cultivation. Haphazard and uncontrolled "rotations" such as these, although sometimes quite effective in replenishing the humic top layer and imparting a semblance of surface soil structure, are likely to be uneconomical, wasteful of time and not sufficiently intensive to meet present-day requirements. On the larger privately-owned estates, leguminous cover-crops (green dressings) are occasionally grown in rotation with cotton, generally once every 3 or 5 years. Apart from green dressings, the only other soil-renovating materials, soil amendments or manures regularly used in Montserrat are cotton-seed meal and pen-manure where livestock is kept. Chemical fertilizers have not yet come into general use.

In Part II of this article, certain ecological aspects of the growth of cotton and times will

\* Report by T. H. Kelsick, Assistant for Cotton Work, Agricultural Department, Montserrat.

be considered, in particular, their nutrient relations. The results of manurial experiments to be considered later, coupled with the findings of soil analysis presented and discussed in a previous section, have indicated a shortage of available phosphate in most of the soil-types of Montserrat (notably Lithosol, Brown Earth and Shoal), as well as a border-line level of available potash. The most significant shortage, especially in eroded areas, however, is nitrogen contained in soil organic matter. Loss of the entire surface humic layer exposes the soil parent material which is naturally quite devoid of nitrogen. The substratum may also be temporarily deficient in available phosphate and potash, especially if it consists of fresh mineral material that has not yet begun to weather, as in the case of Lithosol, Alluvial and Colluvial materials.

Attempts to renovate such deeply-eroded mineral soils by planting cover-crops (green dressings) on them, or even by "retiring" them to grass or bush, may be quite unsuccessful for the obvious reason that the new surfaces exposed by profile truncation are so very deficient in available nutrients, including nitrogen, that the renovating crops will not grow properly, especially at first, and may produce only small amounts of herbage for incorporation into the land. This failure may easily be prevented or overcome by the combined use of nitrogenous manures, either organic or inorganic, in conjunction with quick-acting phosphatic manures, augmented where necessary by potassic manures. Immediately a sufficient amount of nitrogen-rich organic matter has been synthesised and added to the mineral surface of the exposed parent material, an upgrade cycle of changes is initiated and a new soil rapidly develops to replace the old. This cycle of changes is especially rapid where the soil parent material contains an abundance of nutrient-rich minerals, such as feldspars and ferromagnesian minerals, which are easily broken down under a hot humid climate thus yielding a continuous and ample supply of plant nutrients. This most desirable condition fortunately obtains in most of the agricultural districts of Montserrat where immature soil-types occur, so that the rapid renovation of eroded soils should prove particularly easy and inexpensive, provided the underlying principles are properly applied. Once a layer of fertile humic soil has been formed over the eroded surface, further upbuild of the organic profile and its enrichment by nitrogen will proceed rapidly under a system of short rotations involving leguminous cover-crops that fix nitrogen from the air. It may still be necessary and imperative in the early stages to manure heavily with phosphate, otherwise the renovating crops might not produce a sufficient bulk of dry matter needed for the successful accomplishment of the scheme. In cases where

soil acidity has developed, lime may also be required to assure the satisfactory growth of leguminous cover-crops whose dependence on both lime and phosphate is well-known to agriculturists.

In sharp contrast to the highly desirable state of affairs outlined above, are the conditions presented by eroded soils whose exposed parent materials are almost entirely devoid of fresh mutable nutrient-rich minerals but consist solely of inert minerals or end-products of rock-weathering such as quartz, kaolinite, ferric oxide and alumina, comprising Red Earth. In such cases the greatest difficulty may be experienced in obtaining satisfactory growth of cover-crops; indeed very poor and quite inadequate yields may be obtained unless heavy dressings of organic and artificial manures are used continuously for some time. "Permanence of fertility" (as has been pointed out by Vageler (7)) depends on the soil's content of nutrient minerals yet unweathered.

## PART II

### THE ECOLOGY OF COTTON AND OF LIMES

The choice of planting date and the probable causes of physiological disturbances affecting the cotton plant in Montserrat introduce certain ecological considerations involving the soil nutrient factor. Similarly, the dying-out of lime trees over most of the area where the crop has been grown for many years appears also to result from unbalanced plant nutrition and may be considered from the same ecological viewpoint.

#### (A) COTTON: CHOICE OF PLANTING DATE

*Introduction:* The choice of planting date for cotton is intimately linked with meteorological conditions of the air and the moisture supply of the soil and with the soil's nutrient status. In Montserrat, dry season cotton planting is at present in vogue. Sowing usually begins in February but is mostly carried out in March, April and May. Prior to 1916, cotton planting was performed in August and September as in most of the other cotton-growing islands of the West Indies. The choice of planting date has been the subject of much controversy. The main reason given in support of early planting is that the crop does not suffer as much from pests and diseases as when planted late. The subject has been considered by the senior author (F. H.) in two recent articles (8) from which the following information has been partly taken.

*Climate: Water relations:* The ideal climate for cotton-growing is one in which the

Monthly rainfall sequence. Growing season beginning in March

Group	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Growth phase	Reproduction
	(Rainfall in inches)													
I	4.8	3.2	3.7	3.6	4.4	4.7	5.4	6.2	6.7	7.2	7.7	5.6	16.4	18.3
II	3.8	2.6	2.7	3.4	4.1	4.0	4.5	5.5	6.0	6.4	7.0	4.6	14.2	16.0
III	3.0	2.1	2.4	2.2	3.1	3.1	3.5	4.9	5.0	5.2	6.3	3.9	10.8	13.4
			Vegetative growth				Flowering ; fruiting			Ripening				

*Rainfall regimes*

Group I : Continuously moist :  
 Group II : Weak dry season :  
 Group III : Marked dry season :

Rainfall, 70-55 ins.  
 Rainfall, 60-50 ins.  
 Rainfall, 50-40 ins.

rainfall increases to a relatively high value during the first four months of vegetative development\*, rapidly diminishing during the next three months when the plants are flowering and the bolls are setting, finally reaching small proportions when the cotton is being picked, five to seven months or more after planting. Too much rain during the reproductive period induces shedding of flowers and young fruits. Once the crop is properly established, however, it can withstand a considerable amount of rain though high humidity at this stage favours the development and multiplication of pests and diseases. The following data show how near the ideal is approached in Montserrat, assuming March sowing, by the average monthly rainfall distribution for the three regional regimes of soil-humidity, differentiated in Table I.

The graphs of monthly rainfalls drawn from these data run nearly parallel and at approximately constant distances apart of 0.7 and 0.8 inch respectively, thus demonstrating that the chief differences between the three regional rainfall regimes are merely differences in monthly quantity rather than irregularity of monthly distribution. Assuming that planting begins in March for all three rainfall groups, then, by reference to the tabulated data, it appears that maturation of the cotton crop must take place during increasingly wet weather and that picking must be undertaken during the wettest part of the year. These circumstances would appear to be far from satisfactory. Assuming instead that planting begins in August, then the vegetative phase will be over by the end of November (the month of highest rainfall); the reproductive phase will then coincide with months of rapidly diminishing rainfall and picking will be carried out in the two driest months of the year, namely March and April. This would seem to be an ideal arrangement for maximum production of cotton. Evidently, however, some other factor must be

involved which out-weighs the climatic factor and favours early planting. It is believed that this may be a nutritional factor depending on soil conditions. The possibility will be considered in a later section.

*Cotton yields and rainfall:* The general dependence of yield of cotton on the amount and distribution of the rainfall in Montserrat has been repeatedly stressed in the Annual Reports of the Department of Agriculture. Thus in the combined Report for 1936-'37-'38, evidence was adduced in support of the contention that "the distribution of rainfall at critical periods in the development of the crop is the primary factor influencing yield". Particularly high yields were obtained in 1934 and 1935. The seed was sown in dry weather during March, April and May in those years. Satisfactory, though not excessively large, rainfall was growing months and the rainfall of the flowering experienced during each of the following four and fruiting period was relatively low, followed by a dry reaping spell. By contrast, the yields in 1936, 1937 and 1938 were very low. The seed was sown early in 1936 over a lengthy period (February to June). In that year, March and April were particularly dry months and much "supplying" (resowing) was necessary. The rains broke suddenly in late May and June was an unusually wet month, as well as the subsequent months when the crop was flowering and fruiting. Consequently, boll-shedding and boll disease were very prevalent in 1936. Similar weather to this prevailed also in 1938. In this year too the rains broke suddenly and the first growing month was exceptionally wet. On the other hand, in 1937, the season started well but June and July were very dry months and vegetative growth and flowering were therefore much retarded so that only a poor crop was set. The monthly rainfall data for the years in question are given below; they should be compared with the mean data for the three rainfall zones given in the previous table.

\* The late W. Robson, formerly Curator of the Botanic Station in Montserrat, considered the ideal rainfall sequence for the first four months of growth after planting to be, 2, 4, 6 and 8 inches respectively.

Monthly rainfall sequences. Good years and bad years.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Growth phase	Reproduction
(Rainfall in inches)														
<b>GOOD YEARS</b>														
1934	4.9	1.9	4.1	0.9	3.3	3.9	5.5	8.4	4.1	2.5	10.6	7.3	12.2	18.0
1935	1.7	2.1	3.1	2.8	3.8	5.4	5.0	4.4	5.5	8.1	7.7	4.6	15.1	14.9
			Vegetative growth				Flowering ; fruiting			Ripening				
<b>BAD YEARS</b>														
1936	4.3	2.4	1.2	1.7	7.2	5.6	7.0	9.4	8.6	11.8	5.9	5.3	12.5	22.0
1938	3.7	2.7	2.2	1.8	1.8	7.1	4.4	12.7	6.7	4.3	3.5	5.6	8.5	24.2
			Vegetative growth			Flowering ; fruiting			Ripening					
1937	10.1	5.2	1.7	3.3	3.1	2.2	2.8	6.4	6.4	7.7	5.9	4.3	10.3	15.6
			Vegetative growth				Flowering ; fruiting			Ripening				

*Date-of-planting experiments :* The effect of planting date on the development and yield of the cotton crop was experimentally investigated in Montserrat by one of us (W.R.E.N.) in 1942 and 1943. Earlier unpublished work (by S. A. Schouten in 1938) had shown "a rapid and regular falling-off in total fruiting material" as the sowing date was set later in the year. The 1942-43 investigations likewise demonstrated a large diminution in yield of cotton lint between crops planted in March, April and May respectively. The records for the 1943 experiment, which will alone be considered here, indicated that (1) March-sown plants received adequate rain; they flowered freely in late July but ripening was prolonged. Pests and diseases were sparse, however, and did

no appreciable damage. A very heavy crop (1,650 lb. ac.) was reaped. On the other hand, (2) April-sown plants developed their fruits in the rainy weather of August and September and boll-shedding, accompanied by pests and diseases later were very prevalent. The crop yield was 900 lb. ac. Similarly, (3) May-sown plants were also badly affected by the wet August and September weather; much boll-shedding occurred and pests and diseases were rampant in the reaping season near the end of the year. The yield in consequence was very low, only 200 lb. acre. The experiment was carried out on Richmond Estate which is situated in the continuously moist zone on Lithosol. The actual monthly rainfalls for the period were:—

Monthly rainfall sequences. Date of planting experiment.

1943	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Growth phase	Reproduction
(Rainfall in inches)														
	5.4	2.4	4.6	3.0	6.8	3.6	5.6	9.6	8.9	6.6	4.2	5.5		
(1)	Vegetative growth				Flowering ; fruiting				Ripening				18.0	24.1
(2)	Vegetative growth				Flowering ; fruiting				Ripening				18.9	25.1
(3)	Vegetative growth				Flowering ; fruiting				Ripening				25.6	19.7

The failure of crop (3), planted in May, is easily accounted for by the continued wet weather throughout the flowering and fruiting season, but it is difficult, on the same grounds, to explain the marked superiority of the March-planted crop (1) over that planted in April (2). The dry spell in June may have been partly responsible for that superiority in that it favoured flowering and boll-setting in the March planted crop whereas it retarded bud formation in the crop planted in April, resulting in a short reaping season. The results obtained in the 1942 experiment were very similar; they also demonstrated the great advantage of planting cotton early in the year in Montserrat, although the main cause of the larger yields is obscure.

*Nutrient relations:* It has been suggested that the superiority of the March-sown crop might be attributed to a high level of available nitrogen at sowing time. This possibility has been considered by the senior writer in the recent articles previously referred to (8). Based on the information afforded by the results of the chemical analysis of the large number of representative soil samples collected in Montserrat and in other cotton-growing islands, the general conclusion has been reached that the cotton soils of the British West Indies tend to be deficient in total nitrogen because of their deterioration under cultivation, whereby their original organic matter content has gradually diminished. The main reason for this deterioration is believed to be soil erosion, although biological degeneration, favoured by inadequate amounts of plant residues returned to the soil, may also have operated.

The relevant laboratory data for Montserrat soils are contained in Tables II, III and IV and in Table V (summary) in which the mean organic matter and total nitrogen contents and carbon-nitrogen ratios for free-draining soil-types, as compared with those for impeded-draining soil-types, are given as 1.80 percent, 0.11 percent and C/N 10.5, as against 2.88 percent, 0.165 percent and C/N 10.0 respectively. The difference in organic matter contents is statistically highly significant and is doubtless the result of the operation of environmental conditions which decide the rate of organic breakdown in the two contrasted kinds of soil.

Evidence of the gradual loss of soil organic matter in Montserrat is afforded by a comparison of the values recorded by Watts and Tempany in 1905 (9) who applied exactly the same analytical methods as ours for the determination of total carbon and total nitrogen, to a series of 12 soils which could be closely matched by samples taken by us. The mean results are set out below:—

The data show a diminution in organic matter of 34 percent and of total nitrogen of 30 percent; the concomittant lowering of carbon-nitrogen ratio implying a diminished supply of fresh organic residues.

The chief form of nitrogen which the cotton plant is capable of absorbing and utilizing is probably nitrate. The capacity of a soil to produce abundant nitrate depends on several factors of which the following are the chief:— (1) a high total nitrogen content, (2) a suitable micro-organic flora, (3) sufficient soil oxygen (air), (4) sufficient soil water, (5) a reaction not far removed from neutrality with a supply of base to neutralise liberated acids and (6) a carbon-nitrogen ratio below a certain critical value. This last condition depends on the fact that, when the proportion of carbon to nitrogen in soil organic matter exceeds a certain value, given as 12.0 for British soils (10), the surplus is eliminated as carbon-dioxide and the nitrogen remains as complex microbial protein. Under West Indian conditions, the critical value of the carbon-nitrogen ratio for cotton soils seems to be less than this and probably lies around 10.5. (8). Determinations of nitrate-producing capacity (or nitrifying efficiency) in some typical West Indies cotton soils has shown that about 3.4 percent of the total nitrogen present is converted into nitrate when the soils are incubated for 28 days at 30°C.

Nitrifying efficiency values for cotton soils of other countries are:— Queensland, 3.4 percent (8); Sudan, 2 to 13 percent; India, 1 to 6 percent; South Africa, 5 percent; U.S.A., California, 5 to 10 percent; Utah, 3 percent; Texas, 5 to 10 percent. Washington, 1 to 5 percent (11). The mean value is about 5 percent.

It follows therefore that, under field conditions in Montserrat, typical free-draining cotton soils, containing 0.11 percent of total nitrogen, should, in theory, be capable of producing up to a maximum of about 40 parts per million of nitrate-nitrogen, provided the supply of air and moisture in the soil is satisfactory and the reaction is not too acid, and assuming the presence of a suitable nitrifying micro-organic flora. Similarly, typical impeded-draining soils, containing 0.165 percent of nitrogen, should theoretically be capable of producing a maximum of about 60 p.p.m.  $\text{NO}_3\text{-N}$ . Whether or not these maxima can be realised in the field depends on environmental circumstances and on the deficit or excess of total nitrogen content from the average value for the soil type.

	No. of cases	Total org. matter %		Total nitrogen %		C/N ratio	
		1903	1940	1903	1940	1903	1940
Free-draining soils	8	2.38	1.56	.128	.083	11.0	10.7
Impeded-draining soils	4	2.32	1.60	.128	.102	10.5	8.8

In Queensland, Australia, it has been found (8) that soils whose maximum nitrate-producing capacity is above 60 p.p.m.  $\text{NO}_3\text{-N}$ , growing cotton in a climatically-normal year, generally produce plants that "bolt", that is, they develop dark-green sappy growths which are very susceptible to insect attack and set few bolls. Such high nitrate-producing soils characterise "old lands" that have been growing cotton for a considerable number of years. On the other hand, soils having low nitrate-producing capacity, that is less than 30 p.p.m.  $\text{NO}_3\text{-N}$  produce normal plants in favourable years. Such soils characterise "new lands" that have been recently brought into cotton cultivation from forest or grass.

"New land" soils in Queensland generally show no nitrate content when field spot-samples are chemically analysed; their C/N ratios lie around 11.2; the best of them comprise certain phases of Allucial soil. On the other hand "old land" soils give values between 30 and 50 p.p.m.  $\text{NO}_3\text{-N}$ ; their C/N ratios are generally less than 8.5; typical examples are Red Earth. Soils one year in cotton give values around 14 p.p.m.  $\text{NO}_3\text{-N}$ ; they have intermediate C/N ratios; typical cases are Black Earth.

Comparison with the Queensland soils indicates that the cotton soils of Montserrat definitely belong to the "old land" category, and that the impeded-draining soils would be expected to be much more liable to produce plants that "bolt" than the free-draining soils when both are brought to optimum moisture content. This conclusion is indeed supported by actual experience, for physiological disturbances, known locally as "logger-head" and "chibble leaf", frequently affect the cotton plant in Montserrat, and particularly cotton grown on Shoal soil having marked drainage impidence. It is interesting to note that these physiological affections are unknown in cotton grown on Shoal soil in Nevis; the planting season in Nevis begins in August to October, however, so that growth takes place under a diminishing rainfall and not, as in Montserrat, during increasingly wet weather.

The various growth phenomena exhibited by the cotton plant in Montserrat may readily be explained in terms of nitrate fluctuations as determined by variations in soil moisture content resulting from changes in the weather affecting soils showing different degrees of drainage impidence and containing different amounts of total nitrogen. During a normal dry period within the zone of marked dry season, free-draining sandy soils dry out rapidly and nitrate may accumulate in the surface layer in amount depending mainly on total nitrogen content. On the other hand, sandy soils occurring within the continuously moist zone may accumulate little or no nitrate because of the constant leaching. With impeded-draining

clayey soils the result may be different; nitrate may accumulate in these soils in considerable quantity. Since the free-draining sandy soils of Montserrat generally contain a low content of total nitrogen, however, nitrate accumulation may never reach an appreciable amount, but considerable accumulation may occur in the impeded-draining clayey soils which, as we have seen, generally contain a much greater amount of total nitrogen.

The nitrate content of the soil at the time of planting cotton largely determines the subsequent behaviour of the crop.—If planting is early, full benefit will be gained from nitrate accumulation, and provided other nutrients, especially phosphate and potash, are adequate and available in balanced proportions with nitrate, vigorous growth and normal behaviour may be expected. If excessive quantities of nitrate have accumulated, however, and phosphate and potash are inadequate for balanced uptake, then bolting may occur or other physiological disturbances may arise. If planting is late, nitrate accumulation may have been dissipated by the wet season rains, especially in free-draining soils, so that nitrate may be deficient and operate as a limiting factor to growth.

Mason and Phillis have demonstrated by pot-culture experiments in the greenhouse (12) that, for a low level of nitrogen supply in the soil, greater growth is obtained in the cotton plant under moist shady conditions than under dry sunny conditions. They also found that more nitrogen (and more phosphate) are needed to give maximum yield under dry sunny conditions than under moist shady conditions, and that the reverse holds for potash which therefore serves "as an insurance against sunless summers". Thus, under moist conditions, a relatively small amount of available nitrogen may produce the same yield response as a much greater amount under dry conditions. It was established that the yield of cotton is largely decided by the quantity of nutrient taken up during the first three months of growth; when fruiting begins, nutrient uptake is severely checked.

It is seen, then, that the growth, behaviour, and ultimate yield of the cotton crop is mainly decided by the interplay between soil, climate and the date of planting. The first and the last of these factors can to some extent be controlled; they may exhibit inter-relationships which could be examined experimentally by means of long-continued and carefully-planned manurial trials with the cotton crop. How far the results of experiments carried out in recent years in Montserrat support this thesis, will next be considered.

TABLE VIII: Relationship between Results of Manurial Experiments and Chemical Analytical Data for Plots on Different Soil Types.

(Data for composite soil samples from no-manure plots, top 6-ins. layer)

Control plots	Soil type	Index of Text. (I.T.)	C/N Ratio	Total N %	Prob-able nitrate (NO <sub>3</sub> -N) p.p.m.	Avail. phosphate (P <sub>2</sub> O <sub>5</sub> ) p.p.m.	Avail. potash (K <sub>2</sub> O) p.p.m.	Results of manurial experiments
					<b>1940 Experiment</b>			
Wh.	Brown Earth	7	12.6	.110	37	36	227	S/A 12% increase; Super 9% Potash none.
					<b>1941 Experiments</b>			
R. 1.	Litho-sol	0	12.0	.076	26	213	191	S/A 29% increase; Super 11% S/Pot nil.
2.	"	0	11.2	.069	23	225	190	
3.	"	0	11.3	.067	23	290	211	
E. 1.	Shoal	21	10.5	.217	74	876	1268	Only slight response to any manure
2.	"	22	9.7	.182	62	175	888	
3.	"	15	10.4	.223	76	26	343	Super appreciable increase; S/A, S/Pot nil.
					<b>1942 Experiments</b>			
R. B.	Litho-sol	0	12.7	.076	26	132	140	S/A 30% and 49% increase; Super and S/Pot nil.
		0	11.4	.072	24	157	467	
OG.	"	10	12.8	.127	43	127	600	No increase from any manure
O.R.	Allu-vial	0	11.4	.085	29	227	144	Damaged; no results
Tr.	"	0	14.7	.074	25	80	501	NaNO <sub>3</sub> 60% increase; Super slight; M/Pot nil.
B.F.	"	0	12.0	.059	20	320	109	Damaged; no results
A.	Brown Earth	6	11.7	.111	38	53	107	Damaged; no results
Tu.	"	7	12.8	.124	42	38	111	M/Pot 17% increase; S/A 10%; Super 5%.
T.R.	"	5	11.4	.107	36	78	200	S/A 40% increase; Super 2%; M/Pot nil.
P.	"	0	11.5	.091	31	113	179	S/A 12% increase; Super 69%; S/Pot nil.
E.	Shoal	9	12.1	.123	42	123	413	Damaged; no results
O.R.	"	12	12.4	.171	58	23	90	Super 40%; S/A 11% increase; M/Pot slight
WW.	"	10	12.4	.161	55	53	222	Spolt

NOTE: (1) Values in black denote deficiencies

(2) Provisional limits of adequacy for cotton accepted for these experiments:

Total nitrogen, 0.120 percent  
 Nitrate, 40 p.p.m. (Incubation test)  
 Phosphate, 40 p.p.m. (Truog test)  
 Potash, 140 p.p.m. (Exchangeable potash).

### Interpretation of Results of Manurial Experiments on Cotton

The relevant experiments were carried out in 1940, 1941 and 1942 on the main soil-types occurring in different parts of the island.

#### Experiments of 1940

These were laid down on *Brown Earth* soil at Whites Estate. Chemical analysis showed the soil to be somewhat deficient in total nitrogen (0.11 per cent) and in available phosphate, though abundantly supplied with available potash (Table VIII). The monthly rainfalls during 1940 were below the average, except for February which was unusually wet; 4.7 ins. of rain fell in that month. The area was planted up in late March. On the whole the plants grew well and gave excellent crops. Pests and diseases scarcely affected them. The largest increase in yield was given by ammonium sulphate (2 cwt. per acre). The average yield increment was 12 per cent greater than that given by treatments containing no nitrogen. Superphosphate (2 cwt. ac.) gave a yield increment of 9 per cent above that given by no-phosphate, owing entirely to the larger number of bolls that matured. Potassium sulphate (1½ cwt. ac.) gave no yield increment.

The response to nitrogenous and phosphatic manures accords with deficiencies in these nutrients in the soil. The heavy rains that fell just before the plots were planted may have been partly responsible for the increases due to nitrogen, since any nitrate that might have accumulated would have been leached out of the soil before the seed was sown. It is possible that greater response to phosphate may have been obtained had the dressing of superphosphate been larger.

#### Experiments of 1941

These were laid down on *Lithosol* at Richmond Estate and on *Shoal Soil* at Elberton, 1½ miles distant. Heavy rains fell in May. The crop was planted in March and suffered considerable damage by rain. Later in the year, a heavy attack of Cotton Leaf Worm occurred but it affected all the plots equally. The monthly rainfalls were:—

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	
3.2	1.0	3.7	3.2	9.7	4.9	6.6	4.7	3.1	4.2	inches

Total for growing months, 21.5 ins. (which is exceptionally high), and for fruiting months, 14.4 ins. The two sites will be considered separately.

(i) *Richmond*: The *Lithosol* soil here (Belle Field) was very deficient in total nitrogen (0.07 per cent N) but contained ample available phosphate and potash according to the

results of chemical tests (Table VIII). The largest increase in yield was given by ammonium sulphate (2½ cwt. ac.) nearly 29 per cent above the yield of the no-nitrogen treatments. Superphosphate (2½ cwt. ac.) gave an increment of about 11 per cent over no-phosphate, but potassium sulphate (1½ cwt. ac.) gave no increment in yield.

The response to nitrogenous manure accords with the results of chemical soil analysis. Positive response to phosphatic manure is to be expected in view of the fact that, even though fresh volcanic ash soils give abnormally high values for available phosphate with the Truog test, this result is not substantiated by pot-tests. The incidence of wet weather soon after planting probably removed accumulations of soil nitrate before the nitrogenous manure had begun to nitrify.

(ii) *Elberton*: This experiment comprised two pairs of blocks laid down on a field whose soil, according to chemical tests, contained adequate amounts of available nitrogen, phosphate and potash, and a third pair laid down on a field whose soil was evidently very deficient in available phosphate though not lacking nitrogen nor potash (Table VIII). Very little response was obtained to any manure in the first case but a large response to superphosphate manure was obtained in the second case. Through an error, one of the blocks had to be resown a month later than the others. The cotton plants in this block afterwards developed typical physiological abnormalities which reduced the yield by about 90 per cent. This implies that, if the sequence of weather which occurred over this area had been advanced one month, practically the whole of the crop would have been lost. This indicates how delicate is the balance between the vegetative and the reproductive phases of the growth of the cotton plant on impeded-draining soil. The association of high nitrate production and high moisture content of the soil was doubtless the cause of the severe physiological upset in this experiment.

#### Experiments of 1942

These were laid down on *Lithosol* at Richmond, Bethel and O'Garas Estates in the leeward, windward and southern coastal belts respectively, on *Alluvial Soil* at Old Road, Richmond and Trants in the leeward and windward areas, on *Brown Earth Soil* at Amersham and Parsons in the leeward belt, and at Tuits and Tar River in the windward belt, and on *Shoal Soil* at Elberton, Old Road and Waterworks in the leeward belt. Chemical analysis (Table VIII) showed that all the soils except Shoal were deficient in total nitrogen (mean, 0.085 per cent N), that the *Brown Earth* and the *Shoal* soils tended to be deficient in available phosphate, and that potash deficiency occurred

in some examples of each of the four soil-types, the results for potash being variable.

The plots were sown in March and April. The subsequent weather was unfavourable to normal growth, particularly in the leeward belt. The rainfall in March and the first part of April had been low and seed germination in consequence had been poor. Many of the plots had to be resown. Heavy continuous rains fell in July causing excessive vegetative growth and boll-shedding, especially in the late-planted blocks on the Brown Earth and Shoal soils at Amersham and Elberton. Pests and diseases completed the damage in these blocks. Similarly, heavy rains and pests destroyed the crops on Alluvial soil at Old Road. Black Boll disease ravaged the crops on Brown Earth and Shoal soils at Tar River and Water-works. The only blocks that yielded normal undamaged crops were those at O'Garas (Lithosol), Richmond (Alluvial) and Old Road (Shoal) in the southern and leeward coastal belts, and at Bethel (Lithosol), Trants (Alluvial) and Tuits (Brown Earth) in the windward belt. The results obtained for the different soil-types occurring at these various sites are considered separately below.

(i) *Lithosol*: Response to nitrogenous manure was very marked at Richmond (30 per cent increase in yield) and at Bethel (49 per cent increase) where the soils were deficient in nitrogen (0.07 per cent N) but there was no response at O'Garas where the soil contained adequate nitrogen (0.13 per cent N). The nitrogen-treated plants grew taller and produced more bolls than those which received no nitrogenous manure. No appreciable response was obtained to phosphatic manures at any of the sites; all three soils showed abundant available phosphate contents. No response was given either to potassic manures. The Richmond soil showed a border-line content of available potash; the other two showed a large excess by the chemical test.

(ii) *Alluvial Soil*: The only site on this soil-type where the crop was not spoiled by pests and diseases was Trants. The response given here to nitrogenous manure was very striking. The soil was definitely deficient in total nitrogen (0.074 per cent N). Sodium nitrate (3½ cwt. per acre) gave a large increment in yield approximating to 60 per cent over that given by plots receiving no nitrogenous manure. Whereas the cotton plants on the no-nitrogen plots were only two feet tall at maturity, those of the nitrogen plots were 4 to 4½ feet tall. The response to phosphatic manure was not so marked nor definite, though the soil was deficient in available phosphate. Incompatibility between sodium nitrate and superphosphate may partly have accounted for this result. An

appreciable increase in yield was indeed obtained but only when the nitrogenous manure was not applied along with the phosphatic manure. Response to potassic manure was *nil*; the soil at Trants contained a superabundance of available potash.

(iii) *Brown Earth Soil*: The crops at Amersham were so badly damaged by insect pests that the results were completely vitiated. At Tuits where the soil contained a border-line content of total nitrogen but was slightly deficient in available phosphate and potash, the response to nitrogenous manure was appreciable; an increase in yield of 10 per cent was here registered. The nitrogen-treated plants were a darker green colour than those of the no-nitrogen plots. Their bolls were better filled but shedding was greater, otherwise the final yields would have been much higher. Response to phosphatic manure was slight though deficient (5 per cent increase) and response to potassic manure was largest of all (17 per cent).

At Tar River where the soil was deficient in total nitrogen (0.11 per cent N) but apparently contained adequate amounts of available phosphate and potash, the response to nitrogenous manure was also very marked, amounting to a 40 per cent increase in yield. A superiority of the phosphate treatment over no-phosphate was also shown, provided no nitrogen was applied in addition. Potassic manure gave no response. It was observed that the plants growing in the nitrogen-treated plots lost more bolls through disease than those growing in the other plots, mainly because they developed later in the season and their maturation during the wetter weather was prolonged.

At Parsons, responses to both nitrogenous manure and particularly to phosphatic manure were obtained. The soil here was deficient in nitrogen (0.09 per cent N) though apparently not deficient in available phosphate. The increase in yield from nitrogenous manure was about 12 per cent and from phosphatic manure nearly 70 per cent. This last result is difficult to explain. The Parson's soil is not deeply weathered, however, and seems to occupy a boundary position with Lithosol so that the result of the Truog phosphate test might be abnormal. No response was given to potassic manure; the soil was not deficient in potash by the chemical test.

NOTE: The Brown Earth soils of Montserrat embrace a wide range of sub-types or phases, exhibiting important differences in depth, slope, truncation by erosion and stoniness, as well as in degree of maturity. They thus merge imperceptibly into Yellow Earth and Lithosol. These variations are reflected in their productivity for cotton, their nutrient status, and their responsiveness to different manures.

There seems to be no doubt that many of the Brown Earth Soils will respond profitably to nitrogenous manures when planted early in the year (March planting), both because they tend to be deficient in total nitrogen, and because they occur mainly in the continuously moist zone of rainfall which prevents nitrate from accumulating to any marked extent in the topsoil.

(iv) *Shoal Soil*: The crops at Elberton were so badly damaged by heavy rains and insect pests that no reliable results were obtained from the manurial trial.

At Old Road (near Olveston), where the soil was apparently deficient in available phosphate and potash but contained an adequate supply of total nitrogen (0.17 per cent N), cotton plants growing in plots receiving nitrogenous manure were at first definitely superior in general appearance to all the others. The heavy July rains, however, caused considerable flower and boll shedding on the nitrogen-treated plots, as well as a mild form of "chibble-leaf". Bolls set before the rains became persistent were invariably held by the plants growing on nitrogen-treated plots but, on the plots receiving no nitrogenous manure, the plants had set all their bolls before the heavy rains set in. The slight superiority of the nitrogen-treated plants established early in the season was not lost in spite of the unusually rainy weather, and a yield increase of about 11 per cent in favour of nitrogenous manuring was established. The effect of phosphatic manuring was well marked in this experiment, superphosphate producing a 40 per cent increase in yield over the controls. Very little yield increment was shown by the potassic manure treatment even though the soil was apparently somewhat deficient in this nutrient.

It is evident from these results that the incautious use of nitrogenous manures on Shoal soils growing cotton in Montserrat has doubtful economic value. Although the soils contain fairly large total amounts of nitrogen, yet they sometimes show appreciable response to nitrogenous manure. When the rainfall is excessive, however, serious physiological disturbances may develop which indicates that the treatment of these soils with nitrogenous manures is a "gamble on the weather".

#### **General Conclusion: Nitrogen Relations of Cotton**

The results for 1940 show that, with a somewhat free-draining soil (Brown Earth) containing a fair but not quite adequate amount of nitrogen, a slight but appreciable (12 per cent) response to nitrogenous manure was obtained in a season when marked leaching of the soil had apparently preceded the time of planting.

Similarly, the results for 1941 show that, with a freer-draining soil (Lithosol) having a marked deficiency of nitrogen, a medium but not very large (29 per cent) response to nitrogenous manure was obtained in a season when soil leaching before planting had probably not been particularly great, but when leaching had been heavy 4 to 6 weeks after planting. With an impeded-draining soil (Shoal) containing an adequate amount of nitrogen, no response to manurial nitrogen was obtained under the same conditions of rainfall. These results are fully in accord with prediction based on a consideration of the interactions between rainfall, degree of drainage and nitrogen status of the soil.

The results for 1942 similarly show that, with free-draining soils (Lithosol, Alluvial Soil) having marked deficiency of nitrogen, large (about 50 per cent) responses to nitrogenous manure were obtained in a season when leaching before planting was negligible, so that a considerable store of nitrate had probably accumulated in the soil, thus augmenting the supply added as manure. With another free-draining soil (Brown Earth) containing a greater though still inadequate amount of nitrogen a fairly large response (around 20 per cent) to nitrogenous manure was obtained. This again agrees with prediction. With an impeded-draining soil (Shoal) containing more than adequate nitrogen, not only was there little response to manurial nitrogen, but definite symptoms of physiological disturbance developed under the same rainfall conditions. This may imply that the extra supply of nitrate, which presumably had accumulated in the soil, raised the content of available nitrogen to a high level and thus produced unbalanced nutrition. These results again agree with expectation.

#### **Recommendations**

The findings discussed above suggest that the whole question of the best planting date for cotton in Montserrat should be experimentally investigated from the aspect of ecological interactions between soil moisture and total nitrogen content in relation to nitrogen-producing capacity (nitrifying efficiency) and the effects of adding nitrogenous manures to the soil. In this investigation the effects on nutrient balance of phosphate and potash and of other nutrient entities, both naturally present in the soil as well as added in manures, should also be studied.

#### **(B) LIMES: THE "DYING-OUT" PROBLEM**

*Introduction*: Ever since its inception in 1852, the lime industry of Montserrat has been beset with great difficulty, mainly owing to the unsatisfactory growth of the lime tree under the environmental conditions that obtain in the plantations. Deterioration was apparently very

rapid after the disastrous hurricane of 1899, and the Annual Reports of the Botanic Station from 1906 onwards make frequent reference to the unsatisfactory condition of the lime fields. The decline has mainly taken the form of a gradual cessation of growth, accompanied by a dying-back of twigs and branches and a yellowing or mottling of the foliage. An almost invariable symptom of the dying-out is the rapid spread of scale insects infesting the leaves and bark, of beetle grubs damaging the roots, and of fungi attacking the tips of the stems and roots.

Many different theories have been advanced to account for the dying-out condition ranging from the view that it is a direct result of infestation by scale insects or of the damage caused by pathogenic organisms or beetle larvae, to the opinion (apparently first expressed in 1915 by W. Nowell, Mycologist to the Imperial Department of Agriculture) that it is the result of physiological maladjustment of the tree to its environment, in particular, to unsatisfactory water relations. Consequently, when the services of a plant physiologist (T. G. Mason) and a soil chemist (F. Hardy) were available on the Staff of the Imperial Department of Agriculture in 1920, it became possible to investigate the problem from an ecological standpoint. The results of a preliminary study of the subject made during a brief visit by these two officers to Montserrat in April, 1921, are set out in two papers (13) which substantiate the view that the dying-out problem is essentially an ecological one. Mason demonstrated by reference to a distinct alternation of compact and diffuse rings of woody tissue which he found to occur in the twigs of dying trees, that marked periodicity of dry and wet spells must have been incident in the environment, and that this set up a "water-strain", resulting in peripheral desiccation during dry weather. Mason's conclusion was supported by the field and laboratory evidence adduced by Hardy who investigated the soil supporting contrasted groups of dying trees and healthy trees. It was noticed in those areas where lime trees were growing satisfactorily and showed no dying-out symptoms that conditions precluded the development of extreme variations in atmospheric humidity and soil moistness, because of shelter from wind or suitable physical features of the soil associated with free drainage.

Since 1921, the investigation of the dying-out of lime trees in Montserrat has mainly comprised mycological studies by R. E. D. Baker (14) and detailed entomological studies by R. G. Fennah (15). The conclusions reached by these investigators have fully supported the earlier ecological findings, namely, that insect pests and fungus parasites, involved in the dying out of limes, are facultative or secondary rather than causative or primary.

Thus, to quote from a recent comprehensive publication on the subject (by R. G. Fennah (15)), "From a consideration of the (meteorological) data, it appears that the distribution of living (lime) cultivations is limited, or is becoming so, to areas where the relation of water-supply to water-loss is least subject to violent fluctuation, or where the aridity of the atmosphere does not occur concomitantly with aridity of soil and with wind . . . . . Survival is possible only in the absence of three of the following four factors:— (1) low dry season humidity; (2) low available soil moisture in the dry season; (3) an un aerated or usually water-logged soil; (4) Wither-tip Disease to a severe degree in the wet season". (p. 48).

With regard to the significance of the incidence of scale insects which received so much attention in the early reports on lime dying-out in Montserrat, R. G. Fennah concluded from the results of nutrient injection experiments (*ibid.* p. 37) that freedom from scale insects depends on "the physiological state of the sap of a vigorous tree being an unsuitable pabulum". He considers that (*ibid.* p. 64) the most satisfactory way to control scale attack is "to alter the composition of the insects' food . . . . . to be achieved by agricultural means aimed principally at stabilising the relation between water uptake and loss by the tree, and by preventing periodical desiccation. The provision of shelter from wind and irrigation in time of drought are suggested, while measures to promote root aeration need to be considered in areas where physiological drought is likely to occur through the presence of too much water in the soil for prolonged periods".

#### Nutrient Relations of the Lime Tree

It is important to note that Fennah found that scale attack could be reduced by injecting certain mineral nutrients into affected young lime trees, but that his preliminary manual experiments, involving the application of cultural solutions to sand or soil contained in pots in which young orange trees were growing, or to plots of soil growing orange trees, gave no definite positive results in the control of scale, though the experiments were admittedly only of a preliminary nature. The notion that an unsatisfactory nutrient status of the soil may be responsible, at least in part, for the dying-out of lime trees, and may thus be a predisposing cause of susceptibility to attack by scale insects and root fungi, had previously been suggested by other investigators.

- (i) *Nitrogen*: Certain Californian citrus authorities have expressed the view that an unsatisfactory nitrogen supply in the soil is an important factor causing dying-out or decline in Citrus, especially when associated with an irregular water-supply, but

the danger of over-manuring with the object of rectifying this deficiency is stressed. It is noteworthy that the most striking nutritional feature of the lime-growing soils of Montserrat has been found by chemical analysis to be a *marked deficiency of total nitrogen* (as in the case of cotton soils), owing to a low content of organic matter which has resulted mainly from long-continued soil erosion and unreplenished wastage of plant residues by oxidation.

- (ii) *Phosphate*: Although phosphate appears not to be generally so important a nutrient in the growth of Citrus as nitrogen and potash, and to be required only in relatively low amount, yet phosphate-deficiency is known to restrict root activity and to encourage the excessive uptake of nitrogen. Available phosphate has been found to be greatest in the Lithosol, Alluvial and Yellow-Earth soil-types and least in the Brown-Earth, Rendzina, Terras and Shoal soil-types in which phosphate may be regarded as definitely deficient.
- (iii) *Potash*: Potash is an important nutrient deciding "quality" in fruit trees; the amount of available potash present in the Montserrat soils seems generally to be adequate, although it is relatively low in the Yellow Earth and Shoal soil-types. No evidences of potash-shortage (for example, as revealed by a prevalence of leaf-scorch) have been noted, however, in the lime fields of Montserrat.

#### Manurial Experiments on Limes

No large-scale manurial experiments along modern lines have been systematically carried out in recent years with the lime crop in Montserrat, although from the earliest times (that is, since 1884), simple plot trials of nitrogenous, phosphatic and potassic manures, gypsum and common salt, and of cattle and sheep manure, have spasmodically been made. The reports of various lime-plantation managers between 1876 and 1909 give conflicting evidence of the value of different kinds of manures, both artificial and organic, for lime-growing. Results were mostly judged by eye and actual yields were seldom measured. No regular policy of manuring has emerged from these efforts and, beyond the use of leguminous cover crops and the occasional application of cotton-seed meal, no attempt has been made to restore lost fertility nor to build up soils that have been badly eroded.

#### The Special Role of Calcium

Particular significance has been attached to calcium as nutrient in the growth and development of Citrus in general. The leaf-ash of

normal healthy Citrus usually contains an exceptionally large amount of lime (over 50 per cent calcium oxide (CaO) in the ash), so that Citrus trees have been described as "voracious lime feeders". Thus Haas, a Californian authority, states that "a deficiency of soluble calcium may exert a tremendous effect upon the absorption process and therefore upon the health of Citrus". In some of Haas' experiments with young orange trees grown in calcium-deficient sand cultures, premature leaf-shedding was frequently observed, accompanied by severe die-back of twigs. The effects were also associated with excessive uptake of potassium. The ash of the rind and juice of normal Citrus fruits is also rich in calcium, which is believed partly to account for their high dietetic value. Yield and quality of Citrus fruits are claimed to have been markedly improved by liming the soil and even by spraying the foliage of the trees with lime-water, which also is stated to have reduced scale infection.

#### Relationships Between Dying-out of Limes and Chemical Composition of Lime-Leaves and Soils Growing Limes

The relationship between the lime content of lime-leaves and the incidence of the dying-out condition has been specially investigated by us. Three fields were selected as showing typical stages of dying-out, as follows:

- (i) *John Dowdy Field*, Elberton (Site (14), Appendix Tables) *Terras* soil-type: Dying-out severe and well advanced.
- (ii) *Horse Stable Field*, Richmond (Site (2), Appendix Tables) *Lithosol* soil-type: Dying-out not so far advanced.
- (iii) *Middle Piece*, Elberton (Site (18), Appendix Tables) *Rendzina* soil-type: Healthy lime trees; no dying out evident.

Samples of lime-leaves were collected from several trees growing in each of these three fields. Care was taken not to pick senile or senescent discoloured leaves but only leaves that had just reached maturity. Eventually, these leaf materials, after drying and powdering, were sent to an expert in London for special spectrographic analysis. At the same time, sifted samples representative of the soils in which the lime trees were growing were also submitted for spectrographic analysis. Another set of similar leaf samples was collected for bulk chemical analysis at the College by standard quantitative analytical methods.

During the soil survey (described in Part I of this Report), soil profile samples were collected from pits dug in each of the three fields and special composite soil samples were procured to the 6-inches depth from a large number of the spots around the sites of the profile pits.

TABLE IX: Results of Soil Analysis  
(Composite 6-ins. surface samples)

Dying-out condition of lime trees	Index of Texture (I.T.)	Reaction (pH)	O.M. (%)	Total N (%)	C/N Ratio	Avail. P <sub>2</sub> O <sub>5</sub> (p.p.m.)	Avail. K <sub>2</sub> O (p.p.m.)
(i) Severe	16	6.6	2.88	0.17	10.0	94	279
(ii) Not severe	7	6.5	2.26	0.12	11.1	57	143
(iii) Healthy	29	7.2	3.09	0.17	10.2	89	243

TABLE X: Results of Leaf-Analysis

Dying-out condition of lime trees	Total Ash	PERCENT OF ASH					NUTRIENT RATIOS		
		Total Nitrogen	Total Phosphate	Total Pot-ash	Total Lime	Total Magnesia	N / K <sub>2</sub> O	N / P <sub>2</sub> O <sub>5</sub>	CaO / K <sub>2</sub> O
		N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	CaO	MgO			
(i) Severe	16.0	14.4	4.1	11.2	44.0	5.8	1.29	3.5	3.9
(ii) Not severe	15.5	14.4	2.6	9.5	42.8	6.3	1.51	5.4	4.5
(iii) Healthy	18.1	12.1	1.9	4.7	48.5	6.0	2.57	6.4	10.4
COMPARE:— Standard Californian Citrus; healthy grapefruit leaves.									
	17.7	13.5	2.1	7.2	48.4	—	1.90	6.4	6.7

TABLE XI: Results of Spectrographic Analysis: Leaf Materials and Soils

Element	LEAF ASH			SOIL		
	(i) Severe	(ii) Not severe	(iii) Healthy	(i) Severe	(ii) Not severe	(iii) Healthy
Boron	100	100	100	10	10	10
Lead	10	10	1	10	10	1
Tin	2	1	0	10	10	1
Zinc	10	10	10	1	1	0
Antimony	2	1	0	0	1	0
Cobalt, Nickel	0	0	0	1	1	1
Copper	1	1	1	2	2	2
Barium	20	20	20	20	10	10
Strontium	20	20	20	10	10	5
Manganese	10	10	10	20	20	20
Chromium	1	1	1	2	2	2

The results obtained by the analysis of soil and leaf samples are presented in Tables IX, X, and XI, (and in the Appendix Tables, Sites (14), (2) and (18) respectively).

Discussion: (a) Soil data: The soil of each of the three selected fields belongs to a quite different soil-type; that of the severely affected field and that of the healthy field are

somewhat clayey; they overlie bouldery and stony agglomerate at 24 inches depth. In the first case, however, the bouldery layer is cemented and indurated into terraces which markedly impedes downward drainage. In the second case, the boulders are thickly encrusted with pure white calcium carbonate (possibly of solfataric origin) which does not impede the drainage.

The abundance of lime in the third profile (associated with healthy lime-trees) has evidently greatly affected the composition and properties of the soil. Thus, the surface layer is nearly black in colour, crumbly and friable in structure, alkaline in reaction and contains quite a high amount of available phosphate. It also contains large traces of free calcium carbonate. By contrast, the clayey surface soil of the field whose lime trees show severe dying-out is sepia-brown in colour, very hard, coherent and intractable, slightly acid on top to slightly alkaline below, and its content of available phosphate is low. This soil contains no free calcium carbonate anywhere in the profile. A marked difference in lime status between the two clay soils is also shown by values for readily-available exchangeable calcium and for degree of saturation by lime which were found by experiment to be 5,700 p.p.m. CaO and 86.2 per cent saturation for the "healthy" soil, but only 2,900 p.p.m. CaO and 72.3 per cent saturation for the "severely-affected" soil (Table XII).

TABLE XII: Results of Tests for Soil Lime Status

Dying-out condition of lime trees	Exchangeable calcium content (p.p.m.)	calcium (CaO) (mg. equiv. percent)	Degree of saturation by calcium (percent)
(i) Severe	2900	10.2	72.3
(ii) Not severe	1700*	5.9	68.6
(iii) Healthy	5700	20.3	86.2

\* Sample (ii) is a sandy soil; the others are clayey.

Other features of the two contrasted clayey soils are not very different; for example the organic matter and nitrogen contents and the potash status are about the same, though the "healthy" soil is considerably more clayey than the "severely-affected" soil.

(b) *Leaf data*: The difference in soil lime status is also clearly reflected in the chemical composition of the leaf-ash of lime-trees grown in the two contrasted clayey soils (Table X). The lime content (CaO) of ash is 48.5 per cent in the "healthy" leaves and 44.0 per cent in the "severe dying-out" leaves. Potash contents show reciprocal relationship with lime contents (as is usual), the "healthy" leaves having a much less potash content of ash (4.7 per cent) than the "dying out" leaves

(11.2 per cent). These and other differences in chemical composition have markedly affected the nutrient ratios of the leaf materials, which, on the whole indicate, when compared with published analyses, that the composition of the "dying-out" leaves is abnormal, while that of the "healthy" leaves approximates very closely to the composition of leaves of highly productive Californian grapefruit trees taken as standard of reference in our studies of citrus in Trinidad (16).

(c) *The intermediate samples*: The chemical composition and chief features of the soil and lime-leaves collected in the third field where dying-out is not so severe though the trees were moribund, are intermediate between those of the materials procured from the other two fields. The soil of this field is acid, devoid of free calcium carbonate, deficient in available or exchangeable calcium, and has a low degree of saturation by calcium (Table XII).

The soil of the intermediate field is very stony and sandy throughout the full depth of the profile and exhibits very free drainage. It is a typical Lithosol. Its component sand particles consist mainly of fresh single mineral grains (lime-felspar, augite and magnetite chiefly). In these respects, it differs markedly from the more clayey soils of the other two fields whose profiles are better developed and whose parent materials are geologically older and more profoundly weathered.

#### Calcium-deficiency Symptoms in Citrus

The following information is taken from a recent book on deficiency diseases of crops (17).

Calcium-deficiency has never been reported from the field, and it appears rather doubtful that it will develop on the soils commonly used for Citrus. On very acid sands in Florida, available calcium may be so low as to result in an unusually large intake of potassium, but positive results from applications of calcium compounds to the soil have not been obtained, except in-so-far as they were associated with the correction of acidity and with base saturation of the colloidal complex in the soil. On such soils, lime has given a response by producing more favourable soil-fertility conditions, but the use of other calcium sources which did not materially affect the reaction of the soil failed to produce any result that would indicate a condition of calcium-deficiency as far as the trees were concerned. This was true even though the level of calcium in the soil was so low as theoretically to affect soil fertility adversely. The alkaline soils of California are well supplied with calcium and irrigation waters in that State also provide this element. Symptoms of calcium-deficiency have also been reported from

sand cultures by Reed and Haas in California, and further information has been developed by Chapman in work now in progress.

### Symptoms

Some of the early culture work is difficult to evaluate, since the so-called "vein chlorosis", in which the veins fade to a much lighter colour than the surrounding tissue, is reported as a symptom, whereas it may be due to rotting of the roots and a consequent reduction of mineral intake. This symptom is the common result of girdling, damaged root systems, or other conditions which disrupt the transfer of nutrients. Omitting this as a definite diagnostic symptom, it was found that leaves on calcium-deficient trees in sand culture developed a fading of the chlorophyll along the margins and between the main veins. Small necrotic (dead) spots developed in the faded areas, and in the case of lemon leaves, these developed into larger burned areas. There was a premature shedding of these leaves, followed by the development of additional leaves which also fell prematurely. The twigs died back from the tip and weak shoots developed from the lateral buds, but these soon died. Reed and Haas reported some rotting of roots, but Chapman did not find this in his cultures. No effects on fruit have been reported, as the trees presumably did not live long enough to produce fruit. These symptoms are probably far more acute than any that might be developed in the field, since, under field conditions, calcium would always be presented in fair amounts.

(d) *Spectrographic data*: The results submitted by the expert spectrographers are summarised in Table XI for leaf-ash and sifted soil taken from each of the three fields. Data for the major elements are omitted, as well as those for minor rare elements that were sought for but not found, namely, arsenic, beryllium, bismuth, cadmium, lanthanum, molybdenum, thallium and tungsten. The recorded values are not absolutely quantitatively accurate, although they are strictly comparable. The value 100 indicates a heavy trace, probably over 0.1 per cent, while the value 10 indicates a trace only, probably over 0.01 per cent, and the value 1 denotes slight but definite indication of the presence of the element sought for.

The chief conclusions to be drawn from the spectrographic data are:— (i) Dying out of lime trees is not associated with deficiency of any particular minor element or elements. *Boron* and *manganese*, to which much importance is now-a-days attached in studies of the significance of "trace" elements, are equally abundant in all three sets of samples. (ii) The

values for heavy metallic elements, especially *lead*, in the leaf-ash show a positive relationship with the dying-out condition, suggesting that their presence in the soil may be toxic to lime-trees.\* In the case of *zinc*, however (an element regarded as especially important in the nutrition of Citrus), little or no difference is recorded for the leaf-ash samples, but the values for the soils show slight differences, the soil supporting "healthy" trees failing to give positive evidence of the presence of zinc.

(iii) Alkaline earth metals (*barium* and *strontium*) appear to be unusually abundant in the leaf-ash and in the soil, but no significant differences which might be associated with dying-out are apparent.

On the whole, the spectroscopic evidence fails to support the contention that the dying-out of limes in Montserrat is caused by deficiency of any essential minor element (such as boron, zinc, manganese, copper or cobalt), nor does it afford strong enough evidence that the condition is caused by toxic effects of heavy metals, such as lead, tin or antimony.

### Conclusions

The only consistent and striking difference between the soil supporting healthy lime-trees and the soil supporting unhealthy trees showing symptoms of dying-out is its *relatively higher calcium status*. This may be attributed to its origin and formation from rock materials impregnated and encrusted with calcium carbonate. The chief effects of the abundance of free lime have been two-fold; firstly, it has imparted a high content of easily-available soil calcium (an important and essential plant nutrient, especially in the nutrition of Citrus species) and secondly, it has greatly improved the structure of the clay so that soil-water and soil-air relations (drainage and regularity of water-supply; aeration and adequacy of oxygen-supply to the roots) are probably superior to those of the clay-soil lacking lime, associated with trees showing the dying-out conditions.

The calcium status of the inferior clay-soil associated with dying-out and that of the soil supporting dying or moribund trees, would not in either case, however, be regarded as dangerously low. None of the soils is highly acid and none exhibits a really low exchangeable lime content. The difference is merely one of degree. Nevertheless, the higher calcium status of the soil supporting healthy trees is clearly reflected in the higher lime content of their leaves and their better nutrient ratios, implying a greater capacity of the soil for supplying nutrient cal-

\* NOTE: A second spectrographic examination by an authority in the United States of America failed to substantiate the first indication of a difference in heavy metal content of the leaf-ash samples.

cium and a better general nutritional balance. It is evident from the discussion of the laboratory data that the indications of calcium-deficiency which they reveal may be illusory and that the dying-out symptoms are solely the manifestations of unsatisfactory or unbalanced mineral nutrition, such as might result from maladjustment between the lime tree and its soil environment.

While there is no doubt that the general level of fertility of the soils of Montserrat is somewhat too low for the nutritional needs of the lime tree, other ecological soil factors such as water-supply, air-supply, soil-temperature and root-room, may not be present in adequate amount, or their fluctuations may be large enough to cause physiological upset within the tree. The conclusions have been confirmed by Fennah after a full consideration of the available information; they are expressed in his recent publication (15) by the statement that living lime cultivations are confined to "areas where the relation between water-loss is least subject to violent fluctuation or where aridity of the atmosphere does not occur concomitantly with aridity of the soil, and with wind" (p. 48).

#### Root Relations of the Lime Tree

Perhaps the most significant suggestion that has so far been offered to account for the dying-out of limes growing in an unsatisfactory environment is that offered by Fennah as a result of field studies of affected trees, who states in the summary of his report (*ibid*, p. 64) that dying out is "caused by desiccation of the conducting tissues following the death of fibrous feeding-roots". He asserts that "no organism has been found which can be considered responsible for the death of the small rootlets"; hence their death must be due to unavoidable environmental circumstances. The probability that "root disease" which is so closely associated with the dying-out of limes in Montserrat is primarily caused by injury and decay of the absorbing root-system opens up an entirely new field of investigation, for such a condition alone could satisfactorily explain the maladjustment which apparently exists between the lime-trees and the soil which leads to unbalanced nutrient relations as is clearly indicated by the results of leaf analysis.

No detailed studies of the root-system of the lime tree as developed in different soil-types or in any one soil-type presenting variable environmental conditions have yet been made in the West Indies. If and when any such studies are attempted, the significance of the organic matter status of the soil (organic profile) in relation to root distribution should receive primary consideration.

The effect of soil organic matter on root growth may be both physical and chemical.

Fennah considers that the death of rootlets cannot justifiably be assigned to any cause other than temporary lack of water, but he nevertheless agrees that this hypothesis presents certain difficulties. It is well known that a high organic status of the soil and the occurrence of undisturbed surface litter and soil crumb, such as normally develop under natural forest conditions in the wet tropics, vastly improve the water and air relations of a soil and favour the attainment of a wide and diffuse root distribution. The use of vegetable mulches and dressings of bulky organic manures for improving the healthiness and productivity of tropical tree crops is rapidly gaining favour. The benefits derived therefrom are generally attributed to the greatly improved root systems that appear to develop when the organic matter content of the soil has been raised, or when the normal organic profile has been reinstated. In this connection the possible importance of the occurrence of mycorrhizae in Citrus soils should not be overlooked.

From the chemical aspect, it is nowadays considered probable that certain root-stimulating substances are manufactured in small amounts by decaying soil organic matter or organic mulches and manures added to the soil to improve it, and that their presence might aid in root development. Finally, the possibility that fibrous rootlets themselves, once they are suitably established, possess a special function in producing growth-promoting hormones affecting the general health and vigour of the plant must not be overlooked (18). Dr. F. W. Went in California has found that such hormone-producing rootlets (of tomato) develop profusely in well-aerated organic surface soil, litter or mulch. Abundant soil aeration, favourable to root development, is thus (to quote Went) "not required solely for water and nutrient uptake (which requirement is relatively small) but for increasing the growth rate of the stems and preventing chlorosis".

#### Recommendations

In future studies of the dying-out of lime trees, it would be desirable to pay attention to root relations, root development and root-room in Citrus plantations, especially in-so-far as they are affected by soil structure, by the organic status of the soil, and by organic materials, crop residues and organic manures applied in sufficient quantity to modify the properties of the soil and to bring the land back to its original primeval "forest" condition. When the root system of the tree has developed properly and is functioning normally, the possible value of different artificial manures and amendments may then be tested by means of field experiments. It would seem to be futile to attempt to investigate the response of the lime crop to artificial manures unless or until its roots have become thoroughly adjusted to the conditions in the soil and to the prevailing climate.

## SUMMARY

## PART I

(1) The *first part* of the Report deals with the soils of Montserrat considered as natural objects developed by the weathering of the characteristic rocks of the island under the influence of climate, vegetation, topography and time. Each of these soil-forming factors is considered in turn.

(2) The *rocks* of Montserrat chiefly comprise fragmental volcanic ejecta composed of quartz andesite. Lava flows (of basalt) are rare. Six different volcanoes have been identified and their relative ages estimated. The oldest (Silver Hill) was active in the Middle Miocene era and the newest (Soufriere Hills) in the Recent geological period, say 25 thousand years ago. At that time the island was partly submerged and its area greatly reduced by the return of water to the ocean when the great continental ice sheets of the Glacial age melted.

(3) The *climate* of Montserrat varies from continuously moist with no marked dry season and mean annual rainfall lying between 70 and 55 inches in the leeward and central regions, to one with a more-or-less well-marked dry season having mean annual rainfall lying between 60 and 40 inches in the windward, north and south regions. Temperatures range from 73° to 87° F; humidity seldom falls below 65 per cent. The island is in the hurricane zone. Six different site categories with regard to insolation and exposure are recognisable.

(4) The *natural vegetation* of Montserrat has been greatly modified by man's activities and by wind damage. Few traces of the original forests remain, particularly in the agricultural areas lying below the 1,000 or 1,500 feet contours. The chief crops are cotton, limes, tomatoes, vegetables and sugar-cane. About one-third of the island's surface is cultivated. Former private estates are being divided into peasant holdings.

(5) The *topography* of Montserrat varies from mature and smooth in the north where the remnants of the oldest volcano occur, to young, steep and rugged in the south where the youngest volcanoes are situated. The lower slopes of the newest volcanoes have been dissected longitudinally into deep "ghauts" or "guts".

(6) The *time* during which soil formation may have proceeded has been longest in the north and shortest in the south. Denudation has prohibited soil development and soil accumulation over most areas, so that the present-day soils are mainly shallow.

(7) Eight soil-types have provisionally been identified, described and roughly

mapped; their differentiation is based on the nature of the parent soil materials and on the degree of drainage impedence which partly depends on the extent to which they have been sealed up by cementation in the illuviated B-horizon. The soil-types have provisionally been named:— (1) *Lithosol* and (2) *Alluvial and Colluvial Soils*, developed over fresh, loose materials; (3) *Brown Earth*, (4) *Rendzina* and (5) *Yellow Earth*, developed over partly weathered materials; (6) *Terras* and (7) *Shoal*, developed over well-weathered cemented materials and (8) *Red Earth*, developed over profoundly weathered residual materials. The Zonal type for the area (No. (8), Red Earth) occurs only at the summit of Centre Hills. Soil-types Nos. (6) and (7) are Hydromorphic Intrazonal soils showing variably impeded drainage; Nos. (3), (4) and (5) are Calcimorphic Intrazonal types in which lime is prevalent; Nos. (1) and (2) are Lithosol Azónal types.

(8) Laboratory data are given for 576 soil samples taken from 65 soil profiles representing these soil-types. The laboratory methods employed in their analysis are outlined at the end of the Report. The results indicate that none of the soil-types is really clayey though the impeded-draining soils contain most silt and clay. None is markedly acid. Organic matter and nitrogen contents tend to be low though highest in the impeded-draining soils. Available phosphate and potash are variable and also tend to be low, especially in Shoal soil.

(9) The chemical and mineralogical transformations involved in the formation of Terras and Shoal are briefly traced from the results of laboratory examination of representative profile samples. The pedological relationships of these two soil-types are discussed.

(10) Soil erosion in Montserrat is reviewed and the main kinds of erosion are differentiated and classified. The chief are *débris avalanche*, *mudflow*, and *earthflow*. These are serious, however, only when the rainfall is continuous and large. Typical occurrences are described. Landslide movements were particularly prevalent during the earthquake period, 1933-37. Mention is made of the wastage of soil caused by continual hoeing downhill ("hoe-rosion").

(11) Methods suitable for controlling soil erosion in Montserrat are briefly discussed, and the results of an anti-erosion experiment are examined.

(12) The question of soil renovation on eroded lands is considered and the value of appropriate artificial manures in rebuilding the soil by means of cover-crops is stressed.

## PART II

(13) The *second part* of the Report deals with some ecological aspects of the cotton and lime crops in Montserrat, particularly in relation to choice of planting date and the occurrence of physiological disturbances in the former, and the problem of dying-out in the latter.

## (A) COTTON

(14) The dependence of cotton yields on the amount and monthly distribution of rainfall is indicated by actual examples. Late-planted cotton usually suffers from boll-shedding; this is generally attributed to the effect of excessive wetness during the second half of the year. Early planted cotton, by contrast, develops under gradually increasing rainfall and therefore sets and retains a much larger number of bolls. These may be badly affected, however, by pests and diseases during the reaping season.

(15) It is thought that late-planted cotton may lack an adequate supply of soil nitrate, and that growth failure may therefore primarily be caused by an insufficient amount of organic nitrogen in the soil at the time of planting, coupled with excessive leaching which may have removed nitrate accumulated during the previous dry season. These circumstances affect the free-draining soil-types more than the impeded-draining soil-types which contain intrinsically greater amounts of nitrogenous organic matter and are less liable to excessive leaching.

(16) Late-planted cotton frequently develops physiological abnormalities ("chibble-leaf"; "loggerhead") in wet weather on certain impeded-draining soils particularly rich in nitrogen, presumably because of excessive production of nitrate exaggerated by nutrient imbalance brought about by deficiency of phosphate and sometimes potash.

(17) By contrast, early-planted cotton may benefit from nitrate accumulated during the dry season and not yet leached out by the rains.

(18) This nutrient hypothesis is supported by the results of manurial experiments, in which nitrogenous manures, applied to soils found by chemical analysis to be deficient in nitrogen, have regularly given large increments in yields of cotton under favourable rainfalls. Phosphatic manure has also proved beneficial when applied to phosphate-deficient soils.

## (B) LIMES

(19) The history of the dying-out of lime cultivations in Montserrat is traced and the different theories advanced to account for it are

reviewed. Latest opinions favour unsatisfactory water relations as the most likely cause; scale insects, root grubs and stem and root fungi are regarded as secondary parasites. The chief cause is believed in some way to concern the nutrition of the tree. The nutrient relations of Citrus, described in literature, are accordingly briefly discussed.

(20) In order to examine the relationships between the chemical composition of soil and leaf-ash and the dying-out condition of lime trees, samples representative of severely-affected, moribund and healthy trees were collected and analysed chemically and spectroscopically. The results indicate a lower lime status of the soil and leaves of dying-out trees and a general nutrient imbalance which may be accounted for by unsuitable soil conditions, in particular, an unsatisfactory organic status, and not by gross deficiency of any major or minor nutrient element.

(21) The finding (due to Fennah) that dying-out of limes is associated with "the desiccation of conducting tissues following the death of fibrous feeding roots" suggests that malnutrition results from an inefficient root-system and that the primary cause of dying-out should be sought in those soil conditions and factors that control root development, including root-stimulating hormones.

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#### LABORATORY METHODS OF SOIL ANALYSIS

The following determinations were made on the air-dried soil samples after pulverising and passing through a sieve having round holes 2 mm. in diameter.

##### (1) Gravel, Coarse Sand, Silt and Clay:

*Gravel*; particle diameter above 2.0 mm.; expressed as weight percentage of air-dry soil.

*Coarse sand*; particle diameter 2.0 — 0.2 mm.; wet sieving through 0.2 mm. sieve.

*Silt and Clay*; particle diameter below 0.02 mm.; settling in water through 11.8 cm. depth in 4 min. 48 sec., at 27° C.

##### (2) Index of Texture (I.T.)

Derived from values determined for sticky point moisture content (P) and coarse and fine sand content (S) by the formula,  $I.T. = P - S/5$ . The index assesses the degree of clayiness or sandiness as a single value. The following arbitrary scheme is employed:—

INDEX OF TEXTURE	TEXTURE
60 — 55	Heavy clay
55 — 40	Clay
40 — 30	Silt
30 — 20	Loam
20 — 10	Sand
10 — 0	Light Sand

(Reference: F. Hardy, *Journ. Agric. Sci.*, 1928, XVIII, pp. 252—256).

##### (3) Reaction (pH)

Quinhydrone electrode method, checked by glass electrode method applied to suspensions of one part soil to 4 parts water.

pH VALUE	REACTION
8.0 — 7.5	Highly alkaline
7.5 — 7.0	Alkaline
7.0	Neutral
7.0 — 6.5	Slightly acid
6.5 — 6.0	Acid
6.0 — 5.5	Markedly acid
5.5 — 5.0	Highly acid

##### (4) Organic matter (O.M.)

Watts' wet combustion method; 0.5 to 2.0 g. soil oxidised by 3 g. chromic acid and 10 cc. conc. sulphuric acid; carbon-dioxide measured over mercury in nitrometer. Result (carbon content) multiplied by 1.724 to bring to approximate O.M. content and then by correcting-factor 1.33, experimentally determined.

(Reference: F. Hardy; *Journ. Agric. Sci.*, 1929, XIX, pp. 727—733).

(Sands and Loams)

O.M. PER CENT (corrected values)	ORGANIC STATUS
8.0 — 6.5	Very high
6.5 — 5.5	High
5.5 — 4.5	Fairly high
4.5 — 3.5	Medium-high
3.5 — 2.5	Medium
2.5 — 1.5	Medium-low
1.5 — 0.5	Low
0.5 — 0.0	Very low

(5) *Total Nitrogen (N)*  
Kjeldahl's standard method

(Sands and Loams)

N PER CENT	NITROGEN STATUS
0.45 — 0.35	Very high
0.35 — 0.30	High
0.30 — 0.25	Fairly high
0.25 — 0.20	Medium-high
0.20 — 0.15	Medium
0.15 — 0.10	Medium-low
0.10 — 0.05	Low
0.05 — 0.00	Very low

65 — 50	Fairly high
50 — 40	Medium-high
40 — 35	Medium
35 — 30	Medium-low
30 — 20	Low
20 — 0	Very low

(6) *Carbon-Nitrogen Ratio (C/N)*

Calculated from carbon (corrected) and nitrogen contents. The magnitude of this ratio provides a rough index of the degree of decomposition and humification of soil organic matter, low values being associated with high degree of breakdown.

(7) *Available Nutrients*

Estimated by measuring the electrical conductivity of a water suspension of the soil, 50 cc. distilled water, 10 g. air-dry soil, in contact for 21 hours, by the Kohlrausch - Wheatstone Bridge method. Easily-soluble salts (nitrates and bicarbonates chiefly) are extracted. Values are mhos x 10<sup>-6</sup>. When above 200, they may denote presence of abnormal salts (saline, alkaline, calcareous, gypseous soils).

(Reference : W. R. G. Atkins, *Journ. Agric. Sci.*, 1924, XIV, pp. 198-203).

Avail. nutr. (mhos x 10<sup>-6</sup>)

over 200	Very high
200 — 150	High
150 — 125	Fairly high
125 — 100	Medium-high
100 — 75	Medium
75 — 50	Medium-low
50 — 20	Low
20 — 0	Very low

(8) *Rate of Solution* (potential nutrients)

Estimated by measuring electrical conductivity as above, but after 7 days' standing and subtracting value for Available Nutrients. Slowly soluble salts (such as gypsum) and soluble products of mineral hydrolysis and oxidation are extracted. Values are mhos x 10<sup>-6</sup>.

(Reference :— as last)

RATE OF SOLUTION (mhos x 10<sup>-6</sup>)

over 85	Very high
85 — 65	High

(9) *Available Phosphate* (Avail. P<sub>2</sub>O<sub>5</sub>)

Truog's coeruleo-molybdate colorimetric method applied to extracts obtained by shaking for 30 minutes 2 g. soil with 400 cc. of a 0.01 per cent solution of sulphuric acid buffered at pH 3 with ammonium sulphate. Results are expressed as parts P<sub>2</sub>O<sub>5</sub> per million of air-dry soil.

(Reference : E. Truog, *Journ. Amer. Soc. Agron.*, 1930, XXII, pp. 874-882).

P <sub>2</sub> O <sub>5</sub> p.p.m.	AVAILABLE PHOSPHATE STATUS
120 — 95	Very high
95 — 75	High
75 — 60	Fairly high
60 — 45	Medium-high
45 — 30	Medium
30 — 15	Medium-low
15 — 5	Low
5 — 0	Very low

(10) *Available Potash* (Avail. K<sub>2</sub>O)

Cobalti-nitrite volumetric method applied to extracts obtained by leaching 25 g. soil with 1 litre of 3 per cent acetic acid. Results are expressed as parts K<sub>2</sub>O per million of air-dry soil.

(Reference : G. Milne, *Journ. Agric. Sci.*, 1929, XIX, pp. 541-552).

K <sub>2</sub> O p.p.m.	AVAILABLE POTASH STATUS
350 — 250	Very high
250 — 200	High
200 — 175	Fairly high
175 — 150	Medium-high
150 — 125	Medium
125 — 75	Medium-low
75 — 25	Low
25 — 0	Very low

(11) *Base Status* (Not recorded in Appendix tables)

This may roughly be assessed by means of Comber's reagent (4 per cent potassium or ammonium thiocyanate in 95 per cent alcohol), 5 cc. reagent, 3 g. soil. Depth of red colour inversely proportionate to base status and therefore to pH value.

(Reference : N. M. Comber, *Journ. Agric. Sci.*, 1920, X, pp. 420-424).

MARK	COMBER COLOUR	BASE STATUS	pH VALUE
0	Colourless	Very high	Above 7.0
2	Nearly colourless	High	7.0 — 6.5
4	Pink	Medium	6.5 — 6.0
6	Light red	Medium-low	6.0 — 5.0
8	Red	Low	5.0 — 4.0
10	Dark red	Very low	4.0 — below

(12) *Calcium Carbonate* ( $\text{CaCO}_3$ )

Collins' calcimeter method. This was only applied to samples having highly alkaline reactions and giving appreciable effervescence with diluted hydrochloric acid.

*Profile Cards*

Values for (1) base status (Comber), (2) reaction, (3) texture, (4) calcium carbonate, (5) organic matter, (6) rate

of solution and (7) available phosphate, are displayed in that order in columns of colours on cards, one for each profile. All these factors for all the layers of the soil profile are represented thereon. The charts are drawn to scale. They include columns of representative soil, finely ground and mixed with cellulose varnish and painted onto the cards. A set of cards for the Montserrat soils has been presented to the Agricultural Department of Montserrat and another has been filed in the College Soils Laboratory.

## PROVISIONAL LIMITS OF ADEQUACY

*Three chief nutrients for the main crops grown in Montserrat*

(Surface 6-inch layer of soil)

Crop	Total nitrogen %	Nitrate ( $\text{NO}_3\text{-N}$ ) * p.p.m.	Avail. phosphate ( $\text{P}_2\text{O}_5$ ) p.p.m.	Avail. potash ( $\text{K}_2\text{O}$ ) p.p.m.	Avail. lime ( $\text{CaO}$ ) p.p.m.
Cotton	0.120	40	40	140	—
Limes	0.075	25	50	200	2250
Tomatoes, etc.	0.180	60	60	150	—
Sugar-cane	0.135	45	25	120	3500

\* Assuming nitrifying efficiency factor 3.4 per cent.

## APPENDIX

## SOILS OF MONTERRAT, B.W.I. (1940)

## Laboratory Data

## (I) RICHMOND ESTATE

## (1) RICHMOND 1. BELLE FIELD

Cotton field; "best field in Richmond" for past 20 years. Green dressing every 3 or 5 years; cotton-seed meal, but not in 1940. Slight slope on W.S.W. of St. George's Hill. Windbelts of Bread-and-Cheese. Dry powdery soil. 2-part composite profile; (1) 0-49 ins; (2) 49-down; changes also in ash composition at 22, 29 and 40 ins. Brownish B-horizon, 15-29 ins., indicating slight profile differentiation; grey gravelly sand below with variable composition. LITHOSOL soil-type. Very high available phosphate, high available potash, but very low total nitrogen. Land strewn with angular boulders up to 6 ins. diameter.

	Dpth (ins.)	Grav- el (%)	Crse Sand (%)	Silt and Clay (%)	I.T.	Reac- tion (pH)	O.M. (%)	N. (%)	C/N Ratio	Avail. Nutr. (mhos x 10 <sup>-6</sup> )	Rate of Soln. (p.p.m.)	Avail. P O <sub>2</sub> 5 (p.p.m.)
MSR.												
1. Composite	6	18	46.6	25.8	3	6.7	1.43	0.08	11.1	131	30	353
(First Part)												
2. Grey, loose	3	17	52.0	26.3	3	7.1	1.22	0.06	11.1	92	55	522
3. Compact	10	18	50.0	27.8	3	7.0	1.03	0.07	8.9	87	51	336
4. Transition	15	27	45.0	31.0	6	7.2	0.58	0.04	8.2	68	37	144
5. Brown	22	12	42.0	35.0	9	7.1	0.36	0.03	6.9	57	34	124
6. Bright brown	29	34	62.7	22.3	0	7.1	0.19	0.01	7.9	46	29	111
7. Grey-brown	40	21	74.5	15.5	0	7.1	0.14	0.02	4.3	44	24	127
8. Fine gravel	49	38	91.7	2.3	0	7.1	—	—	—	27	19	115
(Second Part)												
9. Black	54	19	42.2	39.9	7	6.9	1.76	0.06	17.9	48	35	47
10. Ditto.	60	8	41.5	40.5	8	7.1	1.63	0.05	17.9	44	45	45
11. Speckled	72	19	50.2	33.9	0	7.3	0.68	0.03	12.1	45	25	43

Avail. potash; MSR.	1	221 p.p.m., K <sub>2</sub> O
	3	274 " "
	5	81 " "
	7	60 " "
	9	92 " "
	11	116 " "

## (2) RICHMOND 2. HORSE STABLE FIELD

Cotton field for last 5 years; previously limes. No green dressings; cotton-seed meal. Soil "not so good as last"; "not top of first class", but "very good". "Does best in dry years". Abundant wind-breaks, Bread-and-Cheese. Harsh gravelly soil; LITHOSOL soil-type. Slight brown B-horizon, 18 or 24 ins. to 34 ins., paler brown to buff-grey below. Simple profile but change in ash composition evident at 18 ins., with gradual decrease in clayiness with depth. Coarse, harsh, gravelly sand with occasional boulders up to 2 feet diameter. Medium to low available phosphate and potash and medium-low total nitrogen. Typical "die-back" lime field; moribund trees.

MSR.												
12. Composite	9	35.8	34.2	7	6.5	2.26	0.12	11.1	93	42	57	
13. Dark grey	5	11	42.5	40.8	10	7.1	2.85	0.14	11.9	154	114	41
14. Black	12	19	40.0	43.6	11	6.4	1.76	0.08	12.6	81	24	11
15. Dark grey	18	32	47.5	39.0	10	6.5	0.87	0.05	9.5	89	18	11
16. Black chocolate	24	33	54.9	31.9	0	6.5	0.49	0.03	8.8	80	16	21
17. Red brown	34	40	62.5	27.5	0	6.6	0.26	0.02	8.1	57	17	33
18. Paler	48	33	60.0	26.5	0	6.7	0.24	0.02	7.6	70	16	32
19. Ditto	60		62.0	25.5	0	7.1	—	—	—	65	13	41

Avail. potash; MSR. 12. 143 p.p.m., K<sub>2</sub>O

## APPENDIX—Continued.

	Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P O <sub>5</sub>
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		(p.p.m.)

## (3) RICHMOND 3. INDIGO WORKS FIELD

Cotton field though soil not really suitable for cotton; Site 50 yds. from forest edge, 700 ft. altitude, S. W. slope of St. George's Hill. Very uniform; chocolate-black, humic fine sand; dries grey. Changes at 24 ins. and at 48 ins. former soil surfaces; 3-part composite. No stones anywhere in profile, though abundant on land surface. *YELLOW EARTH* soil type. Medium to low available phosphate and potash; medium-low total nitrogen. Fairly uniform organic matter content throughout.

## MSR.

30. Composite		11	40.6	30.4								
(First Part)												
31. Black chocolate	5	7	46.0	41.0	13	6.6	3.86	0.21	10.8	205	109	61
32. Do. soft	9	22	43.0	42.5	9	6.4	2.07	0.13	9.6	93	47	28
33. Ditto.	12	20	44.9	40.1	6	6.4	1.19	0.07	9.5	69	28	20
34. Ditto.	18	15	45.5	40.5	6	6.6	0.93	0.05	9.8	66	17	36
35. Compact	24	13	42.0	43.6	7	6.6	0.93	0.05	10.6	68	24	40
(Second Part)												
36. Darker	36	4	43.5	44.5	8	6.7	1.35	0.05	15.0	53	16	52
37. Ditto.	48	2	42.5	44.0	7	6.7	1.32	0.05	16.4	47	17	30
(Third Part)												
38. Black chocolate	60	7	43.5	40.5	6	6.7	1.43	0.05	16.6	33	3	30
39. Ditto.	72	6	41.5	43.5	6	6.8	1.09	0.04	15.8	36	12	38

Avail. potash; MSR. 30. 162 p.p.m., K<sub>2</sub>O

## (4) RICHMOND 4. NEGRO HOUSE FIELD

Cotton field; formerly limes. Buried by mud-flow in 1936. Green dressings recently ploughed in. Very stony land; flat; Transported mudflow material forms surface 16 ins. Humic sand below, 16 to 28 ins.; then sudden change to stony sand; stones up to 2 ins. diameter; slightly cemented. Perhaps 3-part composite profile. *LITHOSOL* soil-type; alternations of scarcely-altered coarse sand, gravel and stones with recent mudflow. High available phosphate, medium available potash, very low total nitrogen; low organic matter throughout.

## MSR.

20. Composite		20	59.2	17.6	0	6.2	1.26	0.07	10.0	87	37	300
"Mudflow"												
21. Loose	5	34	77.2	12.8	0	6.9	0.72	0.04	10.5	111	44	311
22. Speckled	9	17	91.5	2.5	0	7.5	0.10	0.01	5.3	55	31	181
23. Speckled	16	19	92.5	2.5	0	7.3	0.06	0.01	6.8	36	19	178
Original Soil												
24. Humic	22	36	72.5	16.3	0	7.2	0.44	0.02	10.3	46	25	81
25. Brown-grey	28	26	77.2	14.6	0	7.0	0.31	0.02	10.6	41	23	120
(Third Part)												
26. Stony	37	51	85.0	8.5	0	7.3	0.08	0.01	5.2	29	20	77
27. Green-grey	45	26	87.5	4.8	0	6.7	—	—	—	24	10	81
28. Speckled	54	24	87.4	6.1	0	7.1	—	—	—	25	12	105
29. "Pepper-and-salt"	60	35	89.4	5.1	0	6.9	—	—	—	31	12	264

Avail. potash; MSR. 20; 179 p.p.m., K<sub>2</sub>O

## APPENDIX—Continued.

	Dpth	Gravel	Crse Sand	Silt and Clay	I.T.	Reaction	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P <sub>2</sub> O <sub>5</sub>
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		(p.p.m.)

## (5) RICHMOND 5. PLUM TREE FIELD

Lime field; 1 year out of nursery; weedy field (*Commelina*); foot of St. George's Hill; flat land. Site 50 yds. E. of main road. 3-part composite profile; 0-21; 21-48; 48-72. LITHOSOL soil-type. Fairly uniform; dark brownish-grey colour throughout, almost black. Uniformly stony and coarse-sandy; very slightly acid. Very low total nitrogen content; high to very high available phosphate, medium to medium-low available potash.

MSR.												
40. Composite		19	57.9	18.6	2	6.4	1.22	0.07	10.3	56	34	180
(First Part)												
41. Yellow-black	6	18	73.4	15.1	0	6.6	1.21	0.07	10.7	125	34	170
42. Yellowish	12	20	73.5	13.5	0	6.7	0.58	0.04	9.2	67	19	88
43.	21	17	88.0	6.5	0	6.8	0.22	0.02	7.9	43	16	91
(Second part)												
44. Nearly black	24	19	41.0	36.0	6	7.0	0.64	0.03	10.9	52	16	94
45. Black	31	20	57.5	27.0	3	6.9	0.97	0.04	13.4	52	23	69
46. Brownish	36	19	56.5	25.0	2	6.8	0.61	0.03	10.7	44	22	81
47. Dark-brown	48	42	79.2	11.8	0	6.9	0.29	0.01	13.9	33	17	104
(Third part)												
48. Black	54	17	53.0	30.5	3	6.9	1.11	0.04	15.0	45	21	93
49. Black	60	27	64.5	24.5	2	6.8	1.31	0.05	16.2	37	20	94
50. Pale brown	72	15	74.0	15.0	0	7.1	0.28	0.02	8.5	27	18	92

Avail. potash; MSR. 40; 113 p.p.m., K<sub>2</sub>O

## (6) RICHMOND 6. SANDBOX FIELD

Lime-field; young budded limes. Site further N. than last; roadside; flat land. Formerly cotton; land in banks. Soil slightly cemented. YELLOW EARTH soil-type. Probably entire; not composite. Black to 22 ins., gravelly, red-brown, nearly black, sand to 60 ins.; clay band, 48 to 50 ins.; incipiently cemented below 60 ins. Fairly marked differentiation; soil seems well-developed or "mature". May belong to Garibaldi Hill mass, or border between this and St. George's Hill mass. Acid; medium-low nitrogen content medium available phosphate; medium-high available potash.

MSR.												
51. Composite	6	9	34.4	32.6	10	6.5	2.29	0.12	11.1	117	44	165
52. Choc. sepi	5	18	30.5	54.5	16	5.9	2.86	0.14	11.7	117	30	91
53. Ditto.	10	11	34.0	47.0	11	6.0	1.97	0.09	12.4	65	24	47
54. Choc. black	16	13	34.5	50.0	12	6.3	2.17	0.09	14.0	49	27	40
55. Ditto.	22	12	35.5	50.1	14	6.5	2.07	0.09	13.8	53	32	21
56. Red-brown	32		49.5	39.5	10	6.7	0.76	0.04	9.9	60	25	15
57. Ditto.	44	15	40.5	44.5	10	6.7	0.44	0.03	9.2	60	24	18
58. Ditto.	48	29	46.0	37.5	6	6.9	0.36	0.03	7.9	82	21	19
59. Paler brown	50	16	44.0	38.5	7	6.9	—	—	—	71	30	21
60. Paler brown	60	11	44.0	43.0	9	7.0	—	—	—	78	34	36
61. Cemented	72	41	55.5	34.0	8	6.7	—	—	—	85	19	29
62. Harder	80		55.0	31.0	5	6.7	—	—	—	—	—	80

Avail. potash; MSR. 51; 152 p.p.m., K<sub>2</sub>O

## APPENDIX—Continued.

Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P O <sub>5</sub>
(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		(p.p.m.)

## (7) RICHMOND 7. GARDEN PIECE

Cotton field; gentle slope from Lynch's Hill, foothill of St. George's Hill. Site 100 yds. E. of main road; near Cork Hill rise. *YELLOW EARTH* soil-type, though nowhere clayey. Black to 18 ins., loose, brownish-grey gravelly-sand becoming finer below. Black band at 62 to 72 ins. May be a 3-part composite profile, but not definite. Distinctly yellowish-brown between 42 and 48 ins. depth; loose throughout. Colour yellowish rather than reddish-brown. Medium to medium-low nitrogen content; *extremely high* available phosphate; medium available potash. High phosphate extends full depth of profile. Markedly *alkaline*. Alkalinity associated with occurrence of *free calcium carbonate*; source unknown. Peculiar, abnormal profile; may be 3-part composite. 0-16; 16-48; 48-72.

NOTE: Shoal outcrop seen in field W. of site, nearer main road. Site on border between Garibaldi and St. George's Hills, but soil-type probably same as that of St. George's Hill.

## MSR.

63. Composite	19	52.1	26.6	6	6.6	2.47	0.12	11.5	113	47	323
64. Black	5	33	59.0	28.0	8	7.1	2.72	0.13	12.1	152	590
65. Black	10	44	58.5	30.5	7	6.8	2.34	0.10	13.3	91	744
66. Black	16	47	58.5	30.6	6	7.5	2.07	0.01	12.0	145	1488
67. Brown	24	48	89.4	4.8	0	7.4	0.38	0.02	8.8	59	287
68. Paler	33	48	92.0	3.4	0	7.4	0.14	0.01	5.9	40	178
69. Paler	42	30	76.4	10.4	0	7.8	—	0.00	—	68	309
70. Yellow-brown	48	22	47.7	25.0	0	7.6	—	0.01	—	72	480
71. Darker	55	20	67.0	18.3	0	7.6	—	0.03	—	60	402
72. Yellow-brown	62	47	86.2	4.9	0	7.5	—	0.01	—	73	273
73. Black-brown below	72	12	46.5	33.4	6	7.6	1.22	0.04	16.5	87	134

Avail. potash; MSR. 63; 147 p.p.m., K<sub>2</sub>O

MSR. 66; 0.6 percent CaCO<sub>3</sub>

## (8) RICHMOND 8. TAMARIND GHAUT FIELD

Recently cotton, now grass. Site N. of last, ¼ mile, 60 yds. E. of main road. Hollow in gently-sloping field, foot of Lynch's Hill. Closely resembles No. (6); *YELLOW EARTH* soil-type. Probably disturbed; site of house. Water-table at 43 ins., swampy hollow; partly impeded drainage. Stiff soil mostly, gravelly and somewhat harsh. No clay-pan. Dark chocolate to 23 ins. Not really typical. Yellow Earth though clayey. Medium-low nitrogen; medium available phosphate; medium-low available potash.

## MSR.

74. Composite	6	18	39.7	30.5	7	6.5	1.90	0.10	10.6	65	34	50
75. Choc. friable	6	21	42.0	39.6	7	6.3	2.21	0.11	11.3	54	25	40
76. Ditto.	13	10	32.7	50.9	11	6.5	1.61	0.09	10.2	49	24	23
77. Ditto.	18	42	69.4	21.3	0	6.6	0.71	0.04	9.6	43	23	28
78. Clay-sand	23	37	55.8	30.2	3	6.5	0.87	0.05	10.5	50	17	29
79. Sepia	36	18	38.7	39.7	7	7.1	0.90	0.06	9.9	44	24	25
80. Red-brown	43	16	51.7	35.1	5	6.5	0.72	0.05	9.1	58	32	74
81. Below <i>w. table</i>	48	16	49.7	33.1	6	6.7	0.78	0.04	10.3	70	24	70
82. Clay-sand	60	10	31.6	56.1	16	6.5	0.76	0.05	8.0	62	15	19
83. Streaky grey	72	14	35.6	36.1	15	6.6	0.39	0.04	6.2	—	—	—

Avail. potash; MSR. 74; 95 p.p.m., K<sub>2</sub>O

## APPENDIX—Continued.

Dpth	Grav-	Crse	Silt	I.T.	Reac-	O.M.	N.	C/N	Avail.	of	Avail.
(ins.)	el	Sand	and		tion	(%)	(%)	Ratio	Nutr.	Rate	P O <sub>5</sub>
	(%)	(%)	Clay		(pH)				(mhos x 10 <sup>-6</sup> )	Soln.	(p.p.m.)

## (9) RICHMOND 9. FFRY'S BOTTOM FIELD . . .

Cotton field; limes up to 1939; now cotton. Site W.N.W. of No. (6); W. of main road, 150 yds. Foot of Garibaldi Hill. Resembles No. (7), but *not* alkaline nor calcareous. *YELLOW EARTH* soil-type. May be 2-part composite profile; 0-33; 33-72 ins. Dry, grey-black, dusty soil; coarse loose sand to 31 ins., then paler browner band, 2 ins., then sudden change to fine black peaty band, 15 ins., which may be buried old soil. Red-brown-tinger, loose, coarse sand below.

## MSR.

84. Composite	18	53.7	21.8	0	6.6	2.38	0.13	10.2	126	51	135
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## (First Part)

85. Black	6	17	50.6	22.2	6	6.0	2.10	0.11	10.9	111	49	106
86. Black, stony	12	21	51.1	21.1	5	6.3	1.28	0.08	9.6	75	36	76
87. Gravelly	18	12	35.5	27.3	10	6.6	1.41	0.06	12.8	64	31	121
88. Black sand	23	23	53.1	23.9	4	6.7	1.42	0.06	12.9	49	31	58
89. Black grit	31	36	70.6	15.2	0	7.0	0.72	0.03	15.4	50	24	71
90. Brown sand	33	31	82.5	9.9	0	6.9	0.56	0.02	17.2	57	19	101

## (Second Part)

91. 2nd Black layer	42	3	36.8	32.7	9	6.1	2.91	0.08	21.1	65	34	52
92. Similar	48	5	50.3	25.9	5	6.9	1.28	0.05	16.1	44	28	44
93. Pale-brown	60	16	63.3	18.6	0	6.8	0.45	—	—	40	19	—
94. Similar; paler	72	29	65.2	18.0	0	7.0	0.12	—	—	47	21	54

Avail. potash; MSR. 84; 108 p.p.m., K<sub>2</sub>O

## (10) RICHMOND 10. CISTERN BOTTOM FIELD

Lime field; diseased, planted 1928-29. Yields, 42, 45, 57, 81 barrels per acre in 1932-33 and three successive Flat field; sand ghaut borders it on N. side. W. of main road, 250 yds. Black soil to 24 ins.; sandy gravel; coffee-brown slightly clayey sand below 29 to base. Cemented gravel layer, 29 to 43 ins.; hard round stones with black peaty layer above it. Probably *LITHOSOL* soil-type. Medium to medium-low nitrogen; high available phosphate; fairly-high available potash.

NOTE: Sections in ravine at boundary of next field but one show old buried land surface (black sandy-clay) having undulating surface. Cover consists of loose boulders, gravel and sand with fine cindery layer at base. Possibly flood-wash, or stratified deposits, including incipient "peat", laid down in basin or broad hollow ("bottom").

## MSR.

95. Composite	—	12	38.8	33.0	11	6.7	2.86	0.15	10.7	144	61	154
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96. Sepia-choc.	6	19	40.1	26.7	9	6.7	2.52	0.13	11.0	129	59	133
97. Nearly black	10	9	30.4	33.6	10	6.6	1.79	0.10	10.0	95	40	97
98. Black, stony	17	20	31.7	31.1	11	5.9	1.86	0.08	12.7	85	34	62
99. Peaty	24	2	25.7	40.3	13	6.6	2.26	0.06	21.5	59	25	30
100. Transition	29	4	30.8	35.6	12	6.9	1.42	0.06	14.5	57	20	—
101. Cemented	43	49	56.1	22.3	0	6.6	0.60	0.03	10.5	47	17	42
102. Less cemented	54	23	55.8	22.2	0	6.8	—	—	—	74	15	—
103. Loose sand	66	6	17.0	44.2	0	6.6	—	—	—	69	19	51

Avail. potash; MSR. 95; 207 p.p.m., K<sub>2</sub>O

## APPENDIX—Continued.

	Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P O <sub>5</sub>
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		(p.p.m.)

## (11) RICHMOND 11. TWENTY-SEVEN ACRE FIELD

## (Bransby Ridge)

Cotton-field formerly limes, now banked for cotton. Side of gentle hill-slope facing S; overlooks Bath flat. Previously 15 yrs. in bush. Black clay soil, grading through brown to 48 ins.; sudden change to white-encrusted boulders of rotten andesite. Encrustation proved to be *calcium carbonate*. *RENDZINA* soil-type; *Bransby Clay*. (See also No. (18). Source of lime possibly solfataric. Medium nitrogen content; medium-low available phosphate and potash.

## MSR.

104. Composite	—	12	18.2	57.8	29	6.5	3.40	0.21	9.4	168	14	23
105. Black, plastic	6	8	18.2	52.5	20	6.8	4.24	0.20	12.3	257	208	60
106. Ditto. V. stiff	12	7	18.2	47.8	19	6.8	2.90	0.14	11.8	161	51	22
107. Ditto. moist	18	7	13.5	58.3	25	6.8	1.65	0.10	9.2	155	59	16
108. Dark brown	24	6	13.7	67.2	26	7.1	0.74	0.04	11.9	146	54	13
109. Coffee-brown	30	8	17.5	60.5	22	6.8	0.56	0.05	7.2	142	56	—
110. Paler brown	36	3	19.4	57.0	23	6.9	0.50	0.04	7.4	153	37	14
111. Stony; gritty	48	18	28.3	43.5	0	7.0	0.29	—	—	330	44	—
112. Calc. cement	—	—	54.5	21.5	0	8.0	—	—	—	675	115	—
113. Calc. crusts	—	—	62.0	10.0	0	8.2	—	—	—	—	—	—
179. Encrusted boulders	—	—	—	—	—	—	—	—	—	—	—	—

Avail. potash; MSR. 104; (0-6 ins.) 139 p.p.m., K<sub>2</sub>O  
MSR. 105 0.0 CaCO<sub>3</sub> percent  
" 112 34.0 "  
" 113 26.5 "

## (12) RICHMOND 12. BATH FIELD

Cotton field. Alluvial or flood-wash flat. May be continuation of mud-flow covering Negro House Field (No. (4)); outwash in 1936 from St. George's Hill. Foot of Bransby Ridge. Very stony land. *ALLUVIAL* or *COLLUVIAL* soil-type. Loose coarse sand, gravel and boulders; irregular vertical distribution. No cemented layer; numerous pebble beds; big boulders below 48 ins. Brownish-grey colour. Low nitrogen content; very high available phosphate; medium-high available potash.

## MSR.

114. Composite	—	17	59.3	16.0	6	6.5	1.02	0.06	9.9	111	24	195
115. Loose sand	6	27	54.0	16.7	0	6.6	1.18	0.06	11.3	135	47	180
116. Ditto. Stony	12	28	65.4	13.8	0	6.9	0.80	0.05	9.6	112	46	144
117. Coarser	18	16	79.1	8.4	0	6.9	0.25	0.02	8.5	38	17	168
118. Ditto. gravel	26	11	81.4	6.3	0	7.1	0.16	0.01	8.6	35	17	131
119. Darker	36	24	67.5	15.0	0	7.2	0.32	0.02	8.0	45	21	—
120. Less gravel	48	23	57.0	20.5	0	7.1	0.58	0.03	11.1	59	24	137
121. Boulders	60	25	73.5	19.3	0	6.9	0.18	0.01	11.8	63	22	—
122. Sand: boulders	72	50	84.7	6.8	0	7.1	0.12	0.01	8.9	—	—	237

Avail. potash; MSR. 114; 153 p.p.m., K<sub>2</sub>O

## APPENDIX—Continued.

	Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P O <sub>2</sub> 5
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		(p.p.m.)

## (i) RICHMOND 13. BAKER FIELD No. 14

Lime-field; diseased, planted 1928-29, seedling W.I. lime. Yields, 15, 26, 42, 64 barrels per acre in 1932-33 and three successive years. Slight slope to west, fairly well sheltered by new windbreaks; healthy vigorous trees; slight *Diplodia* dieback in patches. One area of 80 trees, contained 56 dead or dying trees, killed by root-disease (*Diaprepes*). Some of the trees, both in healthy and diseased areas, have been silted up to 9 ins. or 1 foot, producing a second root-system above the old one. Both systems contain healthy and diseased roots. Soil, deep light loamy-sand; surface layers down to three feet, composite. LITHOSOL soil-type. Very low nitrogen, very high available phosphate, low available potash.

RDB.												
1.	3	72	—	—	—	7.1	0.75	0.04	10.3	—	—	162
2.	6	25	94.2	1.8	—	7.3	0.60	0.02	15.3	43	16	137
3.	12	44	90.6	4.0	—	7.0	0.14	0.01	14.9	36	8	137
4.	24	40	66.6	12.5	—	6.8	0.43	0.03	8.8	57	19	—
5.	36	45	66.8	15.2	—	6.6	0.31	0.03	6.8	76	12	142
6.	48	31	71.9	15.2	—	6.9	0.22	0.02	6.7	53	6	—
7.	60	51	—	—	—	6.6	0.44	0.03	8.6	56	15	143
8.	72	55	—	—	—	6.9	0.68	0.03	13.1	—	—	129

Avail. potash; RDB. 1, 2; 76 p.p.m., K<sub>2</sub>O

## (ii) RICHMOND 14. BAKER FIELD No. 14

Lime-field; healthy conditions as last, except outside of patch of 80-dead or dying trees. LITHOSOL soil-type. Higher nitrogen and available phosphate; low available potash.

RDB.												
9.	3	48	—	—	—	6.4	1.33	0.07	11.3	—	—	229
10.	6	26	58.5	19.2	—	6.6	1.39	0.08	10.8	68	28	237
11.	12	43	55.5	23.6	—	6.6	1.23	0.07	10.8	77	29	139
12.	24	38	64.7	16.4	—	6.7	0.43	0.02	11.0	52	17	—
13.	36	25	38.3	30.0	—	6.6	1.28	0.04	15.8	58	6	53
14.	48	19	38.4	28.1	—	6.8	0.44	0.03	8.5	64	9	—
15.	60	18	42.0	31.8	—	7.0	0.20	0.02	5.8	51	20	54
16.	72	26	39.4	31.6	—	7.0	0.18	0.02	5.1	72	5	66

Avail. potash; RDB. 9, 10; 72 p.p.m., K<sub>2</sub>O

## (iii) RICHMOND 15. FFRY'S GARDEN PIECE, No. 17A

Lime field; diseased. Worst affected field; trees now nearly all dead. Six acres planted 1923-24, and 6 acres, 1928-29. Yields, 37, 35, 57, 46 barrels limes per acre in 1932-33 and three successive years. Hillside; fair slope to north. Very exposed, except to south. Field nearest to old sugar-cane cultivations, abandoned, after 1928 hurricane. Healthy trees in sheltered part, vigorous and well-grown. Field once very good. Soil, stony, light sandy-loam, especially stony below 4 ft. depth. LITHOSOL soil-type. Medium-low nitrogen; high available phosphate; fairly-high available potash.

RDB.												
17.	3	34	47.2	28.4	—	6.4	2.30	0.13	10.7	186	6	98
18.	6	34	50.0	24.1	—	6.6	2.15	0.11	11.1	131	30	61
19.	12	46	43.5	29.8	—	6.6	1.77	0.11	9.8	95	47	32
20.	24	34	40.0	32.3	—	6.7	1.29	0.08	9.7	69	18	—
21.	36	45	39.1	34.0	—	6.9	1.17	0.08	8.8	58	8	15
22.	48	41	48.0	28.6	—	6.9	0.95	0.06	9.5	66	0	23

Avail. potash; RDB. 17, 18; 221 p.p.m., K<sub>2</sub>O

## APPENDIX—Continued.

	Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P O 2 5
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		(p.p.m.)

## (iv) RICHMOND 16. DELVIN BOTTOM FIELD No. 20

Lime field; diseased. Planted in 1929-30. 6 ac. budded and grafted trees on sour orange stock; 4 ac. seedling limes. Yields, 13, 20, 31, 29 barrels per acre in 1932-33 and three successive years. Slight slope to west, fairly exposed to wind; inadequate windbreak. *Diplodia* dieback present. Trees attacked by *Diaprepes*, 4 budded, and some seedlings also; first noticed at end of 1935. Soil, lighter than Cistern Bottom Field. Very stony below 3-foot depth. LITHOSOL soil-type. Medium-low nitrogen; very high available phosphate; medium available potash.

## RDB.

23.	3	35	56.0	25.8	—	6.5	2.39	0.13	11.1	88	28	80
24.	6	41	56.2	21.8	—	6.4	1.35	0.08	9.8	78	22	120
25.	12	16	56.2	21.1	—	6.7	0.75	0.05	8.9	65	7	92
26.	24	54	64.3	20.7	—	7.0	0.92	0.05	10.8	61	13	—
27.	36	75	67.0	17.9	—	6.8	0.59	0.03	10.0	—	—	61

Avail. potash; RDB. 23, 24; 136 p.p.m., K<sub>2</sub>O

## (v) RICHMOND 17. CISTERN BOTTOM FIELD No. 21

Lime field! diseased, planted 1928-29. Yields, 42, 45, 57, 81 barrels per acre in 1932-33 and three successive years. Very slight slope to west. Well sheltered; adequate wind-breaks. Little or no *Diplodia* dieback nor scale. *Diaprepes* damage in one patch of 15 trees in middle of field, and 12 more scattered about the field. First noticed, Jan. 1936; some trees dead by March 1936. Best lime field on the estate. Soil, sandy-loam, few large stones, overlying clay. LITHOSOL soil-type. Medium-low nitrogen; fairly high available phosphate; medium available potash.

## RDB.

28.	3	13	45.2	31.8	—	6.6	2.42	0.13	11.1	126	55	78
29.	6	20	42.5	33.7	—	6.7	2.07	0.10	12.5	90	35	69
30.	12	17	61.0	12.5	—	6.8	0.86	0.05	10.3	59	11	60
31.	18	14	82.0	10.0	—	6.8	0.33	0.02	8.2	53	8	60
32.	24	0	14.7	51.4	—	7.3	2.32	0.08	15.3	76	15	50
33.	30	0	12.2	54.4	—	7.1	2.76	0.08	18.6	71	9	33
34.	42	35	33.4	39.2	—	6.9	0.61	0.04	8.8	84	0	40
35.	54	35	42.5	31.5	—	6.9	0.48	0.03	8.8	69	7	57

Avail. potash; RDB. 28, 29; 123 p.p.m., K<sub>2</sub>O

## (vi) RICHMOND 18. RILEY'S FIELD No. 7

Lime field; diseased, planted 1928-29. Yields 42, 45, 9, 13, 24, 47 barrels per acre in 1932-33 and three successive years. Slight slope to south-west. Exposed site; suffered at first severely from *Diplodia* die-back; but field improved as windbreaks grew. *Diaprepes* attack confined to two trees in middle of field, noticed in March, 1936. Soil, high sandy-loam; stony below 3-feet. LITHOSOL soil-type. Medium-low nitrogen; high available phosphate; medium-low available potash.

## RDB.

36.	3	37	70.5	15.3	—	6.4	2.14	0.11	11.1	64	24	99
37.	6	46	64.0	18.1	—	6.4	1.91	0.10	10.7	60	29	84
38.	12	42	58.7	22.2	—	6.5	2.00	0.07	15.8	60	19	87
39.	24	69	70.7	15.4	—	6.5	1.27	0.04	18.7	55	5	—
40.	36	72	86.4	7.7	—	6.8	0.24	0.02	7.6	—	—	132

Avail. potash; RDB 36, 37; 118 p.p.m., K<sub>2</sub>O

## APPENDIX—Continued.

	Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P O 2 5
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		(p.p.m.)

## (vii) RICHMOND 19. RILEY'S FIELD NO. 7

Lime field; slightly diseased. See last; same kind of soil, but has higher nitrogen content. Medium available phosphate; medium-low available potash.

RDB.												
41.	3	26	44.9	30.7	—	6.4	2.81	0.14	12.0	76	26	54
42.	6	40	47.7	27.4	—	6.4	2.76	0.13	12.2	103	28	45
43.	12	18	49.0	27.4	—	6.6	1.93	0.09	11.9	76	23	43
44.	24	50	49.1	30.9	—	6.5	1.46	0.06	12.9	95	11	—
45.	36	30	53.1	26.3	—	7.0	0.49	0.03	9.1	57	9	35
46.	48	34	56.9	24.1	—	7.0	0.30	0.02	9.6	—	—	49

Avail. potash; RDB. 41, 42; 89 p.p.m., K<sub>2</sub>O

## (II) ELBERTON ESTATE

## (13) PIT IN ELBERTON ESTATE YARD

Deep Well, 17 ft. Cracked clay to 2 ft., changing gradually to hard, pale yellow-brown coarse ash, partly cemented (incipient Terras), then suddenly at 4 ft., into dusty creamy-grey, loose, stoneless, uniform ash to 5 ft., then another thin layer (6 ins.) of partly-cemented ash; then 6 ins. layer of loose gritty ash, then 4 ins. layer of creamy loose ash. Between 6 ft. 4 ins. (76 ins.) and 8 ft. 2 ins. (98 ins.) is a zone of iron-cemented, yellow-orange sand, with 4 thin streaky bands of pale-grey, loose ash, containing a very conspicuous irregular pure-white layer of putty-like *calcareous clay* or chalk (42.5 per cent CaCO<sub>3</sub>), 87½ to 88 ins. Below 98 ins., material consists of stratified, uniform, pinkish-brown-grey, stony, loose ash, partly *lime-encrusted*, containing red specks of iron-oxide-coated sand.

MSR.												
123. Grey ash	60	28	74.5	13.5	0	7.4	0.18	0.01	7.6	82	27	17
124. Streaky ash	84	66	39.1	27.2	0	7.6	0.19	0.01	10.9	129	46	37
125. Calc. clay band	87-8	—	10.0	56.1	0	7.9	—	—	—	—	—	—
126. L. crust. ash	10-11 ft.	50	28.8	36.2	26	8.1	0.19	0.02	6.4	200	71	18
127. Flaky clay	17	—	—	—	—	7.7	—	—	—	66	35	148

Calcium carbonate (CaCO<sub>3</sub>); MSR. 124; 0.04 %

" 125; 42.5 %

" 126; 4.5 %

" 127; 0.05 %

## (14) ELBERTON 1. JOHN DOWDY FIELD

Lime and cotton field. Lime trees 4 yrs. old; fairly good; some "die-back". Site on gentle slope in valley. Sepia clay to 2 ft., changing suddenly to semi-coherent sand, cemented hard below 43 ins. Iron-cemented bands, 50 to 54 ins. and 59 to 64 ins. Sharp change at 64 ins. to hard "pepper-and-salt", uniform, cemented gritty-ash. No lime-encrustations anywhere, but reaction highly alkaline within incipient Terras below 2 ft. TERRAS soil-type, though not cemented solid. Medium nitrogen content medium to medium-high available phosphate; medium to fairly-high available potash.

MSR.												
128. Composite	6	8	20.6	51.4	16	6.6	2.88	0.17	10.0	102	33	94
(Clay Soil)												
129. Sepia; plastic	3	12	31.2	39.3	13	6.5	3.52	0.17	12.1	148	37	69
130. Brown-black	6	4	27.2	43.3	14	6.9	2.34	0.13	10.1	102	12	43
131. Friable; paler	10½	4	28.4	43.1	13	7.1	1.70	0.11	9.1	78	36	24
132. Brown; nut	15	1	21.7	50.1	20	7.2	0.99	0.08	7.4	78	49	11
133. Stiffer	21	3	19.7	53.5	19	7.2	0.63	0.05	6.7	86	52	—
134. Transition	25	8	29.6	46.2	15	7.2	0.36	0.04	4.7	107	29	9
(Incipient Terras)												
135. Yell. brn. sand	33	8	41.2	31.1	6	7.2	0.21	0.03	4.7	93	25	—
136. Harsh sand	43	10	60.4	28.4	3	7.3	—	—	—	96	28	24
137. Cemented	50	—	53.2	17.1	0	7.3	—	—	—	94	24	44
138. Pepper-and-salt	64-78	—	80.5	8.1	0	7.3	—	—	—	52	20	307

Avail. potash; MSR. 128; 279 p.p.m., K<sub>2</sub>O

## APPENDIX—Continued.

	Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P O <sub>5</sub>
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		(p.p.m.)

## (15) ELBERTON 2. SLOB FIELD

Lime-field; trees 3 years old. Site on flat at base of steep slope, E. of last site (No. 14), facing S. Wind-swept, exposed. Sepia clay to 10½ ins. then sudden change to hard cemented terras, hardest at greatest depth. Grey-white terras, 10½ to 30 ins., then brown and coarsely sandy; few stones. No lime nor iron oxide concretionary material seen anywhere in profile. *TERRAS* soil-type. Medium nitrogen content. low available phosphate, low to medium-low available potash.

MSR.													
168.	Composite	6	11	25.5	44.9	27	6.7	2.48	0.16	9.2	86	28	23
	(Clay Soil)												
169.	Sepia choc.	3	5	36.4	41.2	11	6.8	3.52	0.18	11.4	143	59	21
170.	Similar	6	4	36.9	46.6	11	6.5	2.36	0.15	9.0	109	39	17
171.	Rich brown	10½	4	35.6	46.2	12	6.5	2.22	0.15	8.5	98	50	14
	(Hard terras)												
172.	Cemented	18	—	45.5	24.0	0	6.8	0.14	0.02	4.7	85	16	43
173.	Similar; grey	24	—	39.6	22.7	0	7.1	—	—	—	73	19	—
174.	Similar; grey	30	—	50.6	19.4	0	7.1	—	—	—	63	13	20
175.	Brown; hard	38	—	53.1	18.2	0	6.9	—	—	—	94	22	—
176.	Loose; brown	48	—	50.2	18.6	0	6.9	—	—	—	64	15	8
177.	Cemented	60	—	57.5	19.3	0	6.7	—	—	—	81	34	—
178.	"Oolite"	72	—	49.0	21.5	0	6.7	—	—	—	76	27	26

Avail. potash; MSR. 168; 120 p.p.m., K<sub>2</sub>O

## (16) ELBERTON 3. OLD WORKS FIELD

Lime-field; cotton 1939. Lime-trees 3 years old; previous lime crop died in 1935. Site on hill-slope 500 yds. E. of Manager's house. Open exposed site; flat at end of small ravine between mounds of Garibaldi Hill. Sepia clay to 19 ins.; sudden change to partly-cemented terras of coarse, harsh yellow-brown sand to 40 ins., then loose, dry, pale-grey uncemented, incoherent, soft ash. *TERRAS* soil-type, but terras occurs only as band, 21 ins. thick. Medium-low nitrogen, low to medium-low available phosphate and potash.

MSR.													
139.	Composite	6	6	18.7	50.5	14	7.0	1.79	0.12	9.0	71	42	38
	(Clay Soil)												
140.	Brown	3	4	32.0	48.3	13	6.8	2.22	0.12	9.8	121	23	27
141.	Rich brown	6	3	29.0	53.3	15	7.1	1.57	0.11	8.3	90	22	13
142.	Similar	9	2	26.5	58.8	19	6.6	1.25	0.10	7.5	79	36	10
143.	Waxy	14	0	27.5	56.8	16	6.5	0.68	0.07	5.9	75	32	9
144.	Transition	19	2	36.0	46.5	11	7.1	0.52	0.05	5.9	84	36	—
	(Hard terras)												
145.	Cemented	23	—	47.0	40.0	7	6.9	0.30	0.03	—	65	11	9
146.	Similar	30	—	58.5	24.6	3	7.0	0.22	0.02	—	60	28	15
147.	Yellow-brown	40	—	67.2	14.8	0	6.7	—	—	—	34	17	61
	(Loose Ash)												
148.	Grey, uniform	72	—	47.2	33.9	0	7.2	—	—	—	49	8	73

Avail. potash; MSR. 139; 138 p.p.m., K<sub>2</sub>O

APPENDIX—Continued.

	Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P <sub>2</sub> O <sub>5</sub>
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		(p.p.m.)

(17) ELBERTON 4. CAESAR'S GRAVE FIELD

Young lime field ; budded, 3 years old. Cotton 1939. Site most westerly of the Elberton sites ; open flat, foot of Garibaldi Hill, facing S. Chocolate clay to 25 ins., partly-cemented, yellow-brown, coarse, uniform sand to 52 ins., loose, uncemented, dusty, dry grey ash below, as at last site (No. (16) ), which this profile closely resembles. *TERRAS* soil-type, but *terras* occurs as a band, 27 ins. thick. Medium-low nitrogen ; high available phosphate and potash.

MSR.		6	11	18.8	54.0	15	6.8	2.17	0.13	9.5	85	51	113
149.	Composite												
	(Clay Soll)												
150.	Sepia	6	1	24.8	44.0	11	6.7	1.97	0.12	9.7	113	51	144
151.	Sepia-black	11	2	22.6	45.2	11	7.3	1.42	0.09	8.7	83	50	59
152.	Chocolate	15	0	16.6	60.4	20	7.1	0.84	0.07	6.6	88	35	16
153.	Waxy	25	3	19.5	57.5	17	7.3	0.58	0.06	5.5	92	43	8
	(Hard terras)												
154.	Transition	29	4	26.3	42.7	13	7.5	0.34	0.04	5.3	117	54	—
155.	Cemented	40	—	27.5	33.0	9	7.7	0.28	0.03	5.9	84	47	16
156.	Yellow brown	52	—	44.5	21.0	1	7.6	0.21	0.02	5.5	67	41	51
	(Loose Ash)												
157.	Loose, grey	72	—	48.2	21.3	0	7.6	—	—	—	48	20	177

Avail. potash ; MSR. 149 ; 401 p.p.m., K<sub>2</sub>O

(18) ELBERTON 5. MIDDLE PIECE. (BRANSBY RIDGE)

Lime-field ; trees remarkably healthy, little die-back. Field also grew cotton 2 years ago. Grassy ; sparse herbaceous weeds. Same hillslope as No. (11) ; facing S., overlooking Bath flat and sea. Very exposed and windy ; near Bransby Point. Sepia-chocolate clay to 20 ins., stony clayey-sand to 33 ins., packed round stones below, encrusted with white *calcium carbonate*. *RENDZINA* soil-type ; (See also No. (11) ). Source of lime possibly solfataric. Less rich in organic matter than No. (11) ; medium-low nitrogen content ; fairly-high to high available phosphate ; medium-low available potash.

MSR.		6	8	15.0	61.0	29	7.2	3.09	0.17	10.2	182	164	89
158.	Composite												
159.	Choc. sandy-clay	6	8	20.0	62.5	23	7.7	2.48	0.14	9.9	203	150	160
160.	Clay sand	12	9	18.0	64.3	22	7.8	1.72	0.10	9.7	174	137	82
161.	Sepia clay	20	6	18.0	66.3	24	7.1	0.84	0.07	7.1	116	99	14
162.	Transition	24	9	20.7	64.3	24	7.4	0.70	0.06	7.1	117	82	12
163.	Stony layer	33	—	24.2	63.3	21	7.5	0.32	0.03	5.8	95	47	—
164.	Stones	43	—	34.5	44.5	19	7.2	0.34	0.03	5.7	243	50	14
165.	Coated stones	48	—	51.5	34.5	16	7.7	0.34	0.03	6.2	360	68	—
166.	Line	—	—	—	—	—	—	—	—	—	—	—	—
167.	Boulder	—	—	56.5	28.2	—	8.5	0.44	0.02	—	343	72	—

Avail. potash ; MSR. 158 ; 243 p.p.m., K<sub>2</sub>O

“ 166 ; 14.6 % Calc. carbonate (CaCO<sub>3</sub>).

“ 167 ; 22.6 % “ “ “

(III) ILE'S BAY ESTATE

(19) ILE'S BAY 1. PEN PIECE, FIELD 5

Cotton field ; previously limes to 1938, all died. Site on alluvio-colluvial flat of Balham R., elevated 10 ft. above level of river, 150 yds. to N. Steep hills to S. of site. *ALLUVIAL-COLLUVIAL* soil-type. Chocolate clayey sand to 18 ins., coarser sand and gravel to 36 ins., well-rounded large boulders and water-borne gravel to 60 ins. Soil slightly pebbly ; a few large boulders. Low to medium-low nitrogen content, medium-low to medium-high available phosphate ; medium available potash. Slightly acid ; well leached.

MSR.		—	9	40.6	35.9	9	6.3	2.52	0.14	10.5	108	43	84
180.	Composite												
181.	Choc. sand	6	6	48.0	32.0	4	6.6	1.51	0.09	9.5	60	23	21
182.	Black	12	0	50.0	33.3	10	6.7	1.05	0.09	6.6	50	21	19
183.	Brown	18	0	45.0	37.5	11	6.9	0.69	0.05	8.9	52	20	20
184.	Coarse sand	24	3	53.0	32.5	5	7.0	0.45	0.04	6.7	39	20	59
185.	Gravelly	30	11	82.5	11.8	0	7.1	0.19	0.02	7.1	25	15	98
186.	Pebbly	36	51	86.7	10.1	0	6.9	0.12	—	—	30	21	84
187.	Matrix	60	35	86.7	9.1	0	6.8	—	—	—	39	16	111

Avail. potash ; MSR. 180 ; 127 p.p.m., K<sub>2</sub>O

## APPENDIX—Continued.

	Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr. Soln.	Rate of Soln.	Avail. P O 2 5
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		(p.p.m.)

## (20) ILE'S BAY 2. CISTERN PIECE, FIELD 4

Young lime field; cotton 1939. Limes budded at stake. Site on Balham R. alluvial flat; very bouldery and stony; W. of last (No. (19)), and near Old Road Bay, forming estuary of river. Boulders up to 4 ft., sub-angular to round, strewn over bare surface. River 100 yds. to N. Area said to be liable to floods. *ALLUVIAL-COLLUVIAL* soil-type. Brown sandy soil to 9 ins. (possibly recent flood sand), sharply overlying darker, sepia coarse-sand and sparse stones to 21 ins., sharply overlying black sand, with bouldery layer below 34 ins. (cpr. last site (No. (19))), where bouldery layer began at 36 ins.). Medium-low to low nitrogen content, fairly high to high available phosphate; fairly high available potash. Slightly acid reaction; well leached.

## MSR.

188. Composite	—	3	33.4	32.6	12	6.5	2.22	0.12	10.7	97	42	120
(First Part)												
189. Pale brown	6	1	58.0	27.0	0	6.9	1.37	0.08	9.7	78	38	123
190. Paler	9	6	67.5	17.5	0	6.8	0.51	0.04	7.8	54	25	73
(Second Part)												
191. Sepia	15	15	48.0	33.8	5	6.8	0.96	0.06	8.8	65	23	37
192. Clay-sand	21	3	42.5	38.0	8	6.9	1.37	0.07	10.7	55	23	29
(Third Part)												
193. Black sand	27	0	32.7	42.3	11	6.9	1.45	0.07	12.6	51	10	—
194. Sepia sand	34	2	46.2	34.3	8	6.9	0.76	0.04	11.4	41	28	62
195. Boulders	44	19	57.2	26.8	4	6.9	0.59	0.03	11.4	56	20	—
196. Boulders	66	39	76.2	16.4	0	7.1	0.28	0.03	6.4	54	21	94
(Matrix)												

Avail. potash; MSR. 188; 183 p.p.m., K<sub>2</sub>O

## (21) ILE'S BAY 3. BAY PIECE, FIELD 1

Cotton field, formerly limes which died; severe hurricane damage in 1928. Site at base of steep hill, near old works, 150 yds. to N., and bluff, 200 yds. to S., forming end of spur between Old Road flat and this concave hill-face. West face of Garibaldi Hill. Slope shows erosion effects. At present bare, stony, bouldery, with path half-way up along contour. Abundant Nut Grass. Chocolate clay to 20 ins., sharply overlying hard cemented creamy-buff shoal, composed of gravel. Unable to dig below 3 ft. *SHOAL* soil-type. Sharp differentiation between clay and hard sandy shoal. Medium to medium-high nitrogen content; very-high available phosphate and potash. Unusually high nutrient status; organic content only medium.

## MSR.

197. Composite	—	17	28.2	42.3	18	6.4	3.76	0.21	10.6	175	0	169
(Clay Soil)												
198. Sepia-clay	3	18	38.0	47.6	13	6.3	3.52	0.18	11.4	170	17	201
199. Ditto.	6	17	41.0	45.0	13	6.4	3.33	0.18	10.8	163	9	224
200. Paler; streaky	9	7	28.0	58.0	17	6.7	2.14	0.14	8.9	135	27	210
201. Brown	12	9	25.0	65.0	24	7.1	1.70	0.12	8.1	143	74	109
202. Snuff-brown	20	2	13.4	77.6	33	7.3	0.85	0.09	5.8	192	93	35
(Hard Shoal)												
203. Cemented	23	—	77.0	13.0	0	7.2	—	—	—	254	82	23
204. Deeper shoal	33-36	—	90.0	3.2	0	7.2	—	—	—	196	47	47

Avail. potash; MSR. 197: 482 p.p.m., K<sub>2</sub>O

„ 203; 0.06% calcium carbonate (CaCO<sub>3</sub>)

APPENDIX—Continued.

	Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P O 2 5
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		(p.p.m.)

(IV) OLVESTON ESTATE

(22) OLVESTON 1. FIELD 8

Young lime field; budded limes planted in holes 1939; previous limes died. Pigeon Pea inter-rows. Site near main road in open, weedy field, gently-sloping seaward. Brownish-black plastic gritty clay to 28 ins., sharply overlying hard cemented shoal. SHOAL soil-type. Centre Hills. Thin, black, waxy, humic band separates clay from shoal. Surface of shoal irregular; black band discontinuous, accompanied by red-brown iron-staining. Not brashy. Clay mottled at base; tawny splotches; gritty; small stones present. Medium to medium-high nitrogen content; low available phosphate and potash.

MSR.													
220.	Composite	—	5	16.9	61.4	22	6.1	3.88	0.22	10.2	79	48	21
	(Clay Soil)												
221.	Brown-grey	3	—	27.2	42.2	18	6.0	4.55	0.23	11.4	124	220	24
222.	Brown-black	7½	—	30.4	42.8	15	6.2	3.08	0.18	9.9	89	122	14
223.	Mottled	13	7	28.2	43.0	18	6.1	1.17	0.09	7.5	120	76	12
224.	Yellow-brown	18	7	29.0	44.2	17	6.5	0.55	0.05	6.6	124	29	6
225.	Rusty spotted	25	8	31.2	41.8	18	6.5	0.36	0.04	5.6	114	41	4
226.	Similar	28	—	39.7	38.7	16	7.1	0.57	0.05	6.8	127	41	6
227.	Black wax	28½	—	52.7	34.3	0	6.7	3.70	0.14	14.8	74	35	8

Avail. potash; MSR. 220; 94 p.p.m., K<sub>2</sub>O

(23) OLVESTON 2. GLEBE FIELD

Lime field; old trees; tall wind-breaks, grassy, *Gliricidia* shelter. Site near last (No. (22)) but opposite side of ghaut and further N. Wind-swept though sheltered by trees. Black, gritty, waxy clay sharply overlying hard cemented shoal at 18 ins. depth. SHOAL soil-type; Centre Hills. No definite brashy layer; no waxy humic band. Medium-high nitrogen content; low available phosphate and potash.

MSR.													
213.	Composite	6	7	19.5	45.5	20	6.3	4.22	0.24	10.0	93	19	27
	(Clay Soil)												
214.	Black; stony	3	10	34.6	41.8	20	6.1	5.86	0.29	11.9	130	237	34
215.	Similar; hard	6	14	23.6	53.4	22	6.2	1.90	0.12	9.2	77	41	11
216.	Tough; dirty	9	10	20.6	54.2	22	6.3	1.23	0.08	8.6	83	36	6
217.	Similar	15	5	26.0	37.1	27	6.9	1.01	0.08	7.4	130	65	11
218.	Waxy; gritty	18	—	31.3	44.3	28	6.8	0.64	0.05	7.3	145	76	10
	(Shoal)												
219.	Cemented	—	—	63.4	21.6	0	8.1	—	—	—	333	73	8

Avail. potash; MSR. 213; 99 p.p.m., K<sub>2</sub>O

(24) OLVESTON 3. FIELD No. 10

Lime field; cotton in 1938. Young limes, 1 year old; very grassy and scrubby open field; wind-swept. Site ½ mile from sea, 300 ft. altitude, on hog's back ridge from Centre Hills, between two shallow ghauts; rolling topography. Sepia, plastic, waxy clay, humus-streaked, overlying brash with hard cemented shoal at 24 ins. depth. No humic waxy band. Brash consists of rotten round boulders and stones. SHOAL soil-type. Medium nitrogen content; low to medium-low available phosphate, medium-low available potash.

MSR.													
205.	Composite	6	13	15.2	58.2	34	6.4	3.43	0.19	10.3	98	50	31
	(Clay Soil)												
206.	Grey, friable	3	13	25.2	44.1	16	6.4	3.77	0.20	11.1	114	55	24
207.	Neutral grey	6	13	15.5	58.3	22	6.3	2.40	0.15	9.3	137	72	15
208.	Similar; waxy	9	7	12.8	65.9	24	6.5	1.74	0.12	8.3	191	75	12
209.	Dull sepia	12	5	12.0	72.6	26	6.6	1.05	0.10	6.4	302	65	9
210.	Similar	18	5	12.5	75.3	28	6.1	1.19	0.08	8.6	419	61	9
211.	Brashy "fudge"	24	23	27.5	55.8	25	5.7	0.79	0.06	7.4	495	40	5
	(Shoal)												
212.	Cemented	36	—	70.5	12.9	0	7.8	—	—	—	288	36	—

Avail. potash; MSR. 205; 158 p.p.m., K<sub>2</sub>O

## APPENDIX—Continued.

	Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P O <sub>5</sub>
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		(p.p.m.)

## (V) O'GARA'S ESTATE

## (25) O'GARA'S 1. BAY FIELD

Cotton field; cotton every year; manured with cotton-seed meal; yields up to 1,500 lb. seed cotton. Site near short below main road; 140 yds. from sea; near graveyard; base of small hill. Very stony bouldery land; boulders piled up. Coastal shelf. Dry area; low rainfall, exposed. Black gravelly sand overlying grey gravel, sand and rounded stones and boulders. *LITHOSOL* soil-type. Irregular organic matter distribution denoting composite nature of profile; probably 4-parts; bottom part overlies grey, fresh ash, sand and round stones in lenticular masses. Very low nitrogen content; extremely high available phosphate, medium available potash; results of manuring. Markedly alkaline throughout.

## MSR.

228. Composite	—	20	59.8	14.7	0	6.8	0.97	0.06	10.0	93	21	325
(First Part)												
229. Black, dusty	6	21	61.2	17.4	0	7.0	0.96	0.05	10.6	69	34	334
230. Dark brown	13	39	63.2	18.1	0	7.3	0.57	0.04	7.6	66	33	539
(Second Part)												
231. Black sand	19	10	51.2	24.1	1	7.2	0.87	0.04	12.6	69	42	387
232. Stony	22	37	74.7	12.9	0	7.4	0.43	0.02	11.4	52	36	95
(Third Part)												
233. Black sand	24	39	60.0	19.0	0	7.5	0.75	0.03	12.9	69	44	80
234. Gravelly	36	22	68.5	15.5	0	7.5	0.45	0.03	10.2	72	56	69
(Fourth Part)												
235. Black	40	16	42.0	30.5	6	7.6	0.88	0.04	11.3	161	100	—
236. Grey ash	52	36	71.0	15.5	0	7.9	0.28	0.02	7.8	60	54	69

Avail. potash; MSR. 228; 207 p.p.m., K<sub>2</sub>O

## (26) O'GARA'S 2. RIVER FIELD

Cotton field. Manured yearly with cotton-seed meal. Yields said to be higher than those of last site; up to 1,800 lb. seed cotton per acre. Site near sea margin, 30 yds. away, and 100 yds. E. of river emerging from deep ghaut, 400 yds. W. of estate building. Probably not typical of field as a whole; composite accordingly collected over a wider area. Bouldery stony land. Boulders piled up in field. Brownish-black clayey sand to 20 ins. compact boulders and rusty stones below, 1 to 3 ft. diam. Not stratified; profile sample. *LITHOSOL* soil-type. Medium-high nitrogen content; extremely high available phosphate, very high available potash, probably results of manuring. Alkaline throughout.

## MSR.

237. Composite	—	24	39.3	33.7	10	7.7	1.91	0.10	10.8	235	161	2880
238. Dark grey	6	23	49.2	31.4	13	7.3	4.77	0.23	12.3	604	146	1832
239. Sepia black	12	21	45.5	39.8	13	7.2	2.34	0.14	9.5	482	90	940
240. Stony	20	26	37.5	44.6	15	7.5	1.20	0.08	8.4	356	109	497
241. Ash	54	34	36.7	40.1	18	7.2	0.59	0.05	6.6	1725	135	101

Avail. potash; MSR. 237; 557 p.p.m., K<sub>2</sub>O

APPENDIX—Continued.

	Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P <sub>2</sub> O <sub>5</sub>
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		(p.p.m.)

(27) O'GARA'S 3. HOLLINGS FIELD

Cotton field; unplanted, resting. Limes up to 1925. Site on side of very steep spur E. of house, 400 yds. Altitude 100 ft. Open, exposed, windswept slope; angle of slope, 25°. Tall grass; Acacia scrub, *Cleome* weed. Black powdery sand and cinders to 16 ins., overlying purplish-grey, slightly calcareous ash (dust, sand, cinders, stones). Limestone prevalent in vicinity; possibly Pleistocene limestone known to occur in this area. LITHOSOL soil-type. Medium nitrogen content; extremely high available phosphate; very high available potash. High alkalinity throughout.

MSR.		6	39	47.9	24.6	13	6.9	4.86	0.29	9.7	405	182	284
242.	Composite												
243.	Cindery	3	44	48.7	35.1	8	8.0	3.26	0.18	10.6	178	184	512
244.	Fine sand	6	40	48.2	34.1	6	7.5	2.46	0.13	10.6	116	161	222
245.	Loose	9	37	48.0	35.0	7	7.5	2.12	0.12	9.9	118	154	206
246.	Stony	12	36	45.7	37.1	8	7.5	1.81	0.11	9.3	169	172	165
247.	Stony	16	40	48.7	32.6	8	7.7	1.59	0.11	8.6	150	166	115
248.	Grey ash	28	51	71.5	15.3	0	8.4	0.30	—	—	124	142	119
249.	Limestone	—	—	—	—	—	8.6	—	—	—	—	—	—

Avail. potash; MSR. 242; 561 p.p.m., K<sub>2</sub>O  
 " 248; 0.23% Calcium Carbonate (CaCO<sub>3</sub>)  
 " 249; 32.3% " " "

(28) O'GARA'S 4. RILEY'S COVE FIELD

Peasants cotton land; formerly limes, abandoned 1920, land reverted to pasture, now cotton. Unmanured. Grassy, *Acacia* bush, xerophytic plants; Cactus, Prickly Pear, *Vinca*. Site near end of narrow spur composed of coarse, cemented, black, bedded conglomerate, below conspicuous shelf 100 yds. away, 50 ft. higher. Altitude, 80 ft., hillface. Near Well Bottom. Parent rock in soil profile, lime-encrusted, bedded, gravelly conglomerate, dipping at fairly high angle sea-wards. Profile, 31 ins., deep; sepia humic gritty sand and gravel to 15 ins., sharply overlying purplish-grey, loose, fine gravelly-sand to 31 ins. then lime-encrusted bedded conglomerate, thinly veined vertically with calc. carbonate. Medium to medium-low nitrogen content; extremely high available phosphate; very high available potash. Highly alkaline throughout.

MSR.		3	38	53.9	16.5	7	7.1	2.24	0.13	10.2	152	65	216
251.	Sepia ash												
252.	Stony	6	50	61.0	14.5	3	7.3	1.51	0.10	8.8	105	59	208
253.	Gravelly	9	43	67.2	9.3	0	7.5	0.92	0.07	8.0	83	59	161
254.	Brown	15	39	66.5	11.0	0	7.5	0.65	0.05	7.2	83	45	515
255.	Grey ash	25	39	62.7	12.1	0	7.7	0.71	0.05	7.6	77	48	—
256.	Pinkish	31	64	68.2	10.0	0	8.1	0.45	0.04	6.4	100	85	342
257.	Crusts	31½	—	—	—	—	8.1	—	—	—	—	—	—
258.	Rock	34	—	—	—	—	8.4	—	—	—	—	—	254
259.	Gravel	72	57	—	—	—	8.3	—	—	—	—	—	—
260.	Limestone	—	—	—	—	—	7.9	—	—	—	—	—	—

Avail. potash; MSR. 251; } Top 6-ins., 356 p.p.m., K<sub>2</sub>O  
 " 252; }  
 " 257; 15.8% calcium carbonate (CaCO<sub>3</sub>)  
 " 258; 10.2% " "  
 " 259; 0.31% " "  
 " 260; 21.4% " "

## APPENDIX—Continued.

	Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P O 2 5 (p.p.m.)
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		

## (VI) TRANTS ESTATE

## (29) TRANTS 1. ALLAN DUEL FIELD

Cotton-field; Site near ghaut separating hog-back deposits of Farm and Bethel from alluvial deposits of Trants. Left bank of ghaut washed away; debris may form part of material of the soil at this site. Large black boulders strewn over land, especially south of the site. Sepia coarse sand no stones, blacker below to 14 ins., changing suddenly to speckled pale brownish-grey gritty-sand and gravel to 50 ins. overlying bed of large round pebbles or small boulders. Coarse loose ash bands at 36 and 43 ins., not sampled. *ALLUVIAL* or *COLLUVIAL* soil-type; loose and uncemented. Deposits may be partly water-sorted (marine or torrential). Low nitrogen content; extremely high available phosphate; very high available potash, perhaps results of manuring. Nearly neutral reaction; low organic content.

## MSR.

287. Composite	—	9	43.6	25.5	3	6.6	1.43	0.08	10.8	182	19	292
288. Sepia	7	5	64.5	20.3	0	6.9	1.11	0.06	11.1	112	37	190
289. Black	14	11	67.5	18.5	0	7.1	1.03	0.05	11.7	65	42	78
290. Speckled	20	32	72.0	16	0	7.1	0.40	—	—	52	35	63

Avail. potash; MSR. 287; 351 p.p.m.; K<sub>2</sub>O

## (30) TRANTS 2. PIGEON HOUSE FIELD

Cotton field since 1906, but sugar-cane, 1918–20; tenancy, 1933–35, estate since 1936. Regarded as good cotton soil. Yields about 1,000 lb. ac. Pen manured regularly since 1906, with occasional C. S. meal, say once in 4 yrs. and artificials. Soil dries out badly; water-table (in well) at 20 ft. Site near estate buildings; 50 yds. from Trants house. Flat land, forming low shelf running up to hill-cliffs on N.W. and W. May be partly marine alluvium. Profile shows 3 layers: (i) dark grey-brown humic sand, 0–11 ins. (ii) black, fine, soft sand, 11–27 ins.; (iii) speckled brownish-grey coarse sea-shore sand to 88 ins. Occasional stones only; one gravel layer near base *ALLUVIAL* soil-type. Composite; different layers deposited at different times. Low to medium-low nitrogen content; extremely high available phosphate; very high available potash, possibly results of manuring. Alkaline throughout.

## MSR.

261. Composite	—	6	48.7	24.5	3	7.3	1.72	0.09	11.6	171	123	2920
(First Part)												
262. Brown	7	8	52.7	24.6	2	7.3	1.71	0.09	11.4	107	57	1856
263. Greyish	11	9	55.6	24.1	2	7.4	1.74	0.09	11.7	76	28	1936
(Second Part)												
264. Black	15	7	57.7	22.3	4	7.3	2.26	0.10	13.1	81	59	2880
265. Black	21	7	56.5	21.0	3	7.3	2.03	0.09	13.7	67	54	3016
266. Paler	27	8	54.8	18.7	0	7.4	0.94	0.05	11.1	72	36	—
(Third Part)												
267. Grey-brown	34	13	65.8	16.7	0	7.2	0.39	0.03	9.0	67	32	1468
268. Speckled	41	19	73.1	13.7	0	7.2	0.22	0.01	9.0	50	26	—
269. Coarse	52	26	75.5	10.3	0	7.1	—	—	—	47	24	788
270. Gravelly	64	41	82.5	8.5	0	7.2	—	—	—	45	22	—
271. Coarse grit	76	30	92.7	3.3	0	7.2	—	—	—	32	19	15

Avail. potash; MSR. 261; 389 p.p.m., K<sub>2</sub>O

## APPENDIX—Continued.

	Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P O 2 5
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		(p.p.m.)

## (31) TRANTS 3. OLD HOUSE FIELD (EAST)

Cotton field; History and reputation as next (No. (32)). Good yields. Site south-west of last. Profile shows traces of composite nature; buried humic soil, 6-12 ins. speckled brownish-grey, coarse sea-shore sand to 25 ins. overlying gravel and boulders, up to 1½ ft. diam. ALLUVIAL soil-type. Layers show vague stratification caused by deposition at different times; the layers dip at low angle to west. Low nitrogen content; extremely high available phosphate; high available potash. Markedly alkaline throughout, but no trace of free calcium carbonate.

MSR.												
282. Composite	—	5	46.0	30.6	4	6.9	1.72	0.09	11.6	113	38	364
283. Grey	6	9	59.2	26.6	4	7.2	1.51	0.07	12.2	73	55	356
284. Black	12	7	58.2	21.3	0	7.3	1.64	0.07	13.4	57	59	205
285. Grey-brown	18	8	70.2	14.8	0	7.4	0.40	0.03	9.3	46	37	130
286. Speckled	25	10	69.3	15.0	0	7.0	0.14	0.02	5.3	40	33	124

Avail. potash; MSR. 282; 289 p.p.m., K<sub>2</sub>O

## (32) TRANTS 4. OLD HOUSE FIELD (WEST)

Cotton field. Limes up to 1910; not diseased. Estate cultivation to 1933, tenancy since. One sugar-cane crop 1920-22. Cotton yields high; 1,000 lb. seed cotton ac., 300 lb. lint. Nut Grass abundant. Only occasionally manured, pen manure. Site near hill-cliff on west side of Trants flat. Hill rises abruptly 120 yds. away. Sepia, soft, coarse, stoneless sand to 10 ins., black humic sand to 16 ins., sharp change to coarse, clayey, stony sand to 24 ins., coarse, soft, speckled brown sand to 28 ins., overlying coarse, slightly cemented gravel and boulders, vaguely stratified, perhaps colluvial. Soil slightly clayey, older material, more leached, more acid than that at other Trants sites. ALLUVIAL soil-type; slightly differentiated. Low to medium-low nitrogen content; fairly-high to very high available phosphate; high available potash. Low organic content. Slightly acid neutral reaction.

MSR.												
277. Composite	—	4	37.5	31.7	4	7.0	1.58	0.08	11.9	94	41	170
278. Sepia	10	7	50.0	30.0	3	6.9	1.31	0.07	11.3	56	33	64
279. Black band	16	7	50.0	29.4	4	6.8	0.99	0.05	10.6	42	25	24
280. Gritty	24	12	53.0	24.8	4	7.0	0.56	0.04	9.1	38	28	30
281. Speckled	28	24	61.0	23.5	0	6.9	0.41	0.03	7.0	35	22	49

Avail. potash; MSR. 277; 248 p.p.m., K<sub>2</sub>O

## (33) TRANTS 5. BAY FIELD

Cotton field; estate cultivation to 1932, tenancy since. Never in limes. One sugar-cane crop 1920-22. Cotton yields, fair. Land dries out badly. Occasionally pen-manured, but not since 1930. Site, near sea-shore; 150 yds. from sea; dense belt of Horse Nicker, Sea-Grape, &c., between it and sea-beach. Uniform, crisp, pale-brown sand throughout; tends to compact. Not saline. No change to 6 feet; stoneless. ALLUVIAL soil-type; derived from sea-shore marine deposits. Very low nitrogen content; medium-high available phosphate, high to very high available potash. Highly alkaline throughout.

MSR.												
272. Composite	—	4	35.9	26.9	3	6.9	1.01	0.06	9.9	125	30	76
273. Coarse sand	6	3	52.0	26.5	0	7.4	0.56	0.04	8.1	56	25	43
274. Ditto	12	2	51.0	23.8	1	7.7	0.35	0.03	6.6	54	45	37
275. Ditto	18	5	51.0	23.2	0	7.6	0.26	0.04	4.0	57	50	40
276. Ditto	24	3	46.9	23.6	0	7.5	—	—	—	63	50	53

Avail. potash. MSR. 272; 268 p.p.m., K<sub>2</sub>O

## APPENDIX—Continued.

	Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P O 2 5
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		(p.p.m.)

## (VII) HERMITAGE ESTATE

## (34) HERMITAGE 1. RANGE FIELD

Site W.N.W. of buildings. Elevation, 1,000 ft.; rainfall 70 ins. Middle part of glacia from Castles Peak. Well-watered, cool, misty slopes. Cotton land but sugar-cane for 100 years previous to 1929. Grows good tomatoes; seed cotton yields, very high, up to 1,550 lb. ac. Never manured as far as known. *BROWN EARTH* soil-type. Sepia-chocolate humic sandy-loam with small stones to 15 ins., overlying ginger-brown crumbly loam with abundant soft decomposed stones becoming bouldery below. Medium contents of organic matter and nitrogen; medium-low available phosphate and potash. Deep organic penetration.

MSR.												
291.	Composite	—	27	33.8	33.8	9	6.1	2.43	0.14	10.3	76	33 46
292.	Chocolate	5	40	42.8	25.5	6	6.1	2.78	0.13	12.8	79	31 34
293.	Friable	9	26	39.2	27.5	7	6.3	2.24	0.11	11.7	52	37 23
294.	Brown	12	23	38.6	27.7	7	6.3	2.02	0.09	12.5	49	18 16
295.	Transition	15	23	37.1	29.1	9	6.5	1.78	0.08	12.4	52	24 9
296.	Red-brown	24	13	32.8	33.8	9	6.5	0.94	0.05	11.4	54	23 4
297.	Iron-stained	36	16	34.8	31.5	4	6.7	0.83	0.04	11.8	60	26 3

Avail. potash; MSR. 291; 102 p.p.m., K<sub>2</sub>O

## (35) HERMITAGE 2. GARDEN FIELD

Site west of Whites chimney; elevation 800 ft.; rainfall, 70 ins.; cool and misty. Cotton land, high yields; also grows vegetables, sugar-cane in past 20 years. *BROWN EARTH* soil-type. Dark-chocolate friable loam with black band at 10-18 ins., changing below to dark-brown soft stony clay, orange-speckled when cut. Stones abundant below 24 ins., mostly well-weathered. Medium-low organic matter and nitrogen; high available phosphate; medium-high available potash. Deep organic penetration.

MSR.												
298.	Composite	—	18	28.5	38.9	9	6.1	2.47	0.12	11.4	145	20 128
299.	Chocolate	6	14	46.8	23.5	4	6.1	2.03	0.09	12.7	87	35 117
300.	Gritty	10	20	46.2	22.5	5	6.1	2.21	0.11	12.1	66	39 109
301.	Black band	18	—	49.7	22.7	6	6.5	2.02	0.08	15.2	53	21 48
302.	Red-brown	29	—	34.7	39.0	9	6.7	0.84	0.05	10.8	50	9 13

Avail. potash; MSR. 298; 166 p.p.m., K<sub>2</sub>O

## (VIII) WHITES ESTATE

## (36) WHITES 1. POTTERS FIELD

Site, cropping and reputation, similar to last. Cotton land for many years, sugar-cane before 1920; green dressings regularly grown. Share-cropping for last 3 years. Elevation, 700 ft.; rainfall 60 ins. Site due north of Whites chimney. *BROWN EARTH* soil-type. Shallow profile; chocolate-brown sandy-clay; black humic band below 9 ins.; soft rotten boulders and stones to 15 to 36 ins.; very large, less weathered boulders below 36 ins., with red-brown clay between. Low organic matter and nitrogen, deeply penetrating; high available phosphate; medium-high available potash.

MSR.												
303.	Composite	—	17	35.5	32.5	6	6.5	1.86	0.09	11.5	142	37 192
304.	Dark brown	5	22	43.8	29.6	5	7.0	1.81	0.08	12.5	101	61 196
305.	Gritty	9	15	38.4	31.2	7	6.5	1.81	0.09	12.4	68	37 53
306.	Black band	15	15	35.5	32.3	9	6.5	2.24	0.09	14.3	253	16 44

Avail. potash; MSR. 303; 159 p.p.m., K<sub>2</sub>O

APPENDIX—Continued.

	Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P O <sub>2</sub> 5
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		(p.p.m.)

(37) WHITES 2. PASTURE FIELD

Site half a mile from sea-coast; lower part of great glacis from Castle Peak; elevation, 190 ft.; rainfall, 40 ins. Slope, 5°. Whites ghaut nearby to north. Cotton since 1937, pasture 10 yrs. previously; cotton 10 years; sugar-cane previously. No manures applied since 1937. Cotton yields, 700-800 lb. ac. seed cotton, depending on rainfall. LITHOSOL soil-type. Loose, dark grey sandy-ash, similar to Richmond soil. Few stones, hard, unweathered. Medium organic matter and nitrogen to 36 ins.; medium-low available phosphate; high available potash.

MSR.												
436. Composite	—	10	27.4	33.0	7	6.3	2.36	0.11	12.6	169	24	44
437. Grey ash	5	10	43.7	35.3	6	6.4	2.33	0.11	12.6	64	22	29
438. Compact	12	14	37.5	38.5	6	7.0	1.88	0.08	13.1	82	33	25
439. Looser	18	12	30.2	43.7	10	7.2	2.62	0.10	15.2	125	53	34
440. Very loose	24	14	39.0	41.5	9	7.2	2.34	0.09	15.5	175	42	32
441. Paler	36	13	38.5	40.0	8	7.1	1.36	0.06	13.9	284	15	18
442. Brown	48	27	44.2	33.6	6	7.0	1.07	0.04	14.4	226	13	13

Avail. potash; MSR. 436; 227 p.p.m., K<sub>2</sub>O

(IX) BETHEL ESTATE

(38) BETHEL 1. NEGRO HOUSE FIELD

Site on glacis trending N.N.E. from Castle's Peak to coast below Farm Estate. Elevation, 500 ft.; rainfall, 45 ins., variable. Cotton land; few large boulders over land surface but stones up to 6 ins. diameter very abundant. BROWN EARTH soil-type, with affinities with YELLOW EARTH. Dark sepia sandy-clay to 12 ins., changing to tawny-brown soft weathered stones with sandy-clay matrix to 48 ins., then change to khaki-brown sandy-ash. Medium-low organic matter and nitrogen rapidly diminishing below. Low available phosphate; medium-high available potash.

MSR.												
307. Composite	—	14	25.3	37.0	7	6.5	1.85	0.11	10.2	114	19	31
308. Sepia	6	17	37.0	36.0	7	6.6	2.12	0.11	11.1	135	19	28
309. Stony ash	12	21	35.0	36.0	6	6.9	0.99	0.07	8.1	66	28	8
310. Brown	18	—	39.0	32.2	7	6.8	0.52	0.04	7.0	51	19	9
311. Tawn ash	24	37	45.0	32.0	8	6.6	0.34	0.03	6.3	76	15	13

Avail. potash; MSR. 307; 148 p.p.m.; K<sub>2</sub>O

(39) BETHEL 2. STILL HOUSE FIELD

Site on same slope as last but at lower elevation; 300 ft.; rainfall, 45 ins., 150 yds. N.E. of buildings. Land representative of lower good Cotton grounds; Cotton for last 30 years; formerly sugar-cane; pen manured up to 1939, every third year. Stony land; stones up to 9 ins. diameter. YELLOW EARTH soil-type, bordering on to LITHOSOL. Pale-brown uniform clayey-sand with few small angular stones; changing at 24 ins. to stiff, compact, clayey-grit, stained with iron and manganese oxides. No boulders to 6 ft. Low organic matter and nitrogen, very high available phosphate and potash.

MSR.												
312. Composite	—	15	34.8	31.4	6	6.4	1.36	0.09	8.9	363	6	340
313. Pale brown	6	13	46.5	27.8	3	6.6	1.33	0.08	10.0	205	44	352
314. Compact	9	10	42.7	33.1	4	7.1	0.93	0.06	9.5	95	42	272
315. Darker	15	11	42.8	34.6	3	7.3	0.67	0.04	9.4	78	49	128
316. Transition	18	14	44.6	30.8	2	7.1	0.54	0.04	8.8	70	37	89
317. Stiff	24	11	39.0	38.4	4	7.1	0.44	0.03	8.8	63	33	60
318. Clayey	31	23	37.7	37.9	8	7.0	0.35	0.04	5.6	75	33	24

Avail. potash; MSR. 312; 676 p.p.m., K<sub>2</sub>O

## APPENDIX—Continued.

	Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P O <sub>5</sub>
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		(p.p.m.)

## (40) BETHEL 3. LONG RANGE FIELD

Site 600 yds. N.W. of Bethel mill tower; 30 yds. from Farm Road, 250 yds. E.N.E. of Church,  $\frac{1}{4}$ -mile from sea. Elevation, 280 ft., rainfall 45 ins. Same slope as last two; 5° N.E. Cotton only; representative of best cotton land in this district; Pen manured every 5 years; 10 tons ac.; occasional green dressings. 500 lb. ac. 1939 (a dry year). Average years, 900 lb. ac. Exposed and wind-swept. Stony soil. *YELLOW EARTH* soil-type, with *BROWN EARTH* affinities. Sepia clayey-sand to 10 ins., then mass of rotting stones, with incipient cementation, to 49 ins., then looser greenish-brown sandy-ash, crumbly and devoid of stones, becoming purplish and more stony below 51 ins. Low organic matter and nitrogen; medium-high available phosphate; fairly high available potash.

## MSR.

449. Composite	6	21	25.8	37.7	6	6.3	1.28	0.07	10.1	108	36	45
450. Sepia, friable	5	25	47.0	29.0	3	7.4	0.85	0.05	9.5	124	76	78
451. Compact	10	39	40.0	31.8	6	7.3	0.70	0.05	7.8	103	73	31
452. Rotting stones	15	—	46.0	36.8	9	6.9	0.55	0.05	6.9	204	14	10
— Cemented stones	49	—	—	—	—	—	—	—	—	—	—	—
453. Grey ash	51	—	67.0	20.0	0	7.0	—	—	—	97	20	110

Avail. potash; MSR. 449; 198 p.p.m., K<sub>2</sub>O

## (X) TUIITS ESTATE

## (41) TUIITS 1. GARDEN FIELD

Site on glacia to north of Castle's Peak; slope, 8°, elevation 700 ft.; rainfall 55 ins. One mile W.N.W. of Whites; on N. side of Whites ghaut, 75 yds. distant, and 200 yds. W.N.W. of Hog Hole Village. Cotton since 1937; previously pasture. Yield, 900 lb. ac., seed cotton; best in dry years. No manuring. Stock do not thrive. *BROWN EARTH* soil-type. Gritty sandy-clay, sepia-black colour, with sparse small rotting stones to 16 ins.; paler and more stony with stones up to 5 ins. diameter, mostly unweathered above, but increasingly weathered and soft with iron-staining, below 24 ins. Medium-low organic matter and nitrogen; medium available phosphate; fairly high available potash.

## MSR.

443. Composite	—	11	21.2	45.1	17	6.5	3.80	0.19	11.3	199	53	37
444. Black	5	13	32.2	39.3	11	6.5	2.65	0.15	10.5	105	46	37
445. Gritty	10	17	29.5	40.5	11	6.6	1.72	0.08	11.8	71	26	9
446. Sepia	16	21	29.7	42.1	11	6.9	1.04	0.06	10.3	66	21	6
447. Paler	24	11	29.0	42.8	10	7.0	0.57	0.04	8.1	64	1	5
448. Rotten stones	30	—	34.0	42.0	10	7.1	0.49	0.02	15.7	59	20	4

Avail. potash; MSR. 443; 204 p.p.m., K<sub>2</sub>O

## (XI) TAR RIVER ESTATE

## (42) TAR RIVER 1

Site on sloping land, 20 percent grade, E.N.E. of Castle's Peak, 30 yds. S. of Great Ghaut and 30 yds. N.E. of main road. Elevation 960 ft.; half-a-mile inland from coast. Rainfall, 45 ins. Cotton land; regarded as fair; grows tomatoes well; 2,000 lb. ac. Pen-manured, 10-15 tons ac. for last 3 years; no artificials nor cotton seed meal applied. *BROWN EARTH* soil-type, Humic brown to 10 ins., rotten stony layer to 14 ins., rotten rock to 34 ins. with sticky clay matrix, stained brown with iron and manganese oxides; cemented somewhat below, with component stones grey and not very much weathered, and larger in size (above 4 ins.). Medium-low organic matter and nitrogen; fairly high available phosphate; very high available potash.

## MSR.

480. Composite	—	20	41.0	41.8	14	6.6	2.55	0.17	8.6	129	49	71
481. Pale brown	5	24	37.7	37.8	9	6.7	2.26	0.13	10.0	92	32	86
482. Stony	10	35	36.0	38.5	10	6.6	1.83	0.12	8.9	84	35	38
483. Compact	14	37	30.5	43.3	11	6.8	1.26	0.09	8.0	75	42	11
484. Rotten stones	20	—	30.0	46.3	13	6.9	0.74	0.06	7.5	69	25	5
485. Rotten	32	—	24.7	51.1	20	6.8	0.42	0.04	6.8	109	19	4
486. Rotten	34	—	13.7	65.8	33	6.7	0.75	0.04	11.5	80	24	3

Cemented below; not sampled

Avail. potash; MSR. 480; 276 p.p.m., K<sub>2</sub>O

APPENDIX—Continued.

	Dpth	Gravel	Crse Sand	Silt and Clay	I.T.	Reaction	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P <sub>2</sub> O <sub>5</sub>
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-5</sup> )		(p.p.m.)

(43) TAR RIVER 2

Site 400 yds. beyond end of main road. 600 yds. S.E. of Long Ground Village and Great Ghaut; 100 yds. S.E. of Billy Ghaut. Elevation, 800 ft., rainfall 45 ins. Cropping and manuring as last. Tomatoes; yields as last; somewhat low for this district possibly because of adverse weather. *BROWN EARTH* soil-type. Soil more humic than last, and generally richer, but organic distribution irregular, with dark band at 8 to 15 ins. Brown stony clay; coarsely-crumbly; compact. Stones mostly less than half inch but many up to 2½ ins., and mainly only slightly decomposed; markedly stony layer, 15 to 28 ins., stony up to 5 ins., less stony below but more rotten, with brown clayey matrix, somewhat cemented below 34 ins., large stones at base. Medium organic matter and nitrogen; high available phosphate; very high available potash.

MSR.												
475. Composite	—	33	42.5	39.0	16	6.4	3.21	0.18	10.6	156	40	72
476. Pale brown	4	30	39.5	38.0	13	6.6	2.76	0.16	10.1	200	12	105
477. Stony	8	28	34.7	41.6	12	6.5	2.02	0.13	9.4	83	43	50
478. Humic	15	24	28.0	49.3	16	6.3	2.19	0.13	10.0	60	24	26
479. Very stony	28	46	29.5	48.0	17	6.5	1.97	0.12	9.4	70	19	15

Cemented below; not sampled

Avail. potash; MSR. 475; 415 p.p.m., K<sub>2</sub>O

(XII) RILEYS ESTATE

(44) RILEYS 1. YARD DIAMOND FIELD

Area typical of land between Paradise and Lees Estates; wet district, 75 ins. rainfall per year. Elevation, 1,200 ft. Site 50 yds. N.E. of Riley's chimney. Slope 8°; base of Soufriere Hills near divide between them and Centre Hills; near main road; open spot; slight mound. Estate cultivation; sugar-cane, tomatoes, carrots and sweet potatoes; beans. Pen manured, 15 tons ac., every 3 years; cotton seed meal, 800 lb. ac., no artificials. *BROWN EARTH* soil-type with affinities to *TERRAS*. Irregular profile; greenish to golden-brown, friable sandy-clay with numerous stones up to 2 ins. diameter, mostly rotten and crumbly, changing at 36 ins. to less-decomposed material, chiefly golden-brown, dark speckled sand with sticky clay matrix, overlying faintly stratified, partly cemented, ginger-coloured "terras", devoid of stones, greyer and ashy below, uniformly fine-grained and speckled. Low organic matter and nitrogen; very low available phosphate; medium-low available potash.

MSR.												
401. Composite	—	9	16.8	56.1	19	6.2	1.77	0.11	9.0	48	17	9
402. Black	6	30	31.7	43.1	13	6.4	1.79	0.11	9.7	60	8	15
403. Brown	9	16	20.0	57.9	29	6.5	1.60	0.11	8.8	63	12	8
404. Clayey	12	13	16.4	69.5	35	6.2	1.12	0.08	8.7	92	0	7
405. Crumbly	18	8	17.5	66.4	32	6.5	0.95	0.08	6.7	68	0	7
406. Mixed	24	16	17.3	66.4	34	6.6	0.73	0.04	9.8	68	9	7
407. Crumbly	36	8	16.2	67.2	30	6.3	0.62	0.04	8.8	55	10	7
408. Change	48	—	24.1	63.4	25	6.6	0.29	0.03	6.8	43	13	6
409. Rotten rock	58	—	22.3	60.9	27	6.8	0.24	0.02	6.4	56	16	5
410. Finer	70	—	32.2	45.8	12	6.9	0.18	—	—	51	23	13
411. Ashy	76	—	51.5	26.2	0	7.1	0.18	—	—	39	22	75

Avail. potash; MSR. 401; 101 p.p.m., K<sub>2</sub>O

(45) RILEYS 2. CHURCH YARD FIELD

Site N.N.E. of last; 150 yds.; 30 yds. from main road. Beetroots. Similar soil. *BROWN EARTH* type with affinities to *TERRAS*. Main crops for last 5 years, tomatoes, carrots, potatoes, beetroot, beans. Pen manured, 10 to 15 tons ac., and green dressings. No cotton seed meal; no artificials. Surface sample only collected. Black sandy-clay to 6 ins., then ginger-brown stiff clay to 16 ins. stony, gritty with golden-brown clay matrix below to 31 ins., with rotten stones; transition to 35 ins., then pinkish-grey, partly cemented "Terras" below, with some boulders, mostly fresh and hard. Medium-low organic matter and nitrogen; low available phosphate; fairly-high available potash.

MSR.												
412. Composite	—	9	13.9	57.3	19	6.1	2.31	0.13	9.9	56	27	14

Avail. potash; MSR. 412; 196 p.p.m., K<sub>2</sub>O

## APPENDIX—Continued

	Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P O 2 5
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		(p.p.m.)

## (46) RILEYS 3. MOUNTAIN FIELD

Highland site; 1,350 ft. elevation; 80 ins. rainfall. Site ½ mile S. of Rileys' chimney; 500 yds. from foot of hill forming part of Soufriere Hills Gentle slope; upper part of north-trending glacis on which last site occurs. Pasture for last 15 months, formerly sweet potatoes, sugar-cane, etc., no records kept. Share-cropped for last 20 years. No manuring. *BROWN EARTH* soil-type with affinities to *TERRAS*. Sandy soil, packed hard at surface, but softer below. Golden-yellow-brown colour. Very uniform; crumbly to powdery; few stones to 15 ins., but gritty and stony below; stones up to 1½ ins.; mostly rotten; slightly cemented below 27 ins. depth; forming yellow-grey to pink "terras", hard and compact to 46 ins., loose to 54 ins., then cemented again below to 76 ins. (bottom of pit). Medium-low to medium organic matter and nitrogen; extremely low available phosphate; fairly-high available potash.

MSR.												
413. Composite	4	9	10.0	62.0	33	5.9	3.48	0.21	9.6	48	11	5
414. Gold-brown	4-9	9	20.2	60.1	32	5.7	2.95	0.20	8.7	42	15	4
415. Ginger	15	6	19.1	65.9	37	5.8	1.77	0.14	7.4	42	6	4
416. Compact	19	25	20.4	62.0	36	6.0	1.33	0.10	7.5	55	6	5
417. Rotten stony	27	17	20.3	60.7	37	5.9	1.27	0.09	8.2	260	73	4
418. Transition	40	—	53.8	29.3	0	6.3	0.82	0.03	14.5	44	10	4
419. Cemented	46	—	82.0	11.0	0	6.3	0.14	—	—	34	7	5
420. Loose	54	—	86.2	2.0	0	6.3	0.22	—	—	20	3	10
421. Cemented	76	—	78.0	8.2	0	6.5	—	—	—	37	6	19

Avail. potash; MSR. 413; 190 p.p.m., K<sub>2</sub>O

## (XIII) FARRELL'S ESTATE

## (47) FARRELL'S SLOB FIELD

Site within a shallow col with slopes on three sides; 1175 ft. elevation; 65 ins. rainfall. Pond 50 yds. to S.W. Abnormal spot; represents only 10 ac. of land. *BROWN EARTH* soil-type. Soil may be mostly hill-wash. Grey-chocolate-brown, horny, stiff clay to 66 ins. (bottom of pit), with three distinct gritty bands; no stones. Upper partly only sampled. Low organic matter and nitrogen; extremely low available phosphate; medium-low available potash.

MSR.												
422. Composite	—	8	28.0	41.5	10	6.1	1.79	0.10	10.5	57	16	12
423. Clay sand	6	6	35.0	39.3	7	6.2	1.33	0.08	9.3	54	8	4
424. Compact	12	9	16.5	61.8	18	6.4	0.94	0.07	7.8	43	7	2
425. Pale brown	20	0	10.2	76.8	33	6.6	0.54	0.05	6.7	54	9	3
426. Grit	26	0	20.2	57.8	22	6.7	0.29	0.02	7.0	57	5	3

Avail. potash; MSR. 422; 106 p.p.m., K<sub>2</sub>O

## (XIV) GAGES ESTATE

## (48) GAGES. BRAMBLE FIELD

Site 50 yds. north of Gages house; 50 yds. west of river, 50 yds. S.E. of main road and of steep hill on opposite side of road. Slight slope. Elevation, 650 ft.; rainfall 60 ins. Yams, 1935; formerly sugar-cane. Pen manured, 10 tons ac., every 2 years; no cotton seed meal, no green dressings no artificials. *YELLOW EARTH* soil-type with affinities to *ALLUVIAL-COLLUVIAL* soil, and to *TERRAS*. May be mostly hillwash or alluvial-colluvial material. No boulders on land surface near pit. Composite profile, distinct horizontal stratification. Bright yellow-brown variable bedded sand and gravel to 17 ins.; feebly cemented stone-and-grit layer to 26 ins.; sharp change to dark chocolate-brown, friable, fine sandy humic soil to 40 ins., then another stone-and-grit layer, feebly cemented to 49 ins., overlying loose sand and fine grit to bottom of pit at 72 ins. Medium-low organic matter and nitrogen; very high available phosphate; high available potash.

MSR.												
427. Composite	—	20	46.0	28.1	7	6.6	1.79	0.11	9.6	87	37	170
428. Brown	6	29	59.2	21.8	2	6.8	1.17	0.07	9.6	110	34	165
429. Paler	12	14	49.7	26.6	8	6.8	0.68	0.05	8.5	72	20	117
430. Yellowish	17	10	21.0	38.3	14	6.7	0.74	0.05	8.0	83	18	62
431. Stony	26	30	53.2	27.8	3	6.9	0.53	0.04	8.8	49	21	47
432. Sandy	32	15	53.2	27.8	13	6.9	1.72	0.09	10.6	70	24	52
433. Humic	40	15	27.4	43.6	15	6.9	1.26	0.09	7.9	63	27	24
434. Gritty	49	—	55.5	24.1	5	6.9	0.47	0.04	7.3	61	19	30
435. Coarse sand	60	—	53.4	28.2	7	7.0	0.27	0.02	7.2	59	17	47

Avail. potash; MSR. 427; 226 p.p.m., K<sub>2</sub>O

## APPENDIX—Continued.

	Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P O 2 5 (p.p.m.)
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-5</sup> )		

## (XV) DAGENHAM ESTATE

## (49) DAGENHAM 1. BAG FIELD

Site near coast N.W. of Plymouth; 80 yds. S.W. of St. Anthony's Church, and across main road. Elevation, 60 ft., rainfall, 50 ins. Gentle slope, 5° near base of St. George's Hill. Cotton field. Share-cropped land, seed-cotton, 1,400 lb. ac. 1939; 1,600 lb. 1938; rested 1937; usually cotton for 4 years, then fallow for one year. Estate land up to 1933; cotton since about 1902; previously sugar-cane. No manuring since 1933. Considered a good field, *LITHOSOL* soil-type; St. George's Hill material; no large boulders on land surface, though field to E. (Soufriere Hills material) is very bouldery, the boulders now being crushed for road metal. Very uniform profile; humic gritty sand to 16 ins.; progressively finer and paler brownish-grey colour and less stony-gritty below; occasional small stones, less than half inch diameter, in upper 48 ins. part. Low to very low organic matter and nitrogen; very high available phosphate; high available potash.

MSR.												
319. Composite	—	13	36.4	30.4	7	6.6	1.55	0.09	10.5	137	38	388
320. Sand	5	11	43.2	29.3	4	6.9	1.23	0.07	9.9	75	43	249
321. Crisp	10	9	39.2	43.1	7	7.1	0.92	0.06	8.8	56	31	96
322. Gritty	16	9	31.8	39.7	7	6.6	0.88	0.06	8.1	53	29	30
323. Compact	24	9	31.5	49.3	10	6.8	0.39	0.04	5.1	40	20	19
324. Brown	36	10	35.2	48.1	12	7.1	0.28	0.04	4.5	44	10	15
325. Stony	48	13	39.5	35.5	6	7.2	0.24	—	—	42	23	15
326. Sandy	60	8	50.0	25.0	0	7.2	0.37	—	—	36	23	44

Avail. potash; MSR. 319; 244 p.p.m., K<sub>2</sub>O

## (50) DAGENHAM 2. SHOY FIELD

Site due east of last, quarter mile; 800 yds. from foot of St. George's Hill; 70 yds. N.N.E. of Dagenham cotton gin. Elevation 90 ft.; rainfall 50 ins.; gentle slope, 5°, to coast north of Plymouth. Cultivations and cropping, as last. Bouldery land surface; stones up to 2 ft. diameter. Soufriere Hills material. *LITHOSOL* soil-type; profile irregularly-stratified; sand and gravel. Black humic sandy clay to 16 ins., paler and more gritty to 27 ins.; stony to 36 ins.; yellow sandy to 46 ins.; very stony to 62 ins.; layer of very fine sand to 67 ins.; coarse and fine sand alternations below. Medium-low organic matter and nitrogen; extremely high available phosphate; high available potash.

MSR.												
327. Composite	—	14	37.2	30.9	7	6.5	2.14	0.11	11.1	131	45	780
328. Humic	5	14	45.0	32.8	7	6.5	2.21	0.12	11.1	106	28	1260
329. Humic	11	9	43.7	35.3	6	6.8	1.63	0.09	10.7	69	21	755
330. Humic	16	8	39.5	37.5	8	7.0	1.59	0.08	12.3	61	16	555
331. Sandy	20	6	40.5	34.5	7	7.0	0.86	0.05	10.2	53	10	912
332. Paler	27	6	36.4	40.6	9	7.1	0.80	0.05	8.6	57	17	550
333. Stony	36	17	38.5	40.0	10	7.2	0.36	0.03	6.1	54	11	488
334. Gritty	46	14	48.5	30.5	9	7.1	0.18	0.02	5.1	49	34	130
335. Bouldery	62	60	59.5	23.5	0	7.1	—	—	—	62	25	190
336. Fine sand	67	4	40.5	29.5	0	7.3	—	—	—	52	16	200
337. Coarse sand	72	2	77.5	8.8	0	7.1	—	—	—	29	21	53

Avail. potash; MSR. 327; 292 p.p.m., K<sub>2</sub>O

## APPENDIX—Continued.

	Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P O 2 5
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		(p.p.m.)

## (51) DAGENHAM 3. LONG FIELD

Site N.E. of No. 50 and on same slope; 300 yds. from foot of St. George's Hill. Elevation, 150 ft., rainfall, 50 ins. Share-cropped, 1933-7; rested as pasture, 1938; share, 1939; estate cultivation 1940. Cotton mostly, though considered a poor field; bushes smaller than at last Site (No. 50). Manured with cotton-seed meal, 800-900 lb. acre. Land surface stony but not bouldery; many boulders may have been removed. Probably Soufriere Hills material. LITHOSOL soil-type. Stony, coarse, grey-brown sand to 13 ins., coarser to 18 ins.; change to compact moist very fine sand and silt to 27 ins., then black grit and stones forming loose pebble bed to 40; sandy below to 72 ins. (bottom of pit). Medium-low organic matter and nitrogen; extremely high available phosphate; high available potash.

MSR.												
338. Composite	—	16	53.0	21.1	2	6.4	1.36	0.08	10.2	117	33	490
339. Stony	5	29	61.6	20.2	0	6.6	1.66	0.09	10.6	139	25	802
340. Stony	13	30	66.2	20.6	0	6.9	0.94	0.05	10.9	75	37	484
341. Sand	18	8	79.2	10.8	0	6.9	0.31	0.02	9.5	49	13	196
342. Very fine	27	9	37.2	33.8	6	7.1	1.39	0.06	13.4	74	33	291

Avail. potash; MSR. 338; 231 p.p.m., K<sub>2</sub>O

## (52) DAGENHAM 4. THOMPSON FIELD

Site immediately west of Grove Experiment Station, 300 yds. away; field opposite side of main road; foot of St. George's Hill; gentle slope, 2°. Fallow; dry banks. Elevation, 60 ft., rainfall 55 ins. LITHOSOL soil-type; St. George's Hill material. Humic stony dark grey sand to 12 ins., coarser and more stony (round stones, half inch diameter) to 18 ins., coarse sand, few stones; pale brown colour, becoming finer and moister below to 38 ins., then a 4-ins. band of coarse sand, then a 20 ins. belt of partly-cemented angular stones, size up to 4 ins., with gritty matrix, then sharp change to dark chocolate humic sand, doubtless representing a former surface soil, now buried under 62 ins. of newer material, probably mudflow, on top. Low organic matter and nitrogen; very high available phosphate; fairly high available potash.

MSR.												
454. Composite	—	14	46.5	27.7	4	6.6	1.45	0.08	11.1	130	41	312
455. Dark grey	5	18	53.0	27.5	3	6.9	1.19	0.06	10.7	61	21	226
456. Sandy	12	20	51.5	30.1	4	6.9	0.91	0.06	9.3	56	24	168
457. Coarse	18	19	61.0	24.3	0	6.8	0.43	0.03	8.7	56	16	66
458. Coarse	25	13	71.5	16.0	0	7.0	0.25	0.02	7.3	36	14	83
459. Finer	30	13	58.0	14.9	0	7.0	0.21	0.01	8.5	34	14	101
460. Very fine	38	8	25.0	29.6	0	7.2	0.32	0.03	7.2	49	16	139
461. Humic	62-72	23	19.5	56.5	14	7.4	1.53	0.06	15.5	57	42	267

Avail. potash; MSR. 454; 172 p.p.m., K<sub>2</sub>O

## (XVI) WEBBS ESTATE

## (53) WEBBS. GATE FIELD

Site 100 yds. S.E. of Webbs' old mill tower, opposite side of big ghaut to main road; foot of Round Hill. part of Soufriere Hills, gently-sloping ground, 5°. Share cultivation since 1934; Cotton mainly but poor yields; dropped from 400 lb. ac., in 1934. Occasional Bengal Beans. Land surface devoid of large boulders. YELLOW EARTH soil-type showing affinities with TERRAS. Sepia-grey, slightly clayey sandy-grit to 10 ins., darker, more clayey and stony layer to 18 ins., transition yellow sand to 21 ins., then harsh, yellowish, partly cemented, less stony sandy-ash to 49 ins., becoming greyer and looser below to bottom of pit at 60 ins., with some large boulders at base. Medium-low organic matter and nitrogen; medium-low available phosphate and potash.

MSR.												
379. Composite	5	10	28.3	41.1	9	6.5	1.79	0.10	10.8	87	29	70
380. Mid-brown	5-10	8	34.4	38.2	7	6.6	1.88	0.11	10.3	72	25	25
381. Darker	18	12	30.9	42.9	8	6.8	1.44	0.08	10.1	68	20	27
382. Yellowish	21	17	29.4	49.2	19	6.9	0.82	0.06	7.6	59	16	9
383. Cemented	24	—	40.2	41.4	13	6.9	0.28	0.02	6.7	54	25	8
384. Cemented	33	—	58.4	26.2	4	7.1	—	—	—	40	19	15
385. Loose	49	—	71.2	11.9	0	6.8	—	—	—	39	19	297

Avail. potash; MSR. 379; 111 p.p.m., K<sub>2</sub>O

APPENDIX—Continued.

	Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P O 2 5
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		(p.p.m.)

(XVII) PARSONS ESTATE

(54) PARSONS 1. COTTON TREE FIELD

Site 150 yds. west of estate buildings and east of wireless station. Elevation, 700 ft.; rainfall 73 ins. Estate cultivation always; sugar-cane to 1940, cotton since. Pen manured, 3 tons ac., every year since 1934; cotton-seed meal, 200 lb. ac., every 3 years; no green dressings; no artificials. Cotton yields, over 800 lb. ac. Narrow flat ridge, half-way down glacis of Chances Mountain, Soufriere Hills. Land surface strewn with boulders. *BROWN EARTH* soil-type. Sepia, humic, stony, sandy-clay to 24 ins., overlying iron-stained golden-brown, friable sandy material, composed of rotten stones, to 36 ins., over tightly-packed grey stones and boulders, mostly undecomposed, up to 36 ins. diameter, variable sizes with matrix of gritty sand. Medium-low organic matter and nitrogen; low available phosphate, except in (manured) surface soil; medium-high potash.

MSR.												
373. Composite	—	9	20.8	46.7	12	6.5	1.98	0.10	11.2	95	24	103
374. Sepia	4-9	27	28.7	47.4	13	6.8	1.54	0.09	9.9	92	39	29
375. Compact	12	31	36.2	41.4	12	6.9	1.03	0.08	7.7	84	25	9
376. Stony	18	29	33.2	42.9	12	6.9	0.80	0.06	8.1	57	22	6
377. Brown	24	—	49.2	32.3	9	6.8	0.61	0.05	6.8	55	12	9
378. Rotten	36	—	70.0	17.0	2	6.7	0.17	0.02	6.1	46	15	9

Avail. potash; MSR. 373; 169 p.p.m., K<sub>2</sub>O

(XVIII) AMERSHAM ESTATE

(55) AMERSHAM 1. SAVANNA FIELD

Site 500 yds. E.S.E. of old mill tower; elevation, 700 ft.; rainfall 70 ins. Half way up glacis from Chances Mountain, Soufriere Hills, west of depression between twin peaks. Grassy rocky land; numerous walls and mounds of heaped-up boulders. Estate cultivation to 1930, rented since; share cropping 1940. Originally planted in limes which died out. Tomatoes, cotton, sugar-cane. Pen manured, but no cotton-seed meal nor artificials applied. *BROWN EARTH* soil-type with some affinity with *TERRAS*. Sepia, humic, crumbly clayey-sand with rotten rusty soft stones to 6 ins., overlying more clayey sand with soft stones to 24 ins., over incipient grey hard "terras", variably iron-stained, containing sparse encrusted kaolinised boulders up to 24 ins. diameter. Medium-low organic matter and nitrogen; medium-low available phosphate; low available potash.

MSR.												
386. Sod	3	26	18.2	50.8	16	6.7	2.03	0.12	9.7	85	37	32
387. Sepia	6	49	22.2	50.0	14	6.8	1.11	0.08	7.7	84	27	12
388. Rusty	12	—	22.0	58.3	25	6.8	0.55	0.05	5.9	91	28	7
389. Mottled	18	8	22.9	53.7	26	7.0	0.28	0.04	4.3	91	31	5
390. Rotten	24	—	25.2	50.8	24	7.1	0.29	0.03	5.6	139	20	10
391. Boulders	—	—	—	—	—	7.0	—	—	—	58	25	8

Avail. potash; MSR. 386, 387; 66 p.p.m., K<sub>2</sub>O

(56) AMERSHAM 2. GARDEN FIELD

Site 50 yds. N.W. of mill tower. Slight hollow in gently-sloping land. Cotton since 1925; vegetables previously. Pen manured, 1½ tons ac. every other year; no cotton seed meal; no artificials; no green dressings. Elevation, 400 ft., rainfall 50 ins. *BROWN EARTH* soil-type with affinities with *TERRAS*. Black sandy soil to 20 ins., sparse stones, overlying rotten stony layer to 32 ins., overlying "terras" to 56 ins., becoming incoherent below, purplish and ashy. Medium-low organic matter and nitrogen, penetrating to 24 ins., extremely high available phosphate to 24 ins., medium-low below; very high available potash.

MSR.												
392. Composite	—	21	26.3	41.5	8	6.9	1.79	0.10	10.8	175	56	376
393. Black	6	21	37.0	35.5	7	7.0	2.02	0.11	10.6	137	38	429
394. Brown	12	20	35.5	38.5	8	7.0	1.91	0.10	11.0	98	41	376
395. Compact	20	19	35.0	39.0	9	7.2	2.10	0.11	11.5	114	44	292
396. Stony	24	35	33.0	42.5	12	7.2	2.21	0.10	12.2	95	69	113
397. Rusty	32	—	31.0	47.3	16	7.2	1.02	0.06	9.3	91	46	23
398. Cemented	34	—	46.7	29.6	10	7.1	0.22	0.02	5.4	81	29	8
399. Cemented	54-56	—	62.0	20.8	3	7.1	0.19	0.02	5.2	113	25	20
400. Loose	58-60	—	61.5	18.3	0	7.1	—	—	—	107	35	37

Avail. potash; MSR. 392; 406 p.p.m., K<sub>2</sub>O

## APPENDIX—Continued.

	Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P O 2 5
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		(p.p.m.)

## (XIX) SWEENYS ESTATE

## (57) SWEENYS' 1. RIVER PIECE

Site on gentle slope to west of Central Hills, north part. Elevation, 500 ft.; rainfall, 48 ins., Cotton with some lime-trees; estate cultivation. *SHOAL* soil-type. Black clay to 15 ins., overlying iron-stained cream-coloured "shoal" (25 percent pore-space determined), with thin waxy humic layer at interface, covered by iron oxide deposit. Medium-low to low organic matter and nitrogen, medium available phosphate, fairly high available potash.

MSR.												
343.	Composite	—	25	30.0	44.8	13	6.8	2.02	0.11	10.5	89	35
344.	Black	5	9	42.9	29.0	7	7.0	1.70	0.10	9.9	90	32
345.	Plastic	9	23	27.9	49.6	17	6.6	1.45	0.10	8.1	98	32
346.	Stiff	13	14	29.2	51.5	25	6.8	0.77	0.07	6.4	109	19
347.	Brashy	15	—	25.7	56.4	31	6.9	0.78	0.07	6.2	181	13
348.	Shoal	16	—	—	—	—	7.0	0.18	0.02	5.7	117	8
357.	Sample of shoal											

Avail. potash; MSR. 343; 205 p.p.m., K<sub>2</sub>O

## (58) SWEENYS' 2. SPY GLASS PIECE

Site on top of small flat hill 200 yds. east of last, and east of mill tower. Cotton since 1933, except sugarcane in 1938. Limes failed. Pen manured occasionally; also treated with cotton seed meal and artificials. One of best fields in upland part of north Centre Hills district. Elevation, 600 ft., rainfall, 50 ins. *SHOAL* soil-type. Black clay to 12 ins., overlying brashy, crumbly, sandy, buff-coloured veined "shoal" (17 percent pore-space), with waxy organic layer at interface. Medium-low organic matter and nitrogen to 16 ins., low available phosphate; fairly high available potash.

MSR.												
349.	Composite	—	19	29.4	43.8	10	6.5	2.07	0.11	10.7	95	55
350.	Black	6	11	35.0	47.4	16	6.7	1.66	0.10	9.7	115	28
351.	Gritty	11	6	30.0	50.6	23	6.8	1.07	0.08	8.0	141	8
352.	Organic	11-12	6	19.0	67.2	33	6.0	1.26	0.14	5.1	187	7
353.	Shoal	16	—	77.5	7.5	0	6.4	1.26	0.08	8.7	97	4
354.	Shoal	18	—	70.0	11.8	0	6.0	0.14	0.02	4.7	171	4
355.	Shoal	43	—	61.2	12.4	0	6.9	—	—	—	93	5
356.	Vein	40-43	—	92.0	0.8	0	6.1	—	—	—	175	—

Avail. potash; MSR. 349; 207 p.p.m., K<sub>2</sub>O

## (XX) WOODLANDS' ESTATE

## (59) WOODLANDS' 1. MOUCHELL HEAD FIELD

Site east of main road, opposite house; 300 yds. uphill. Elevation, 250 ft. rainfall 60 ins., small plateau near ghaut; margin of forest. High forested peaks above. Bouldery land; boulders piled up in heaps. Cotton for last 2 years, formerly limes; once arrowroot. Cotton yield, 1,200 lb. ac., 1939. *SHOAL* soil-type. Chocolate-brown coarse sand to 12 ins., stony to 22 ins., bouldery, with gritty-clay matrix, to bottom of pit at 66 ins. Boulders mostly unweathered greenish-grey and purple andesite. Presumably "geological" shoal; i.e. cemented agglomerate below. Medium-low organic matter and nitrogen; low available phosphate; medium-low available potash.

MSR.												
358.	Composite	—	11	18.1	55.3	16	6.0	2.38	0.14	10.2	83	18
359.	Chocolate	6	12	36.4	51.9	12	6.3	1.74	0.11	9.3	61	15
360.	Purplish	12	13	33.0	53.0	12	6.6	1.19	0.09	7.4	55	11
361.	Stony	22	22	38.1	48.1	12	6.8	0.60	0.05	6.8	49	9
362.	Bouldery	29	21	48.5	39.5	9	7.0	0.40	0.03	7.0	56	10
363.	Matrix	42	16	42.2	44.2	9	7.3	0.38	0.03	7.1	45	8
364.	Matrix	54	32	46.5	40.8	8	7.3	0.21	0.03	4.5	45	11
365.	Matrix	66	15	44.2	42.1	9	7.2	0.19	0.02	5.0	43	14

"Geological shoal" below.

Avail. potash; MSR. 358; 114 p.p.m., K<sub>2</sub>O

APPENDIX—Continued.

	Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P <sub>2</sub> O <sub>5</sub>
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		(p.p.m.)

(60) WOODLANDS' 2. MACAREE FIELD

Site west of main road, south of house, on shallow hog-back ridge, north side of Bay Ghaut, between it and another ghaut. Elevation, 200 ft.; rainfall, 60 ins. Cotton; yields not so high as last. No manuring. Share cropping. Indigo bush common. Bouldery land. SHOAL soil-type. Black clay to 12 ins., brown clay with rotten rusty and hard grey stones, overlying pink "shoal" at 31 ins., with traces of humic waxy interface and iron-cemented crust. Shoal exposed at ground level at top end of field near road through hoeing; soil thicker at bottom end. Medium to medium-low organic matter, nitrogen and available phosphate; medium-low available potash.

MSR.

366. Composite (bottom)	—	36	19.0	54.4	19	6.4	3.84	0.20	11.0	110	31	44
372. Composite (top)	—	25	36.6	41.4	12	6.7	2.79	2.15	11.2	112	31	39
367. Humic	12	28	37.0	50.0	12	6.4	2.15	0.11	11.1	87	38	32
368. Brown	19	11	25.0	63.0	19	6.6	0.62	0.06	6.2	79	22	9
369. Transition	31	—	39.0	47.6	14	6.5	0.29	0.03	5.9	84	6	6
370. Crust	32	—	20.0	75.4	—	6.8	—	—	—	—	—	12
371. Shoal	35	—	74.0	10.0	—	7.0	—	—	—	51	12	78

Avail. potash; MSR. 366; 121 p.p.m., K<sub>2</sub>O  
372; 112 p.p.m., K<sub>2</sub>O

(XXI) SPECIAL SITES

(61) CORK HILL :ROAD CUTTING

Site, a small quarry or excavation on right of leeward main road at base of Cork Hill, about 1½ miles from Plymouth. SHOAL soil-type. Section shows (a) upper layer, 24 ins., black cracked clay; (b) cemented grey "shoal" or "terras", 24-72 ins., soft below 60 ins.; thin hard crust at base; (c) purplish-white uncemented loose gritty-ash containing small white pumiceous round stones, 72-116 ins. (bottom of section). The black clay soil contains medium-low organic matter and nitrogen and medium-low available phosphate and potash.

MSR.

489. Black	6	8	37.9	44.6	19	6.2	1.55	0.10	9.3	165	21	17
490. Cracked	12	7	40.9	34.1	11	6.3	1.86	0.10	10.8	145	39	22
491. Clay	18	5	35.9	44.1	18	6.3	1.71	0.11	9.2	107	27	18
492. Ditto.	24	7	40.9	40.1	16	6.3	1.38	0.09	8.7	124	36	16
468. Cemented	24-27	—	59.2	20.3	0	6.9	0.33	0.03	7.7	411	39	11
469. Terras	69-72	—	72.5	12.0	0	7.3	0.13	0.01	7.7	254	36	163
470. Loose	116	—	80.0	8.9	0	7.7	0.07	0.01	7.8	30	14	259

Avail. potash; MSR. 489; 80 p.p.m., K<sub>2</sub>O

(62) PARSONS-AMERSHAM :EROSION SAMPLES ("HOE-ROSION")

Three sites (peasants' plots) in a straight line, about half mile apart, comprising typical examples of downhill drag caused by hoeing. Pairs of composite surface soil samples taken from banks occurring at the bottom and top of each plot respectively. Bottom of plot in each case ends in an "erosion escarpment", and the soil here is deep. Top usually exhibits "shoal" exposures and shallower soil. The plots are between 40 and 80 yds. long i.e. distance between bottom and top sampling spots. BROWN EARTH soil-type; stony and bouldery; set out in banks for planting at time of sampling. Samples taken from banks. Medium-low organic matter and nitrogen; medium-low to very high, but variable available phosphate. Data show no regular differences in soil composition between bottom and top parts of hoed plots.

MSR.

426. Bottom	6	18	34.0	38.8	12	5.8	1.42	0.13	11.4	81	40	98
463. Top	6	13	35.9	33.2	9	6.4	1.57	0.13	12.2	123	47	114
464. Bottom	6	19	33.0	37.5	10	6.5	1.41	0.12	11.6	140	35	81
465. Top	6	14	33.9	37.1	12	6.3	1.39	0.14	10.2	95	38	25
466. Bottom	6	21	33.9	35.8	10	6.4	1.69	0.13	13.3	125	25	111
467. Top	6	11	29.2	39.4	17	6.6	2.23	0.18	12.4	105	34	34

## APPENDIX—Continued.

	Dpth	Grav- el	Crse Sand	Silt and Clay	I.T.	Reac- tion	O.M.	N.	C/N Ratio	Avail. Nutr.	Rate of Soln.	Avail. P O 2 5
	(ins.)	(%)	(%)	(%)		(pH)	(%)	(%)		(mhos x 10 <sup>-6</sup> )		(p.p.m.)

## (63) MANGO HILL. EROSION EXPERIMENT

Site on slope of small hill belonging to St. George's Hill, overlooking Elberton Valley. Experimental area where various methods of erosion control are being tested by Department of Agriculture. Soil samples comprise composites collected from made-up banks at 40 spots along same contour at top of slope and at bottom of slope. Duplicate (A and B) samples collected. *YELLOW EARTH* soil-type. Medium-low to medium organic matter and nitrogen; medium available phosphate; medium-high to high available potash. Data show no significant differences in soil composition between bottom and top parts of slope.

## MSR.

471. "A"; Hill top Bank	13	27.0	45.6	11	6.4	2.14	0.12	10.7	94	28	32
472. "B"; do. "	12	26.4	46.1	11	6.4	2.12	0.11	10.8	98	31	23
473. "A"; Hill base "	15	27.2	40.0	9	6.3	2.40	0.12	11.2	147	46	31
474. "B"; do "	13	30.6	38.8	8	6.3	2.22	0.13	10.0	150	40	32

Avail. potash; MSR. 471; 224 p.p.m., K<sub>2</sub>O  
 " " " 472; 196 " "  
 " " " 473; 160 " "  
 " " " 474; 153 " "

## (XXII) FOREST SITES

## (64) CENTRE HILLS. FRENCHMAN HILL

North east spur of central massif. Elevation 1,700 ft., moderate slope, north aspect, near hill ridge top. Rainfall, 100 ins.; parent rock, agglomerate; *RED EARTH* soil-type. Vegetation, relic of Lower Montane Rain Forest (*Dacryodes-Stonea*). Drainage somewhat impeded.

## MSR.

512. Litter	—	—	—	—	—	—	—	—	—	—	—
513. Root mat	—	—	—	—	—	—	—	—	—	—	19
514. Humic	½	—	4.5	75.5	65	4.8	12.44	.521	13.9	—	24
515. Brownish-red	1½	—	3.2	75.6	53	4.5	10.33	.453	13.2	—	11
516. Ditto. crumb	3	—	2.4	81.2	50	4.3	7.41	.326	13.2	—	0
517. Med. red	6	—	2.4	78.7	44	4.6	1.60	.070	13.3	—	5
518. Ditto.	9	—	3.0	79.3	44	4.5	3.55	.185	11.0	—	2
519. Ditto.	12	—	3.0	80.3	44	4.6	2.57	.119	12.5	—	4
520. Ditto.	18	—	3.0	78.9	45	4.5	5.16	.223	13.3	—	6
521. Dark red	24	—	2.5	80.9	44	4.5	1.14	.092	7.2	—	—

Avail. potash; MSR. 515; 140 p.p.m., K<sub>2</sub>O

## (65) SOUFRIERE HILLS. CHANCE'S MOUNTAIN

Summit between Chance's Pond and crater river; Small plateau at edge of English's crater. Elevation, 3,000 ft., moderate slope. Very wet; continuous rain; temp. 65° F. Igneous rock (?Volcanic plug). *BROWN EARTH* soil-type. Palm Brake (*Euterpe-Hibiscus*) Drainage free.

## MSR.

522. Litter; mat.	—	—	—	—	—	—	—	—	—	—	—
523. Brown crumb	½	—	18.5	60.3	—	5.2	30.69	1.287	13.8	—	35
524. Ditto.	1½	—	31.5	53.6	—	5.3	22.44	1.035	12.6	—	25
525. Ditto.	3	—	31.7	48.1	—	5.3	18.38	.843	12.6	—	13
526. Ditto.	6	—	41.2	36.8	—	5.3	10.28	.576	11.1	—	14
527. Paler, gritty	9	—	29.4	33.6	—	5.4	6.53	.397	9.6	—	7
528. Ditto.	12	—	35.2	29.3	—	5.6	4.54	.263	10.0	—	0
529. Yell. rotten rock	18	—	38.4	32.1	—	6.2	0.64	.039	9.5	—	9
530. White rock	24	—	33.2	31.4	—	6.6	0.24	.015	9.3	—	66

Avail. potash; MSR. 525; 265 p.p.m., K<sub>2</sub>O

MONTERRAT, B.W.I.

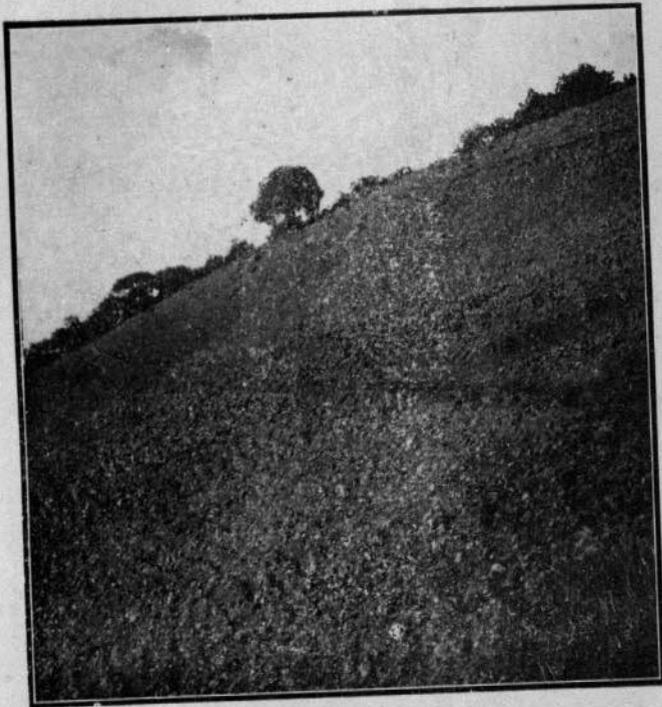


FIGURE 1 : Site (21) Bay Piece, Ile's Bay Estate.

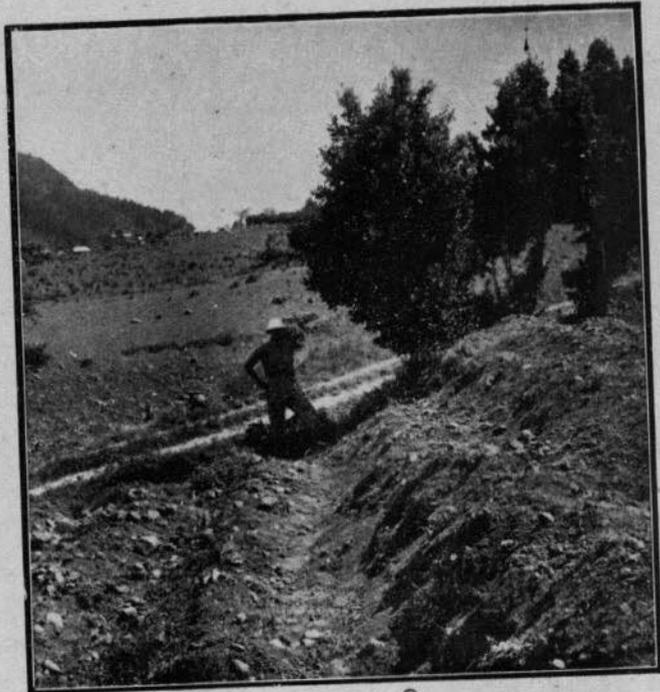


FIGURE 2 : "Hoe-rosion" Parson's

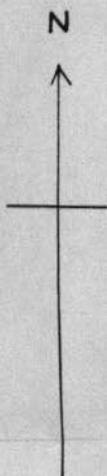
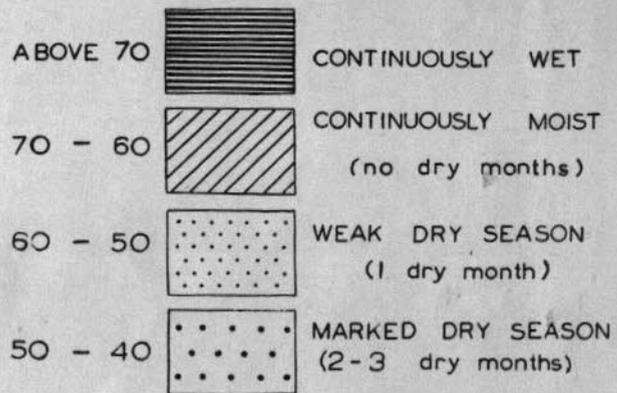


FIGURE 3 : Soil Conservation Experiment : stone wall barriers : St. George's Hill.

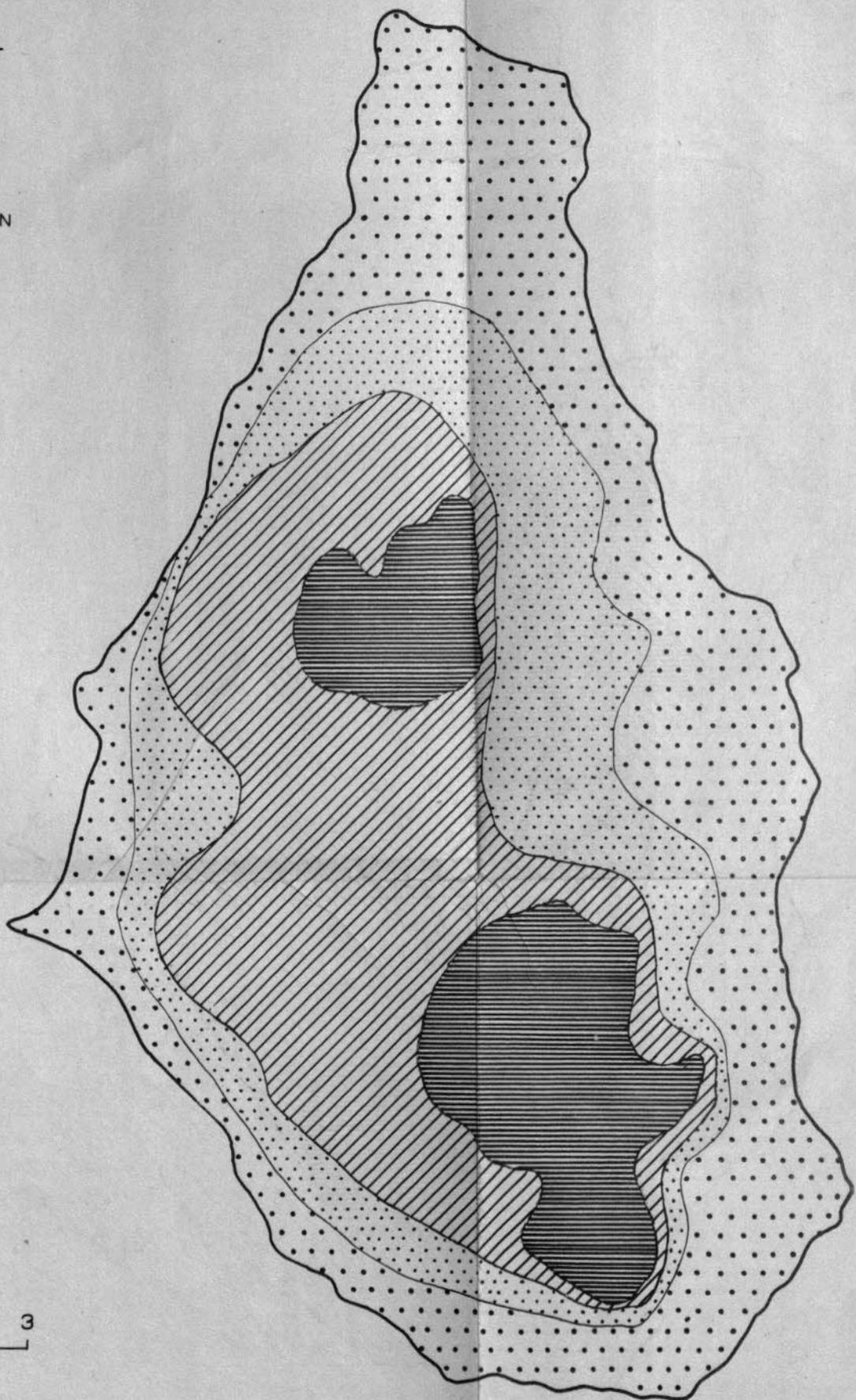
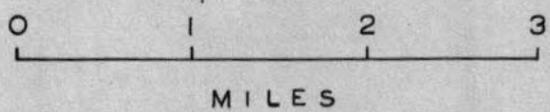
# EFFECTIVE RAINFALL MAP (MOHR)

## MONTSERRAT

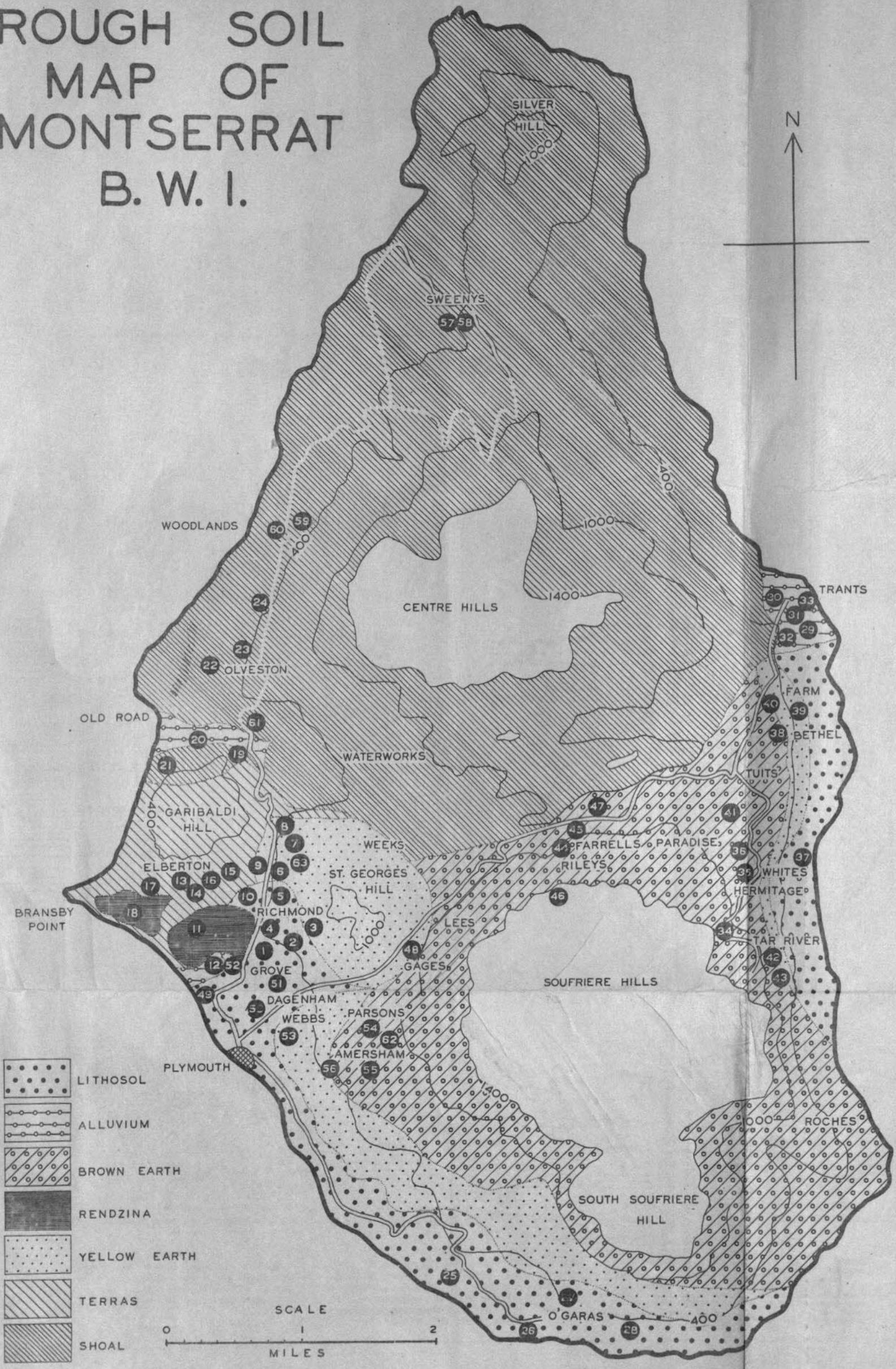
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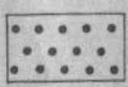
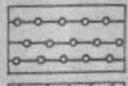
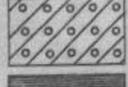
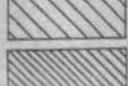


SCALE



# ROUGH SOIL MAP OF MONTSERRAT B. W. I.



-  LITHOSOL
-  ALLUVIUM
-  BROWN EARTH
-  RENDZINA
-  YELLOW EARTH
-  TERRAS
-  SHOAL

SCALE  
0 1 2  
MILES

FIG. 1 SILVER HILL

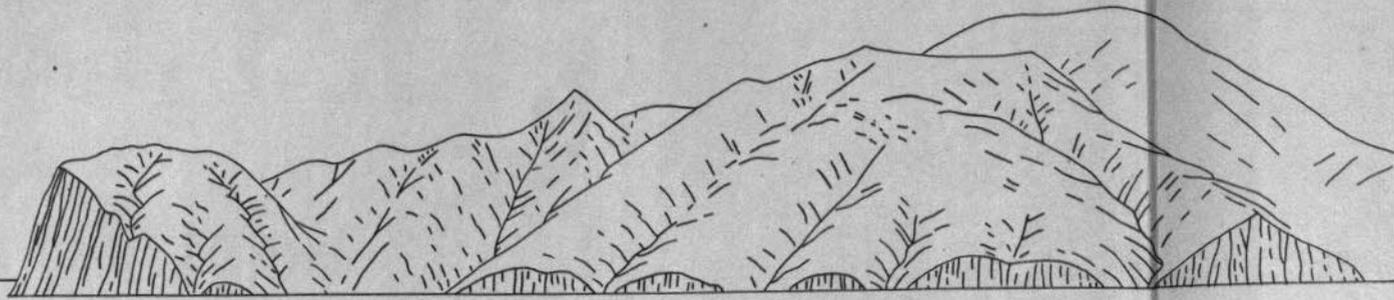


FIG. 2 CENTRE HILLS

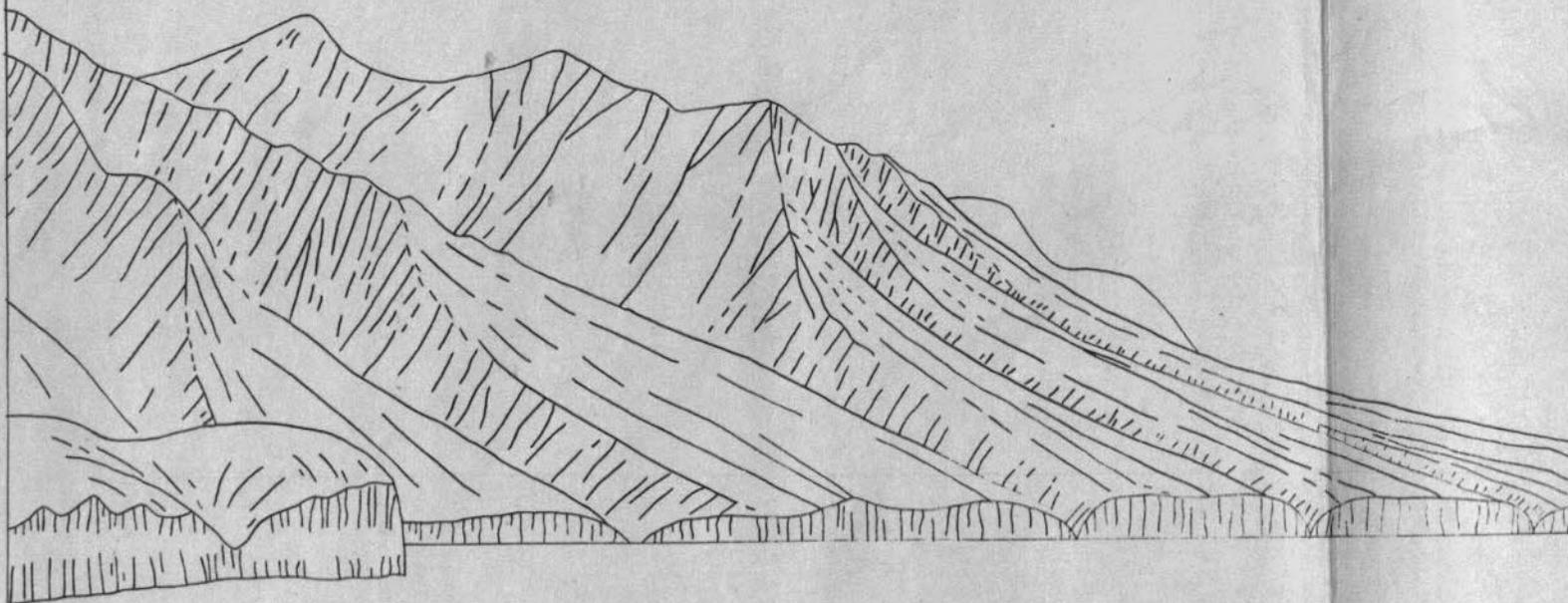


FIG. 3 SOUFRIERE HILLS

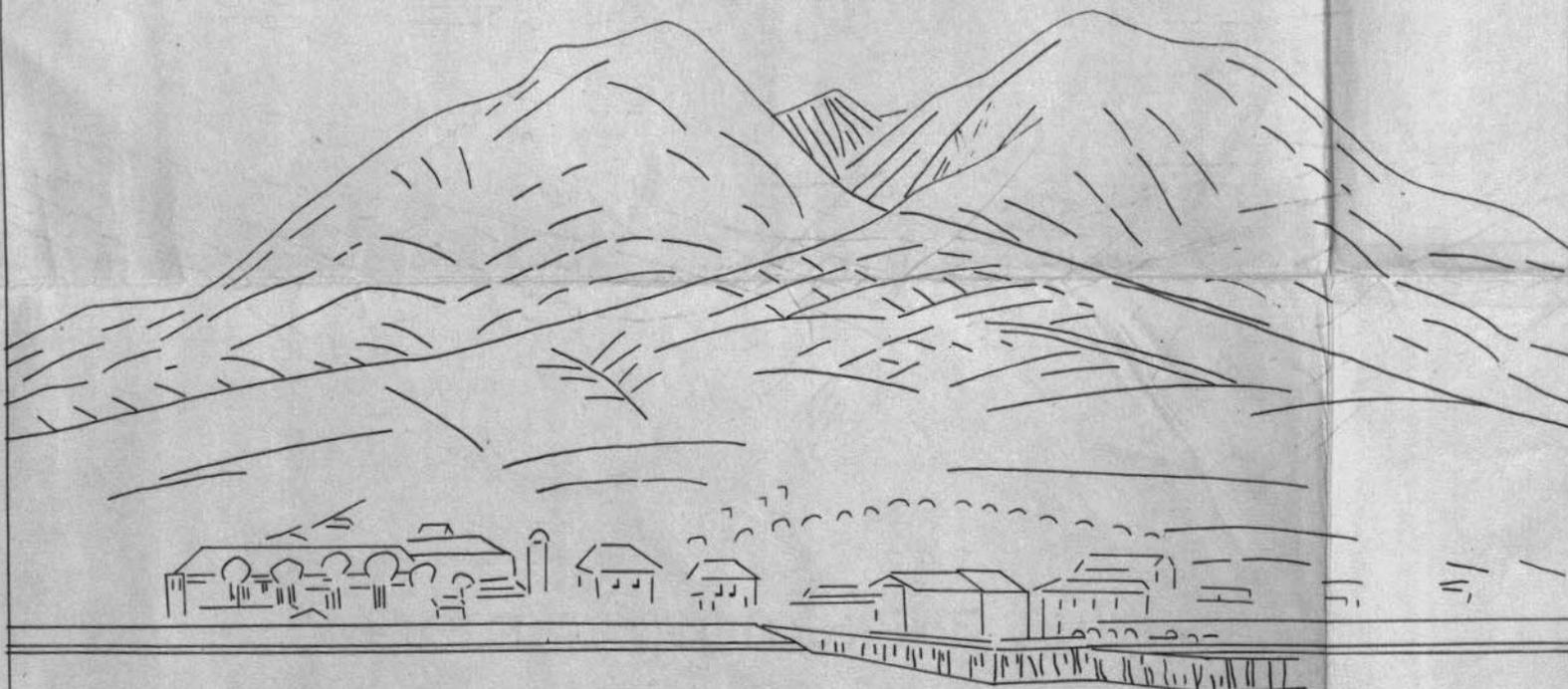


FIG. 1.  
Silver Hill, from W., showing the maturely-dissected, oldest volcano, and N. W. Bluff, 450 feet high, one of the highest sea-cliffs in the West Indies (after W. M. Davis, 1926).

FIG. 2.  
Centre Hills, from N. N. W., showing the moderately-dissected next-oldest volcano, with deeply-incised valleys and sharply-serrated ridges and low sea-cliffs. The higher cliffs in the left foreground are part of Silver Hill (Fig. 1). (after W. M. Davis, 1926).

FIG. 3.  
Soufriere Hills, from W., showing the young extinct volcano, deeply cleft in centre. Chances Mt., the highest point of Montserrat, forms the right-hand (South peak). Plymouth town on coast line, with jetty. Note "nuée ardente" volcanic ash deposits, forming a broad fan-shaped area occupied by cultivated fields in the foreground and middle distance. (from photograph, F. H. Perret, 1939).

# Topographical Map OF MONTSERRAT

