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[PLATES 21–39.]

REPORT ON THE ERUPTIONS OF THE SOUFRIÈRE, IN ST. VINCENT, IN 1902,

AND ON

A VISIT TO MONTAGNE PELÉE, IN MARTINIQUE.—PART I.

BY

TEMPEST ANDERSON, M.D., B.Sc., F.G.S.,

AND

JOHN S. FLETT, M.A., D.Sc., F.R.S.E.

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IX. *Report on the Eruptions of the Soufrière, in St. Vincent, in 1902, and on a Visit to Montagne Pelée, in Martinique.—Part I.*

By TEMPEST ANDERSON, *M.D., B.Sc., F.G.S., and* JOHN S. FLETT, *M.A., D.Sc., F.R.S.E.*

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[PLATES 21–39.]

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INTRODUCTION.

THE islands of the Caribbean chain have been occupied by European colonists for several hundred years, yet they cannot even at the present day be said to be thoroughly known or sufficiently explored. Though small, they are for the most part mountainous, and present usually a ridge or backbone of high land forming the main axis of each island, with sharp spurs on each side running down to the sea. Cultivation is practically confined to the lower grounds, where alone there are good roads, and the interior is covered with dense tropical forest, the aspect of which varies greatly with the altitude, and through which there are only rough bush paths. The valleys are usually very deep and narrow, and the steep slopes are covered with plantations of arrowroot, limes, cocoa, coffee, banana or plantain, while most of the level alluvial ground in the valley bottoms is given up to the growth of sugar cane.

In all the British islands, at any rate, the principal peaks and ridges have been ascended, and the main features of the country are delineated on the Admiralty charts, which are the best, and in fact the only available maps. As regards the coast-lines and the lower grounds generally, they are very accurate; but in the interior only the more important points, the principal mountain summits and the like, have had their position sufficiently determined. The rest of the country has apparently been sketched in more or less carefully—but many of the details as, for example, the courses of the smaller streams, and the number of their branches, cannot be relied on. The want of a good map on a fairly large scale is a great drawback in geological work, and prevents the structure of the country being laid down with any approach to minuteness.

This difficulty is increased by the rich mantle of tropical forest which covers all the surface except those parts which are highly cultivated. In the forests one may walk for hours along narrow winding paths, obstructed by fallen trunks and branches, by the roots of the larger trees, and the tough stems of the lianas, without seeing any exposure except of the deep soft soil, which in a thick layer covers the rock beneath. The branches of the trees meet overhead, shutting out the sun and affording a delightful shade; but to the right and left it is impossible to see for more than a few yards, so dense is the vegetation. Even where in such forest paths the surface of the rocks is exposed, the moist climate and the abundance of decaying vegetation are so powerful in effecting decomposition, that it may be a very difficult matter to ascertain what is their nature, and impossible to obtain specimens sufficiently fresh for microscopic examination. The great rapidity with which the volcanic rocks weather under these conditions, and the great depth to which they are covered with soft earthy decomposed material, is a source of never-failing astonishment to the geologist, and powerfully impresses on his mind the rapidity with which denudation may take place in tropical countries. The rivers and streams in the lower parts of their courses flow, as a rule, through alluvial deposits of gravel and boulders, but in the higher valleys good rock exposures are more frequent, and much may be learned from an examination of their banks. This is, however, no easy task; so dense is the growth, so frequent are cascades and waterfalls, and so numerous the large boulders obstructing the streams, that such exploration is a most laborious undertaking. If we add to this the difficulty of continuous exertion in a temperature approaching 80° F., and an atmosphere saturated with moisture, it will be seen that minute geological mapping is not to be accomplished under the circumstances.

On the other hand, the broad general features of the geology of the country usually can be easily made out with fair accuracy. As already stated, the conditions are all in favour of rapid erosion. The islands are so narrow and their central mountain axes so high that the ground slopes steeply on each side into the sea. The rainfall is heavy, averaging perhaps 100 inches on the low grounds, and much greater at higher elevations, and it is so distributed as to produce the maximum of geological effect. It is greatest in the rainy season, which in most of the islands lasts from the beginning of July to the end of September. In the dry season there is sometimes no rain for days. It usually takes the form of short heavy showers which are soon over and leave the streams in raging flood, and not unfrequently an inch of rain falls in an hour, and a rainfall of several inches in a day often takes place. This is sufficient to make streams which are usually quite dry, rise and overflow their banks in floods which sweep everything before them to the sea. Even the smaller brooks, which are often dry in fine weather, have their channels filled with very large boulders, 8 feet or more in diameter, which show by their rounded and worn surfaces that they have been transported for some distance. When we remarked this to one of the planters in St. Vincent, he gave us numerous instances in which streams apparently of trifling size had moved large rock masses, and had done great damage to bridges, retaining-walls and other structures. Engineers have encountered great difficulties in making roads through the British colonies to withstand the devastation occasioned by the heavy rains. All the less important thoroughfares and the bridle-paths are frequently rendered impassable by the water cutting across the road and washing out deep channels. These are then filled up by a band of labourers with large hoes, who dig up the soft rotten rock from any convenient spot by the road side and cast it into the furrows, some of them 6 or 10 feet deep.

These deluges of rain not only greatly increase the cutting power of the streams, but they also saturate the soil and render it particularly liable to slip when it is lying on steep ground. Much of the ground under arrowroot cultivation on the leeward side of St. Vincent lies on the side of ridges and slopes at angles approaching 40°. When the plants have been dug up and the surface is left nearly bare, a few showers of heavy rain may cause extensive landslips, and the planter may have all the valuable soil stripped from a considerable part of a field in a few minutes. So deep and narrow are the valleys, that on each side the material is resting practically at the angle of repose, and anything which facilitates interstitial movement or lessens the cohesion of the particles, is sufficient to cause a landslide. Thus it will be readily understood that in a typical Caribbean valley the experienced eye can perceive how every feature of the surface is determined by the underlying geological structure. The coulées of lava stand out as vertical cliffs, which give foothold to only a few scattered plants which have managed to take root in the crevices and cracks. The columnar jointing, though often rude, is usually sufficiently pronounced to yield characteristic surfaces, and to indicate the nature of the rock from a distance. This, however, is not always a safe criterion, for it is possible to find beds of tuff which weather in much the same way. As a whole, the tuffs are softer and crumble more readily than the lavas, yielding abundance of loose material which gathers in sloping taluses on the flanks of the valleys. These weathered ash beds form rich soils, and, where possible, are cultivated; but even in the higher elevations, where there is little cultivation, they are clothed with luxuriant vegetation, and contrast strongly with the bare cliffs of lava.

In most of the islands the coast sections are very fine, and as it is possible to row in smooth water along the leeward shore, much information can be obtained in this way. The sharp spurs running down from the main axis end as a rule in prominent headlands with high rocky cliffs which give good natural exposures of the geological structure. Between these promontories the streams debouch in little bays, which show a sandy or gravelly beach in their centre. A sail along the leeward shores in a small boat, which keeps close to the land, is a very pleasant and instructive experience for the geologist. Each headland furnishes a clean cut geological section, while in crossing the bays magnificent views are obtained of deep valleys, steep sided, gloriously picturesque, cultivated below, but higher up clothed in tropical forest, and in the background lofty peaks with their summits veiled in mist.

In many respects the investigation of the geological history and structure of the Antilles is one of the most fascinating branches of geological research. The evidence of repeated and prolonged eruptive activity, of great changes of level in comparatively recent times, of profound alterations in the distribution of land and sea, of enormous erosion, and the accumulation of great detrital deposits and masses of organic limestones, have combined to excite the interest and awaken the enthusiasm of geologists. But so far as concerns the recent eruptions and the islands involved in them, there is no need to enter into a discussion of the many interesting and difficult problems of Caribbean geological history.

St. Vincent, Martinique, Dominica, St. Lucia, and Grenada are almost entirely volcanic, and there is no reason to believe that their rocks are older than the Pleistocene. They are built up principally of tuffs and agglomerates, with a smaller proportion of lava flows—the preponderance of fragmental ejecta being typical of the group. The epoch of maximum volcanic activity has probably long since passed away, though there are records of eruptions in historic times in Martinique, St. Vincent, St. Lucia, and Dominica; and in Grenada there is a well-preserved crater with a lake—the Grand Étang. All the islands show abundant solfataric action; most of them contain one or more "Soufrières" emitting steam and sulphuretted hydrogen.

In Guadeloupe and in Antigua there are fossiliferous deposits possibly of Miocene age interbedded in the volcanic tuffs, and it may be that eruptive activity in the Leeward Islands dates back to the Eocene. But in the Windward Islands the oldest fossiliferous beds are Pleistocene or recent. Rocks of this age occur at elevations of several hundred feet above the sea in Martinique, St. Lucia, and Grenada, and to whatever period the outbreak of volcanic activity is to be assigned, there can be no doubt that it has continued through the Pleistocene up to the present day.*

* R. T. Hill, "The Geology of Jamaica," 'Bulletin of the Museum of Comparative Zoology at Harvard College, 1899,' vol. 34 (Geological Series, vol. 4), p. 223.

THE PHYSICAL FEATURES AND GENERAL GEOLOGY OF ST. VINCENT.

The Lavas and Tuffs of the Old Volcanoes of the South End of the Island.

The outline of St. Vincent is the elongated oval which is characteristic of the Windward Islands, the main axis lying north and south, and corresponding with the direction of the group as a whole. The length of the island is 18 miles, the greatest breadth 11, and the total area is estimated as 150 square miles. In the coast line there are no important indentations, the largest being Kingstown Bay, near the south end, on which the principal town stands. The only villages of any size are Georgetown, on the windward side of the island, near its north end, and Barrualli and Chateaubelair on the leeward, the latter almost opposite Georgetown. The population of Kingstown is estimated at 7000, that of the whole island at 40,000, and is for the most part black or coloured, there being only 1500 whites. Arrowroot is the staple product—St. Vincent arrowroot has long had a high reputation. Sugar has almost gone out of cultivation, but cocoa, coffee, cocoanuts, nutmegs, bananas, and a great variety of fruits grow well, and are to some extent exported.

The island may be described as almost mountainous, there being little flat land except in the valley bottoms and around the shores of the larger bays. On the windward or eastern side there are old terraces or benches of marine erosion which form a narrow rim of comparatively level country skirting the coast. On the leeward side the land slopes steeply to the sea. The average density of the population is high —nearly 300 per square mile—or almost equal to that of the Isle of Wight and some of the less populous English counties. Yet it is only the valleys and the low ground near the coast which are really inhabited, for the higher ridges are covered with forest and bush, through which there are few paths. Some of the mountain peaks have rarely been ascended, as may be understood when it is explained that a journey in these regions cannot be made without several sturdy labourers armed with cutlasses with which to hew a way through the dense undergrowth which often obstructs and may obliterate the paths. Owing to the fertility of the soils, the warm climate and the abundant rains, a very small plot of ground is sufficient to support a black man and his family in comfort. They require little clothing, and there is almost no demand for luxuries. Many of the blacks are employed as labourers and as servants on the estates, but it has of late years been the policy of the Government to plant them out on the Crown lands as peasant proprietors, each on his own small allotment. The best ground, however, is always occupied by the arrowroot and sugar estates, many of which have been in cultivation for nearly 200 years.

A ridge of hills runs along the centre of the island in a north and south direction, the principal peaks being the Grand Bonhomme (3193 feet), the Morne Garu and

Richmond Peak (3528 feet), and the Soufrière (4048 feet). If we except the last, which forms the north end of the chain, we may say that the form of all these mountains indicates that they have suffered prolonged and intense erosion. Though of volcanic origin, none of them shows a crater or a well-preserved cone. A series of radiating valleys, very deep and narrow, has been cut into the old volcanic pile, and between these valleys there are high steep-sided spurs, the summits of which are knife edges often only broad enough to serve as a footpath. In the recent geological history of the island erosion has been of vastly more importance than accumulation. This is due to the causes already enumerated; and nowhere better than in St. Vincent can the rapidity with which denudation takes place in a moist tropical climate be studied and exemplified. Excepting on the steepest slopes, where loose accumulations will not rest, the rocks are deeply covered with weathered material, which has either been formed *in situ* or has been carried down by landslips or as rain-wash.

The rainfall is not equally distributed over the year, as June, July, and August are usually the most rainy months, while January and February, March and April, constitute the "dry season." It averages about 110 inches in the year, according to the records kept for many years in the Botanic Gardens at Kingstown.* Among the mountains, however, especially on the windward side, it is much greater than this. Most of it falls in short heavy showers, which fill the rivers up to their banks, and make them difficult or dangerous to cross when they are of any size. Even after gentle showers the water is muddy from the quantity of sediment it carries. The smaller brooks have usually their channels encumbered with large boulders, which have obviously been brought down in floods and left stranded when the water subsided. The steep and winding road which passes along the leeward shore is in this way often obstructed by falls of earth or rock. A very brief residence in the Windward Islands is sufficient to convince a geologist that erosion is there proceeding with great rapidity, and that although the volcanic masses have been deeply sculptured, they are not necessarily of great geological age.

The axial mountain ridge is as a whole fairly continuous, at any rate from Mount St. Andrew, which overlooks Kingstown to Richmond Peak, which is a few miles south of the Soufrière. Some of the streams, however, in cutting back the heads of their valleys from opposite sides of the island, have nearly succeeded in meeting across the main ridge and uniting to form a low open channel from side to side of the island. The valley of the Buccament has been cited by Professor SPENCER as "crossing the

* Mr. HENRY POWELL, Curator of the Botanic Gardens in Kingstown, St. Vincent, has kindly furnished us with tables of the rainfall at that station during the last seven years (including this year up to the end of November). The average monthly rainfalls for that period are as follows:—January, 5·78 inches; February, 4·29 inches; March, 3·79 inches; April, 4·22 inches; May, 9·85 inches; June, 12·87 inches; July, 11·34 inches; August, 11·97 inches; September, 13·69 inches; October, 10·84 inches; November, 12·05 inches; December, 9·78 inches. It will be seen that the first four months of the year constitute the "dry season." The average yearly rainfall is about 110 inches.

island to the sea, so that a comparatively small submergence would convert it into a strait."* But a better instance of this is the broad open valley on the south side of the Soufrière, between that mountain and the Morne Garu. It is a significant fact that there is no good road from the leeward to the windward side over the mountains, and that the only passable footpath was an old Carib track which started from Chateaubelair and went to Georgetown. It led right up to the edge of the crater of the Soufrière before descending on the other side, an ascent of 3000 feet. It stuck to the summits of the spurs between the valleys, where the vegetation was least dense, and there was least probability of a wash-out due to the sudden rains and floods. At first glance it would have appeared easier to follow the course of the valley across the island, but this would have passed through dense forests, and the lateral streamlets descending the side of the valley to join the rivers would have been difficult to cross in time of flood, and would have caused much damage to any road carried over them. In such a situation a road would also have been exposed to landslides and falls of rock, which would have often rendered it impassable.

In consequence of the small size of the island, none of the rivers of St. Vincent are of any magnitude. Their courses are remarkably short and straight, being mostly nearly at right angles to the coast-line. The drainage is of a very simple "consequent" type, and intimately connected with the geological structure of the island. The most striking feature of the stream-valleys is their great depth, especially in their upper parts, where they present many of the characteristics of cañons. This is best seen in the devastated country, where the surfaces are now quite bare and have a desert aspect.† The casual streamlets which descend the valley walls after sudden rains form niches which furrow the surface, and the alternation of vertical cliffs of lava with sloping taluses of weathered ash produces features which strongly recall those of the cañons of western North America. As the streams are still cutting rapidly along most of their length, it is rare to find any extensive plains of alluvial deposit except near their mouths. The sea is too deep for the formation of deltas, but in many of the bays there is a small stretch of flat ground with usually a curved storm beach facing the sea. Higher up the valleys narrow flood plains may be found, but they are few; and sugar cultivation, which is best carried on on level ground, is almost entirely confined to the coast.

The whole of St. Vincent is of volcanic origin. There are no marine sedimentaries, and no organic limestones. All the available evidence goes to show that the island is the product of prolonged volcanic activity, and that the materials accumulated on a land surface, without any intervals of depression during which marine sediments were formed. By far the most common type of rock is a coarse volcanic tuff or agglome-

* J. W. SPENCER, "The Windward Islands of the West Indies," 'Trans. Canadian Inst.,' vol. 7, p. 364.

† TEMPEST ANDERSON and JOHN S. FLETT, "Preliminary Report on the recent Eruption of the Soufrière in St. Vincent," 'Proc. Roy. Soc.,' vol. 70, Plate 2, 1902.

rate, sometimes containing blocks 20 or 30 feet in diameter, and nearly always full of bombs and ejected fragments a foot across or more. These beds are red or brown in colour, and are principally andesitic or basaltic in composition. As a rule, their bedding is very rough, many thick masses showing only faint and inconstant bedding planes several feet apart. Splendid sections of these agglomerates are to be seen along the leeward coast, where cliffs several hundred feet high are built up entirely of such materials (see Plate 22, fig. 1). It gives the impression that in the Antillean volcanoes violent explosive action has been far more frequent than the outpouring of streams of lava, and that the recent eruptions are in this respect typical of the region to which they belong. But when we compare the beds of ash which have been laid down during the present year with those of older date which may be traced in the cliff sections, we are led to the conclusion that in comparison with former convulsions this last is a pigmy affair.

The possibility that in these thick masses of coarse volcanic ejecta we may have the remains of former craters—necks, dissected and exposed in the cliffs by the erosive action of the sea—is one which at once suggests itself to the mind of the observer. But nowhere did we see a section which could be regarded as that of a typical neck, whether plugged by agglomerate or by crystalline rock. Wherever the structural relations of these masses of coarse ash to the surrounding rocks were well seen, they proved to be those of thick irregular beds, lenticular in character, and passing laterally into thinner and more uniform sheets. The rapid variation in coarseness of material when traced along the strike, the irregular thickness of the beds, and the imperfect development of the bedding planes, together with the absence of fossiliferous intercalations, are best explained on the supposition that we are dealing with a series of purely sub-aerial volcanic deposits. The rarity of necks is partly a consequence of the simple character of the Antillean volcanoes, as exemplified by the Soufrière and several others recently extinct but still well preserved—where parasitic or lateral craters are exceptional.

Further evidence of land conditions is furnished by the numerous sections of old stream-valleys in the agglomerates (see Plate 22, fig. 1). Some of these are well shown in the cliffs near Cumberland, a little north of Chateaubelair. Deep gullies have been cut out of the beds of ash, and these have been filled up with material, which at the sides slopes steeply towards the centre of the trough, while in the middle the bedding planes are flat or slightly concave. Some of these valleys must have been veritable gorges, deep and narrow. A peculiar volcanic conglomerate, composed of blocks weathered out of the old ash beds or lava streams, but water-worn and well rounded, is the deposit which usually occupies them. It is easily recognised after a little practice, as it is very different in appearance from the purely volcanic tuffs. The sorting action of running water is often exemplified in these conglomerates. Some beds consist almost entirely of large, well-rounded boulders, while others are much finer grained, and composed of sandy sediment deposited by gently flowing streams. Such alternations give a pronounced stratification to these accumulations, yet the individual beds are never persistent but always very local, and the irregularities of the bedding and of the dip are explained by the rapid variation of tropical streams in volume and velocity of flow.

Although lava flows are not the predominant feature of the coast sections, and are far less important than the ash beds—yet it is not to be imagined that they are rare or absent. There are many fine examples of them on both the leeward and the windward shores of St. Vincent. Their mass is often considerable, as they are frequently 40 feet and sometimes 80 or 100 feet thick, and some are nearly a mile in length. They are mostly andesites or andesitic basalts, porphyritic, with large crystals of pyroxene, plagioclase felspar, and commonly olivine. On the fresh fracture their dark colour and vitreous lustre often indicates the presence of considerable amounts of a glassy base.

The thickness of these lava flows and the large area they cover are two of the most striking features of the geology of the island. Among the more important examples may be mentioned the lava which outcrops on the south side of Kingstown Bay, that which occurs below Petit Bordel, at Chateaubelair, and that which forms the Black Point, south of Georgetown. On the leeward coast, near Cumberland, and also near Barrualli, thick streams of lava may be seen in the sides of the valleys a little distance inland. By the vertical cliffs they form they can be easily traced as they run up the valleys, and it is clear that they are of considerable age; for, as they appear on both sides of the stream at the same level, they were at first continuous, and have been cut up into separate blocks as the streams deepened their course and worked through them into the softer ashes below. It is this alternation of ash beds with columnar-jointed lavas which yields under the influence of sub-aerial erosion those picturesque and varied effects which make the island of St. Vincent famous for the beauty of its scenery.

It is possible that a certain number of those crystalline rock masses may really be not lavas which flowed out on the surface, but massive intrusive sheets injected between the bedding planes of the ashes; and in that tropical climate, amid the dense forests, and on such difficult ground, it would be a task of no small labour to establish in every case what is their true nature. Wherever it was possible to investigate thoroughly their structural relationships, they proved, with very few exceptions, to be true lava flows, though they are not frequently scoriaceous, even on their upper surfaces. The bedding of the ashes in which they lie is, as already stated, rough and irregular, so that it is not easy to show that they are strictly interbedded or conformable. Small discrepancies between the apparent bedding of the tuffs and the lava flows are not to be regarded as important. On the whole the greater lavas form flat sheets with a gentle uniform dip which agrees with that of the tuffs where these exhibit a good bedding. Owing to their greater regularity in this respect, the lavas afford better evidence to the geologist as to the true dip and structure of the country than the irregular, inconstant, and often tumultuous deposits of tuff.

The lavas, like the ash beds, have certainly accumulated on a land surface. Occasionally we may see where a lava flow has entered an old valley and has partly or completely filled it up, and frequently the base of the lavas is so irregular as to show that the surface over which they flowed had been sculptured by sub-aerial erosion into numerous ridges and furrows. The curved outcrops not unfrequently suggested that folding had taken place and thrown the beds into little anticlines and synclines, but examination always revealed the eroded character of the underlying material, while no proof of folding on such a small scale was ever obtained.

A layer of bright red earth very commonly lies directly below the lavas, and where the rocks are utterly decomposed, this may be one of the best indications of the nature of the overlying mass. It is undoubtedly an old terrestrial soil in which the hydrous iron oxides have been changed to hematite by the action of the hot lava flow. This layer is usually about a foot in thickness and consists of a decomposed ash bed (only very rarely do two lavas come together in the sections) in which the fragmental structure is becoming obliterated, baked and hardened into a splintery red clay or porcellanite, especially where it is fine grained and in immediate contact with the lava. We did not find any remains of burnt wood or other fossils in these old soils or in any part of the tuffs.

Intrusive sheets also are not lacking in St. Vincent, though according to our experience they are few and small. There are some sections which show junctions so decidedly transgressive that they can only be due to the injection of molten masses into fissures in the tuffs. Good examples are to be seen at Dark Head, on the leeward coast, and Duvernette Island, near Calliaqua. They are so rare, however, that it would not be difficult to enumerate every instance which came under our notice. In no case are these masses of great size, but some of the more important lava flows attain to such great thickness, and are so lenticular in character, that they greatly resemble laccolites. One of these in the Cumberland Valley, about a mile above its mouth, forms a beautiful columnar cliff nearly 300 feet high, overlooking the stream. There was not, however, sufficient available evidence to prove that it might not be a lava flow occupying an old valley channel, and very thick in consequence. There is another great cliff of crystalline and columnar-jointed rock in the Mariaqua Valley, and from the regularity of this mass in dip and thickness it is most probably a lava flow.

In the splendid sections on the leeward side of the island, dykes are as rare as intrusive sheets. The exposures are so good that this is sufficient to indicate their scarcity, but in the interior of the island, owing to decomposition of the rocks and the thick growth of forest, they would be practically certain to escape detection. Three or four dykes were seen cutting the tuffs near Layu.

The rarity of dykes, intrusive sheets and necks, are characteristic features of the Antillean volcanoes, which find their explanation in the peculiarities of their methods of eruption. They have been mostly explosive volcanoes, emitting great quantities of ashes, bombs, and ejected blocks, with occasional flows of lava. In this way great simple cones have been built up, mostly with one or more craters near their summits. Parasitic craters and lateral outlets have been rare, owing to the great strength of the volcanic structures, and as a rule the old orifices have been repeatedly made use of in the eruptive history with few and unimportant modifications. This has been the story of the recent outbursts, and is in accordance with the structure of the best preserved dormant or extinct volcanoes of the Caribbean chain. They are simple cones, sometimes breached, or surrounded by an old "Somma" wall, and consist for the most part of ash with more or less abundant coulées of lava.

So far as it was possible for us to ascertain, the geological structure of St. Vincent is very simple. All around the coasts the dip of the rocks as indicated by the great lava flows and the more persistent beds of ash, is outwards from the centre. On the leeward side the lavas dip to the west at gentle angles (averaging about 10°). At the south end and near Kingstown the dip is mostly south, while on the east or windward side the dip is also towards the sea. The ash beds are more irregular in this respect, and within short distances may show considerable variations. But, taken as a whole, they always agree fairly well with the dip of the lava flows, and they practically never show an inclination towards the centre of the island. We are, in fact, dealing with a highly eroded volcanic pile, a chain of old volcanoes, and the position of the craters and outlets must have nearly corresponded with the central ridge of hills. The radial outward dip is a reflex of the slopes down which the lavas flowed, and on which the ash beds gathered. Over these surfaces the streams ran in more or less direct courses to the sea.

Along this central ridge, apparently, no craters, except that of the Soufrière, can now be found, and none are indicated on the map. Erosion, most rapid on the higher grounds, has already obliterated them. But it is there they are to be searched for, and though the task is a well-nigh hopeless one, the remains of them may yet be found. In all probability most of them are filled with agglomerate, but some may be represented by great bosses of crystalline rock like the Pitons of St. Lucia. We searched carefully in the streams which descend from the main ridges, and along the shores of the whole island for specimens of true plutonic rocks of dioritic character, but none were found, and this helps to demonstrate the comparatively recent nature of the whole island, and corroborates the evidence drawn from other sources as regards its geological history.

It is, of course, possible to regard the island as an anticline or dome rising on the summit of a great earth fold, such as is indicated by the soundings on the charts as separating the Caribbean Sea from the Atlantic. But there are certain facts to be enumerated shortly which this would not explain, and in the whole island there is a remarkable absence of folding, contortion, crushing and faulting. Small faults were occasionally seen, but very rarely. None of the big masses of lava could be proved to be cut by any considerable faults, and the irregularities in their outcrops were to be explained by the variation in thickness due to outflow over a rough eroded country rather than as a consequence of folding or deformation. In some of the other islands evidence of faulting is far more abundant than in St. Vincent, though it may be admitted that, except they cut the more persistent lava streams, it might be very difficult to establish the existence of faults, as the ash beds are so lenticular in character and so irregular in their dip.

The Morne Garu and Richmond Peak, which stand just south of the Soufrière, are the best examples of highly eroded extinct volcanoes in the whole central mountain chain. We lived for several weeks at either Chateaubelair or Georgetown, on opposite sides of this mass, and had many opportunities of observing the disposition of its rocks, especially as on its north side the bush had been burnt or overthrown during the recent eruption. On the west, great lava streams descend by Richmond, Richmond Vale, and Chateaubelair to the sea. On the east there are important lavas behind Georgetown and at Black Point, with an easterly inclination towards the coast. On the north side the dip is northwards, towards the Soufrière (see fig. 2, Plate 29), and on the south side of Morne Garu at least many of the lavas have a dip towards the south. Hence it appears that the rocks are so disposed as to dip outwards on all sides from the centres or summits of these mountains, and this agrees with the supposition that they are the remnants of a highly eroded volcano (or less probably two adjacent volcanoes), which in its prime was probably of considerably greater magnitude than the Soufrière. Few men have ascended to their summits. We could find only one who had been there—a black guide, and from what he told us, it seemed certain that there are no craters, but that the extreme top is formed by sharp knife-edged arêtes between deep valleys as is indicated on the map (see Plate 39). Even in that case it is likely that of all the extinct volcanoes of St. Vincent, this was the last to die out. In the deep radial valleys which have been carved out of the mass, we find the consequences of its former conical surface. It seems probable that volcanic activity has persisted in the north end of the island long after it ceased at the south.

The Upraised Sea Beaches.

One of the most marked features of the geography of St. Vincent is the presence on the windward side of considerable stretches of comparatively level country, which contrast strongly in general character with the highly eroded and deeply sculptured uplands. There is no such belt along the leeward shore, and consequently the largest and richest estates are to be found on the east side of the island, where also the population is most dense. The road from Kingstown to Georgetown, the only carriage road in the island, after crossing the ridge behind Kingstown, passes entirely through this flat country, with rich cultivated land on each side, except where it skirts the sea shore. The Carib Country at the base of the Soufrière, north of Georgetown, is part of this tract of low ground, and on it stood some of the largest and best estates in the island, now devastated and covered by volcanic ashes (see Plate 21, fig. 1).

The difference in aspect between the flat-terraced coastal plains on the windward, and the sharp spurs and deep valleys which on the leeward side run right down to the sea, is so striking as to call for explanation. The windward plains are eroded and cut into by valleys, but these have none of the rugged steepness which makes the leeward coast so picturesque. The ridges between the valleys are broad and flat-topped, with fine fields of sugar-cane and arrowroot. They differ entirely from the knife-edges which separate the ravines on the higher grounds and the narrow ridges between the deep valleys on the western shore. In some places the low, round-backed hills have rather the appearance of a chalk country in the south of England.

The line of demarcation between these two terranes is in many places fairly well defined. Its altitude is about 700 feet above the sea. Not unfrequently, however, the one type of country blends with the other; there is no sharp boundary, but the hollow, concave, deeply incised features of the uplands soften and gradually give place to the rounded, convex, somewhat flowing outlines of the plain country beneath.

In some places this coastal plain is beautifully terraced. Flat benches, separated from one another by steep declivities, mark successive levels of the sea during some previous epoch of submergence. One very persistent terrace is almost 200 feet above the sea level. It is very conspicuous about Mount Pleasant and Brighton on the windward road, 6 or 8 miles from Kingstown. Below it two lower flats can also be seen, and above it there are others. The highest well-preserved beach which we saw was on the south side of the Mariaqua Valley, at about 690 feet above sea level, but, as a rule, the higher terraces have suffered from erosion far more than the lower, and are much less perfect and less easily traced. In all there are at least six or seven of these old sea levels, though, in the absence of an accurately contoured map, much time would have been required to ascertain their exact number. In some places near Brighton it is possible to make out four, one above another.

They are never capped with uplifted coral reefs as are some of the raised beaches of Dominica and Grenada. Careful inquiry showed that there was no limestone in St. Vincent, and that all the lime used was obtained from blocks of coral taken from the living reefs along various parts of the shore. Nor, so far as we saw, are they covered with deposits of beach gravel, as in the more recent raised beaches of Dominica. This may be so in some places, but it cannot be by any means common. Good sections of these terraces are quite frequent on the windward road, which often runs upon their surfaces for short distances, and these show them to be rock platforms carved by marine erosion out of the tuffs and lavas of the island.

The absence of coral and gravel deposits, the depth and number of the valleys cut across the beaches, the imperfect preservation of the lower ones, and the fragmentary condition of the higher, all prove that they are not of recent date, but have been for a very long time exposed to sub-aerial denudation, and are in process of decay and disappearance. The cliffs behind the ledges have had their outlines softened and rounded, the streams have cut deep channels in the rock platforms, reaching new base levels at greater depths, and as the valleys widened they have encroached, to a large extent, on the flat-topped ridges between. Any superficial accumulations which formed on them have long since disappeared. They may, however, have been quite unimportant. Coral is not very abundant around St. Vincent, possibly because the streams flowing through the soft and weathered tuffs discharge great quantities of mud into the sea, discolouring it, after heavy showers, for several hundred yards from the shore. The surf, which constantly beats on the weather side of the island, has carved a broad submarine plateau opposite the headlands. In the bays and across the stream-mouths sand and gravel gather, but on the points between the bays there is usually no beach, but only a flat platform, all awash and covered by the sea. It is on these headlands that the old raised beaches are most conspicuous, and in such situations there is no mistaking their meaning. As seen in profile they have mostly a slight but perceptible slope towards the water. In section parallel to the coast they are sensibly horizontal. But in the sides of the valleys and up the stream-courses it is far less common to find these beaches well preserved. For this there are several reasons. The cutting power of the sea is least in these places, and accumulation of gravel is more common than erosion and removal of the solid rock. Rock ledges may never have been cut, or, if cut, must have been quite small. Any gravel beaches formed in such bays would be rapidly carried away by the streams which took possession of them when the sea retreated. Moreover, it seems probable that the lower courses of most of the less important streams are subsequent to the terraces and have been carved out of them, so that in the formation of the stream-valleys the beaches must have been removed by erosion.

Further evidence of the great age of these features is afforded by the depth to which the rocks composing them have weathered under the attack of atmospheric agencies. On the leeward side of St. Vincent, and everywhere also in the higher elevations, although decomposition is rapid, there are abundant exposures of fresh rock, for the steep slopes facilitate removal of loose material, and landslips and the washing action of the rain keep the surfaces clear. On the lower grounds often a great thickness of rotted rock may be found in certain situation. The taluses on the valley sides, where not exposed to the main streams, may be very deep. The soft ash weathers readily into a fine, friable dark soil, and after a heavy rainfall the lateral rivulets may cut into this to depths of 30 feet without exposing solid rock beneath, but this is local. On the windward side, however, it is the exception to see fresh rock exposed on the surface of the terraces. So advanced is the decomposition that it is often very difficult to distinguish a weathered lava from an ash bed. A brown earth covers everything, fine as a whole, but often full of rounded stones, which are usually the bombs and ejected blocks of the tuffs, more resistant to decay than the finer matrix between. Occasionally a lava assumes this appearance, and then it is only by proving that all the rounded masses have the same petrographical character, or by finding that the matrix shows the same porphyritic crystals as the harder kernels it incloses, that we can establish what the rock was originally. The presence also of the red layer of baked soil beneath the lavas often confirms the diagnosis. The more basic lavas weather spheroidally, and the brown, rotten earth shows then innumerable spheroids, large and small, composed of concentric shells. The weathered material is known in St. Vincent as " Pozzuolana," and is much used for dressing the surface of the roads.

On the coast, a little south of Georgetown, a peculiar brown earth covers the volcanic rocks to a considerable depth. The road just north of Colonarie Point passes beneath cliffs of this material, over 50 feet in height, which continue up to near Black Point. It is dark-yellow or brown in colour, soft, fine-grained, with numerous blocks and rounded fragments scattered through it. Occasionally it shows a fairly good bedding, the division planes being 2 or 3 feet apart. Some of the larger stones are vesicular volcanic bombs, others are pieces of various lavas, all of types frequent in the island. This deposit contains no fossils, and apparently has not accumulated beneath water, for there has been no sorting of the materials, and the rough imperfect bedding is quite unlike that of an aqueous formation.

Its most significant feature is the dip of the rude bedding planes. When the material lies on slanting ground the dip is down the slope and parallel to the surface. On the rounded backs of the ridges between the valleys the beds lie flat. In other words, the bedding shows an intimate relationship to the surface configuration of the country. Not infrequently "unconformabilities" are to be observed (see Plate 22, fig. 2), slanting layers overlapping others nearly horizontal. The nature of the material above such an "unconformability" and below it does not differ.

The origin of this formation is somewhat of a problem. In many features it resembles a pulverulent ash which has been showered down from above, and has covered every irregularity of the surface with a layer of fine ejecta. Each bed might be supposed to represent an eruption, and the larger fragments might be bombs and ejected blocks. Such loosely aggregated ash might be expected to be especially liable to rapid decomposition. But a coating of this nature would certainly be readily eroded by the tropical rains, and washed off the slopes into the valleys. It should occur mostly near the Soufrière, as that is the only volcano in the island which shows any evidence of having been in activity for a long time past. This deposit, however, is not well seen on the Soufrière, but may often be found in patches near the south end of the island, and is fairly common around Kingstown. It is only found on the low grounds which are covered with vegetation. There decomposition goes on rapidly, but erosion and deportation are least effective.

A more satisfactory hypothesis is that this is a weathered rock rubbish, which has accumulated on the flatter grounds where the rain has little power of washing away fine fragments, especially as the roots of the vegetation serve to hold the soil together and prevent its removal. When saturated with rain such incoherent materials will tend to slip under the action of gravity, and the slow creeping of the soil down the principal slopes may sometimes give it a roughly-bedded appearance. The bombs and crystalline blocks are the larger masses enclosed in the old tuffs from which the brown earth has mostly formed. In many respects it bears a strong resemblance to the "head" which covers the rocks in Cornwall, only the appearance of bedding is more frequent.

A fact of some importance in connection with the geographical development of

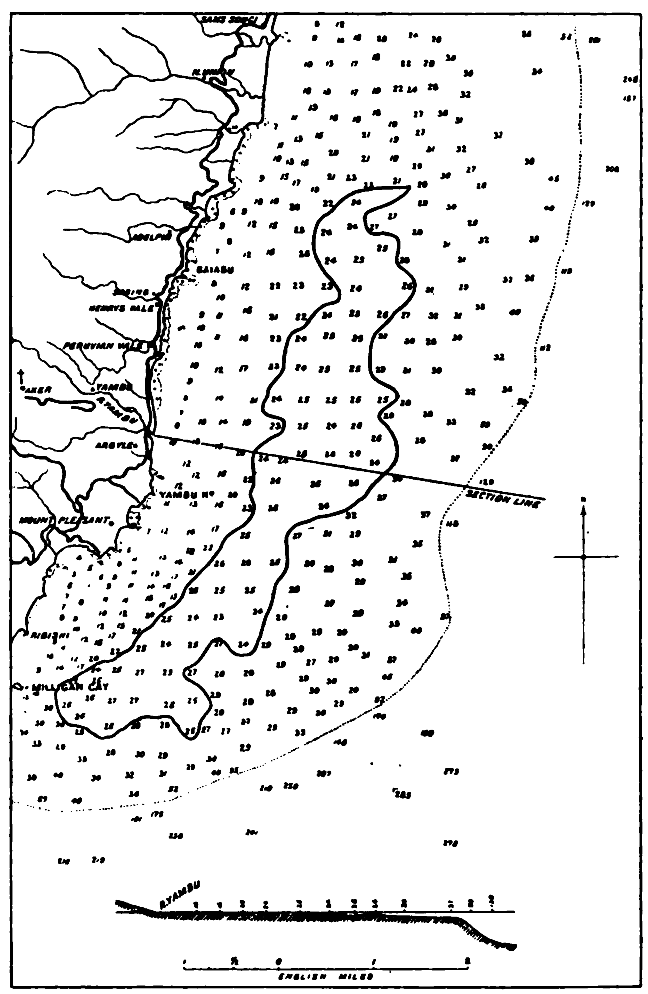

FIG. 1. Map of the south-east corner of St. Vincent. A line is drawn to enclose depths of 24 to 26 fathoms, indicating the submerged beach platform. The section at the base shows the coastal shelf.

St. Vincent is the occurrence of a well-marked submerged terrace off the south-east coast of the island. The soundings of the Admiralty chart show that opposite the mouth of the River Yambu the sea bottom slopes continuously down to a depth of 150 feet in a distance of a mile, then for nearly a mile the depth does not perceptibly increase, but the soundings are uniformly 24, 25, and 26 fathoms. To seaward of this flat ledge there is a gradual descent, and the 50-fathom line is often within a mile of its outer edge. Thereafter the slopes are almost precipitous, and there may be only one-third of a mile between the depths of 200 fathoms and of 50 fathoms—a slope of nearly 1 in 2 (see fig. 1).

Evidently the 50-fathom line separates a gentle slope from one which plunges into the depths which lie to eastward of the lesser Antilles. Above that line we have a surface which has at some time or other been part of the land; below that we have the face of the great earth fold on the crest of which the Windward Islands stand. This is the real boundary of St. Vincent in a strict geographical sense. The flat ledge with an average depth of 150 feet can only be regarded as an old sea-cut terrace. Like the beaches on the windward shore it has no relationship to the geological structure of the country, and the slopes cannot be old escarpments, as the dips are all seawards. It proves that the island formerly stood at least 150 feet higher, and was slightly more extensive in area than at present.

Were it the case that on the windward side of St. Vincent there is a well marked series of raised beaches, while none can be traced on the leeward shores, this would be sufficiently remarkable to call for explanation. Undoubtedly there is no stretch of level ground on the western coast, nor are there well-developed terraces like those to be seen near Brighton, and elsewhere to windward, and it was not till after we had seen these, that it was possible for us to recognise and identify the scanty remains of similar features near Chateaubelair and Barrualli (see Plate 21, fig. 2). But even here there are occasionally level stretches on the headlands at heights of 200 feet and more above the sea. They are narrow, and are most easily recognised from some short distance out at sea, where they appear as obvious breaks in the sloping sky-line presented by the ridges of the spurs. In one or two places (near Cumberland) two or three can be made out, one above the other, with steeper intervening slopes representing the old bluffs behind the shores. Their insignificant development is a natural consequence of the sheltered condition of this coast line. Erosion is much more rapid on the windward side, where the billows, driven before the trade wind, pound steadily against the rocks. The land-slopes on the western side also are steeper than on the eastern, so that sub-aerial erosion is more effective and the terraces (originally smaller) have been more rapidly cut down and effaced. They occur, as might be expected, mostly on the rocky capes, and are never to be seen in the interior of the bays and valleys. They extend probably to as great a height here as on the other side of the island, and belong to the same period of submergence and marine erosion.

Coastal terraces of another type, only indirectly connected with the eroded rocky platforms already described, deserve also to be mentioned here. Although they cover no very extensive area, they are important, as on them stand many of the most important villages and towns, as, for example, Kingstown, Georgetown, and Barrualli. They consist of alluvial material which has been transported down the steep slopes behind the shore, partly as taluses and landslides, but chiefly by the rivulets and streamlets, which wash away the fine earth after heavy falls of rain. Their upper surfaces are by no means plane, but have always a definite slope towards the shore, and are often somewhat hummocky, uneven, and rounded, as they consist of coalescing fans of alluvium, each of which diverges from the streamlet which has deposited it. The rain rills and small rivulets cannot carry the same load when they reach the gently sloping country at the foot of the hills as they did on the hill sides, and the material sinks and is laid down as sheets of gravel and fine earth. This deposit is often full of vegetable matter and the calcareous fragments of land shells. It does not seem to have gathered under the surface of a sheet of water, as it is never stratified, and contains no marine fossils.

In that stretch of level ground which lies at the eastern base of the Soufrière, and stretches from Georgetown to Overland Village, we have the two types of terrace blended inextricably together (see Plate 21, fig. 1). Here are the remains of the old sea benches, much eroded, rounded off, and nearly effaced; yet that it is a rock platform can be proved in many places by the tuffs and lava-flows which are exposed in the stream sections and the coastal cliffs. The surface of these terraces is deeply weathered, and often covered over by alluvial fans laid down by water descending from the higher grounds. Shortly before we reached Georgetown heavy rains had fallen, and the fields of arrowroot behind the village had been covered by flows of mud which had descended the slopes above Grand Sable House. These mud streams had done great damage to the crops. They had entered the village and knocked down a hut, in which were two black people, who were buried in the falling débris, and were drowned.

This country is partly a terrace of marine erosion, partly a terrace of accumulation. It forms the most extensive stretch of flat ground in the island, and is now covered with the ashes of the eruption and the sand and mud deposited on it by the rains. Formerly it was the pride of the island, as on it stood many fine estates, and it was inhabited by a large and contented population. Georgetown, which contains two fine churches and many good houses, was the centre of trade for the surrounding region. It is covered 2 feet deep with ashes; the gardens of the town and the fields around are desolate as a cinder heap, though here and there the vegetation is reasserting itself. There is hardly an unbroken pane of glass in the whole town, as nearly all were shattered by falling stones, and when we were there a large part of the population was receiving relief from the funds at the disposal of the Governor.

The geological history of the island of St. Vincent, as recorded in the rocks exposed to view within its boundaries, may be summarised as follows :—

The whole island consists of volcanic rocks and the products of their disintegration. The only active volcano is the Soufrière, and all the accumulations may be considered as belonging to recent geological times.

The epoch of maximum volcanic activity was a period of elevation during which the island was certainly more extensive than at present. The eruptions were sub-aerial. This was followed by depression to, at any rate, 700 feet below the present level, and during this subsidence, or the subsequent elevation, a series of rock terraces was cut by the action of the waves.

The elevation which followed was carried to a stage at which the land stood at least 150 feet higher than at present.

Since then there has been a second depression of 150 feet. In all probability this has been the last chapter in the island's history, as the absence of uplifted coral makes it unlikely that there has been any recent elevation.

The Soufrière; its Configuration and Structure.

In external configuration the Soufrière is a very typical example of a volcanic cone. Nearly 8 miles across at its base, it rises to a height of 4000 feet, so that the average slope of its sides is about 15°. Its summit is occupied by a large crater, nearly a mile across, and this gives it a rounded or flat-topped appearance, as seen from Chateaubelair, which is on its south-west side. To the north of the crater there rises a semi-circular ridge, separated from the crater wall by a deep valley, which it overlooks in a series of precipitous cliffs of bare rock, nearly 1000 feet high, fringed with taluses of débris. This ridge forms the extreme summit of the mountain, being 4050 feet in height, while the lip of the crater is only 3000 to nearly 3500 feet high. It surrounds the crater on the north and north-east sides, forming an amphitheatre, the inner side of which is nearly vertical, while externally it slopes down to the sea with the conical form of an eroded volcano. This ridge bears exactly the same relationship to the present crater as Somma does to Vesuvius,* and has undoubtedly originated in the same way by some great explosion, which has blown away the summit of the hill, and left a gigantic depression nearly 2 miles in diameter.

From Georgetown and the base of the mountain on the windward side the conical shape is less obvious than from Chateaubelair, though, so far as our experience went, it was not often that a clear view of the summit could be obtained from this quarter, as the upper regions were nearly always veiled in cloud. From the sea to the north of the island the appearance of the mountain is that of a round-backed deeply furrowed pile, in which there is nothing to suggest strongly the volcanic origin of the

* H. REUSCH, 'Nature,' vol. 66, p. 132, June 5, 1902.

structure. But the encircling Somma wall overlooking the actual crater is so well seen from the south-west that one can divine at a glance the history of the mountain. (see Plate 25, fig. 1). It is in the north-west quadrant of the hill that the conical slopes, determined by the internal structure, are least modified and most apparent. So active are the processes of erosion in the Windward Islands, that there is no part of the hill that does not bear conspicuous evidence of their operation. Deep ravines radiate out on all sides from the summit, as is indicated (perhaps a little diagrammatically) on the Admiralty chart (see Plate 39).

The profound gorges which score the sides of the volcano give it a picturesqueness which otherwise would have been lacking. When we saw them they were bare and naked, all the green vegetation had disappeared during the eruption; only blackened trunks were left to bear witness to the tropical forest which had once clothed the surface. But though the mountain had lost in beauty and variety of colour, it had gained in interest and impressiveness to the geologist. Every detail of cliff and scar was visible from a distance. The Soufrière had been one of the beauties of the West Indies, and travellers had come from far to gaze on its richly-wooded slopes, and to see the marvellous lake which nestled in the crater on its summit. To-day it looks more like a skeleton; the ribs of bare rock stand out everywhere plainly to be seen.

In more than one respect the gorges on the mountain deserve the name of cañons. Some of them must be nearly 1000 feet deep, and they are often so narrow and steep-sided as to render the country almost untraversable. We were told that along the leeward shore there is an old Carib track, but communication is kept up entirely by means of row boats. The mountain was very frequently ascended, in fact this was one of the commonest pleasure trips for the inhabitants and tourist visitors. But, as already mentioned, there was only one track, which served also as the main road from Chateaubelair to Georgetown. After crossing the low ground it struck the slopes of the hill and ascended along the knife-edges between the ravines. The road was fairly good for a bush path in the West Indies, and horses could be ridden along most of the way. As the valleys are radial, the ridges between them swept right up to the edge of the crater, so that the track led up to the lip of the depression, then along it for a short space, and down another spur to Lot 14 on the windward side. The slopes on each side were often 40°, and sometimes still higher, and the back of the ridges so narrow that in many places there was only width sufficient for the path. After the eruption, the bush was all destroyed, and as the roots had served to hold the loose materials together, landslides were frequent, so that the path was dangerous in one or two spots, especially as one never knew what weight the new ashes which had gathered on it were able to bear without slipping. Except by this path, it would have been a matter of the greatest difficulty to reach the summit, and so dense was the undergrowth, and so numerous and profound the ravines, that no one attempted to explore the surface of the hill, and few, except a handful of wandering Caribs, were acquainted with any other part of the higher slopes than those adjoining the footpath.*

Another element of danger is the suddenness and severity of the rain-showers which send torrents down the valleys, which sweep everything before them. The Somma wall behind the crater can only very seldom have been climbed. Certainly the white inhabitants of St. Vincent are not lacking in energy or enterprise, but we did not meet anyone who had ever stood upon the actual top of the Soufrière. During the three weeks we spent at the base of the mountain, we did not once get a clear view of the summit of this ridge, and to climb it in a dense mist would have been not less arduous than unprofitable.

Magnificent sections are afforded by the sea cliffs on the leeward side of the Soufrière, between Morne Ronde and Quashie Point, and in the deep ravines of the Rozeau Dry River, Larikai, and other streams which descend the mountain slopes. On the windward side also there are very fine inland cliffs above Overland and Sandy Bay. We had also frequent opportunities of examining the sections in the gorges on the south side of the mountain in the course of our ascents to the crater. As a result of our study of all the available exposures, it is clear that the Soufrière is a massive volcanic cone, consisting of alternating beds of lava and of ashes which on all sides dip outwards from the summit craters at angles of 12° to 15°.

Some of the lavas are thick (50 to 100 feet), but on the north-west side especially they are thin and numerous. Occasionally seven lava flows with sheets of ashes between can be traced above one another in a single cliff or the side of a ravine. They contrast in this respect with the thick lavas of the southern end of the island and the very massive accumulations of tuff in which they occur.

The centre from which the lavas diverge and have proceeded is the summit of the hill and the craters which occur there. We saw no evidence of parasitic cones or minor eruptive foci. There are also few or no dykes, and intrusive sheets are rare or absent. There is abundant proof that the eruptions took place on a land surface. In these respects the volcano is of the usual Antillean type, and differs only from its extinct neighbours in that its activity has shown less of explosive violence, and more frequent gentle outpouring of lava has been habitual in their case.

The structural relationships of the gigantic crater of the Somma to the present craters within it are not entirely understood, but as the northern wall of the larger of the present craters is composed of lavas and ash beds with a northerly dip, it seems that a new cone has been built up within that depression by repeated flows of lava and showers of ash. On the south side of this crater are tuffs and lavas dipping south, which must have been emitted from the present vent, though no line of demarcation could be drawn between them and the older rocks which belong to

* *See* JAMES ANDERSON, "An Ascent of Morne Garu," 'Phil. Trans. Roy. Soc.,' vol. 75, p. 16, 1785. F. A. OBER, 'Camps in the Caribbees,' 1880. GILBERT HAWTREY, "Lost on La Soufrière," 'The Wide World Magazine,' vol. 9, p. 523, September, 1902.

that earlier cone in which the great Somma crater had been formed. It is possible that the great explosion which removed the summit of the old hill left a crater one lip of which was more than 1000 feet lower than the other, and on this lower lip the present craters have built up their later cone. Or it may be that, after that paroxysm, the hill presented the appearance of a breached cone with a wide, open trough facing the south, and that the actual craters stand on the line of this fissure.

The great valley which has already been described as lying on the south side of the Soufrière, between it and the Morne Garu, is deserving of special description, as it is here that the ejecta of the recent eruption have chiefly accumulated (see Plate 25, fig. 2). It runs across the island, and on the west is occupied by the Wallibu and Wallibu Dry Rivers, on the east by the Rabaka Dry River. The dividing ridge is about 2000 feet high, and is the lowest part of the axial chain of the island, so that it is quite possible to regard the Soufrière as a detached mountain not directly connected with the main ridge to the south. The rivers mentioned run in narrow ravines which have been incised in the floor of an open valley, so that it seems improbable that as they are at present they are the main factors in its formation. It seems rather that during some past epoch, when the physical conditions were different from what they are now, this wide hollow was scooped out, and that subsequently the present rivers have cut depressions in its floor.

It should be remembered that this is a structural depression separating the extinct and much eroded volcano of the Morne Garu from the still active and better preserved cone of the Soufrière. As such it has been a valley from the beginning, and is not entirely to be ascribed to erosion. This is shown by the dip of the rocks, which on both sides is towards the centre of the valley (see Plate 32, fig. 1). It must have been from the earliest times one of the main drainage systems of the surface of St. Vincent.

The streams flowing in this depression appear to have at some time or other reached a base-level, so that their cutting power was in abeyance and their valleys broadened and opened out laterally. This may have been during the subsidence, the climax of of which is marked by the 700 foot terrace. Subsequent elevation has enabled the streams to deepen their courses and to incise deep channels in the old valley bottom.

Another factor which must have been of importance in determining the formation of this trough is the absence of any hard lava streams in this part of the Soufrière—one of the most perplexing features in the structure of the mountain (see Plate 34, fig. 2). Lava flows are abundant on the north, the west, and the east sides of the volcano, but they are not found at the base of the hill on the south side, or in the part out of which these valleys have been eroded, though at higher elevations (above 1200 feet) they are fairly numerous and often seen in the stream sections. As these lavas always offer much greater resistance to the deepening of the river channels than do the tuffs and agglomerates, and generally stand out as cascades and waterfalls, it is easy to see why base levels should have been reached at an earlier date by these streams than by the others in the middle and south of the island, which had thick lavas to cut through.

These masses of tuff are fairly well stratified, and dip towards the south, parallel to the slopes of the volcano. They have obviously proceeded from the Soufrière, and appear to be the latest rocks of the hill. They show that the most recent outbursts have been of purely explosive type, and that lava has not flowed from the craters for a prolonged period. The volcano has undergone a change in the manner of its action, and has passed from what may be called a normal to a virulent and spasmodic condition. This may indicate approaching extinction. It is the opinion of most geologists who have studied the volcanoes of the Antilles, that the heyday of their activity is over, and that a general decadence has taken place. If so, the Soufrière, the last of the St. Vincent volcanoes, may be no exception to the general rule, and its decreasing vigour may have resulted in a change in the *modus operandi* of its out-bursts.

It is not easy to explain why these latest tuffs should have gathered to thicknesses of several hundred feet in this particular valley, and not elsewhere round the cone. It may be that since the eruption which resulted in the formation of the Somma wall, the ejecta have been discharged mostly over the lower or southern lip of the crater, while the lofty northern wall has protected the country behind it. Possibly, also, the "sand avalanche" type of eruption may have been characteristic of the later activity, and great masses of fine ash and débris, as in the recent eruption, may have overflowed the southern rim of the crater and lodged in the depression at this side of the cone. As we shall see later, there is historical evidence in support of this view.

Of the two craters of the Soufrière, the larger is known as the "Old Crater," while the smaller, which originated during the eruption of 1812, has for that reason been called the "New Crater." These names are no longer very appropriate, as the old crater is that which took the principal part in the eruption of this year, while it is doubtful whether any material was emitted from the smaller or "New Crater." In this report the larger or "Old Crater" is meant whenever we refer to the crater of the Soufrière.

This crater (see Plate 37, fig. 2) is very nearly circular in shape, and, according to the map (see Plate 39), appears to have been a little less than a mile across and somewhat smaller in the north and south direction than from east to west. Its northern lip was 3623 feet above the sea, and about 600 feet higher than the southern. But the crater rim did not slope regularly down from its northern to its southern side, but was slightly serrate with alternating projections and depressions. These are clearly indicated on the Admiralty chart.* The slopes on both sides of this rim (which was

* On the western rim of the crater there was a moderately deep notch leading into the valley of the Larikai. This is mentioned by Mr. E. O. HOVEY ("Martinique and St. Vincent: a Preliminary Report," 'Bulletin American Museum of Natural History,' vol. 16, p. 336, 1902). We never had a good view of it, owing to the mist which hung around the crater.

really a knife-edge like that of the spurs between the valleys) were steep, averaging 30° to 40°, and were furrowed by rivulet channels which were shallow, especially near the summit of the ridge.* The water descending to the interior had gathered to form a large lake, rather more than half a mile across, with an outline which was approximately circular. The funnel shape of the crater walls was due to erosion by running water and to the action of landslips, and not to the accumulation of cinders and loose ejecta at the angle of repose for such material. If beds of ash dipping inwards had ever cloaked these slopes, they had been entirely removed, for, from the descriptions of those familiar with the crater lake and from photographs, it is certain that it consisted of lavas and tuffs dipping outwards on all sides, and presenting escarpments and talus-covered edges to the interior cavity. It is more likely, however, that the crater walls had been in large part vertical cliffs which had reached a condition of stability by repeated rock falls and continued erosion.

These rain-furrowed slopes were covered with bush and short timber, but it was a matter of no very great difficulty to descend them to the shores of the lake, though in one or two places the lava sheets formed low vertical escarpments.

The water of the lake was greenish and opalescent, probably from finely-divided particles of precipitated sulphur.† It smelt strongly of sulphuretted hydrogen, especially on a hot day (hence the name Soufrière), but was not warm or even tepid, and the adventurous occasionally bathed in the lake. The level of the surface is given on the chart as 1930 feet, so that the southern wall was 1100 feet high, and the northern about 1700 feet. Probably the amount of water varied slightly with the season of the year. There was no outlet, but the excess of rainfall over evaporation leaked away through the bedding planes and joints of the surrounding rocks.

The depth of this lake is not very accurately known. Mr. P. FOSTER HUGGINS,‡ in 1896, built a small raft of logs and made a series of soundings of the crater lake in that and succeeding years. He found the depth at the centre to be 87½ fathoms, and believes that to the north of this it would have been found to be still greater, but he was never able to complete his soundings in that quarter. The underwater slopes were very steep, as might be expected from the origin of the lake, and on the north side, below the great vertical precipice, a sounding of 43 fathoms was obtained at a distance of only 60 feet from the shore. Apparently the floor of the depression was bowl-shaped, but not uniformly concave, as the deepest part lay to the north of the centre. As measured from the lower lip of the crater the total depth must have been over 1600 feet.

* F. A. OBER, 'Camps in the Caribbees,' 1880, p. 203.

† HANS REUSCH, 'Nature,' vol. 66, p. 132, June 5th, 1902.

‡ P. FOSTER HUGGINS, 'An Account of the Eruptions of the Saint Vincent Soufrière.' Kingstown, St. Vincent, 1902.

The smaller or "new crater" was really parasitic on the north-east lip of the larger. They were separated by a narrow saddle, lowest in the middle, a steep-sloped, knife-edged ridge which it was considered dangerous to pass along. Comparatively few visitors undertook the scramble along the sharp rim of the main crater to the smaller one, which was not so deep as the principal crater, and its bottom was dry. The diameter of the "new crater" was one-third of a mile and the outline nearly circular. On the north side of the two craters was the deep valley, already mentioned as lying at the foot of the precipitous wall of the Somma.

The crater lake of the Soufrière is described by all who had the good fortune to see it as having been a thing of beauty. The mists which roll across the mountain top before the steady trade wind too often obscured the view and cheated the traveller of the reward of his arduous climb. But when the clouds lifted, and the sun breaking through the veil shone on the pearly-green sheet of water, reflecting from its placid surface the swelling mists above, and set in the sloping verdant crater walls, like an opal surrounded by emeralds, the sight was one the memory of which was cherished for a lifetime.

THE ERUPTION OF MAY 7TH, 1902.

Premonitory Symptoms.

For 90 years the Soufrière had slumbered, and few were living who had seen it in eruption. But in the early part of the year 1901, an uneasy feeling began to arise in the minds of those who dwelt on the flanks of the mountain. Earthquakes are by no means infrequent in St. Vincent, though usually of slight severity, but in February and March, 1901, they became so numerous around the north side of the volcano as to awaken suspicion that danger was threatened. There are two settlements of Caribs—the remains of the original inhabitants of the island, most of whom were exported, after the close of the Carib War of 1796, to the island of (Rattan in the Bay of Honduras)—at Morne Ronde on the west, and at Sandy Bay on the north-east of the mountain. It may be that traditions linger among them regarding former disastrous eruptions, or superstitions connected with the crater, for though the Caribs are certainly not deficient in courage, they became so apprehensive that they petitioned to have their settlements removed to some other part of the island, and officials had to be sent to quiet their fears. There is evidence in letters written to the Kingstown newspapers in March, 1901, that general interest had been awakened, and it was widely known that anxiety was being felt regarding the condition of the volcano.

These premonitory earthquakes were accompanied by subterranean rumblings, which appeared to come from the interior of the hill. Apparently they did no damage to buildings or other structures, but so much alarmed were some of the black labourers that the managers and owners of estates had, in some cases, to take steps to allay their apprehension and encourage them to continue working in the district. They appear to have been very local and to have differed greatly in intensity at different parts of the hill. In the Carib Settlement at Morne Ronde more were experienced than anywhere else. Earthquakes and noises continued through the whole of the ensuing twelve months. They were neither violent nor loud, but were more numerous than was usual for that part of the island. The white inhabitants regarded them with indifference or curiosity, for as earthquakes are by no means rare in St. Vincent, the repeated small shocks felt during 1901 were not regarded as necessarily the precursors of a cataclysm. There were some, however, who, aware of the suddenness with which the eruption of 1812 had broken out, could not help suspecting that they foreboded another outburst.

In the latter half of April, 1902, they increased considerably in number and intensity. At Owia, on the 13th of April, at 12.20 P.M., there was a sharp shock, and about that time as many as eight tremors were sometimes experienced there in 24 hours, all slight and of short duration. Along the whole north-west quadrant of the hill the violence of the earthquakes in the last week of April, 1902, was exceptional. They dislodged stones from the cliffs of lava and sent them tumbling down the slopes, and occasioned small landslips in the loose material of the taluses, damaging the crops which were planted there. On Monday, April 29th, three well-marked shocks were experienced at Windsor Forest and Campobello, while at Morne Ronde about this time eighteen earthquakes were counted in one day. It will be remembered that the first signs of activity on Montagne Pelée were observed about the 23rd of April, and that a great earthquake shook Guatemala on the 18th April.* As yet the Soufrière had shown no symptoms of actual eruption. The Caribs at Morne Ronde, however, fully anticipating an outburst, were preparing to evacuate their houses and flee to Chateaubelair and other places of safety.

Preliminary Stages of the Eruption, Tuesday, May 6th.

By 1 o'clock on the afternoon of Tuesday, the 6th May, there could no longer be any doubt that the Soufrière was in eruption. It is said that during the previous night the Caribs had seen a cloud of steam emitted from the mountain and a bright glow on the summit. This is doubtful, but certainly on that morning they were flocking into Chateaubelair, and a general anxiety was awakened in the neighbourhood.

At Wallibu† a rumbling sound like distant thunder was heard from 6 to 8 A.M. on the 6th May, and between 8.30 and 12 that forenoon, seven distinct shocks of earthquake were felt. These tremors were not experienced in Chateaubelair, which is about

* 'Nature,' vol. 66, p. 150. 1902.

† For the position of Wallibu relatively to the Soufrière, see Plate 25, fig. 2.

a mile further south. The day was very clear, and the whole lip of the crater could be perfectly made out by those on the south-west side of the hill. From the north side the crater is concealed by the intervening Somma wall, while the inhabitants of the windward quarter could see none of the upper parts of the mountain owing to the thick trade-wind cloud which covered them.

Between 11 A.M. and 12 noon the labourers on Richmond Estate noticed puffs of steam arising from the crater, and reported the fact to the manager. This seems to be the first trustworthy observation of activity on the part of the volcano. News travels fast among the black people, and word of this was not long in spreading to the adjoining estates. At 1.30 P.M. steam was seen by an observer at Wallibu ascending in a great pillar which spread out like a palm tree. It rose from the centre of the old crater. From Chateaubelair nothing suspicious had yet been noticed, but at 2.40 P.M. there was a loud report like that of cannon, and a great cloud of white steam shot up into the air to an immense height. The people gathered in the streets to see the strange spectacle. There is an excellent system of telephonic communication around the coast, and word was at once sent to Kingstown by the officer in charge of the police station at Chateaubelair, and the news that the Soufrière was in eruption was soon flashing over the island.

In a very short time Chateaubelair was thronged with Caribs from Morne Ronde on their way back to Rosebank, a little further south, where there was another Carib settlement. Some had passed through earlier in the forenoon, and their fears had been mocked at by those whom they met. By 5 o'clock the village of Morne Ronde was deserted.

As the afternoon advanced matters got distinctly more threatening in appearance. The trade-wind cloud hovered as usual over the mountain, but the ridge on the south side of the crater was visible from Chateaubelair. About 4.30 P.M. a big column of steam was seen to ascend from it, and several observers remarked that at the base of this there was a red glow like the reflection of fire. About half-past 5 o'clock there was another outburst, and the red reflection from the cloud was again visible. At 6 o'clock a thick cloud of steam was emitted, and from Wallibu fire was seen forming a ring around the lip of the crater, and a crackling sound was heard, which sounded like "brush on fire." A general stampede ensued in the villages and plantations of Wallibu and Richmond, only a few remaining to look after their property and domesticated animals. The sun was now setting. In Chateaubelair all was animation and excitement. The little village was crowded with refugees from the western base of the hill, and the whole population was standing in the streets and on the beach watching the progress of the eruption. Mr. T. M. McDONALD, who had received warning by telephone from his manager at Richmond Vale, that the Soufrière was emitting steam clouds, landed on the beach a little north of Chateaubelair pier at 6.30 P.M. He says—"The summit of the Soufrière was enveloped in the usual white cloud, and at first nothing unusual was visible. Within a minute or two of landing, however, one of the party exclaimed, 'Soufrière is bursting now,' and on looking toward the mountain I saw enormous vertical columns of white vapour being ejected, virtually noiselessly, and was now quite convinced that an eruption had been, and was now taking place."

At 7.30 P.M. a great explosion followed, accompanied by a loud noise and by slight earthquakes. The discharge of vapour was greater than any of those which preceded it. Mr. McDONALD notes that he observed "flame along the whole line of the top of the crater, forming a thin red sparkling line between the base of the column of vapour and rim of the crater."*

Thereafter at intervals of about two hours similar discharges took place, and some of them were reported to be also accompanied by flame.

By means of the telephone, constant communication was kept up between the police station at Chateaubelair and the head office in Kingstown, and seeing that as the afternoon and evening passed on, Chateaubelair was becoming more and more crowded with refugees, and the excitement hourly became more intense, Captain CALDER, the Chief Constable, decided to proceed thither with an additional force of policemen. Dr. DUNBAR HUGHES, the district Medical Officer, and Dr. CHRISTIAN BRANCH, Medical Officer at Kingstown, accompanied him, and the written notes supplied to us by these three gentlemen form a very valuable body of evidence as to the course of events from this point onward.

Their boat was entering Chateaubelair Bay just about midnight. The night was calm and clear, and on the way north they had passed several boats laden with fugitives fleeing southward. Just as they reached the wharf, a powerful explosion took place. A column of steam ascended "rather higher than the mountain itself, that is to say, about 4000 feet." Dr. BRANCH continues: "The whole width of the mountain top was outlined with leaping flames, red, and having the same appearance as a cane field on fire . . . Immediately, as the flames died down, a rattling roar like that of burning canes reached us." Captain CALDER describes it as follows: "The whole top of the mountain burst into flame, the long flashes of deep red fire travelling from the top downward in a circular track, just like fire bursting from a head of smithy coal when fanned by a strong draught from the bellows. This was immediately followed by an explosion as of much heavy ordnance, dying away in a long-drawn angry grumble." Dr. DUNBAR HUGHES compares the noise to the "sound of a fast-going cab on cobble stones, but much exaggerated." They found the black population madly excited, and standing gazing on the mountain. During the night at least two outbursts took place with a loud noise.

The results of the observations made by persons at Morne Ronde, Wallibu, Richmond, Richmond Vale, and Chateaubelair (all on the sea coast along the south-west side of the mountain) during the day and night of Tuesday, May 6th, may be summed up as follows:—The first emissions of steam were seen somewhat before

* See Appendix II.

mid-day, and earthquakes were experienced about the same time by those at the base of the volcano, but were local. A violent explosion alarmed the whole neighbourhood about 2.40 P.M., and no doubt remained regarding the reality of the eruption. Others followed at intervals of two or three hours, accompanied by loud noises, the most severe being at 7 o'clock, and at midnight. Flames, or the reflection of fire on the steam cloud, were noticed first at 4.30 P.M., and thereafter were seen repeatedly by various observers.

We shall now consider the evidence of a party of fish sellers who left Chateaubelair and crossed to Georgetown on the forenoon of Tuesday. They followed the track already mentioned as leading up the crests of the spurs to the lip of the crater. The party consisted of several black or coloured women and one boy. Fish are obtained only on the leeward side of the island, as the heavy seas on the windward side render small boats unsafe, and these women were accustomed regularly to cross the island, and were in consequence very well acquainted with the appearance of the path and of the crater under ordinary conditions. We cross-questioned them at the refugee camp at Barrualli, in presence of Mr. T. M. McDonald, whose assistance was invaluable, as it is only after long acquaintance with these people that one can enter into their ways of thought and understand their methods of expression.

They left Chateaubelair about 6 o'clock in the morning, and in ordinary course must have reached the edge of the crater between 10 and 11 A.M. They had no reason to suspect that an eruption was imminent till they were just below the summit, when they heard rumbling noises, and felt the hill shaking. The smell of sulphur (sulphuretted hydrogen) from the lake was much stronger than usual, and on looking down into the crater they saw that the water was much discoloured, in places red, in other places milky, but elsewhere bluish-green, as usual. "One part milk, one part blood, rest all same as before." The red colour was probably due to the stirring up of deposits of reddish sand, which would be produced by the weathering of the red ash beds in the crater wall; the milky water owed its colour to the deposits of fine precipitated sulphur which must have gathered on the lake bottom since the last eruption. They all state that the level of the lake was almost the same as before, that no overflow had taken place, and that within the crater the bush was withered but not burnt.

All agreed that the water was boiling and steaming strongly, especially in the centre of the lake. Some say they saw stones being thrown up, but several witnesses maintained that they saw a stone in the centre of the lake, and it was around this that the steam was rising. The last statement is very important, but its meaning will be better discussed when the history of the eruption has been traced a little further.

Another woman travelling by the same path, but in the opposite direction, passed the crater about mid-day. She also saw the water discoloured. It smelt strongly of sulphur, and was boiling out in the centre of the lake, not at the sides. As she was descending on the leeward side and was near the "half-way tree," a well-known landmark, she heard a loud report, and saw a rush of steam, whereupon she dropped her basket and ran. This must have been the explosion which took place about 12.30. She saw no stones on the path either when ascending or descending.

By Tuesday evening everyone in Chateaubelair and on the leeward side of the mountain was well aware that the Soufrière was in eruption. Boats had left Wallibu in the afternoon and gone up along the coast as far as De Volet's and Campobello, carrying the news. Windsor Forest Estate was vacated on Tuesday night, and it was only the scarcity of boats which prevented all the inhabitants north of Chateaubelair from at once taking refuge in the villages to the south.

But at Fancy and Owia, no trustworthy intimation of impending danger had yet been obtained. The crater cannot be seen from this side, and the mountain was capped with cloud. People were somewhat anxious on account of the frequency of earthquakes during the previous weeks, and also because word had reached St. Vincent that Montagne Pelée, in Martinique, was in a state of activity. But so far nothing had been seen or heard which indicated that an eruption of the Soufrière was actually in progress.

On the windward side, in Georgetown and the estates on the Carib Country, there was almost as little apprehension. Telephonic messages had been sent from Kingstown to police headquarters at Georgetown that the people at Chateaubelair had seen steam arising from the crater. But a dense trade-wind cloud covered the mountain, the rumbling sounds were mistaken for thunder, and in the West Indies there is always so much untrustworthy news in circulation that it is not difficult to understand that this unexpected information was received with scepticism. It was believed to be a scare due to the news from Martinique.

The Forenoon of Wednesday, May 7th.

Chateaubelair.—On Wednesday morning day dawned on a scene of great excitement in Chateaubelair. "The usually quiet village resembled a hive of angry bees."* Just about 6 A.M. (at sunrise) there was a large outburst of steam, and as the forenoon wore on, the violence of the activity increased. Work was at a standstill; the magnificence of the eruption absorbed all attention. The last stragglers were coming in from the estates and villages on the leeward side, where few had been brave enough to remain overnight, and most of these, before midday, were convinced that it was advisable to take to flight.

During this time, Mr. T. M. McDonald, of Richmond Vale, and Mr. Mathes, who was his guest, were making constant observations of the eruption. From the

* Captain Calder, 'Century Magazine,' vol. lxiv., p. 634, August, 1902.

verandah of Richmond Vale House the upper part of the Soufrière was clearly seen The notes taken by Mr. McDONALD in his pocket-book have since been published,* and form a most valuable contemporary record of the progress of events.

"No further observation was noted at Richmond Vale House till shortly after 6 A.M. on the 7th, when a discharge took place with the usual column of thick vapour, but beneath this was a much shorter column of almost dense black, and of a heavier nature, as it quickly subsided back into the crater. This was the first appearance noted of what was probably solid matter being erupted, the white vapour being no doubt vapour of water only. At about 7.4 A.M. an enormous high column of white vapour was ejected, and it may be here mentioned that these tall columns rose in a very short space of time—say about a minute—to heights of about 30,000 feet and over, by comparison seven or eight times the height of the mountain (nearly 4000 feet). Outbursts took place now at shorter intervals, and at about 10.30 A.M. the eruption became continuous, enormous volumes of vapour reaching to a very great height.

"11.10 A.M. At this time there was thunder and lightning, showers of black and heavy material could now be seen thrown outwards and falling downwards from the column of whitish vapour, associated with loud noises and more violent outbursts. From the commencement the Old Crater seemed to be the scene of activity, but at times it seemed as though some of the discharges proceeded from what is known as the New Crater, a little north-eastwards from Chateaubelair. The area of the escape of vapour seemed now to be extending in a direction corresponding with Morne Ronde."

By means of Mr. McDONALD's notes and of narratives which were given us by Captain CALDER, Dr. BRANCH, Dr. HUGHES, and others who were in Chateaubelair that forenoon, and by Mrs. KELLY, and Mr. ROBERTSON (who was in Wallibu till 12.30 P.M.), it is easy to arrive at a fairly complete idea of what was going on. The eruption was now assuming an acute phase, and the explosions followed one another with increasing rapidity and violence. At first, the steam clouds emitted from the crater followed one another at intervals of an hour or less, and between the outbursts the crater could be seen gently steaming; but about 10.30 A.M. they had so increased in number that an enormous column of vapour was rising from the throat of the volcano, and spreading out in a great mushroom-shaped cloud above the summit of the mountain. Lightnings played incessantly through the steam-cloud, accompanied by sharp peals of thunder. Several of the observers thought that they could distinguish between the thunder and the noises of the mountain, the latter being not so sharp, but lower and more prolonged. The noises were not as yet very violent, neither were they continuous. At the base of the cloud the red glare was often noticed, and some thought they saw flames.

* 'Century Magazine,' vol. lxiv., pp. 639–642, 1902. 'The Sentry,' Newspaper, Kingstown, St. Vincent, May 16th, 1902. See Appendix II.

Mr. McDonald estimates the height to which the steam shot upwards at 30,000 to 40,000 feet. Mr. Darrell considered that a few hours later it was about 8 miles. A more reliable estimate is probably that of Major Hodder, R.E., who observed the cloud from the military establishment at Morne Fortuné, above Castries, St. Lucia, in the middle of that afternoon, and found its altitude 12° above the artificial horizon. As the distance apart of these two stations is about 27 miles, this gives a height of 5½ miles.

Fine ash was raining all around the mountain. At Wallibu the sugar mill was working, but they stopped it at 9 o'clock owing to the steady showers of dust. No large stones had yet fallen, but at the base of the pillar of steam, dark, heavy matter was seen projected during the greater outbursts and falling back into the crater. It was obvious that the emissions proceeded mostly, if not entirely, from the old or larger crater. At mid-day the hill was still green, at least on the lower slopes, though the bush around the summit had been withered and blasted by the heat. About 1 o'clock in the afternoon the epoch of maximum activity supervened. The noises were now much louder, and, though not continuous, they accompanied all the great outbursts, which followed one another in rapid succession. Steam was seen ascending from the valleys in thin streaks at first, but afterwards in dense clouds which obscured the view of the mountain. Mr. McDonald mentions that at 1 o'clock he saw stones being projected to windward, and again at 1.30 P.M., and in great numbers at 1.50. They were carried up by the steam column to heights of thousands of feet, and showed "tails of fine black matter." "Jets of fine black matter," "showers of blackish material," and "dense black upheavals" were also seen, especially at 12.25 P.M.

On Wednesday morning the fish sellers who had crossed to Georgetown on Tuesday, started at day-break to return. Nothing had been seen on the windward side to make them suspect what was going on at the crater. As they went up the path, however, near the "River Bed" (about a mile above Lot 14), they noticed where stones had fallen and indented the earth. This was early in the forenoon, probably between 8 and 9 o'clock. They pushed on to near the summit of the hill, though they heard noises and saw cracks in the earth, for they little knew the dangers they were facing.

The top of the mountain was covered with mist, and the foremost of them followed the path up to the base of the summit cone. Some went up to quite near the lip of the crater, or possibly even to the actual edge. What they saw there was enough to dismay the stoutest hearts. The lake they could hardly have seen, for the whole of the crater depression was filled with dense steam. The bush within the crater was scorched and withered. There was a strong sulphurous smell, and rumblings within the crater mingled with the hissing sound of the steam jets. The lip of the crater near the old rest house was covered with "soft sulphur," that is to say, a coating of mud, probably sulphurous, from the bottom of the lake. Some said they saw the water of the lake, but this is more than doubtful, others that they saw "where the water run over." The top of the hill was in a continual tremor. They turned and fled back along the path, and, meeting others ascending, told them what they had seen and all returned together. As they passed the estates by the roadside they spread the news that the Soufrière was in eruption, and the lake had boiled over. They were received with incredulity, and when they came to Georgetown they were scoffed at as fools and cowards.

Discharge of the Crater Lake.—It is certain that the lake was boiling, though at its usual level, and in no way much altered on Tuesday at mid-day. That afternoon it was reported at Chateaubelair that the water was at the top of the lip and running over. This statement we were not able to confirm by evidence collected from eye-witnesses, but no serious discharge can have taken place that day or the following night. Mr. ROBERTSON was at Wallibu, and the valleys on the windward side had houses standing on the banks of the streams and full of people. The lake was a quarter of a square mile in area and at least 500 feet deep. Its discharge would have produced tremendous floods of boiling water, much greater than the heaviest of tropical rains could ever have occasioned, and such floods could not possibly have taken place without being noticed. The natural channel of escape for the lake was over the lower or southern lip and down the valleys of these rivers, and we may be sure the bulk of the water had not been discharged before Tuesday morning.

It is in every way probable that the first discharges of the crater lake took place during the night of Tuesday. Mr. MORGAN, of Chateaubelair, told us that early on Wednesday morning large trees were seen floating in the mouth of the bay on which that village stands, "as if there had been heavy floods in the Larikai River." They were uprooted and had lost their branches, but were not burnt, and there had been no heavy showers during the night. Probably gushes of water had flowed down that valley or the ravine of the Rozeau Dry River, and swept before them some of the trees growing on the slopes. We must remember, also, that the fish sellers who were near the lip of the crater on Wednesday, at about 9 o'clock, all agreed in stating that they saw where "the water run over," and that the lip of the crater was covered with soft mud through which they hesitated to walk to where the path descends to leeward. About 11 o'clock, Mrs. KELLY, of Wallibu, who was in a boat off the mouth of the Wallibu River, saw "an upheaval of vapour coming from the Wallibu Dry River, just at the beach." This is the first mention of hot water in any of the stream courses.

Of the first explosion after day-break, that at 6 A.M., Mr. McDONALD states that below "the usual tall column of white vapour" there was "a much shorter column of dense black stuff which seemed heavier, as it quickly subsided back into the crater. This was the first appearance noted of probable solid matter being ejected." It may have been a column of mud and muddy water mixed with stones. The fish sellers, a couple of hours later, found stones lying on the road leading up from the windward side, but if the crater still contained the lake, there can be little doubt that the larger outbursts would project water and mud to considerable heights.

At 11.10 he notes that "the area of escape of vapour seemed now to be extended in a direction corresponding with Morne Ronde." In all probability there was an overflow of steaming water on the south-west edge of the crater. It was just about this time that Mrs. KELLY saw steam in the Wallibu Dry River near the sea.

At 12.25 "Small vents seen forming on slope near old road and facing Richmond Vale. Jets of vapour being emitted seemingly from them, then a more violent outburst, which appears to be extending the crater towards the left (westwards); dark, blacker upheavals, as if the side of the crater toward Morne Ronde broke away and enlarged in that direction." The floor of the crater was now rising, and the boiling water of the lake was being discharged into the streams on the south-west side of the mountain. As the hot water poured down the valleys clouds of steam arose, and this suggested that a fissure had opened and vents formed in the ravines.

Just about this time (12.30 P.M.) Mr. ROBERTSON was leaving Wallibu. He had hardly got on board his boat on the beach when one of them called out, "Wallibu River coming down on fire." Mr. ROBERTSON turned and saw a raging flood of hot water tearing down the valley. He estimated its height at 30 to 40 feet, and states that he never had seen so high a flood in the river before. There had been no rain that morning at Wallibu, or, so far as he knew, on the leeward side of the mountain, to account for this, and he concluded, naturally, that it was the boiling water of the crater lake pouring down the stream.

No doubt similar torrents coursed down the other streams on this side of the island, as the Wallibu Dry River, the Rozeau Dry River, and perhaps also the Larikai. On the windward side a little after 12 o'clock the Rabaka River came down in floods of boiling water.*

In the light of these facts, Mr. McDONALD'S subsequent notes may be readily interpreted.

"12.35. It seemed as if slope to left of old road up Soufrière had formed into fissure, as vapour was issuing from small vents, and at 12.40 these fissures were unmistakable, and discharges from crater were extended to windward.

"12.50. Enormous outburst through vent or front of mountain as far as could be ascertained, the mountain being largely enveloped in vapour, &c."

This last was probably the greatest discharge, and practically completed the emptying of the lake, but again at 1.25 and 1.33 P.M. he mentions volumes of vapour arising from the slopes of the hill. What was happening in the Wallibu and other rivers on the leeward side of the Soufrière at that time we cannot say, as no one who

* Mr. E. O. HOVEY was told that "a wall of water and mud 50 or more feet high (they compared it with the height of a factory chimney) came out of the upper reaches of the river (the Rabaka Dry River) and went out to sea." "Martinique and St. Vincent: a Preliminary Report," 'Bulletin American Museum of Natural History,' vol. 16, p. 341.

was there has survived to tell the tale. If then, as we believe, the lake still occupied the crater till about 1 o'clock on the Wednesday afternoon, one very curious fact requires to be explained. There can be no doubt that the reflection of fire was seen in the steam cloud at 5.20 P.M. on Tuesday and repeatedly after that. All witnesses agree on this point. It could not have been due to the burning of the sulphuretted hydrogen gas, as this gives a colourless flame, and after passing up through boiling water would require contact with something incandescent to ignite it. On the other hand, it may have been, and very probably was in part, the burning of the withered bush which clothed the interior walls of the crater. Many describe the fire, seen after the great outburst at midnight on Tuesday, as "like fire running through a cane brake." On Tuesday morning the bush in the crater was green; on Wednesday morning it was burnt, and it is in every way likely that some of the "flames" were due to bush fires. They may have been ignited by flashes of lightning or by incandescent stones which had fallen, sufficiently hot to set fire to the timber. In the latter case it is necessary to suppose that a cone was built up within the crater sufficiently high to rise above the surface of the lake, and that in the centre of this cone there was a minor crater from which the main explosions proceeded, and in which a surface of molten rock was exposed.

The configuration of the crater floor beneath the waters of the lake is not fully known, and it is by no means improbable that such a cone existed before this eruption, but concealed from view. Descriptions of the crater as it was before the eruption of 1812, state that within the lake there was a conical hill several hundred feet high (see p. 462). From the evidence of the fish sellers it is clear that steam was rising only from the centre of the lake, and this would indicate the presence of an orifice there, comparatively near the surface. Moreover, they stated that on Tuesday stones were being cast up with the puffs of steam, and this would inevitably tend to build a cone around the outlet. In this regard the evidence of a little boy who accompanied these women may be of some importance. He stated that on Tuesday morning he looked into the crater and saw the lake at its usual level, but discoloured and boiling at the centre. Where the water boiled he "saw a stone floating," and the water boiled only when it touched the stone. Though stringently cross-examined, he insisted that there was a floating stone on the surface of the water. This may have been the summit of an interior cone just projecting at that time above the water level. No red reflection was seen till at any rate six hours later, and by that time the lake may have somewhat diminished, or the cone have been built up to such a height as to rise freely above its surface.

According to the soundings published by Mr. FOSTER HUGGINS, since we left St. Vincent, the depth of the depression increased on all sides towards the centre away from the shore. The Admiralty chart shows the lake to have been about half a mile in diameter, and as Mr. HUGGINS gives the greatest distance from the shore on the north east and west, sides to which he carried a chain of consecutive soundings as 200 yards, and on the north as 20 yards, there remains a considerable part of the central part of the lake of which the depth and configuration are not known. No trace of any interior cone, however, can be found in Mr. HUGGINS's soundings, especially as he states that the depth in the centre was about 87 fathoms, and if there was none it certainly seems unlikely that comparatively unimportant outbursts like those of Tuesday, May 6, 1902, should have built up a new cone not less than 500 feet in height. In that case it may be that the ruddy light was the reflection of the surface of molten lava exposed in cracks and fissures in the sides of the crater. It must be remembered that not more than one-third of the depth of the depression was occupied by water, and the level of the lake on Tuesday forenoon did not differ greatly from the normal. Mr. WHYMPER's* description of the crater of Cotopaxi as he saw it, is of great interest in this respect:—" We saw an amphitheatre 2300 feet in diameter from north to south, and 1650 feet across from east to west, with a rugged and irregular crest, notched and cracked; surrounded by cliffs, by perpendicular and even overhanging precipices—some bearing snow, and others apparently encrusted with sulphur. Cavernous recesses belched forth smoke; the sides of cracks and chasms no more than half-way down shone with ruddy light; and so it continued on all sides, right down to the bottom, probably 1200 feet below us . . . . ."

The Northern and Eastern sides of the Mountain.—Apprehension and anxiety prevailed among the inhabitants of the north shore of the island during the forenoon of Wednesday. About 10 or 11 o'clock boats arrived to take away some of the people, and they brought news that from Chateaubelair the Soufrière had been seen giving off clouds of steam, and that a red glow had been visible on the summit during the previous night. About 11 o'clock thick dark grey clouds were noticed over the summit of the Soufrière. As seen from Fancy "they continued to increase and ascend higher in the air and assume the form of flowers bursting into bloom, the dark ashen-grey clouds being interspersed with streaks of silver. Simultaneously there were earthquakes, severe rumbling noises, and flashes of lightning. The volumes of smoke seemed to take a north-easterly course, and as the day was calm their progress in that direction was not impeded."†

Mr. DUN, of Owia, reports that he heard noises at 10.15 A.M., 12.30 P.M., and 12.45 P.M. The first was like the rumbling of a heavy goods train, but the second sounded like a great explosion, and left no doubt in his mind of the reality of the eruption. They were accompanied by earthquakes, and about 11 o'clock a little rain fell containing fine particles of ash.

On the windward side the night of Tuesday had passed without anything having been seen which indicated the proximity of danger. On Wednesday morning it became widely known that it was rumoured from Chateaubelair that the Soufrière was in eruption, but in the absence of positive evidence a general scepticism prevailed.

* E. WHYMPER, 'Travels amongst the Great Andes of the Equator,' p. 152. 1892.

† Narrative furnished by Mr. CUBBIN.

The fish sellers who crossed the island on Tuesday morning had reported that the crater lake was boiling, and through the night rumbling noises had been heard and earth-tremors felt in several places. The black labourers, among whom evil tidings spread with a marvellous rapidity, were far from confident, and though sugar making was started as usual on several estates, and there was no cessation of work anywhere, it was thought advisable by some of the managers to send a party of white men up the mountain to see what was really happening there. This appears to have been determined on after the receipt of a message from Mr. PORTER, the proprietor of most of the estates in this quarter, at Kingstown, that the leeward side had been evacuated, and great anxiety was felt in Chateaubelair. The party started from Turema and Orange Hill, and rode up the path to the back of Lot 14. There they met the fish sellers returning from the summit after their ineffectual attempt to cross to the leeward country. This must have been about 11 o'clock, and fine ash was now falling around the lower slopes of the hill, so, partly for this reason, and partly from the information given by the fish sellers, they returned to Orange Hill, and reported that it was only too true that the Soufrière, after its long quiescence, was once more in eruption.

About 11 o'clock rain began to fall containing particles of ash, and the noises from the mountain became louder, more frequent, and more threatening. On some of the estates, work was then stopped, and many of the labourers took flight to Georgetown. Others continued to work till near 1 o'clock, when there was a sharp fall of gravelly stones; this put an end to all sugar-making, and people fled to their houses, or began to hide in the cellars, or the rooms of the larger residences in which the managers lived. Smoke could now be seen ascending in vast columns from the crater. Many tried to escape to Georgetown, but when they got to Rabaka they found the Dry River there pouring down in high flood, and the water was so hot it was impossible to wade across. There is no bridge over this river, so most of these refugees gathered at Rabaka House, but some returned to their own dwellings.

In Georgetown it was not till about 11 A.M. that it became known with certainty that a catastrophe was impending. Mr. J. W. CLARKE, teacher in the Government school, has given us an excellent account of his experiences that morning, from which we take the following :—

"Previous to the above-mentioned date (7th May) there were signs noticed in some places that the crater was in action, but at Georgetown there was no sign observed till the very day, in fact, one can almost say the very hour. On the morning of the 7th, reports of the Soufrière's activity were being questioned for the simple reason above stated. Then women and children went to perform their various regular duties; everything appeared as usual. I kept my regular 7 to 9 private school. Shortly after 9 A.M., sounds resembling distant thunder were heard, but it was not until 10.15 A.M. when particular notice was taken of the sounds, from their long-continued detonation. I was engaged marking my school register of attendances from 10.15 to 10.30 A.M., during which time the noise increased. At about 10.40 there was a distinct flash of lightning seen from the direction of the mountain, followed by a crackling peal of thunder. At 10.45 I got a little uneasy, and just at the same moment I got a message from

Mrs. BALLANTYNE, asking me to send home her daughter, who was then at school. I hesitated for a few minutes, and, when in consideration of what should be done, another stroke of lightning followed by heavy thunder was seen. I then complied with the request, and, feeling apprehensive of danger, I at once went to the manager of the school, Mr. H. B. ISAACS, and suggested that the school should be dismissed, and the children sent home till matters cleared up. After a few minutes' consideration, the suggestion was granted, and I hurried back, and, in a few words, dismissed the school.

"It was now about 11 A.M., and the rumbling noise still continued. About 11.15 drops of water containing sulphurous matter fell, and that was the first direct sign which told me of the disturbance of the Soufrière. The water continued falling only in drops here and there. At this stage, very minute particles of dust or ashes fell, but were only observable on white material. My boots at this time were besmeared with the sulphurous matter mentioned, as I kept walking from one place to another. At about 12 noon I was standing under the galvanised roof of the Grey's store when small pebbles, about a pea grain size, commenced to fall. This falling of pebbles continued for about an hour, during which time several others along with myself gathered pebbles of the same.

"It was about 1.30 P.M. when smoke was distinctly seen issuing from the crater, and volume after volume rose, only to ascend higher than the former; the clouds of smoke got blacker and thicker, and each mass seemed to travel faster than the first.

"At about 2 P.M., pebbles of a larger size commenced falling, and it was becoming injudicious to move about."

One of the most remarkable features of this eruption is the suddenness with which it broke out. At Chateaubelair steam was seen ascending from the crater on Tuesday forenoon, and the inhabitants had at least 24 hours' notice before the volcanic activity assumed a dangerous phase about noon of Wednesday. But everywhere else around the mountain there was no certainty till about 11 o'clock on Wednesday morning—or only 3 hours before the climax was reached, and the great black cloud swept from the crater to the sea, burning and suffocating those in its path. Had the leeward side of the hill not been clear of mist, so that a view of the crater was obtained by those dwelling there, the loss of life would certainly have been much greater than it was, for the noises would have been mistaken for thunder, as they were at Georgetown.

That even at Lot 14, 3 miles from the crater, the reality of the eruption was doubtful till near mid-day, proves that the outbursts seen from Chateaubelair up to that time were comparatively unimportant, and consisted only of steam and hot water, with a little fine ash and a few showers of stones. They constitute the preliminary stage of the eruption. Thereafter the activity rapidly increased in violence. About mid-day the crater lake was discharged, and this showed that the upward pressure of the lava was overcoming the resistance, and forcing a path to the surface. The throat of the crater was being cleared. Vastly greater steam clouds now shot up into the air, and the noises of explosions, hitherto comparatively few, became numerous and loud, while showers of hot stones with trails of sparks began to fall upon the slopes of the cone. Between 12 o'clock and 1 o'clock P.M. the hill was still quite green up to near the summit. No serious damage had yet been done to the vegetation, and at Wallibu and Lot 14 only a thin film of fine grey ash had as yet fallen, just sufficient to give the vegetation a dusty appearance. At Wallibu, before

Mr. ROBERTSON left at 12.30, a few stones had fallen several inches across, and as he rowed away he noticed that some were floating on the surface of the water.

The Climax of the Eruption. The Descent of the Great Black Cloud.

The climax of the eruption was now at hand. It came with terrible suddenness. With laconic brevity, Mr. McDONALD records it as follows :—

"1.55. Rumbling. Large black outburst with showers of stones all to windward, and enormously increased activity over the whole area.

"A terrific huge reddish and purplish curtain advancing up to and over Richmond Estate.

"At this stage left Richmond Vale House and hurried into and pushed off boat a few minutes after 2 P.M. Saw vapour as we rowed hard across Chateaubelair Bay coming down to sea level past Richmond Point. Sea peppered all round with stones, one of which—about a cubic inch—fell inside the boat, in which were eleven persons.

"The huge curtain referred to was advancing after the racing boat, which never seemed likely to get out of the range of it, or the falling stones, which latter varied from the size of one's fist downward . . . .

"The lightning and thunder at this time were terrific, and there were noises inland.

"Everything seemed to point to a general break up, both on land and sea."

This was the ontburst of the great black cloud, which, charged with immense quantities of red-hot dust, poured from the crater and swept down the valleys to the sea.

It will be noticed that Mr. McDONALD describes it as reddish and purplish. He does not enter into particulars as to its form, except that he states that it was like a curtain. All who have seen the side of this cloud use exactly the same term in describing it. It resembled a curtain hanging in folds, black, dense, solid, and well-defined. The cloud swept out to sea over Richmond ; its southern margin was over the headland on the south side of the mouth of the Richmond River. Richmond Vale House stands in the next valley to the south of Richmond Estate, and it was spared and but little damaged, while Richmond was wiped out and destroyed. Mr. McDONALD's boat was perhaps half a mile south of the edge of the black cloud. Stones fell about it, but there does not appear to have been great darkness for some time after, and he does not speak of suffocating vapours or dust, or of any very great heat.

It is interesting to compare with Mr. McDONALD's description the statements made to us by some black and coloured men, who were just a little further north than Mr. McDONALD, and were caught in the edge of the cloud. They had been at Richmond to remove their personal belongings to Chateaubelair, and their boat was returning when the black cloud swooped down.

The sea was perfectly calm and the day clear, though there had been a few drops of rain in the forenoon. The boat had just rounded the point south of Richmond River, and was on the north side of Chateaubelair Bay. The cloud struck them like a strong breeze, though, being under the shelter of a high spur of land, they did not feel it much. Still it came over the water with a strong ripple and a hissing sound, due to the hot sand falling into the sea and making it steam. In a moment it was pitch dark and intensely hot and stifling. The cloud was highly sulphurous, and this irritated their throats and nostrils, making them cough. The heat was terrible and the suffocating feeling very painful. They threw themselves into the sea to escape burning by the hot sand. It does not appear that the surface of the water was boiling as it was in some other cases. They all dived, and when they returned to the surface the air was still unfit to breathe and the heat intense. So they continued to dive repeatedly, but when they came up again the air was almost as bad as before. How long this lasted they cannot tell, but they thought it might have been several minutes. At last they were all utterly exhausted and could have held out no longer; then they felt the air clearing, the heat diminished, though still very great, and they clung to the boat for a few minutes before they were able to get into it again.

One man was not so good a swimmer as the others, and his strength was soon exhausted. He held on to the gunwale of the boat and took the risk of burning rather than of drowning. He described to us the insufferable heat and the sulphurous smell, and he was rapidly becoming unconscious when the air cleared. The sea around was hissing, and it was so dark that two men hanging on to the boat, side by side, could not see one another, even though they could touch. There was a continuous loud noise, but a person speaking in an ordinary tone of voice could easily make himself heard. This is a curious fact, for the report of this explosion was heard at Barbados. But Mr. McDonald confirms the statement. He noticed particularly that when he gave orders to his men to launch the boat and leave the shore, he did not require to exert himself in the least to make them hear him.

While this man remained clinging to the gunwale the hot sand rained upon him. His woolly head was wet and the sand, was cooled by contact with it, but it gathered above the lobes of his ears, and there the heat was sufficient to dry his skin and produce painful burns. He told us that when the cloud had passed there was enough sand on his scalp to fill his hat twice over (the hat was an ordinary round straw with flat brim). It formed a layer 2 or 3 inches deep. The ash fell dry, there was no rain and no scalding mud. When they got back into the boat they found it nearly filled with fine ash and stones, and these were so hot that had the boat not been leaky and partly filled with water it might have taken fire. Yet these men were only in the outer edge of the cloud. A few hundred yards further north this cloud deposited in some places 40 feet of red-hot sand in a few minutes. It was for this reason also that they experienced no great shock when the cloud struck them, and did not feel it pass like a strong blast, for Mr. McDonald states, a cloud came down with a high velocity. His boat was going at perhaps 8 or 10 miles an hour, impelled by the frantic exertions of a crew fleeing from a dreadful death. But the cloud was travelling at least twice or thrice as fast. The curtain-like lateral margin of the dense black cloud was almost stationary, or consisted of gentle eddies at the side of a rushing torrent.

Another man, who was caught in this cloud and survived, gave us a very interesting narrative which confirms those we have been considering. He was coming south from Campobello on the north shore in a boat with several others. That morning he had gone north from Morne Ronde to rescue his family, and when he got to Campobello the people there knew nothing of the eruption. His party left at 1 o'clock, and a little later they passed Windsor Forest. This was a grazing estate, and he saw that all the cattle were gathered on the beach, running to and fro and bellowing with terror. A few minutes later he heard the sound of a great explosion and saw a huge black mass pouring out of the Wallibu and Larikai Valleys to the south of him. Terrified, he started to return, but at Baleine another similar cloud was rushing down the ravines on the mountain side to the north. No course remained open except to stand right out to sea.

Small stones began to fall in the boat. Then he was enveloped in dense darkness and ash fell, at first wet but afterwards dry and quite cold. By this time they were several miles out from the shore. Another boat was quite near him when the darkness descended. It was never seen again, but with its occupants was totally lost. He thinks it was filled with sand and sunk, for the downpour of ash and stones was so heavy that they had to keep constantly bailing it out. "It rained as fast as if three men were throwing in sand with shovels."

He rowed right out to sea, and that night the tide took him to quite near St. Lucia. When it turned, it carried him back again, and next morning he landed near Chateaubelair.

This narrative proves that the black cloud swept over the north-west side of the mountain, and that here also it poured down the valleys almost like a torrent of water. It was much less dense in this quarter than at Wallibu, and when it had passed a few miles from the shore, though laden with dust and stones, it was quite cold, and was moving so slowly that it did not overturn his boat or raise the sea sufficiently to make it dangerous. He did not mention any great smell of sulphur, but stated that the lightning was terrific, and there was a continuous rumble in the cloud "like the rolling of a barrel."

We have also the reports of several competent observers who saw the cloud from a distance of several miles as it rolled out over the sea past Chateaubelair. The Rev. Mr. DARRELL, of Kingstown, in a brief account of the eruption, which was printed in Kingstown on May 12, writes as follows :—

"We were rapidly proceeding to our destination when an immense cloud, dark, dense, and apparently thick with volcanic material, descended over our pathway, impeding our progress and warning us to proceed no further. This mighty bank of sulphurous vapour and smoke assumed at one time the shape of a gigantic promontory, then a collection of twirling, revolving cloud-whorls, turning with rapid velocity, now assuming the shape of gigantic cauliflowers, then efflorescing into beautiful flower shapes some dark, some effulgent, some bronze, others pearly white, and all brilliantly illumined by electric flashes. Darkness, however, soon fell upon us. The sulphurous air was laden with fine dust that fell thickly upon and around us, discolouring the sea; a black rain began to fall, followed by another rain of favilla, lapilli, and scoriæ. The electric flashes were marvellously rapid in their motions, and numerous beyond all computation. These, with the thundering noise of the mountain, mingled with the dismal roar of the lava, the shocks of earthquake, the falling of stones, the enormous quantity of material ejected from the belching craters, producing a darkness as dense as a starless night, together with the plutonic energy of the mountain, growing greater and greater every moment, combined to make up a scene of horrors."

Dr. CHRISTIAN BRANCH, of Kingstown, was in the same boat, and gives the following description of the scene :—

"We did not go far, for the first point we rounded disclosed a horrid black, solid wall of smoke jutting into the sea, about two or three miles from us. It looked like a promontory of solid land, but it rolled and tumbled and spread itself out, until, when we could last see it sometime later, it must have extended quite 8 miles over the sea to the west. It was evident we could not go through it, and if it overtook us, as it seemed likely to do, we would be lost in darkness, even if nothing poisonous was in it.

"The island to the north of us and north-east was now covered with a mighty black pall of smoke, perhaps two miles deep, and the smoke column was now a vast shapeless blackness. Then began the most gorgeous display of lightning we could conceive. All around us and above, so near, that several times I saw it between us and the cliffs not 200 yards off. It was still bright daylight with us, but the whole atmosphere quivered and shimmered with wavy lines intersecting each other like trellice work. We were encircled in a bristling ring of fiery bayonets. It was too stupendous to terrify; one could only marvel and feel nervous. A few stones plumped in the sea around us, and then fell pretty thickly. They were light pebbles for the most part, and only these fell in the boat. A nasty shower of mud followed the lightning, and then a long shower of gritty sand. After this a fog of fine dust descended, and it got darker and darker, until we could with great difficulty see the shore and points along which we steered."

On the windward side of the island the black cloud descended in probably no less volume than to leeward. Its main current flowed down the valley of the Rabaka Dry River as, at Owia on the north-west side of the island, and at Georgetown, which stands well to the south of the valley, its action, though traceable, was not devastating or lethal.

In the Carib country work in the fields had stopped, and in the sugar works, though they were full of people, no sugar making was going on. Everyone was watching the progress of the eruption in mingled fear and admiration. Small stones began to fall after mid-day, and about half past one in some places there were showers of hot scalding mud. The cattle, horses and mules were mostly out grazing, but nearly all the people had gathered into the more substantial buildings, the managers' houses or the stores and cellars attached to the sugar works, though many were in their huts in the villages adjoining the estates. Some had been struck with falling stones, but as yet probably no one was killed, and but few injured.

Then, with a loud roar, at 2 o'clock the great convulsion came. Those who were in the open air saw the huge black cloud rolling down the mountain in globular, surging masses. They fled into the houses and shut the doors. Onward it rushed with a loud rumbling noise and filled with lightnings. Any who were in the open air perished at once. Many of the negroes' huts were so densely crowded with people, that there was hardly standing room. At Lot 14 the manager and his wife and family had shut themselves up in the rum cellar below the house, and firmly closed all doors and windows. They had a terrible experience, but they survived. All of those in the house itself or in the negro village were killed. It will be understood that as the tropical houses are so built as to secure free entrance of air, it is almost impossible to close them up securely, and the suffocating blast reached the interior and stifled all who were there. All the animals in the fields also perished.

At Rabaka many who were prevented from fleeing to Georgetown by the floods of hot water in the river had gathered in the manager's house. In one large room there were fifty people. When they saw the dark cloud coming, they firmly shut all the windows—fortunately they were substantial and well-glazed—and everyone in this room was saved. They felt the heat most intense. It was quite dry, and there was a very strong and irritating odour of sulphur. Some fainted, but all survived. The overseer told us that from the window he saw the black cloud rolling on towards them; when it reached the house there was darkness, and a sharp fall of stones on the roof. The cloud rolled down upon the sea below the house, and when it struck the water it was "filled with fire." It seemed then to rebound from the surface of the sea and return towards the building, and at this time the wall of a ruined sugar store was knocked down, probably by lightning, as nothing else was overturned. It was when the cloud returned from the sea that the suffocating feeling was experienced. Perhaps this was because it took a little time for the noxious gases to penetrate to the interior of the house. Practically all who were in the negroes' huts or in the open air perished.

At Orange Hill there was a large substantial stone-built rum cellar, which, by the orders of the manager, was left open to afford a refuge for any who wished to avail themselves of it. About seventy crowded together there. The windows were not shut, but they were small and faced the sea, so that the blast did not directly strike them. One man stood by the door holding it ajar, to admit any who fled from the huts in the village. Forty were in the cellar, and all were saved. Thirty were in the passage leading into the cellar, and they were all killed.* None of those survived who remained in the labourers' huts, or were fleeing to and fro about the yard in abject terror. Many shut themselves up in a store with a galvanized iron roof. All died, and were found buried in sand with the roof collapsed and fallen upon them. In the

* Mr. E. O. Hovey states that 132 persons were saved unharmed in this cellar. ("Martinique and St. Vincent: a Preliminary Report." 'Bull. Amer. Mus. Nat. Hist.,' vol. 16, p. 344.) This is an example of how divergent are the statements of different witnesses of the catastrophe. Our informant was caretaker of the estate in June, 1902, and he was an occupant of the cellar during the afternoon of the eruption. (See Appendix III., p. 547.)

under story of the manager's house thirty people died. The manager himself, Mr. FRASER, was found dead on his verandah; his wife's body was lying at the foot of the steps leading up to it. They seem to have been overcome as they were returning from the cellar where they had at first taken refuge. We were told that Mr. FRASER complained that the densely packed crowd of negroes made the atmosphere unbearable, and returned to his house to get some fresh air.

At Turema the fatal cloud did its deadly work quite as effectively. All who were in the manager's house, estimated to number thirty-five, were killed. One woman survived for three days, and was found by the first search parties who went out from Georgetown. She begged for water to drink; they gave her some, and returned to make arrangements to have her taken to the relief hospital, where she died shortly after her arrival. In the "Great House," or Mansion House, four were killed in the kitchen, where the windows and doors had not been effectively closed; two shut themselves up in another room, closing all apertures as thoroughly as possible, and they survived. All who were in the villages or fields perished, without exception.

In Overland village the loss of life was terrible; hundreds were killed. In one small shop by the roadside, in a room perhaps 15 feet square, eighty-seven bodies were found. When we saw this place the ash around was dotted with little hummocks, under each of which lay a heap of bodies, but everything was decently interred, and contrasted strongly with the charnel heaps of bleaching skeletons we saw later on in St. Pierre. One man whom we interviewed had lived in this village; in his house seven died, but four or five survived. When they saw the black cloud coming down, they shut up all doors and windows as tightly as possible. As the hot cloud approached, it was red at first, but changed into black before it passed overhead; the heat was dreadful, and the lightnings very vivid. The air smelt very strongly of sulphur, and their throats were dry and parched. Some burst into spasmodic coughing from the irritant sulphurous acid and fine dust in the air. Many cried out for water, but in a few seconds the suffocating feeling prevented articulation. Then several threw up their hands and fell dead. Others collapsed, but lingered in some cases for an hour or more. Those who survived state that in a few seconds it would have been all over with them. But the air began to clear, there was a slight breeze off the sea, and the windows on that side were thrown open, and, with a sense of great thankfulness, they inhaled again deep breaths of cold pure air. Here, as at Rabaka, those who were watching the cloud state that as it struck the surface of the sea it flashed with fire. One man showed us where the back of his fore arms had been severely burned by hot mud or ash which came down with the black cloud. The parts of his body covered by clothes were protected, but his shirt sleeves were rolled up, and his arms below the elbows were bare.

At Orange Hill, Turema, and Lot 14, there were large herds of cattle, horses, and mules. Every animal on these estates perished. Some were suffocated or burnt extensively; others had apparently been struck by lightning. They were all in the fields or in open pens, and not one survived. It does not appear, however, that before the great outburst, which took place at 2 o'clock, they had shown any peculiar restlessness as if they were aware of the impending doom. At Windsor Forest the cattle had that forenoon been in a state of trepidation, and had fled to the shore, where they ran up and down, bellowing loudly. Probably this was because earth tremors and subterranean noises were more common and more pronounced there than in the Carib Country. At Wallibu, about 12 o'clock, there was a loud sharp noise accompanying an outburst of steam, and the earth shook. The house-dog ran out into the open air howling with terror. On the windward estates, however, it seems that the dogs remained at the houses and hid themselves, but did not run away or endeavour to escape.

Over the northern shore of the island the dark cloud descended also, but there its velocity was less, and the devastation it produced much less considerable than in the valleys on the south of the mountain.

The Fancy estate lies almost due north of the crater, and about 3 miles distant from it. It is actually nearer the focus of eruption than either Wallibu or Lot 14, though those two have suffered much greater damage. Mr. CUBBIN, who was the local teacher, has supplied us with some interesting notes regarding the events of that afternoon. About 2 o'clock there was a fall of stones, which increased in severity till the manager, Mr. BEACH, considered it desirable to collect all the people on the estate in a large iron-roofed main building. Dark clouds were then seen pouring out over the sea on each side, and soon they broadened till only a narrow passage was visible between them to the north. "The mass of falling débris seemed to be closing in upon us, and in a short time it fell, enveloping the building and almost suffocating the inmates; during this time there was almost total darkness. In a few minutes there was a glimering light, as at dusk. The houses in the village, or most of them, were now observed to have been demolished; this was caused by the falling débris and by lightning, and most of the people who remained in the village were either dead or fearfully burnt. Many of them died by next morning."

The estates building was of stone with galvanised iron roof. The windows were all closed, but the door was open at the time the cloud descended, and was shut by the force of the blast. All who were in the building were saved, but about forty were killed in the village. Those who escaped were badly burnt, mostly on the hands, the feet, and the face, but others also on the parts protected by clothes, though their clothing was not scorched or ignited. The dust in the cloud was not red-hot, and consequently did not set anything on fire, the burns being apparently due to steam and other gases.

Much of the damage done on the Fancy estate was apparently due to lightning. Next morning, the shingles from the roofs of the houses, and the galvanised roof of a store, were found dislodged and carried some distance away. The cloud came with a blast, but no one believed that this was sufficient to produce these effects. Moreover, the materials were scattered irregularly, some being found on the beach below the houses, others on the opposite side towards the hill. These facts all point to the capricious action of lightning from the cloud.

Similarly, at Turema and at Wallibu, the factory chimneys were knocked down. As at both places many of the trees are still standing, and as at Turema the houses are comparatively little damaged, there can be no doubt that the chimneys were not overturned by the blast, and it is generally believed to have been the effects of lightning. It is probable also that some of the huts which were set on fire were really ignited in this way.

The first reports of the catastrophe stated that the deaths were practically all the result of lightning. This is certainly not the case, but it is sufficient to show how rapid were the fatal effects as a rule. On the other hand, there can be no doubt that the lightnings were the cause of many fatalities. We were told by one man, who was looking out of the window of the rum cellar at Orange Hill, that he saw a woman starting to run across the yard to the building from one of the huts. That instant there was a bright flash, and she fell dead. The corpses of some of the animals which perished in the fields gave evidence of having been struck by lightning, and everywhere on the devastated estates it is easy to find trees which show the effects of the same agency.

At Owia, according to Mr. EFFINGHAM DUN, small and large pebbles were falling about 1 o'clock, and from 1.30 to 1.45 there was a rain of hot liquid mud. At this time there was a nauseating odour of sulphuretted hydrogen, but it only lasted about half an hour. It now became very dark, and from about 2 o'clock to 3 o'clock the heat was almost suffocating, "and I had to throw water about the house to make breathing possible." At Owia the damage done was comparatively slight. The crops were injured but not buried, and none of the inhabitants were killed.

That the black cloud surmounted the rampart of the Somma wall, which rises to the north of the crater and poured down the northern slopes of the mountain, is most clearly proved by the evidence of the occupants of the boat already mentioned, which at about 2 o'clock was off Windsor Forest on its way from Campobello to Chateaubelair. They saw a dense, impenetrable mass streaming down the Larikai and other valleys to the south of them, and turned to retrace their course, but immediately afterwards a similar cloud was seen descending the valley at Grand Baleine, so being caught between two fires, they had nothing left but to stand directly out to sea. The Grand Baleine Valley is the largest on the north-west quadrant of the hill, and the main volume of the cloud seems to have coursed along it like a fluid. Between this valley and the estates of Fancy and Owia a series of ridges intervenes, and these apparently sheltered the north-eastern corner of the island and deflected the main force of the blast. In this quarter the destruction was less complete than in any other section of the hill.

At Georgetown no lives were lost, and it seems certain that the deadly black cloud did not pass over the town. A little after 2 o'clock the inhabitants heard a very loud sound proceeding from the crater. This was described to us as "a long, loud, mournful, unearthly, death-like roar." The mountain at that time was emitting an enormous column of steam, which expanded and spread out laterally as it ascended in the air, and red-hot stones were tumbling down the slopes, giving out trails of sparks. A heavy fall of scoria and stones followed the outburst. Darkness then set in fairly rapidly, though by no means instantaneously, and the rain of ash began. It continued through the whole evening and the early part of the ensuing night.

The first estate north of Georgetown is Mount Bentinck, and here also no lives were lost, though the fields were buried in ashes. Langley Park stands half-a-mile to the north of Mount Bentinck, and many were killed there. In the main builing some thirty or forty bodies were found. The house was being cleared of ashes when we visited it, and as they had stuck to the surface of the walls, forming a grey layer like fresh cement, it would seem that on the edge of the cloud the dust was in some places moist and adherent. This was also the case in Fancy, where on the morning of Wednesday it was seen that the walls of the houses were plastered over to a depth of half-an-inch with fine wet ashes.

It is clear that the black cloud passed over Langley Park, and that the fatalities which took place there are to be ascribed to its action. Mount Bentinck and Georgetown escaped, and this shows how sharply defined was the lateral margin of that mass of deadly vapours and dust. It shows also how harmless was the rain of ashes from above, as no one was killed south of the limits of the cloud, though a few were injured by falling stones.

The Rain of Ashes.

The history of the later stages of the eruption which followed the descent of the great black cloud cannot be given with the same fulness and detail as that of the earlier phases. Darkness now covered the mountain and much of the surrounding country, and little could be seen except the flashes of lightning and the occasional fall of red-hot stones. The inhabitants had shut themselves up in their houses, and many were engaged in succouring the wounded and dying, so far as that was possible. Others had hid themselves in inner rooms and cellars in momentary expectation of a sudden and painful death. No man was sure of his life for a moment. Everyone believed that most of his neighbours and friends had perished. Many dreaded that the sea would invade the land in great tidal waves. The earth rocked and shook continuously, and those who dwelt in the more substantial stone-houses were afraid that they would fall on them. The air and sky were filled with lightnings, which quivered and played incessantly. Many houses were already on fire, and trees and buildings were frequently struck. Fine ash and lapilli were raining down upon the roofs of the houses, which were rattling under this bombardment. Every now and then a fall of bigger stones would crash with a loud noise on the wooden or iron roofs, and not unfrequently these were perforated by large stones which landed in the rooms among the frightened survivors. Those who ventured abroad protected their heads with pillows or pieces of wood, or even with tubs. The ground was covered with a layer of ashes which, though warm, could without difficulty be walked upon. The air was charged with fine falling dust, which irritated the nasal passages, giving rise to coughing and sneezing. A few remarked to us that immediately after the great outburst which took place about 2 o'clock in the afternoon, the pressure of the air seemed to be increased, and the effect on the tympanic membranes of their ears was such that the sound of the roaring of the mountain was at times acutely painful. As we shall see later, there can be no doubt that the eruption of the great black cloud occasioned a sudden rise of barometric pressure. Dr. DUNBAR HUGHES, of Barrualli, was one of the observers who noted this phenomenon.

Above all resounded the roaring of the mountain, and for about two and a half hours in the afternoon the noise was terrible. Even at Kingstown it was so loud that it resembled no sound with which the observers were familiar. Some compared it to the discharge of an enormous gun, except that it was continuous and not intermittent, and we were reminded that among the Caribs there were old traditions regarding the "Great Gun of the Soufrière." Most people described it, however, as having a long, drawn-out, weird, unearthly character, recalling the roar of a wounded animal in intense pain. It is a curious fact that most observers in St. Vincent state that it did not seem to them to be made up of distinct detonations or reports, or if so, these were so numerous as to be blended together without intermission. The sound, however, rose and fell, being at times distinctly much louder than at others. At the same time in Barbados, St. Lucia, Trinidad and elsewhere, the noises from the volcano were compared to the reports of distant cannonading, and the intermittent nature of the sound was one of its distinctive features.

The air also was laden with sulphurous fumes. Especially was this noticeable during the passage overhead of the great black cloud, when the abundance of sulphurous acid (and also sulphuretted hydrogen) was so great as to produce an intense feeling of irritation and suffocation. Thereafter it seems to have been much less, but continued more or less through the whole night. The sulphuretted hydrogen attacked silver articles, and it was noticed in several cases that the silver bracelets on the arms of the coolie women turned rapidly black. At Kingstown the first fall of ash was accompanied by a sulphurous odour; after that, however, it was much less marked. This was also the case at Barbados, where the sulphurous smell of the dust was one of the reasons which led to an early and general recognition of its volcanic character.

The intense heat, however, was even more oppressive than the sulphurous vapours. Within the precincts of the dark cloud it was terrible. The sufferers cried for water, till the scorching of their throats prevented articulation, and they fell groaning to the ground. But in all the district round the volcano, during the earlier part of the afternoon, the inhabitants felt that the temperature of the air was unusually high, and rendered exertion difficult. Most of them also remarked that their throats were parched and dry, and their thirst excessive. This may have been the effect not only of the high temperature of the air, but also of the fine dust which irritated the mucous membranes. It seems quite clear that the sudden discharge of enormous masses of incandescent sand into the atmosphere was sufficient to raise its temperature all over the northern part of St. Vincent during a period of at least a couple of hours. It is unfortunate that we have no readings of the thermometer which would enable us to ascertain how far these effects proceeded.

Rain does not appear to have fallen in abundance anywhere immediately around the hill that afternoon and night while the eruption was at its maximum or drawing gradually to a close. During the morning and forenoon there were local showers, especially on the windward side, but, though they were heavy, they were certainly not general. As already stated, the climax of the eruption was heralded in some places by showers of hot mud, or wet, hot ashes, which scalded not a few people. But on the leeward side the day was essentially dry, and at Kingstown, though the ash at first fell wet, there were no rains of any consequence. It is not a little remarkable that the discharge of such enormous quantities of water vapour into the air should not have been accompanied by condensation or precipitation on a large scale; but, whatever may be the reasons for it, the fact remains that the great eruption of the Soufrière was essentially a dry eruption.

When the great black cloud was seen rushing out to sea past Chateaubelair, even those whom courage, or a sense of duty, or helplessness, had led to linger in the village, were struck with one impulse to escape. We have some graphic narratives of that flight, which give us a picture of the demoralisation of the black population and the terrors of the eruption, so vivid as to be worth reproducing here. Dr. DUNBAR HUGHES and Captain CALDER, who had both gone there by order of the Administrator, were the last to leave, and Captain CALDER's account of his escape is as follows* :—

"When the black people realised their danger most of them grew madly excited, and in a few minutes everything in the shape of a boat or canoe pushed off from the shore, weighted down to a dangerous degree with human freight, each one excitedly urging on the others. I could then have left with the police in our boat, but with three or four hundred refugees on the shore I quickly determined that our duty was to remain.

"While I was speaking to the people in the street, the excitement and danger were increased by hot, half-melted stones falling from the enveloping cloud. I ordered everyone in the streets to leave the town at once, and, to prevent injury by falling stones, I directed them to take old boards and shingles from the dilapidated houses and cover their heads. Stones up to half a pound in weight were now falling, while the sulphurous fumes and fine light dust rendered breathing difficult. So, with at least three hundred refugees in front, we started out of the Chateaubelair valley, accompanied by the

* 'Century Magazine,' August 1902, p. 636.

prayers of some, the excited yelling of others, and the feeling of despair of nearly all. Men, women, and children of all ages scurried up the steep hill as fast as possible, mothers urging on their young children hardly able to crawl, old men imploring the assistance of the younger and stronger, each helping and encouraging the other, clearly showing the brotherhood a common danger engenders.

"One poor woman, with a brood of at least eight, was kept behind by the inability of the youngest two to keep up the pace. Her agonised cry for help I can never forget, nor the thankful smile I got when I picked them up, one in each arm.

"By this time the dense volume of sulphurous cloud, which chased us like a death pall, began to overtake us, and it was hard indeed to get the people to continue struggling on. As the darkness settled over us, a storm of lightning and thunder broke over our heads, and so near were the flashes that one thought that each surely must strike the people on the road, especially as the dry grass on the hill-sides was ignited. It would indeed be difficult to be more uncertain of another minute's life than on that hill-side that dark afternoon.

"As we gained the summit of the next mountain, the poisonous dusty cloud was held in check by a steady breeze coming in the opposite direction, but for which the death-roll by suffocation must have been appalling. I pushed on for 9 miles, until I got an opportunity of communicating with Kingstown, when I learned that sulphurous dust and ashes, accompanied by semi-fused stone, had fallen there. The stones measured on the average at least an inch in diameter.

"When about 4 miles from Chateaubelair, thinking the danger from falling stones had passed, I removed the board I had tied over my head, and, as a result of my want of caution, I was struck down, and remained in a semi-conscious state for over half an hour.

"It is impossible fitly to describe that awful trek through a continual blaze of lightning, driven, as it were, before that deadly and enveloping cloud of sulphurous dust and ashes. The awful grumbling and rumbling of the volcano continued throughout the night, and as the morning dawned, the deep green of the young arrowroot and cane plants had given place to a smooth leaden colour of dust, several inches deep, not a single green leaf of any description being visible."

Mr. T. M. McDonald left Chateaubelair by boat about the same time as Dr. Dunbar Hughes and Captain Calder started out along the road leading to the south. Two versions of his invaluable diary have appeared, one in the 'Sentry' newspaper of Kingstown, St. Vincent, on May 16th, 1902, the other in the 'Century Magazine' of August, 1902, pp. 638-642. The latter is somewhat amplified, probably by the incorporation of notes given by word of mouth to the reporter. They differ in several respects, but both are obviously copies of the brief notes taken in his pocket book at the time, and these notes we had the privilege of discussing with him on several occasions. On the whole, the version of the 'Sentry' adheres most closely to the original.* His statements are in almost perfect accordance with those of the observers already cited. He does not mention, however, the indraught or steady breeze which, advancing in an opposite direction, held the great black cloud in check. Not a few of the residents of Chateaubelair whom we interviewed when we were there had remarked that an opposing wind sprung up from south or south-east, and regarded it as an important factor in the preservation of the village.

Of the existence of a reverse current or indraught there can be no doubt. That it

* As this edition of the 'Sentry' newspaper was out of print in a few days, a second edition was struck off, which also was soon exhausted. We have considered it advisable to print it in the form of an appendix to this report. (See Appendix II, p. 544.)

was strong or persistent is quite unlikely. Some refugees who fled in boats from Chateaubelair landed near Rosebank and fled precipitately along the road, leaving their boats unfastened in any way. So calm was the afternoon and the ensuing night that these boats were found next morning floating within a few yards of the place where they were deserted. Hence it is clear that the indraught cannot have been vigorous. That any ordinary current of wind could have checked or altered the course of the great black cloud may be regarded as in the highest degree improbable. When it swept past Richmond to the north of Chateaubelair it was travelling with the velocity of a strong breeze or gale, and was so laden with dust that its weight must have been enormous. We may regard it rather as similar to the inrush which takes place when an express train passes at high speed through a railway station—a consequence of the movement of a large mass with a considerable velocity through the air. It may have drawn clear fresh cool air up to the edges of the black cloud, and in this way have mitigated the heat or prevented the lateral diffusion of the foul gases it contained. Possibly it may even have saved the lives of some. But it was a consequence of the great down-rush of dust and gases, and not in any real sense an opposing and countervailing agency. When at a later period we witnessed an eruption of Montagne Pelée the black cloud passed close to us, but although we watched for it carefully, neither of us observed any vigorous opposing indraught of air.

It would seem that immediately around the volcano darkness was absolute while the great dark cloud passed overhead, but that, at least in the district to the south of Chateaubelair and of Georgetown, though it was so dark that lamps had to be lighted in the houses, yet the fugitives could find their way along the roads without much difficulty. Dr. CHRISTIAN BRANCH states that when his boat entered Kingstown about 6 o'clock that evening, the light was still sufficiently good to enable the boatmen to make out clearly the headlands they passed as they rowed southwards along the coast. He says that the darkness was never absolute outside the great black cloud which rolled out of the volcano. Dr. DUNBAR HUGHES, Captain CALDER, and Mr. T. M. McDONALD seem to have been able to travel along the narrow, steep, winding, and in some places dangerous road to Wallibu without any very great inconvenience on account of the darkness. They were able to recognise the people whom they passed, and even to see the features of the land some short distance away. In Georgetown between 2 and 3 o'clock in the afternoon it was very dark, but still people were able to go from one house to another. The danger was rather from the bombs and large pieces of stone which were falling at intervals. During the whole night it was possible to pass through the village with a lantern or even by the light of the innumerable flashes of lightning which shot across the sky. Even in the villages in the Carib Country there is evidence to show that after the black cloud passed, and before night set in, there was a glimmering light sufficient to enable the terrified survivors to flee from one house to another. Within the houses the darkness was greater, and lamps or matches had to be used to furnish light. It is also probable that the darkness was most intense between 2 and 3 o'clock, shortly after the great outburst, and that as the afternoon wore on the light somewhat improved.

Kingstown.—At Kingstown, and in the south end of the island, it was generally known on Wednesday forenoon that the Soufrière had resumed activity, but there were no physical signs to indicate that the eruption was in progress till about 12.30 in the afternoon. Then the loud noises proceeding from the volcano attracted attention, and about 2 p.m. it was seen that a vast cloud of steam was ascending in the northern sky, till its apparent height was twice as great as that of Mount St. Andrew, which overlooks the town.* It was somewhat pointed or tongue-shaped, but broadened out as it rose, and consisted of bulging, globular, rolling masses which were constantly changing in form and increasing in number. The noises from the mountain were continuous and very loud, with a roaring, long drawn-out character which baffles description.

About half past 2 o'clock grey pebbles of a pumiceous character began to fall, and at the same time the atmosphere was charged with sulphurous odours. Some of the stones were almost the size of a hen's egg, but they did little damage in the town except to the large-leaved trees, some of which had their foliage perforated or torn to shreds; many of them were covered with a thin layer of wet mud. Then smaller stones began to fall "like a sharp shower of hail," and these were followed by little pellets of fine moist ash "about the size of small sago." Dry ash followed, and this formed the bulk of the shower, becoming somewhat finer, lighter in colour, and less abundant as the evening wore on. It had a sulphurous smell, though some compared the odour rather to that of guano. Mr. POWELL, of the Botanic Gardens, informed us that the foliage of the more tender plants was blighted and turned yellow, and all the forward bread-fruit dropped, not from the weight, but from the nature of the ash. The plants with stout thick leaves suffered comparatively little damage, and in fact it was noticed that a few days afterwards their foliage was cleaner, greener, and more free from insects than before, so that there was reason to believe that the ash had insecticidal properties.

Lamps had to be lighted in Kingstown about 4 o'clock in the afternoon, and although the darkness was not intense before nightfall, the air was so full of falling dust that the appearances resembled those of a very thick, dark city fog. During the night the noises continued, but apparently no further showers of stones occurred. The lightnings were very vivid and frequent; the air warm, close, and stuffy. The fine dust penetrated into every corner of the houses, and covered the furniture and all the objects in the rooms with a grey film. It had also an irritating effect on the nasal passage and respiratory organs, and on the conjunctiva, especially of those persons who were obliged to be in the open air.

Through the whole of St. Vincent earthquakes and tremors were very numerous

* See despatch from Mr. CAMERON, Administrator of St. Vincent. Blue Book, 'Correspondence on the Volcanic Eruptions in St. Vincent and Martinique, in May, 1902,' p. 25.

during Wednesday afternoon and evening. At Georgetown and in the Carib Country they were so frequent that several observers stated that they gave up the attempt to keep count of them. The fugitives who were making for Kingstown by sea experienced curious sensations as if the boat were seized by something which held it and shook it vigorously. At Wallibu, Barrualli, Warrawarrou, Kingstown, and on the windward coast, all observers noticed that the houses rocked and shook with an almost continuous vibration. They describe the motion as undulatory rather than resembling the sharp shock which characterises the majority of the earthquakes which they experience in the island. Little damage was done so far as we could ascertain. In Chateaubelair one or two of the houses showed cracks in the walls, others had shingles dislodged from their roofs; but no chimneys were cast down, and even in the Carib Country and at Wallibu the demolition of the factory chimneys was ascribed rather to the lightning than to the earthquakes. It was noticed in several cases, however, that, when the first heavy rains came, the roofs were unusually leaky, as if they had been strained by the rocking motion of the ground. The noises, the earthquakes, the dust in the air, the sulphurous odours, and the darkness all combined to terrify the animals at work on the farms, so that they had to be unharnessed early in the afternoon.

The Phenomena observed in the Adjacent Islands, &c.

The Grenadines.—In the Island of Bequia, one of the Grenadines, about 8 miles south of St. Vincent, sounds as of cannonading were heard, rising to a continuous roar, about 2.15 in the afternoon. The sky was unusually cloudy, and darkness set in about 5.30. A rain of fine, impalpable ash continued all the afternoon, and, presumably, most of the night. At first it was slightly moist, and formed clots or droplets, but afterwards it was quite dry. These particulars are taken from notes supplied by the Rev. Mr. DUFFUS, the Anglican rector. He states that the "sea rose in Bequia Harbour about 2 feet 6 inches." It is a curious fact that while sea waves were noticed here and in St. Lucia and Barbados, no one seems to have observed them in St. Vincent. If they took place there, they must certainly have been quite inconsiderable, as many people were launching boats or landing from them along the leeward coast from Chateaubelair southwards, and any sudden change in the level of the sea could hardly have escaped remark. There are many houses in these districts which stand very little above sea-level, and the incursion of a sea wave would have left traces too obvious to be overlooked.

St. Lucia.—A most interesting account of the phenomena observed by him in St. Lucia, has been sent to us by Major HODDER, R.E., who was in Castries during the eruptions. From this we extract the following :—

"About this time (the 7th May) we heard that the volcano in St. Vincent was becoming active, so we observed the sky closely in this direction. About 12.30 P.M. on the 7th, I noticed the sky becoming yellowish in that quarter, and this increased to a darker and more coppery colour, till at 4 P.M. it began to assume the appearance of a London fog. The western (leeward) side of the smoke-cloud remained vertical and fixed exactly in one position, and it could easily be seen to ascend. A good deal of ordinary cloud passed at this time, so the eastern edge was ill-defined, but we could still see the western edge distinctly. This pillar of smoke rose to 12° above the horizon (artificial). Its breadth was about 15° of arc.

"About 6 P.M. we began to see the flashes of lightning play in the dense cloud. They were at the rate of about 3 per minute. They were not like ordinary lightning, but much shorter, and seemed to travel slower. In addition to the "lightning" there were great flashes of a redder colour (the "lightnings" appeared a yellowish-white). The flashes were at intervals of about 5 minutes. The display was much more violent than that of Martinique on the 5th instant; the smoke-cloud was at least double the height, and I concluded that the eruption had been on a vastly greater scale. No detonations were heard, but an earthquake was felt at about 2.45 P.M. by nearly everyone I have spoken to on the Morne, but I did not notice it myself. Next day, so much cloud had come up and rain that we could not see the smoke-cloud; during this time the display of lightning and flashing diminished to, say, one-fifth of its intensity."

Further particulars supplied at a later date by Major HODDER and by Mr. GERALD DEVAUX, of the Cul de Sac Factory, St. Lucia, enable us to amplify the above account in some important respects.

Detonations were distinctly though faintly heard on the 7th May coming from St. Vincent. They were loudest about 2 P.M., and lasted from about half-past one to five o'clock, and resembled distant thunder, or the sound of the discharge of big guns. There seems to have been no considerable fall of ashes and no darkness, but only a slight haze in the atmosphere. The amount of dust which fell was so slight as to form only a film, the thickness of which was too small to be measured. The ash was dry, and was best seen on the surfaces of the leaves, where, it formed a fine impalpable powder.

Mr. DEVAUX adds, also, that "at the time the detonations were most distinct, the sea (at 3 o'clock) receded from the beach five times in half an hour, about 25 feet each time."

Barbados.—As in the eruption of 1812, the island of Barbados, which lies almost 100 miles to windward of St. Vincent, received more of the dust emitted by the volcano than any of the neighbouring Windward Islands. In the month of May there appears to be a strong and persistent upper current of air, flowing in an east or north-easterly direction over the Caribbees, the return trade or upper anti-trade wind. The depth of the trade-wind stream at that time and place is not very accurately known: none of the mountains of the Windward Islands is sufficiently high to overtop it. It must be at least 10,000 feet deep, as the steam puffs which rose from Montagne Pelée, in ordinary circumstances, were invariably carried bodily to leeward. But on the 11th July we were in Fort de France, and saw there the tongue-shaped rolling steam cloud which accompanies the more important eruptions, and this rose to such a height that it was entirely in the upper anti-trade current, and floated away to the east or north-east. This is sufficient to show that in the passage of so large a quantity of dust to the east, over Barbados, we have only a particularly clear example of the operation of causes which are constantly in operation in the region in question.

In Barbados there is a large and very intelligent white population. They were all acquainted with the historical records of the fall of ash in 1812, and great interest was taken in the re-appearance of this phenomenon. We have in consequence a greater mass of exact and reliable information from this island than from any other. The rate of fall of the dust, the thickness of the deposit, its total amount over the whole island, the variations in its character during the duration of the shower, its chemical and mineralogical composition, have all been carefully investigated, together with a great number of other less obvious but hardly less important particulars. We are greatly indebted to Dr. MORRIS, C.M.G., of the Imperial Department of Agriculture for the West Indies, for the kindness with which he placed at our disposal the results of observations made by himself, by the officials of his department, and by many of his friends resident in Barbados.

Mr. W. G. FREEMAN, of the Imperial Department of Agriculture of the West Indies, gives the following account of his observations :—*

"The morning's paper of the 7th brought the news that the Soufrière, at St. Vincent, was showing signs of activity. The morning passed without any striking phenomena, except that the weather, as on the previous day, was close and unpleasant. About 2.40 P.M., two loud reports were heard, as if heavy cannon had been fired. A man-of-war saluting with unusually heavy pieces was the first idea, but no similar reports following, the possibility of the sounds having something to do with the morning's telegram presented itself. The more so as in the eruption of 1812 the people here heard sounds which led them to suppose a naval engagement was taking place; they even put all in readiness to repel the expected French attack.

"Soon a dusky cloud arose to the north-westward, not like an ordinary rain-cloud, but with curiously thin edges. This crept gradually up *against the wind*, accompanied by sounds like distant thunder, but no lightning. By 4.30 P.M. it was very gloomy, and the sky was completely overcast as far as I could see, except a band to the south-east, which was dazzlingly bright. This strip of light was at length blotted out by the advancing cloud. At 4.30 the first flash of lightning was seen, and at 5.15 dust was falling fairly fast. The dust shower increased in intensity, and at about 7 P.M. was quite heavy, the particles falling with a low hissing sound.

"No rain fell, and there was practically no wind. During the night sufficient dampness came just to moisten the ash, but not to disturb it in any way."

Mr. FREEMAN collected the ash which fell on three vessels of known area. This estimate of the mass of the deposit which fell in Barbados, he gives in the following statement :—

"From the calculated results of a series of observations made in Strathclyde, on the fall of volcanic 'ash,' it would seem that, at a low estimate, about 13 ounces fell per square foot between the hours of 5 P.M. on Wednesday and 5 A.M. on Thursday. This perhaps may not appear a large amount; but look at it from another point of view: 13 ounces per square foot means 117 ounces per square yard, and to express it in familiar terms in an agricultural community, no less than 16·2 *tons per acre*.

* In a letter to Professor J. W. JUDD, F.R.S., dated May 10, 1902.

"Leaving for the while minor units, such as acres, we find that 10,240 tons of volcanic 'ash' were rained on to every square mile of this Island during the past 12 hours of darkness. Supposing the fall to have been approximately equal in depth over the whole Island, the almost incredible amount of 1,699,840 tons of solid matter was added to Barbados last night."

He gives the thickness of the deposit as about $\frac{1}{5}$th of an inch, and states that while it was falling there was a slight sulphurous odour, not so strong as to be disagreeable.

In the Barbados 'Agricultural Reporter,' of Friday, May 9, there appears an interesting account of the rain of dust in the city of Bridgetown, and its effects on the population :—

"The volcanic dust which began to fall here on Wednesday afternoon continued throughout the night and up to early yesterday morning. Borne from St. Vincent in the upper strata of the air, and there suspended, this stuff obscured the sunlight and produced the phenomenal darkness mentioned in our yesterday's issue. In colour and consistency it resembles Portland cement. At first the fall was slight and the substance was gritty and coarser than that which fell afterwards. By 7 o'clock, however, a powdery dust was falling thick and fast. Those whose business called them out at this hour and later—those who had no special calling out had sought their places of abode at an early hour—got their faces and hands and all their clothing covered with the stuff, and presented a grimy appearance. Care had to be exercised, too, even by those carrying umbrellas, and travelling on the tram-cars, to avoid receiving injury to their eyes and throats. The dust was everywhere, and upon everything. Passing freely through jalousies and other available openings, it rested on all furniture and other appointments in houses and offices. So early as 8 o'clock the city was deserted, and there prevailed a quietude which contrasted strongly with the activity that ordinarily prevails. Terrific peals of thunder, preceded by vivid flashes of weird lightning, helped to increase the depression of spirits caused by the gloom, and gave rise to a feeling that the worst had not yet been experienced. Judging from appearances at this time, one would have concluded that there was going to take place a heavy downpour of rain. As a matter of fact, however, none fell. The grooves of the tramway rails filled rapidly with the dusty precipitation, and it was simply impossible to keep them clear. As a consequence, the cars ran off repeatedly, and ultimately the service had to be stopped sometime before the usual hour. It should be mentioned as a noteworthy fact in connection with the phenomenon of Wednesday evening, as experienced in Bridgetown, that, while a heavy cloud overshadowed the city and the whole western sky, there was a luminous spot on the southern horizon, just at the extremity of the nebulous area, that offered a striking contrast to the prevailing gloom. There the day-god seems to have entrenched himself, and bidden defiance to the powers of darkness. The light was not bright and cheery, but rather suggestive of an angry mood. Somewhere in the vicinity of 6 o'clock P.M. of the same evening a party of Salvation Army preachers attempted to hold a service in the Upper Green, near the Nelson Statue. The usual singing and exhortation was begun by the detachment, but the falling dust was too much for mortal throat and lungs to endure in the open air, even though engaged in religious work. Besides this there were found few so foolhardy as to accept the invitation to combat the forces of nature. So the party had to desist and retire to cover like the common non-combatants. Full details of the occurrence did not come to hand from St. Vincent on Wednesday evening, and people here retired to bed feeling that the next day would bring news of some awful catastrophe. Loud booming sounds had been heard throughout Barbados during Wednesday, and the natural conclusion was that the experiences in the sister colony must have been awesome. From what was told us in a telegram received about 8 o'clock A.M., these calculations were correct, for the condition of affairs is said to have baffled description.

"Yesterday the atmosphere continued murky, and the city presented the appearance of being enveloped in a heavy mist. The dust which began to fall on the previous afternoon had continued throughout the night, and at daybreak was perceived to lie full half an inch thick on the surface of the ground and on the roofs of houses. The city buildings generally looked dingy, and the general aspect was cheerless and depressing. Gangs of labourers from the city roads and Sanitary Department, under the direction of the Departmental Inspector, and supplied with brooms, shovels, and hand-barrows, were set to work to clean up the streets from an early hour. The dust collected by them was piled in heaps along the roadside and carted away by the scavengers' carts. To ensure as thorough cleansing as possible, hose attached to the hydrants of the water department was employed for washing the surface of the roads and for flushing gutters and drains. But dust continued to be blown from off the roofs of buildings, where it had lodged, and proved a nuisance throughout the day. Various forms of shades were used for protecting the eyes from the dust, some persons using coloured glasses and others using veils. It was a funny sight to see grave city men wearing the sun veils commonly used by ladies. But the object aimed at was the protection of the visual and nasal organs against the inrush of dust, and this the veil did effectually."

Oscillations in the level of the sea were noted in Barbados and Bequia, and St. Lucia. The 'Barbados Advocate' of May 8 contains the following:—

"There was an unusual spring tide yesterday about 3.45 P.M., the Constitution River nearly submerging the reclaimed land known as 'Fort Royal.' After the subsidence of the water, washerwomen were seen running in all directions in search of the clothes which they had spread out in the early morning to be bleached by the sun. Persons of 40 years' standing said they had never before seen such a tide."

JOHN K. KIRKHAM, Harbour Master at Barbados, sends us the following note of observations made by Mr. ASHBY, the Government diver:—

"At 3.10 P.M. the water suddenly rose 2·5 feet in two minutes, and as rapidly fell after one minute; about three minutes later it rose 1·25 feet in three minutes and as rapidly fell, then rose about 0·8 foot in two minutes, and as rapidly fell. The water rose and fell three times in 15 minutes, the rise each time being about one-half what it was before. It was spring tide here that day."

From Barbados also we obtain some interesting facts regarding the changes of barometric pressure which accompanied the outburst of the great black cloud. The Rev. N. B. WATSON, of St. Martin's Vicarage, in the parish of St. Phillips, sends us a very interesting barographic tracing, which shows repeated oscillations of the recording pen attached to the instrument between 1.30 and 6.30 P.M. of that afternoon, and Mr. O'DONNELL, of the American Weather Bureau, states that, on May 7, "a sudden jar occurred in the barograph record at the time of the explosion."

Here also we may mention that in St. Vincent similar rapid changes in barometric pressure were noticed by at least one observer, Mr. EFFINGHAM DUN, of Owia. He writes as follows:—"On May 7 the barometer (mercurial), which had been steady at 29·85, rose within three minutes to 30·12, when it again fell slowly to 29·82, and remained steady at that throughout the night. This is the only change I observed, though I paid great attention to the barometer."

Considerable air-waves appear, in fact, to have been generated by everyone of the greater eruptions, both of the Soufrière and Montagne Pelée. Rapid rise and fall of the barometric column have been noted in Martinique to accompany several of the eruptions there. The outburst at Pelée on the 9th July produced a distinct vibration of the recording pen of the barograph in the American Weather Bureau, in Rozeau, Dominica, as was shown to us by Mr. HOBBS, who was in charge of the station. He told us also that in the observatory in St. Kitts similar effects had been traceable in the barographs on the days of several other eruptions. In every case the air-pressure was temporarily increased by the appearance of the great black cloud. We have already remarked how it was noted in Chateaubelair, St. Vincent, that during the climax of the eruption a peculiarly painful sensation was felt when loud sounds were heard, and this finds its explanation in the sudden rise of atmospheric pressure on the tympanic membranes.

Along the whole chain of the Antilles, from Trinidad to Santa Cruz and St. Thomas, detonations resembling distant cannon firing were heard on Wednesday afternoon. In Trinidad they were very distinct and their origin was at once suspected. In the late afternoon the sky to the north was very hazy and thick, and in Port of Spain there was a slight fall of fine dust.* In Dominica, Guadeloupe, Antigua, Montserrat, St. Kitts, St. Thomas, and Santa Cruz there were loud distant noises heard, especially between 2 o'clock and 3 o'clock in the afternoon. No ash seems to have fallen in any of these islands, and there were no earthquakes of importance. Tidal waves were observed in Martinique and Guadeloupe. In Demerara there were neither falls of ash nor sounds of detonations, though the latter are said to have been heard in Venezuela.† In Jamaica it was observed that from the 7th May onward the atmosphere was hazy, and at sunset and sunrise there were remarkable colour effects in the sky. Mr. S. T. SCHARSCHMIDT, of Hanbury, Jamaica, reports that a thin film of dust was observed on the iron roofing of houses at that locality. He collected it by means of a wet sponge, and found it identical in character with the ash which fell in Barbados, only very much finer. The self-registering tide gauge at Port Royal, Jamaica, showed no effects of sea waves or sudden rise or fall in the sea level.

Falls of volcanic dust from the Soufrière are recorded over a very wide area, which seems to be elliptical in shape. It is broadest from east to west, as it extends from Jamaica to at least 900 miles east of St. Vincent, a total distance of about 2,000 miles. Its north and south diameter is much shorter, as the probable limits in these directions are the north end of St. Lucia and Port of Spain in Trinidad. In both these places the amount of dust which fell was very small, and there is no reason to believe that the actual area covered was much more extensive than this. Far the greater part of the dust cloud travelled eastwards before the upper anti-trade currents, and the heaviest falls of dust were all in that quarter. Many ships passing through that part of the Atlantic which lies to the east and south-east of Barbados encountered dust clouds during the 7th, 8th, and 9th of May. The most interesting

* Despatch from Captain F. L. CAMPBELL, H.M.S. "Indefatigable," printed in Bluebook: 'Correspondence relating to the Volcanic Eruptions in St. Vincent and Martinique in May, 1902,' p. 70.

† 'Nature,' vol. 66, p. 554, 1902.

instance of this is that of the barque "Jupiter," which was 830 miles E.S.E. of Barbados on May 8th at 2.30 A.M., when the dust fell upon its decks. Many of the records of these dustfalls are unverified,* but in this case there seems to be no reason to doubt the accuracy of the report, as, although we did not see the dust, we met several people in Barbados to whom it had been shown, and they all described it as very similar to that which was lying on the houses of Bridgetown at the time, only much finer and somewhat paler in colour.

The dust which fell in Jamaica on the 11th May is very different in composition and appearance from all the other volcanic dusts which we have seen. Mr. SCHARSCHMIDT has sent us a sample of the material which he collected, and it proves to consist very largely of vegetable matter, pollen, δγ-cryptogamic spores, hairs and fragments of the cuticle of plants, desmids and diatoms. In addition to these there are mineral fragments which include small grains of quartz, calcite and impalpable inorganic dust. But there are also small, clear, almost colourless, isotropic grains, which show a very irregular fracture, and have no trace of organic structure. When the dust collected is incinerated on platinum foil at as low a temperature as possible, these fragments remain unchanged. We think it probable that they are pieces of fine volcanic glass, as they closely resemble the fine glassy splinters which can be found in the Barbados dust. There is no augite, no hypersthene, and, so far as we can say, no felspar. This is exactly what might have been expected in consequence of the great distance to which the mineral fragments were carried. The heavier would necessarily sink first and only the lighter glass would reach the limits of the area of distribution. None of these glassy fragments contain any microliths; and the proportion of volcanic glass in the dust sent us is exceedingly small; the average size of the grains is ·02 millim.

This dust is quite unlike that which was collected on the decks of the "Jupiter" at about the same distance from the Soufrière in an eastern direction, and shows that while Jamaica was near the limits of the dustfall to the west, it had a far greater extension to the east, so that the Soufrière does not stand in the centre of the elongated elliptical area of distribution. This is due to the persistent easterly currents in the upper atmosphere. It may well be the case that falls of dust took place over the sea to the east of St. Vincent for considerably more thon 2,000 miles from the island.

Of the total amount of material ejected on the afternoon of Wednesday, May 7,

* Other authenticated records of dustfalls observed on ships which were obtained by the Harbourmaster of Barbados, and published in the 'Agricultural News' (Barbados), June 7th, 1902, are as follows:—

"May 7, 8 P.M., schooner 'Violo,' from Demerara, met the dust 70 miles S. of Barbados, 10 P.M., the Norwegian steamer 'Talisman,' from Demerara, 150 miles S.S.E.

"May 8. Hour not stated, barquentine 'Fanny,' from Pernambuco, 250 miles E.

"May 9 (? 8), 4 P.M., ship 'Monrovia,' from Rio Janeiro, 240 miles S.E."

it is impossible to form even an approximate estimate. When we remember, that on the island of Barbados, which has an area of only 166 square miles, and is 100 miles distant from St. Vincent, 1,700,000 tons fell, it does not seem improbable that several billions of tons of solid matter were projected into the air in that short space of time.

The Closing Scenes of the Eruption of May 7th, 1902.

Thursday and the following Days.

In the north end of St. Vincent the sun rose on scenes of desolation and despair. Three-fourths of the population lay dead in their houses, and many of the survivors were fearfully burnt and suffering dreadful agony. The green and fertile Carib country, which had been covered with rich crops, lay buried beneath several feet of hot and smoking ashes. The Soufrière, which on the previous morning had been a mass of verdure and green forest, was now the leaden hue of the new fallen ash. With the return of light, though the air was still misty with falling dust, many fled and sought refuge in Georgetown and the region to the south of it. Others stayed to succour the wounded or to bury their dead. A weary procession of mangled and injured toiled along the road to Georgetown. Already before dawn some had passed through the village fleeing from Rabaka and Langley Park, and they spread the tidings of death and destruction. Efforts were early made to penetrate the burnt country and help the sufferers. A police-constable went out along the windward coast to ascertain how great the damage had been. The sights he saw were fearful, dead in every village, almost in every house, corpses everywhere along the roadside, dead cattle strewn through the fields, many of the bodies mangled, burnt, and distorted. The injured and terrified survivors, who were unable to make their way along the roads, were lying among the corpses, crying aloud for water to moisten their scorched throats; many had their skin extensively burnt and peeling off their hands and faces. Slate-coloured vapours still ascended from the mountain, every noise struck terror into the minds of the survivors. There is small room for wonder that it was difficult to get men to volunteer to explore that thirsty, burnt, and death-struck country. Yet the officials, the clergy, and the inhabitants of Georgetown nerved themselves to the task, and in a very short time the helpless injured were being gathered into Georgetown and accommodated in temporary hospitals there. The task of burying the dead had perforce to wait. Despairing of assistance, one boy of fourteen buried his father, his mother, and seven brothers and sisters in a trench he dug in the ground outside the house—a fact which throws a lurid light on the sweeping nature of the calamity which had overtaken the inhabitants. It was not till some days had elapsed that the work of burying the dead was finished, so many were they and so long did it take to clear the ashes out of the houses, huts, and yards, and bring the bodies to view. The official estimate of the number interred is 1295.* It is certainly an under-estimate rather than an over-estimate. The story of the ready response which the British colonies in the West Indies made to the call of assistance and relief is an inspiriting one, but hardly falls to be narrated here. From Trinidad, from Jamaica, Barbados, St. Lucia, in fact from all the British islands of the Caribbean Sea, help was sent. The American Government, without delay, despatched the "Dixie" with stores and medical comforts. Lists of subscriptions were opened in England and elsewhere, and money poured in with great rapidity. Nothing was omitted that could be done to save life or mitigate suffering. The efforts of the medical men were crowned with almost unhoped-for success, and comparatively few of those who were able to reach the hospitals and place themselves in the hands of the doctors died of their injuries or burns.

Chateaubelair had been vacated during the afternoon of Wednesday, and its inhabitants were scattered through the villages and houses to the south, but on Thursday morning, as the noises from the mountain had almost ceased, people began to return, as soon as day broke, to see what damage their houses and crops had suffered during the night. From 3 to 5 inches of ashes had fallen in the village, and some of the houses had had their roofs perforated by falling stones. Others had collapsed under the weight of ash that accumulated on them. No buildings, however, had been set on fire, though on the slopes to the south and east of the town in more than one place the grass had been ignited (probably by flashes ot lightning). Most of trees had been stripped of their leaves, and the smaller branches had been broken by the falling stones. The air was still murky with dust, and the mountain almost completely veiled in vapours.

Early in the day, Captain CALDER, Mr. MCDONALD, Dr. DUNBAR HUGHES, Mr. GENTLE, and several others arrived in a boat from Wallibu, and from notes supplied by them and by others who were residing in the vicinity of the Soufrière, it is possible for us to form a fairly accurate idea of the progress of events during that and the following days.

Columns of vapour so densely charged with fine ashy material as to be slate-grey in colour, ascended from the crater, and, as a gentle wind was blowing from the north, the dust was carried directly over Chateaubelair, which was in consequence covered with a thick mist, in which it was difficult to recognise anyone at a distance even of only a few yards. The whole mountain and the region round it were enveloped in this cloud of falling ash, but about 10 o'clock there was a sharp shower of rain which

* Bluebook: "Correspondence relating to the Volcanic Eruptions in St. Vincent and Martinique in May, 1902," p. 65. Despatch from Governor Sir R. B. LLEWELLYN (dated May 23, 1902).

The total number of bodies found dead is	1295
The deaths in hospital from injuries (burns)	70
Missing	200
	1565

somewhat cleared the atmosphere and dissipated the sulphurous fumes. Lightning and thunder accompanied the rain.

About 2.30 P.M. there was a considerable increase of activity, and as the afternoon was fairly clear, it was possible to see that great clouds of smoke were being discharged from the site of the old crater. Captain CALDER notes that at this time "molten lava was coursing down each deep ravine, clouds of white vapour marking its path over the damp earth."* This is the first record of steam eruptions in the valleys after rains due to the action of the water of the streams on the hot ashes through which they flowed. All the afternoon there was thunder and lightning, with possibly also noises from the mountain, and dense clouds, partly of rain, partly of steam mixed with ashes, floated to leeward, obscuring the coast line and the slopes which face Chateaubelair. During the evening there was more rain and thunder, with lightning, which was very vivid, and continued at intervals through the whole night.

On Friday, the 9th May, there were loud noises and rumblings in the early morning, and about 7 o'clock vast masses of dark smoke were ascending from the crater, and what was supposed to be a stream of boiling mud or lava was seen rushing downwards through the valley of the Wallibu to the sea. After this it became very dark in Chateaubelair, the heat was intense, and breathing was difficult. In Georgetown the sound of the eruption was also heard, and there was a shower of small stones, followed by fine ashes. From Kingstown a great column of smoke was seen to shoot upwards in the air above the volcano. The rumbling sound was heard for half an hour or less. Flashes of lightning were visible in the clouds, but not generally over the sky. There was a slight fall of fine dust, and the air was foggy with suspended matter. At Fancy, on the north shore of the island, stones and sand continued to fall for nearly two hours, and during that time there was darkness (though not total).

Although the descriptions of what was seen from Chateaubelair are not very lucid or satisfactory, it is certain that there was an outburst on Friday morning, which may have been accompanied by a manifestation of the black cloud phenomenon on a small scale. The amount of matter discharged was quite inconsiderable compared with that of the great eruption of the 7th, and as the danger-zone was almost completely vacated, no loss of life occurred.

During the whole afternoon of Friday slaty-coloured vapours were emitted by the crater, and fine dust was falling on the leeward parts of the mountain. Showers of rain are recorded as having taken place several times during the day, and there was a good deal of thunder and lightning, with occasional noises from the volcano. From the ravines on the side towards Chateaubelair steam and dark vapours were often seen to ascend. Mr. McDONALD remarks that from some of the valleys discharges ot vapour took place, each accompanied by a flash of lightning and a peal of thunder. He observed that from the ravines clouds of steam were rising, and these led to the belief that fissures were formed in the valleys, or streams of lava were flowing down

* 'Century Magazine,' vol. lxiv, August, 1902, p. 637.

them. As a matter of fact, there can be little doubt that the rain occasioned by the showers was working through the hot sand in the old channels of the streams, and that this was the origin of the clouds of vapour.

On Saturday, the 10th May, it was apparent that the energy of the eruption was spent and a state of quiescence was at hand. For some time after daybreak the crater was almost free from discharges, but about half-past 9 o'clock the steam clouds began to arise again, and continued with intermissions during the remainder of the day. It was obvious to all spectators that the worst was over and that the eruption was drawing to a close.

On the 11th, steam still continued to ascend from the crater, and the mountain was veiled in smoke. On the 12th and 13th, at irregular intervals, sluggish discharges of slaty vapours took place, accompanied by low rumbling noises. The column of steam did not rise more than a few hundred feet above the summit. On the 14th the cloud over the crater was still dense but less lofty. There was a slight rain of small pebbles at Richmond Vale, near Chateaubelair, while steam was seen arising from the crater in the evening.

On the 15th, at 9.30 A.M., there was a slight escape of steam, otherwise the mountain remained clear all day.

By this time on the windward side of the island considerable progress had been made with the work of interment. The wounded had been relieved and removed to hospital in Georgetown and Kingstown. Most of the population of the districts which lay to the north of the mountain, and which had not suffered so severely as the region to the south, had been drawn away and had settled temporarily in Georgetown, Kingstown, and other parts of the island. At Owia, Sandy Bay, and Fancy there were still green fields to be seen, and though many of the inhabitants fled, some remained. Elsewhere everything was covered under a sheet of ashes, very fine on the surface but mixed with lapilli and coarser blocks in the layers beneath. It resembled a desert covered with grey or brownish sand, except for the numerous blasted, broken, leafless trees which rose through the covering of ash. The rains had not yet been sufficient to clear out the old stream channels, and they were filled to the level of their banks with an accumulation of sand. The steam arising from the valleys on the hillsides after rain showed that every shower sent down freshets which, working in the hot ashes, were converted into steam clouds and wholly evaporated before they could reach the sea. At Fancy and in the district around Owia the valleys contained comparatively little deposit, and after a few showers they resumed very much of their old appearance. But immensely greater masses of material had lodged in the river courses on the south side of the hill, and it was seven or eight days before any water was able to flow along their whole length to reach the sea. The Rabaka Dry River was dry for several days after the great eruption, and when it began to flow intermittently after very heavy showers the water came down perfectly black and boiling hot.

From Chateaubelair several parties made a voyage up along the coast in boats, and some landed to examine the burnt-out plantations of Wallibu and Richmond. What chiefly attracted attention was the alteration in the configuration of the surface and in the outlines of the coast. The villages of Morne Ronde and Wallibu had disappeared, and the sea had encroached on the land for a width of about 200 yards at the mouth of the Wallibu stream and for a distance of nearly a mile along the coast to the north of this. The buildings of Richmond Plantation and of Wallibu were surrounded by ashes several feet deep. Richmond had been on fire, and all the woodwork of the houses and the furniture was destroyed, but at Wallibu the barrels in the store, the doors, carts, and furniture were still preserved, though covered with black sand. Some consider that the sand-blast was not hot enough when it passed over Richmond to set fire to combustible substances, but that the house was struck by lightning or that a paraffin lamp, which was left burning in one of the rooms, exploded and ignited the furniture. Mr. McDonald notes that Richmond Village which stood below the plantation house, was seen to be "covered with 30 or 40 feet of ashes, more or less," and that "the general level of all the flat land as far as Frazer's was raised by 40 or 50 feet, and terminated in abrupt almost vertical bluffs at the sea."

At this time the Wallibu stream was perfectly dry and choked with sand, which filled it up almost level across. It was not till seven or eight days had elapsed after the eruption that the water was again seen to make its way to the sea. Frequent discharges of steam were observed in the upper parts of its course. The other valleys which lie to the north of this, the Wallibu Dry River, Rozeau Dry River, and Larikai, were similarly encumbered with deposits of sand, though perhaps not to an equally great extent, and in these also steam explosions took place after rains.

Very interesting and valuable evidence regarding the conditions prevailing at Wallibu and Richmond about this time is afforded by certain photographs, taken by Mr. Wilson, of Kingstown, on the 14th May.* One of them shows the houses of Richmond disroofed and burnt out, surrounded by several feet of ash and mud, out of which rise the leafless, blasted stems of trees. The wooden framework on which the plantation bell was supported is preserved unburnt. This makes it likely that the fire which attacked the houses was the result of an accident and not a direct consequence of the heat of the volcanic blast. On the slopes across the stream which flows by the south of Richmond, the layer of ashes had been thin, and the rain-showers acting on the naked unprotected surface of the mud have cut little furrows and runnels in it. In the foreground of the picture the sheet of ash around the plantation-houses had a smooth, slightly hummocky or rolling character, exactly resembling the effect produced by a considerable fall of snow, or the surface of fine

* These photographs are reproduced in Mr. E. O. Hovey's paper, "Martinique and St. Vincent: a Preliminary Report upon the Eruptions of 1902," 'Bull. Amer. Museum Nat. Hist.,' vol. 16, Article 26, Plates 41 and 38.

blown sand strewn by the wind. The rains had up to that time been sufficient to erode only on the steeper slopes, while on the more level ground they had sunk into the porous, incoherent ash, and the original surface characters were still intact.

Another photograph, taken at the same time,* shows Wallibu plantation and the fields to the north of it, with the Soufrière in the background, emitting a column of black smoke. The wind-strewn character of the surface is here also visible on the flat grounds, while on the steep ridge which rises behind Wallibu the layer of ashes has been much thinner, and is already furrowed with rain-rills, and, to a considerable extent, has been washed away by the running water.

According to the descriptions given us by those who had occasion to visit the devastated country at this time, it was a shadowless wilderness of sand and blasted vegetation, in which not a drop of water could be found to drink. The heat of the tropical sun was reflected from the bare surface of the sand, making the air intolerably hot, and every breath of wind stirred the fine dust which formed the superficial layer of the deposit, and blew it into eyes, nostrils, and throat. The rains had not yet been sufficient to make the mud coherent or to wash away the finer particles, and the ash lay on the level cane fields with an undulating surface resembling that of blown snow. Rain was urgently needed to restore the blighted trees and enable them to put out fresh leaves.

In Georgetown and Chateaubelair confidence was rapidly restored, and, owing to the influx of the refugees, the villages were crowded with people. Rations were now being served out daily to the destitute, and settlements erected for their accommodation, so that there was a bustle of activity, and the streets were thronged. The burial of the dead was over, and the living had had time to count their losses and were congratulating themselves on their escape. A week had elapsed since the great eruption; there had been no further destruction, though the devastated country was deserted. A few of the inhabitants had been able to return to attend to the interment of their relatives and friends, and to remove the most valued of their personal belongings. As a rule, however, a great aversion to visit the scenes of suffering and death was manifested by the refugees, but they readily adapted themselves to their new surroundings, and when the wounded had recovered from their burns and injuries, they settled down without any great reluctance in the quarters provided for them.

THE ERUPTION OF THE 18TH MAY, 1902.

The volcano sank into a state of quiescence. After the 15th May no further loud noises were heard, and the emissions of steam were on a very small scale, and took place without violence. The ordinary occupations of life were resumed, and the mountain was no longer observed, hour after hour, with an interest quickened by

* See footnote, p. 417.

apprehension. But a rude awakening was at hand. On the evening of Sunday, May 18th, a second eruption took place, less violent and far less destructive than the former one, but still sufficiently vigorous to throw the whole population into a state of terror, and make those near the mountain flee for their lives.

The afternoon of Sunday was beautifully calm and clear, and the inhabitants of Chateaubelair could see the mountain from base to summit. Many were in boats along the leeward coast examining the strangely-altered surface of the plantations of Wallibu and Richmond, and the startling modifications which had taken place in the coast line to the north of the village. Not a single cloud veiled the face of the mountain, and the bare, burnt surface showed up in every detail in the evening light. Sunset was followed by a clear, starry night with bright moonlight and a cloudless sky. In Chateaubelair, Kingstown, and Georgetown many people were enjoying a walk in the cool refreshing night air, when suddenly, about 8.30 P.M., a loud, prolonged, ominous groan burst from the mountain. Some residents in Kingstown compared it to the noise made when a war-ship lets go her anchor in the bay and the cable rattles out through the hawse holes. At the same moment a great cloud of steam shot from the crater and rose to an immense height in the air. As seen from Kingstown, it was pointed, and its height was estimated at many thousand feet. In this great mass of vapour, lightnings incessantly scintillated. They were tortuous and snaky, and did not resemble the clear flashes often seen on a tropical night. The noises in Chateaubelair were deafening; many thought they were as loud as on the afternoon of the 7th May. Soon the village was enveloped in total darkness. The inhabitants sprang out of their houses, and, seizing their children, fled along the road that leads southwards past Petit Bordel. Darkness settled down on the fugitives, a darkness so intense that they stumbled over the roads, groping their way along the ditches, guiding themselves by feeling the objects on the way side. The lightnings, the thick darkness, the roaring noises, and the falling ash, dismayed the stoutest hearts, and many were weeping and lamenting loudly as they hurried through the night. Some lost their children in the gloom, others fell into ditches or over the banks on to the sea-shore. When they reached Rosebank the light was beginning slowly to improve, and many took refuge with friends there. About 10 o'clock the sky cleared, the moon appeared again, the noises ceased, and the eruption was at an end. The earthquakes noticed during this eruption were few and insignificant, and the fall of ash in Chateaubelair was very slight, and consisted mostly of very fine dust or sand.

In Georgetown also the day had been exceedingly fine, and no warning was given of the coming outburst. When the steam-cloud rose with loud noises from the mountain a general exodus took place, but later in the night, when the darkness lifted, many returned. The ash which fell was in the form of fine dust, and amounted only to a very thin film, most readily seen on roofs and leaves and the stone pavements around the houses.

In Kingstown the consternation was intense. Some rushed about the streets in terror. Others fell on their knees and prayed aloud, but many shut themselves in their houses, dreading an incursion of the great black cloud. A small quantity of very fine dust fell in the town, but there was no deep darkness.

It was noticed in Chateaubelair and Georgetown that many of the children complained of a painful feeling in their ears.* This phenomenon was already described in connection with the first eruption.

Bishop SWABY, of Barbados, was in Kingstown that night, and gives some interesting particulars regarding the eruption as observed from that place. He was at supper when he heard†—

> "An explosion like that of a bursting shell, followed by a roaring groaning sound which startled the party, and they ran out into the garden and looked in the direction of the Soufrière. They saw an immense column of white vapour ascending high in the air above the mountain, twisting and twirling upon itself till it assumed the shape of a flower, and forked lightning was playing around it incessantly. The curious thing about the lightning was that it embroidered, as it were, the edge of the cloud of vapour, playing around it with a continuous scintillation as of fireworks. The thunder, too, was continuous, but the thing that struck his lordship was the rattling groan of the labouring mountain. Otherwise a deep hush pervaded the region, and served to make the scene more impressive to the beholder. The phenomenon lasted about 15 minutes, and there was an interval till about 10 o'clock, when it came again. The mountain was about 15 miles from Kingstown, where it was viewed, and the watery vapour must have been about 30,000 or 40,000 feet high to have been seen above the mountain as it was."

It is impossible to say whether or not a black dust cloud descended from the Soufrière down the valleys of the Wallibu and Rabaka on this occasion, as no one was residing in the houses there, and in the darkness it was impossible for those in Georgetown and Chateaubelair to see what was going on. On the whole, it seems practically certain that there was a recurrence of this phenomenon, though on a scale so small that the deposits which it produced could not be compared with those which filled the ravines on the 7th May. Next morning it was seen that a thin layer of freshly deposited ash covered the surface of the mountain. Apparently there was a repetition of what happened in the first eruption, though there could be no comparison between the magnitude of the two outbursts. The premonitory symptoms were entirely wanting in this case, and the preliminary stages so brief and inconspicuous as to have escaped notice. The loud explosions and sudden rush of steam may be regarded as accompanying the outburst of the dust avalanche and black cloud, the subsequent noises as the effect of upward steam explosions projecting dust, scoria, and bombs into the air. Many people told us that in their opinion the noises were as loud as on the 7th May, but certainly they were not heard so far, and the disastrous calamity which had previously overtaken the island had left behind a state of nervous apprehension which led to exaggerated estimates of the magnitude of the subsequent mani-

* 'Times,' Kingstown, Thursday, May 22, 1902.

† 'Barbados Advocate,' Saturday, May 24, 1902.

festations. There is no evidence that air-waves or sea-waves of any importance accompanied this outburst.

Estimates of the height to which the steam cloud ascended, as seen from Kingstown, are founded on the angular distance of its apex above the horizon as compared with that of the mountains of known altitude behind the town. But these are fallacious, as the steam cloud which forms part of the avalanche of dust shoots obliquely upwards into the air when the dust subsides, and the steam column was not vertical above the crater, but had been projected southwards, so that as it travelled onward it gradually spread over the town, carrying with it the fine dust which fell there during the evening.

From this time forward there is no satisfactory record of any further eruptions from the Soufrière till the end of August, 1902. It is true that in the local and Colonial papers paragraphs may be found describing violent steam discharges from the crater and rains of ash on the surrounding country, but as the result of careful inquiry on the spot we consider that these are erroneous. It was almost a fortnight after this before any attempt was made to ascend the mountain, or even to examine its lower slopes systematically. Rumbling noises were occasionally heard, but these were partly due to landslips and falls of rock from the crater walls. Several trustworthy observers report that they saw steam gently arising from the crater, but most of the reports are based on nothing more than the appearance of the round-topped masses of cloud which drift across the mountain before the trade-wind,* while others are to be referred to outbursts of steam in the valleys, owing to the action of water in the streams on the hot dust filling the ravines.

In this account of the sequence of events in the eruptions of May, 1902, we have relied principally on the evidence collected by ourselves from the statements of eyewitnesses, and on written accounts of the eruption given us by residents in St. Vincent, at the request of His Excellency the Governor of the Windward Islands. In most cases we were able personally to question these witnesses, and to amplify, and in some cases to correct, their statements in this way. It was a month after the first eruptions before we landed in St. Vincent, and the sifting of the evidence proved to be no easy matter. It is astonishing how widely divergent, even in essential points, may be the narratives of two equally competent observers who were in the same room or in the same boat at the time. We are well aware that there are in this Report not a few statements which would be unhesitatingly contradicted by more than one person who was in a good position to form an accurate opinion as regards the actual facts. Under the circumstances we have been guided in all cases by the balance of good evidence for or against any conclusion, but it is vain to hope that we have escaped errors and mis-statements. We have made little use of the newspaper

* For an instance of these untrustworthy reports and some pregnant remarks on the valueless character of much of the newspaper evidence, see Professor JAGGAR, 'Popular Science Monthly,' August, 1902, p. 353.

reports, which are in many cases highly sensational and grotesquely inaccurate, but a limited number of personal narratives have been published over the signature of persons well known in the islands, which have been of the greatest value to us. Of these we may mention the diary of Mr. T. M. McDONALD;* the notes by Captain CALDER,† by the Rev. Mr. DARRELL,‡ by Bishop SWABY, of Barbados;§ and the account given by Captain FREEMAN, of the "Roddam,"‖ and by the first officer of the "Roraima," Mr. ELLERY S. SCOTT,¶ of the eruption which destroyed St. Pierre, in Martinique.

THE RAINS.

For nearly two weeks the weather had been on the whole remarkably dry, and although showers had fallen on several days, they had been light and local. That steam was seen to ascend on certain occasions from the valleys and ravines on the Soufrière proves that there had been a certain rainfall, but it was probably greater on the higher slopes than on the lower grounds, and all over the island the vegetation was parched and dusty, and the fine ash blowing to and fro caused great inconvenience. A general and considerable fall of rain was urgently needed, and it was not long in coming. On the afternoon following the second eruption, a sharp shower fell on the north end of the island, and the Soufrière smoked all over its surface as the water came in contact with the hot sand. Four days later rain fell in torrents. The record of the rain-gauge in the Botanic Gardens at Kingstown is as follows:—

9 A.M. on	23rd	to 9 A.M. on	24th	2·43 inches
,,	24th	,,	25th	5·16 ,,
,,	25th	,,	26th	0·82 ,,
	23rd		26th	8·41 inches.

A total of nearly $8\frac{1}{2}$ inches in three days.

In the south end of St. Vincent these heavy rains did nothing but good. The parched and dust-laden vegetation was cleaned, refreshed and invigorated. The more tender plants had lost their buds and young foliage, while the stout leaves of many of the trees had been perforated or torn, or, in some cases, even stripped from the branches by the rain of stones and scoria. The woods and fields rapidly reassumed their green aspect, and the beneficial effect of the rains was great and immediate.

But in the north end of the island, where the fields lay buried beneath a layer of

* 'Sentry,' Kingstown, May 16, 1902. 'Century Magazine,' August, 1902.

† 'Century Magazine,' August, 1902.

‡ Printed in Kingstown, and sold for the benefit of the Relief Fund. Dated May 12, 1902.

§ 'Barbados Advocate,' Saturday, May 24, 1902.

‖ 'Pearson's Magazine,' September, 1902.

¶ 'The Cosmopolitan,' July, 1902.

sand and ashes, the results were almost disastrous. The loose materials on the surface were not protected by any covering of vegetation or held together by the roots of growing plants, and every raindrop carried its burden of sand and mud to the rills, which carved innumerable furrows in the fields. The streams were swollen to torrents, so rapidly did the excessive downpour of rain run off the surface of the ground in the absence of growing crops and plants, which in ordinary circumstances would have restrained and checked the violence of the discharge. So much mud was carried into the sea, that for days its waters were turbid and discoloured for several hundred yards from the shore. In many places the ash was washed almost completely off the steeper slopes, even where it had been a foot or more in thickness. Mud avalanches took place on a small scale wherever the gradient was sufficiently steep to allow the moist semi-fluid material to move by its own weight. Behind the plain on which Georgetown stands, there is a stretch of rising ground which overlooks the fields of the Grand Sable estate in bluffs a couple of hundred feet high or less. Currents of mud flowed down upon the arrowroot fields which lie below, and covered them with fans of débris. They even swept across the public road into that part of the village which is known as Browne's Town, overturning several small houses and burying their occupants in the ruin of their huts. In this way two people were killed.

Hitherto the fields of ash which covered the Soufrière had had their original surface characters well preserved, and in their smoothed and wind-strewn aspect had greatly resembled deposits of blown snow. Occasional showers had been sufficient to furrow the steeper slopes, but on the level ground feather-like rain-rills had not yet been developed. But from this time onward that marvellous rain-sculpture of grooves and furrows converging to a central axial stem, which was as astonishing as it was instructive to the geologists who have since visited the volcano, is to be found in all the photographs which have been taken of the scenes of the eruption.

The scientific investigation of the history and consequences of the recent activity of the Soufrière may be said to date from the period of the rains. The United States steamship "Dixie" entered Kingstown harbour on the 23rd, bringing with it a number of newspaper correspondents and a party of American scientific men, including Professor ISRAEL RUSSELL, Professor JAGGAR, Mr. E. O. HOVEY, Mr. CURTIS, and Mr. BORCHGREVINK. They proceeded at once to collect information, and they and Mr. WILSON, of Kingstown, succeeded in obtaining many excellent photographs of the devastated country. These all show the great amount of erosion which had been effected by the tropical deluges of the 25th May. Only the photographs taken by Mr. WILSON some days before the rains indicate the original aspect of the surface. We can rely also on the descriptions given us by those who had been engaged in the work of searching for the wounded or burying the dead, or had visited the Wallibu Valley during the period of quiescence before the second outburst. At Pelée, in Martinique, owing to the repeated discharges of dust, and also to the absence of any torrential downpours in the months of May and June, there was less erosion, and it was not very difficult to understand what had been the appearance of the fields of ash and sand immediately after the great eruption.

For seven or eight days after the 7th May, the Wallibu river had been choked with hot sand, and no water was seen to reach the sea at its mouth. Thereafter the flow was resumed, and erosion of the sand accumulations began, but for some days was inconsiderable. The first photographs taken after the rains, however, show that a deep and narrow gorge had now been cut in the new ash deposits, and on each side of the channel were terraces marking pauses in the progress of erosion. During the days of downpour there must have been magnificent explosions of steam all along this valley as the river ploughed its way through hot banks of ashes, but we did not obtain any descriptions of these from eye-witnesses. Probably the whole mountain was enveloped in clouds of steam, as in all the valleys the same process was going on, and moreover the water sinking into the sand (which was still burning hot a few inches beneath the surface) must have generated enormous masses of vapour.

The lower part of the Rabaka Dry River, which alone had at this time been examined, was, on the 11th and 12th, dry, but not encumbered with any great accumulation of ash. Some days elapsed before water was seen to flow past Rabaka. It was hot and on more than one occasion it came down in floods of boiling mud. These were, no doubt, due to the uneven surface of the sand deposits farther up the valley forming temporary lakes by blocking the course of the stream, and as the barriers were cut down or swept away before the pressure of the water, these lakes suddenly discharged their contents. From the time of the rains onward this river has been seen smoking all along its upper part, though it is only for brief periods after heavy showers that the water reaches the sea, and it is then always black, turbid, and very hot.

On the north side of the Soufrière the thickness of the ash deposits had been comparatively slight, and the streams were able to reassert themselves, and to resume their flow after a few days. The water was unfit to drink, being tainted with sulphuretted hydrogen and mineral matters in solution, and there was a deficiency of rainwater, so that the steamer "Wear" was sent there with supplies. The inhabitants did not entirely desert the district till after the 18th May, when the last were removed by steamer to Kingstown. It is worth recording that at Baleine a spring issues from the rocks, and this was found by Lieutenat ROBINSON* to be unaltered, and its waters perfectly good and fresh. The heavy rains did no great damage on the north shore of the island, but as the crops and trees were in large part unburnt at Owia and Sandy Bay, they were stimulated by the moisture and put out fresh green leaves.

On the slopes above Sandy Bay and Overland Village the standing timber had been broken, overturned, and stripped of its leaves and branches, and a deposit of

* Blue Book 'On the Volcanic Eruptions in St. Vincent and Martinique in May, 1902,' p. 89.

ash had accumulated perhaps a foot or two feet in thickness. The streams here have a short and rapid descent to the sea and flow in deep narrow valleys with steep sides. The heavy rains washed away nearly all the loose sand and the smaller stones, and with them much of the underlying soil. This material was hurried into the sea, which here is comparatively shallow for some distance from the shore. The streams on reaching sea level dropped their load of sand and pebbles, and it gathered in banks along the beach. The strong shore current generated by the steady trade-wind surf which beats against this coast was unable to remove the deposits as rapidly as they accumulated, and in consequence the sea margin receded to some distance from the old shore marks. From Overland Village north to Robin Rock, a distance of nearly a mile, there was a broad beach of black volcanic sand where formerly the waves had washed the base of a lofty cliff. We were assured that there had been no change in the relative levels of land and sea. When we visited this spot it was evident that the action of the waves was gradually reducing the deposit and cutting back the sand banks till they faced the sea in some places in little cliffs some 4 or 6 feet high. It is probable that a thickness of 15 feet or more of sand was laid down along the sea shore in this way. At the wharf, at Rabaka, where the sugar was formerly loaded into boats, it is said that the water is now shallower by about 12 feet. Nevertheless the old rum store stands at the same altitude above the sea level as it did formerly. The breadth of the sand beach was at most about 200 feet, but all the way from Sandy Bay to Colonarie it was evident that much black volcanic sand had recently gathered on the beaches, and that the sea-waves were only slowly distributing it along the shore.

THE GEOLOGICAL EFFECTS OF THE ERUPTIONS.

The South Part of St. Vincent in June, 1902.

When we arrived in St. Vincent, on the 10th June, and landed at Kingstown, it was not without an effort that we could realise that so recently a great eruption had darkened the air with falling dust and scoria. The south end of the island was a scene of tropical beauty—the rugged peaks and narrow valleys being clad in a dense mantle of green vegetation. In Barbados a thin layer of dark mud had been visible on the usually white surface of the limestone roads, the remains of "the dust"; but in Kingstown it required a rather careful search to find traces of the recent deposit. The depth of the fall of ashes had been small—not over half an inch, and the rains had already washed it almost entirely into the sea. As we journeyed along the lee-ward coast it was not till we reached Chateaubelair that any striking evidence of the volcanic activity was visible. To the south of that point a few torn leaves on the trees, a thin layer of scoriaceous pebbles on the fields, or a roof damaged by a falling stone, were all that we saw to testify to the recent rain of ashes

In Chateaubelair the depth of the deposit, as measured on the roofs of the houses, a day or two after the eruption, varied from $2\frac{1}{2}$ to about 4 inches at the south end of the village. It increased rapidly as it was traced northwards, and may have been nearly a foot at the north side of Richmond Vale. Some of the stones which fell there were a foot across. At Petit Bordel the largest stones weighed about 10 pounds. At Barrualli and Layu the thickness of the layer of ash was from $\frac{1}{4}$ to $\frac{1}{2}$ inch, and the largest stones were two or three inches in diameter. In Kingstown the deposit was less than half an inch, and pumiceous stones about the size of a hen's egg were found in the streets.

On the windward side of the island, as we drove to Georgetown, ash deposits were first noticed in the fields about Colonarie, where they had been 2 or 3 inches thick, and after passing Black Point we found abundant remains of the ejecta of the volcano everywhere—on roadsides, arrowroot fields, and on the steeper ground inland. Much of the finer material had been washed away by the rains, what was left was mostly the coarser sand, pumiceous scoria, and fragments of the old andesitic rocks of the mountain, at most 3 or 4 inches across. Nearer Georgetown the sheet of ash was thicker, and in the streets and gardens of the houses in the village the old soil was covered to a depth of 1 to 2 feet. The average original thickness of the deposit may have been 18 inches. As the ground was flat, not much had been washed away except the very finest dust from the surface ; the ash had been trodden down and was heaped up in places where it had fallen from the roofs or had been thrown out of the houses. Stones over a foot in diameter had fallen in Georgetown. The Anglican Minister, the Rev. Mr. BELL, showed us where one had penetrated the roof of his study. In the churches and houses nearly all the windows were broken, there was hardly a whole pane of glass in the village. The damage had been greatest in the windows facing the sea and not in those looking to north, south, or to west. The materials had evidently been projected to a great height in the air, and, falling through the steady current of the trade-wind, had acquired a westward velocity. They had fallen in a slanting direction, for where a window was protected by an overhanging verandah, the panes of glass in the upper part had often escaped destruction. But the windows looking towards the volcano had also suffered, though in a less degree. Not many large stones were to be seen in the fields, but we were told that they fell for the most part on the afternoon of Wednesday, and were covered over by the subsequent rain of small scoria and fine dust. The larger blocks fell in occasional showers, but it was not noticed that these followed any particularly loud detonations from the volcano. The bananas and plantains, the mangoes, the bread-fruit, the cabbage and cocoanut palms had had their leaves torn off by falling stones. Many were still standing leafless, others were putting out new growth. The crops in the gardens were buried, but in the fields behind the town the rains had washed away more of the material and the arrowroot was reappearing in patches. In the south end of the town and around Grand Sable House torrents of thick brownish mud had flowed over the fields and roads from the slopes behind. From these last the ash was mostly washed away and deep furrows had been cut in the naked soil.

A few houses were set on fire, perhaps by lightning or possibly by hot falling stones. Others had collapsed under the weight of the ash which gathered on the roofs, while several had been knocked down by streams of mud on the day of the heavy rains.

The difference between the thickness of the ash deposit and the amount of damage done in Georgetown and at Chateaubelair is so striking as to deserve discussion. Though Georgetown suffered most, it is quite a mile more distant from the crater. There is no reason to believe that the black cloud of dust passed over either of these places; the effects observed are entirely due to the rain of ashes during the afternoon and night of the 7th May. Whatever may be the reason, it is clear that the crater projected a larger amount of material to eastward than to westward. This is in accordance with observations made by Mr. McDonald from Chateaubelair during the forenoon and up till 2 o'clock on Wednesday. He saw many showers of stones "principally to windward." Part of the dust, however, that fell in Georgetown may be due to a slow lateral spreading of the margins of the black cloud after its first velocity and heat had diminished. Chateaubelair is protected by several ridges and spurs which lie between it and the crater, but to the north of Georgetown spreads the level Carib Country. The strength of the trade-wind appears to have been unable to direct most of the material to leeward: it must have been hurled out of the throat of the volcano in an eastward direction against the wind.

All the country north of Black Point (south of Georgetown) on the windward, and from the north side of Chateaubelair on the leeward coast, and of a line passing between these two points and over the summit of Morne Garu, showed on its surface a covering of ashes more or less deep. Within this area there was another less extensive region in which the damage to vegetation had been severe, and everything presented a burnt and scorched appearance. This is the true "devastated country," and its southern border starts about half a mile north of Georgetown, and running along the ridges to the summit of Morne Garu, descends by the spurs on the leeward side to the south side of the mouth of the Richmond River, a mile north of Chateaubelair. It does not include quite the whole of St. Vincent north of this line: as at Owia and Sandy Bay, in the north-eastern corner of the island, there was comparatively little damage done to the vegetation (though the ash gathered to a depth of several inches). The boundary must be represented by a line drawn so as to exclude this quarter. (See map, Plate 39.) In the country included within this line not only was vegetation greatly injured or destroyed, but many of the inhabitants and most of the cattle in the fields were killed. Outside this line no one died directly from injuries received from the volcano. Consequently it marks the limit of the "danger zone."

The Deposits in the Wallibu Valley.

In that great depression which lies on the south side of the Soufrière, between that mountain and the Morne Garu, the ejecta of the recent eruption have accumulated to a far greater depth than elsewhere in the devastated country, and there, also, was the most complete destruction of vegetation, and the greatest loss of life. The western side of the valley is drained principally by the Wallibu River, the eastern by the Rabaka Dry River, and the geological phenomena exhibited along the course of these streams and their tributaries are most interesting and important.

The western valley, that of the Wallibu, is, as already described, unlike the common type of Antillean valleys, in being broad, open, and flat-bottomed, especially in the lower parts. The higher affluents which drain the southern flanks of the Soufrière have that steep-sided character, with drooping taluses of ash alternating with vertical cliffs of lava, which mark the mountain ravines of St. Vincent. But in the lower parts of its course the Wallibu River has a comparatively gentle gradient, and along the coast at its mouth there is a considerable expanse of fairly level ground. This is separated from another similar valley, that of the Wallibu Dry River, on the north, by a flat-topped ridge which rises behind the plantation works of Wallibu. To the north of this, behind the Carib village of Morne Ronde, the mountain rises rapidly and steeply, while on the southern side the rugged mass of Richmond Peak overlooks the plain beneath. To the south, the Wallibu River is separated by a sharp-topped spur from the valley of the Richmond River, which also, in its lower part, has only a slight fall and a comparatively slow current.

The Richmond Valley is carved in an old series of lavas and ash beds which seem to have proceeded from the Morne Garu volcano. They dip gently westwards to the sea. But the valleys of the Wallibu, and Wallibu Dry River have been cut out of that series of ash beds and coarse agglomerates (see Plate 30, fig. 2), well-bedded and without alternations of lava, which constitute the southern part of the Soufrière near its base, and are the record of the most recent phases of its volcanic activity. So soft is this material that on successive visits we could see that the streams flowing in it had deepened their channels by several feet in a couple of days. This may account for these rivers having reached an approximate base level before the others in the island.

From the mouth of the Richmond River to that of the Rozeau Dry River along the coast, and thence up the valleys of the Wallibu and Wallibu Dry Rivers, the surface is covered with a mass of recent ash deposit of irregular and varying thickness (see Plate 25, fig. 2). It is thinnest on the back of the ridge on which stands the dwelling-house of Wallibu—where it attains the depth of four or five feet. Here it was deeply furrowed with rain-rills, which had a pinnate arrangement (see Plate 26). The slopes on each side of this ridge are very steep and on them little ash rested; the rains had already washed the greater part down upon the level ground beneath. The trees where not uprooted and cast down were beginning to put out fresh green leaves. The wet and sticky black mud hung in festoons on the slope, separated by sharp narrow little rivulets cut by the water (see Plate 28, fig. 1).

Along the sea cliffs and on the banks of the streams excellent sections were exposed, both of the layer of new hot ash, and of the older tuffs on which it rested (see Plate 25, fig. 1). The deposits of the recent eruption varied from 5 feet to about 40 feet in depth, as seen in these sections. They formed irregular hog-backed rounded mounds, the long axes of which were roughly parallel to the direction of the valley, resembling in many ways the drumlins of boulder clay which one sees on the low grounds of Scotland (see Plate 25, fig. 1). These rounded mounds of sand bore no very close relationship in their disposition to the pre-existing features of the topography; the thickest deposits were not in every case in the old stream valleys, but the sand seemed to have been irregularly heaped and not spread out into a sheet with level upper surface.

It was not difficult to see that originally the deposits had had a smooth and rolling character, though the rains had scored them deeply with a converging pattern of stream channels. We saw no evidence, however, of wind-rippled surfaces, or of dunes; it looked rather as if a vast mass had been dumped down suddenly in great irregular mounds, and then the rain of ashes and of stones had smoothed the surface over.

In the upper part of the valley of the Wallibu Dry River the rolling surface of the fields of ash, with rain sculpture everywhere, was very like that seen along the shore, but it was only in the main stream channels that the underlying tuffs were visible, and the thickness of the recent accumulation could be ascertained. It was mostly from 5 to 12 feet deep, and here also it presented little uniformity in this respect.

But the channel of the Wallibu River was on the whole more narrow and steep-sided than that of the Wallibu Dry River. It was from 400 to 600 yards wide and from 200 to 400 feet deep. Here the deposit was of greater thickness and had suffered more severe erosion. Its original depth could not be made out with certainty, but at the time we saw it, it was from 60 to 80 feet thick in some places (see Plate 29, fig. 2).

The river flowing through the masses of sand which had been heaped up in its channel had cut a deep narrow gorge, sometimes with perpendicular walls. More frequently on one or both sides of the stream there was a series of terraces which varied in breadth from a few feet to 20 or 30 yards. As many as six of these could sometimes be seen one above the other (see Plate 29, fig. 1). They had all the marks of river terraces cut by water, the highest were always farthest from the stream, and their surfaces had a gentle slope down the valley. Where sections of these terraces were exposed it was evident that they were eroded out of the thick deposit of new hot ash. They were bounded towards the river by sharp slopes, from 1 foot to 10 or 12 feet high, by which the surface descended from one terrace to another, and little landslips frequently took place as the loose material dried after rains and tumbled down the bank upon the terrace beneath (see Plate 29, fig. 2). They were not, as a rule, equally numerous and well-developed on both sides of the stream; commonly on one side there was a vertical cliff, while on the other several terraces might be seen. Traced down the stream few of them extended for more than 70 to 100 yards, and they were best seen during the last mile of the river's course, where it runs on the south side of the flat-topped ridge behind Wallibu estate.

The origin of these terraces is not difficult to explain. Immediately after the eruption the valley was more or less completely filled with fine hot ash, mixed with a certain proportion of coarse blocks and bombs. The river when it resumed its flow found it a matter of no great difficulty to wash out or re-arrange this material. But the rains in St. Vincent are intermittent, and take the form of heavy showers, during which the streams come down in flood and frequently are raging torrents. At other times the quantity of water in their channels is very small, though this stream was never quite dry in the month of June when we saw it. A small body of water, black as ink and thick with mud, was always flowing to the sea, steaming strongly and very hot. It came in gushes which rushed down with a wave in front of them (see Plate 23, fig. 2), several inches or a foot in height, and between these the current was very slight and, in fact, almost ceased. It was not hot water but black boiling mud, and the stronger rushes carried with them pebbles several inches in diameter. On one occasion, when we were returning from an ascent of the mountain, we found one of the smaller streams, which we had crossed dryshod in the morning, so swollen by heavy showers that it was flowing in a thick black current 2 or 3 feet deep and several yards across. It was very hot, and we had to cut down some of the bare tree trunks to form a temporary bridge. Not long after we had crossed, this was carried away by the current.

This thick muddy flow constantly bears much material to the sea. The banks of ash on each side frequently slip down, especially when the hot sand dries after rain, and when it is undermined by the stream, and little landslides take place which temporarily dam back the current till the pressure of water increases and sweeps away the obstruction. Hence the intermittent flow and gushes of hot mud. A process of gentle erosion constantly goes on in which the river, unable to deepen its channel rapidly, keeps widening it by undermining the banks on each side and carrying away the material precipitated into the stream.

But after rains the magnitude and velocity of the current are greatly increased, and its cutting power so enhanced that it trenches deep grooves in the ash filling its old channel. According to our observations the increase of depth may amount to several feet in an hour, so soft is the recent ash and so rapid and powerful are the torrents When the shower is over the flood subsides almost as rapidly as it rose, and the widening of the gorge by the action of the gently flowing stream of thick mud is resumed, though now at a somewhat lower level. A new terrace is in this way formed inside of the old one which has been partly destroyed.

In the upper part of the Wallibu Valley, at a distance of about a mile from its mouth, it widens out to form a comparatively broad expanse, where the principal tributaries join to form the main stream above Petit Wallibu. Here was a wide plain of new volcanic ash (see Plate 28, fig. 2), which at the time of our visit had as yet been comparatively little eroded, and preserved in some measure its original surface configuration. The streams which cross this flat had each cut its gorge in the deposit, but between these there still lay wide stretches of the recent sand, which had hardly been attacked by erosive agents. The surface, though on the whole level, was rolling and irregular, and bore several pools and one lake of greenish turbid water. As seen from a distance of less than a mile this lake was perhaps 200 yards long, and steamed strongly, the water being apparently quite hot. It was impossible to get near to it, as the gorges cut in the hot smoking ash could not be crossed in safety. The swelling, hummocky, gently-rounded features which had originally characterised the ash-deposits, had in this area not yet been masked by the effects of erosion as in the stream valley lower down.

The ash which had gathered in the valleys of the Wallibu and Wallibu Dry Rivers was a fine sand, nearly black when wet, but, when dry and hot, brownish-grey or buff in colour. In the month of June the coating of fine grey dust which had at first formed the surface layer had been washed away, and the mass of the material was about as coarse as an ordinary sea sand or a little coarser. In it lay many lapilli, scoriaceous, yellowish, with white shining crystals of plagioclase and dark pyroxenes. Large rounded bombs were less frequent, but many could be found varying from a few inches up to 3 feet in diameter. They were rounded or flattened, with rough tuberculate or nodular outer surfaces, and when broken up were black in the interior, vitreous and vesicular, with scattered crystals of pyroxene, plagioclase, and olivine. Ejected blocks of the weathered andesites and reddened decomposed andesitic tuffs, which constitute the walls of the crater, were quite as numerous as the fresh spongy vitreous bombs, and entirely distinct from them in character and appearance. About half a mile north-west of Wallibu works were some ejected blocks, roughly cubical and measuring 5 feet by 4 feet by 4 feet. As they lay upon a layer of the new ash they could not have fallen from the cliffs behind, from which also they were several hundred yards distant. In the same place were bombs over 2 feet across.

Many of these ejected blocks when struck with the hammer broke with great ease, and large, flat pieces commonly flaked off their surfaces. They had been intensely heated before being projected from the crater, and rapidly cooled in their passage through the air, and it seemed as if concentric cracks or planes of weakness had been produced by the contraction of the chilled surface on the hot interior, recalling in many ways the perlitic structure shown by certain igneous glasses, and the spheroidal structure of weathered dolerites.

Another type of rock fairly well represented among the blocks imbedded in the ash in the Wallibu was a granular, holo-crystalline aggregate of felspar, brown hornblende, and olivine in very varying proportions. They appeared to be agglomerations of the first minerals to crystallise out of the igneous magma within the crater, but a minute description of these, and a discussion of their origin, may be deferred till they have been more completely investigated.

The most striking feature of the Wallibu deposits was the scarcity of coarse material. Certainly over 90 per cent. of the whole could only be described as a volcanic sand, and often the fragments above a couple of inches in diameter did not form over 3 per cent. of the mass. These statements are based not on the appearance of the surface, where the coarser and heavier materials had been concentrated by the action of rain in washing away the finer stuff, but on the vertical sections afforded by the cliffs, where the ash could be inspected in the condition in which it fell. There were not a few places where we found it impossible to collect any number of stones large enough to yield good hand specimens. Where the larger blocks and bombs did occur they were often numerous, forming fields of stones, and in each area they seemed to be, as a rule, of the same kind, as if the materials had fallen together like the rain of sparks from a rocket. In one place we might find a cluster of bombs, in another of ejected blocks, and so on, and each different part of the area yielded distinct types of rock.

The vertical sections of the new ash did not show any very distinct stratification, nor were the larger blocks more abundant near the lower surface. Most of the material was as little stratified as a recent blown sand. At the base lay the charred crops of sugar cane, not burnt up or destroyed, but rotting where exposed to the atmosphere under the attack of saprophytic fungi, which gave out a stench resembling that of guano.

The ash itself was very hot. Probably it was not quite red-hot, though as we were never on it by night, we cannot say how it would have looked in the dark. But if a walking-stick were thrust several inches into it and withdrawn after a minute or two, the brass ferrule was too hot to handle. The surface when wet was cool, firm, and good to walk upon, exactly resembling a fine cinder path. After showers, however, it soon dried, and the sides and bottoms of the little rain-rills became sufficiently hot to burn the naked feet of our coolie porters. From cracks in the ash, through which water had percolated to the interior, steam constantly ascended in little jets, which deposited thin yellow and greenish incrustations. One day, as we were being rowed to the landing-place at the mouth of the Wallibu River, a landslip took place in the dry, yellowish ash on the top of the low sea cliff. The stump of a tree, which had been entombed in the ash, was in this way exposed. It was charred but covered with a film of grey dust, and as soon as the air touched it, the wood burst into flame and sent up curling wreaths of blue smoke. After a few hours without rain, the surface of the fields of ash ceased to steam, and the haze in the atmosphere gradually cleared. Then all along the valley the blue smoke of burning wood rose from the banks of ashes beside the river.

Where the deposit was thick the interior was certainly not much below a dull red heat, even at the time when we were there. A month after the eruption, it still gave out a dry, stuffy smell, recalling hot lime freshly raked from the kiln.

It may be remarked that in the ash there was much charred wood, mostly the remains of the trunks and the stouter branches of trees. They were mere remnants which had lost every vestige of their original form, and all the bark and the smaller branches had vanished. With the erosion of the deposits in the Wallibu, much of this burnt wood was swept down to the sea and floated about. The villagers diligently gathered it in their boats and stored it up to be used for the fires on which they cook their food.

Although the volcanic sand was very hot, it was a bad conductor. The surface had been cooled by the rains, and only after some hours' drought did it even feel hot to the hand except in the rain runnels. But the water did not penetrate far, and at a depth of a foot the ash was quite dry. The sugar cane, which was exposed in the bottom of the rain rills in the cane fields around Wallibu Works, had probably been covered by the hot ashes for several days, yet it was not destroyed, only charred on the surface. The wet earth beneath had cooled the under layer of the deposit.

The intense heat of the ash explains the extraordinary steam explosions which took place along the streams after heavy rains. Then, from the River Wallibu, immense clouds ascended which might quite fairly be compared to those emitted by Vulcano or Stromboli during an eruption. Often, when the mornings were wet, we watched them from the windows of Sea View Cottage, near Chateaubelair, rising in great masses over the ridge which lies to the north-east of the village (see Plate 23, fig. 1). They drifted to leeward before the trade-wind, strewing the waves of the sea with dust. Great globular, turgescent pillars of steam would shoot up in a few seconds to heights of about 2000 feet, their surfaces covered with rounded swelling excrescences, expanding and multiplying as they rose, and when their upward velocity was spent, they floated slowly away before the wind. They were exactly like the cauliflower clouds which used to rise from the fissure on the southern side of Pelée. Often at their base they were grey, but, as they ascended, their margins and upper surfaces would change to brilliant white as the sun illuminated them. Half an hour after the rain was over they ceased to appear, or were very much diminished in size and number.

We had more than one opportunity of seeing their origin on the Wallibu River, though after heavy rains it was not possible to approach very near the banks. But even when the water was low, steam puffs would go up at intervals. They invariably occurred where the stream was washing out the base of a cliff on the outside of its bends. The loose sand, undermined in this way, would tumble down, and at the contact of the hot ash with the water a great column of steam would shoot into the air. Very little noise attended these outbursts; as a rule, only a low, faint rumble. In dry weather the river of steaming mud flowed quietly along its channel, effecting little erosion, and few explosions were to be seen. But when it came down in flood, the fine ash was ploughed out like snow, and enormous outbursts followed one another in rapid succession.

It is not desirable to be caught in a tropical downpour of rain on the Soufrière, as the streams rise so rapidly that they cannot be crossed, the more so as they are filled with boiling mud. But on one occasion, when we were descending from the crater, a short but heavy shower overtook us. The Rozeau Dry River lies to the west of the trail. It had been dry when we were going up; as we came down it was filled with a thundering inky torrent, 30 feet broad, roaring along at 20 miles an hour. The new ash had already been very thoroughly cleaned out of the upper portion of the valley, but down below there were still remains of the hot sand deposit, and as the torrent spread down the stream, it carved into the banks of ash, which seemed to melt away before its attack. As the water touched the hot sand, pillars of black mud capped with a great club-shaped cloud of steam towered into the air. It was a marvellous and beautiful spectacle, the column of water curving outward at its apex, and dropping down like a fountain, while over it played the delicate feathery steam cloud, the height of which we estimated at 700 to 800 feet. It might well be compared to a geyser of boiling mud, and the contrast between the black base and the pearly apex heightened its beauty.

The Carib Country and the Valley of the Rabaka Dry River.

On the windward side of the island, in the Carib Country, and the ravine of the Rabaka Dry River, the phenomena already described in the valley of the Wallibu and Wallibu Dry River, on the leeward side, are repeated in all their essential features, though with a few not unimportant differences. The topographical conditions are here considerably simpler than on the western side, as in the Carib Country we have a broad triangular plain, the base of which rests on the sea shore, and extends from south of Georgetown to Overland Village, while the apex is placed some distance above Lot 14 estate (see Plate 21, fig. 1). It slopes gently to the sea coast, and though its surface shows traces of old eroded terraces, masked with an accumulation of loose surface deposits, it is crossed by no prominent ridges, but forms a smooth expanse, which is entirely under cultivation, and before the eruption was considered the best agricultural district in the whole island. Across this sloping plain several streams flow in shallow valleys, the most important being the Rabaka Dry River.

The conditions already described as prevailing at Georgetown are typical of the whole Carib Country. It is buried under a sheet of ashes, the depth of which to the south of that village is only a few inches, but increases as it is traced northward to Rabaka, Waterloo, and Orange Hill, where it is often 3 feet. At Overland the deposit again thins out to less than 1 foot, and from thence to Victoria Village must probably have been at first less than this, though the powerful action of the rains on the steep hill slopes in this quarter had removed the greater part of it before our arrival. Traced inland, this sheet of sand and scoria gradually thickens, and above Lot 14, on the flat ground known as the Mahoe, it was probably in many places 5 feet deep. Over the whole of this country the rains had caused immense erosion, and everywhere the surface was sculptured with furrows and runnels (see Plate 21, fig 2). Where these united, they had formed considerable streams, which had cut downwards into the soft red earth which underlay the new ash, and sometimes in the midst of a level cultivated field a gully 20 feet wide and 12 feet deep would testify to the rapid and intense erosion which these transient torrents had effected.

The original surface configuration of the fields of ash had been greatly modified before the middle of June, when we were there, but it was clear that they had at first been characterised by a smoothed and strewn appearance resembling that of a fall of snow. They were covered with rain-rills, the arrangement of which depended to a considerable extent on the slope of the ground, for where that was slight, the tributary furrows united to form a main channel at comparatively high angles, and were often tortuous; but where the slope was high the rills were straight and nearly parallel. For yards they would run side by side, separated only by a narrow ridge, a foot or more in height, and they united to form larger channels only where the gradient diminished (see Plate 28, fig. 1).

The finer dust had disappeared from the surface, and only the coarser sand, lapilli, bombs, and ejected blocks remained. On the whole there seemed to be a greater abundance of coarse material and large stones than in the Wallibu Valley. This may have been a consequence of the greater rainfall on the windward side of the mountain, which had removed the finer ingredients more completely, and it must also be borne in mind that two rainy weeks had elapsed since we had explored the valley of the Wallibu. Still, an impression was left on our minds that bombs, ejected blocks and large lapilli were commoner here than on the leeward side.* This did not, however, efface that distinctive character of the ejecta of the Soufrière already noted, for still the fine material greatly preponderated, and the new ash might best be described as a sand and dust deposit. Bombs, 2 or 3 feet in diameter, were not uncommon, and the different kinds of rock found at Wallibu were all present here also.

In the Carib Country there were none of those round backed ridges of sand—30 or 40 feet deep in their centres—which were seen on the Wallibu Dry River. The uniformity in depth of the sheets of ashes and their smoothed upper surfaces

* Mr. E. O. HOVEY is of the same opinion: "Martinique and St. Vincent: a Preliminary Report upon the Eruptions of 1902" 'Bull. Amer. Museum Nat. Hist.,' vol. 16, p. 339, 1902.

were far more noticeable here than on the leeward country. There was nothing to show that the material had been dumped down suddenly in irregular heaps by an avalanche; it was more easy to suppose that it had fallen in a steady rain from above and the regular thinning away in all directions outwards from the crater greatly favoured this supposition.

During the days of heavy rain true mud lavas, on a small scale, had flowed down some of the streams. They were thick, pasty currents of black volcanic sand mixed with water, and sometimes had not been sufficiently fluid to reach the sea, as the gradients in the lower parts of the streams are low. At Waterloo a flow of this mud could still be seen to occupy parts of the stream courses. It was 3 feet thick, and consisted mostly of the fine material from the surface of the fields of ash.

In the estates along the shore of the Carib Country the damage done to trees and buildings was by no means so great as might been have expected. The chimney of the factory at Turema and the wall of an old store at Rabaka were knocked down, probably by lightning. The iron roofs of some stores and verandahs and many of the ill-built, trash-roofed, wooden huts of the labourers had collapsed under the weight of the pile of ashes which accumulated on them. Some of the thatched huts had taken fire, it may be from flashes of lightning, or possibly from hot falling stones, for we were told that some stones broke when they struck the ground, and their interior was red hot. The trees had had their branches broken and their leaves stripped by the rain of scoria, but were mostly still living and renewing their foliage. Some, however, had been struck by lightning and their trunks had been split asunder. We were told that many had had their branches weighted down to the ground or broken off the stems by the ashes which gathered on them in the afternoon and night of the 7th of May. But in the managers' buildings, though everything was very dirty from the layer of ashes which had covered all walls and furniture, little had been destroyed. The glass in the windows was often broken and the roofs sometimes perforated by falling stones, but the furniture, the stores in the cellars, the machinery, the pictures, had not been destroyed and were apparently very little damaged.

At Lot 14 the damage had been greater, the village of labourers' huts was ruined, partly by fire, partly by the weight of ashes that gathered on the roofs. But the sugar works and the manager's house were not much more injured. In the house the windows were broken, and a verandah had collapsed, but nothing was burnt, and in the cellar below, in which the manager and his family had taken refuge, everything seemed to be in its normal condition.

The stream known as the Rabaka Dry River heads in a series of tributaries which flow in deep ravines down the slopes on the northern side of the Morne Garu and the south side of the Soufrière. These unite to form a main trunk which descends to the Carib Country, at first through a valley which, though not so precipitous on its sides as is usually the case in the mountain gorges of St. Vincent, is still a deep and well-marked trough, but about half a mile above its mouth the river enters a shallow open broad channel, which is partly filled with terraced masses of ash. This is known as "the lava bed," and the accumulation is said to be the product of the eruption of 1812. Before that time the river is believed to have flowed more or less continuously, but since then it often dries up for weeks together, and its flow is considerable only after rains. That at Wallibu so much more water should be found than in the larger stream at Rabaka is certainly a curious fact, and one for which it is not possible to offer an explanation without making a thorough study of the geology and physical features of its drainage area—an investigation which could not be undertaken in the present condition of affairs.

In the upper part of the Rabaka Dry River enormous accumulations of hot sand have been piled up exactly like those already described in the Wallibu Valley (see Plate 32). We were told by Mr. SPENCE, who is well acquainted with the district, and visited it along with us, that in some places this deposit could not be less than 200 feet thick. Certainly it had almost completely obliterated the old valley of the river at more than one point, and where formerly there had been a deep trough, there was now a rolling plain of black sand, through which, after rains, a sluggish stream of mud wound its way, but on a dry day the steaming channel was streamless. Here erosion had produced much smaller effects than on the leeward side, and in many places the ash had been practically unattacked, and the original nature of the surface could be well seen (see Plate 34, fig. 1). It was flattened on the whole, but rolling, hummocky, and uneven, so that pools of water had gathered in the hollows, and in these little deposits of alluvium had formed from the fine materials washed into them by the rain. These pools were now mostly dry, and the dark surface of the ash was freely steaming. After a couple of hours of dry weather, spots of grey would appear where the heat had been sufficient to dry the upper layers. Then our porters could with difficulty cross it with bare feet; when wet it was quite cool to walk upon. The deeper parts of this deposit must have been at a very high temperature. Where the hot, grey ash was exposed by landslips in the banks of the stream, it had a stifling stuffy smell. A good deal of charred wood was mingled with the sand, and there were many spongy, vitreous bombs, but angular broken pieces of the old rocks of the hill made up far the greater portion of the coarse material in the mass. As a whole, however, it was an accumulation of sand and dust; bombs and ejected blocks were more numerous than on the Wallibu, but formed only a small percentage of the mass.

In the main valley of the Rabaka Dry River vast quantities of this material had been heaped, but, strange to say, the tributary valleys contained far less of it, and the great pile of ash in the main channel often formed dams across their mouths, behind which lakes of water and of liquid mud had formed (see Plate 34, figs. 1 and 2). On several occasions great and sudden floods of mud had rushed down the stream, and it was clear that they might have originated by the water eroding these dams till they were so weakened that they gave way before the pressure of the lake of mud behind them, and a large part of the contents of one of the lateral valleys was suddenly discharged into the river. In some of the ravines these lakes of thick, black mud were quite half a mile long, and if heavy rains should cause rapid erosion by the main stream, flows of mud-lava may yet take place on a large scale.* The hot sand in the Rabaka Valley does not readily form mud. It is too hot for the rain to penetrate far below the surface, and the water evaporates rapidly. The mud lakes had been filled with the cold material from the slopes above, which had been washed into the depressions by the heavy rainfall.

The terraces and other features due to steam erosion exhibited on the Wallibu were repeated in all their essential features in the valley of the Rabaka Dry River, only here the process was far less advanced, owing to the smaller body of water which characterised this stream. The new cut gorge was not over 20 or 30 feet deep, the terraces on the whole less numerous and closer together (see Plate 32). Two or three of them could often be seen, 3 or 4 feet apart, and as the valley was broader than that of the Wallibu, the terraces were better preserved and more extensive. But much of the deposit retained its original rolling surface, and only a part of the sheet of sand in the valley had been remodelled by running water. The faces of the terraces and the banks overlooking the stream often slipped and the hot grey ash was then exposed. It showed only a rudimentary and very imperfect stratification, and at a depth of a foot or so the sand was grey and quite dry, while the upper part was moist and of a darker colour.

Only after rains did water occupy the stream channel; usually it was empty, and the moist, stony mud on the bottom continuously steamed. But after a heavy shower great steam explosions rose from the whole upper course of the river, and probably they were no less violent than those on the Wallibu (see Plate 31, fig. 1). As the banks were lower, the landslides of hot ash were smaller, and great rolling sudden steam-jets were not so frequent as on the leeward side. Sometimes the river flowed hot, black, and thick with mud, right down to the sea, and on one occasion we had to ride our horses through the surf, as a current of mud, several inches deep, was flowing in the river, and was too hot for our horses to cross it. This was only after severe rains, as in most cases the water was completely evaporated in passing through the hot sand in the upper part of the channel.

In more than one place in the valley of the Rabaka Dry River we observed large, circular, flat-bottomed depressions, some of which were perhaps 20 yards in diameter, while others were not more than 8 or 10 feet (see Plate 33, fig. 2). At most they were 8 feet deep, and often they occupied the apex of a low flat cone, the diminutive size of which, as compared with the broad, flat central basin, reminded one of the lunar craters. Very commonly the surface of the ash fields around such a crater was covered with scattered blocks in considerable numbers. They were most frequent

* As this proof is being corrected for the press, we learn that such mud-flows have actually taken place, 'Sentry' newspaper, Kingstown, November 28, 1902.

around the larger pits, and from their arrangement it was impossible to avoid the conclusion that they had been emitted from the funnel around which they lay. The sharp cut walls of ash surrounding these depressions showed that they had been blown out of the deposits of ashes by a large steam explosion. Usually they were situated on the course of the stream (we observed none at any distance from the main river or its tributaries), and in one place there were three of them in contact with one another, planted on the river banks. They were incomplete, less than half of the whole circle remaining in each case, as the side next the river had been cut away as the stream deepened its gorge.

We did not see any of these pits in operation, but the method of their origin is probably as follows:—water in some way gets access to the undermost and hottest layers of the ash, probably by the river cutting suddenly into its banks at their base and undermining them. A large part of the bank then at once subsides into the stream, and when the hot ash touches the water large masses of steam are immediately generated, and the explosion lifts the super-incumbent mass and carries it upwards into the air. In some cases many tons of material must have been thus projected into space. The finest dust floated up to great heights, and was wafted away by the wind; many of the stones must have been shot up obliquely and have fallen on the fields of ash which surrounded the focus of eruption. But a very large part of the material subsides again into the funnel-shaped cavity through which the steam explosion ascended. It is, however, not sufficient to fill it up, and the basin-shaped depression is a measure of the amount of material which was borne away by the wind or projected beyond the lip of the funnel. The low, flat cone around the crater is formed by the sand and stones which fell just outside the edge of the cavity. There was no evidence that more than one explosion had taken place from each funnel, but in more than one place a group of pits was seen which suggested that the same process was several times repeated at approximately the same spot.

It is not likely that they were occasioned by water penetrating through cracks on the surface and reaching the hot mass below, for cracks were few and small except where landslides were taking place on the stream banks, and in no case were fissures seen in connection with the pits. Possibly, however, after heavy rains, springs rising in the bottom of the valley may introduce water into the basal layers of the deposit, and in this way steam explosions would be produced with exactly similar effects.

In the valley of the Wallibu Dry River we found a low, flat cone some 30 yards across at its base, and about 10 feet high, with a large flat central crater on its summit, perhaps 15 feet across, circular, some 3 feet deep, with a layer of mud in its interior, and around the lip of this crater were three others, smaller but almost equally perfect. The rains had somewhat destroyed the structure, a little lake had formed in the main crater, and had drained out through a notch on one side. It stood about 15 yards from a deep narrow gully occupied by a small stream, and not far from the base of a high bluff, so that the introduction of water below the surface might have been due either to the undermining action of the stream, or to the uprise of springs from below. On the whole the latter seemed the more probable explanation. Similar cones, but less perfect, were seen elsewhere in the same valley (see Plate 31, fig. 1, and Plate 28, fig. 2).

The Slopes of the Mountain.

The condition of the southern flanks of the Soufrière presents in most respects a very complete contrast to that of the Wallibu and Rabaka Valleys which lie beneath them, for while in these much deposition of new material has taken place, and erosion, though rapid, has not yet been able to bring the former surface to light, on the higher grounds the accumulation has been slight, and erosion is proceeding at a very rapid rate. On the sharp knife-edged spurs and deep ravines of the south side of the mountain the washing action of the rains has had great effect. Everywhere the surface of the new ash is furrowed with rain-rills, and where the slopes are steep the wet mud has often slipped bodily into the valley bottoms. The deposit must have been several feet deep on the lower part of the hill slopes, but exactly how deep it was can no longer be determined, as only a remnant of the original mass remains, quite insufficient to enable a judgment to be formed regarding its original thickness and disposition.

The sides of the valleys incline at angles averaging 40° (which appears to be about the angle of repose of the taluses of weathered ash), except where the edges of the few lava beds visible in this quarter form vertical cliffs. On the gentler slopes the ash still hangs in festooned masses, the discontinuous remains of a sheet once spread over the whole surface. The rain has cut down to the old soil and laid bare the scorched vegetation, which, as its roots, being surrounded with damp earth, were often not destroyed, is slowly recovering and sending up scattered leaves of fresh green among the dreary wastes of mud.

The rain sculpture furnished a most interesting subject of study, for it presented a very great variety of forms which depended principally on the original slope and configuration of the surface on which it rested. Where the ground was steep the rills were many, narrow, and straight, with small furrows joining them on each side in a manner reminding one of the pinnules of a feather. They ran side by side down the slopes, converging only slowly to unite to form a main channel of a higher order. The intervening ridges were 2 or 3 feet high, and perhaps twice as broad at their base, their summits gently rounded, their sides fluted with minor furrows. Often one of these ridges had collapsed or slid down, and its remains been washed away; and this somewhat diversified the usual regularity of the features. As erosion advanced the furrows broadened, as the loose ash was more easily removed than the old rock beneath the soil, and the ridges between wasted away, getting thinner and thinner.

On the more level ground the sculpture recalled rather the tributaries of a river, tortuous, irregular, converging and frequently uniting to form a large main trunk. A study of the photographs will give a better idea of the features of these rills than pages of description.

In many places the sides of the valleys were absolutely bare, and not only had the new ash been removed, but with it much of the old soil had also disappeared, as might be seen from the manner in which the roots of the broken trees projected above the surface, and in the lakes of water previously mentioned as forming in the lateral valleys of the Rabaka Dry River, a red mud from the eroded soil was mixed with the black mud furnished by the new volcanic ash. Often we could see areas of many hundred square yards absolutely divested of the covering of black mud, and sometimes the whole side of a valley showed it only in one or two patches (see Plate 34, fig. 2).

Fine sand with little lapilli had formed the greater part of the material which lay upon the slopes. Stones of any size were very few, for when they fell they could not rest unless they buried themselves in the hot sand, but rolled down into the ravines. This was, in fact, one of the dangers of the ascent, as the rains had loosened many stones in the old agglomerates, and when once they were set in motion nothing could stop them till they landed in the stream hundreds of feet below. The ash, as a rule, held together very well when it was wet, but every now and then the pressure of the foot started small landslips, which tumbled down the slopes.

In the deep narrow valleys which score this side of the mountain little of the new ash was left (see Plate 30, fig. 2). At the higher elevations a patch here and there, on the extremities of the bends or behind a projecting bank, was all that could be seen. Further down, flows of the black liquid mud had congealed in the channels, unable to travel further. Once a sharp shower, brief but heavy, overtook us as we were descending. Below us was a place, " the river bed," where the path crossed a tributary of the Rabaka, dry except after rains. As we did not wish to be cut off by a raging torrent, we hurried down to get over the crossing. The stream was pouring in cascades over the rocks in the upper part of its course, but when we reached the "river bed" there was no water there. Looking up the stream we saw a creeping mass of stiff black mud slowly winding its way down the channel like a serpent. The water was so loaded with sand and mud that it almost ceased to flow. Had the rain continued, of course an inky torrent would have rushed down into the lake of mud in the lower end of the valley. Further down, where the ravines entered the plains of the Carib Country, and on the flat ground near Wallibu, some part of the masses of ash originally piled up there still remained (see Plate 31, fig. 2).

We have mentioned the explosions of hot ash and water in the lower part of the Rozeau Dry River. The remains of the deposit were terraced and deeply cut into, a mere shadow of their former selves. So great had been the erosion along the whole course of these steep valleys, that it would be rash to say to what extent they had been encumbered with hot sand immediately after the great eruption. In more than one place there were still 40 feet of ashes in the bottom of the gorges (see Plate 30, fig. 2).

Possibly the original thickness had been twice or thrice as great. The terracing of these deposits was often very fine, and in other places subsidences and landslides had taken place, and the surface of the ash was fissured, broken, and highly irregular. Great stones, 12 feet across and more, lay in this ash, whether ejected during this eruption or fallen from the old agglomerates in the cliffs, we could not say.

On the knife-edges of the spurs the new mass still lay, firm, coherent, forming an excellent pathway, so smooth that one might have thought it had been prepared expressly for the foot (see Plate 35). When the sun shone after heavy rain, the smooth, narrow, winding strips of fine wet ash on these ridges reflected the light, and they seemed like lines of silver traced on the dark-grey background of the hill. On them the rain had little power of erosion, as they formed, in fact, the only tracts of level ground on the whole mountain. The fine dust was washed away, and the coarser sand exposed by the beat of the raindrops. They were, as a rule, from 2 to 5 feet wide; laterally, as the slope increased, little rivulets formed, at first so small that they had almost no cutting power, and on each side of the smooth central line there was a strip fluted with little furrows. This passed in turn into the sculptured rill-marked surfaces of the sides of the valleys. The division line between these surfaces was wonderfully sharp, for as each channel deepened it pushed its head upwards, and the steep upper parts of the erosion curves produced little rapid descents, by which one type of surface graded into another.

At heights above 2500 feet the gradient of the path became somewhat steeper, and as the surface here was covered with 5 feet or more of fine ash, which when wet became a pasty mud, it was more toilsome to climb this slope than any of the lower parts of the hill. The foot sank deeply in the soft, wet ash, which was furrowed with shallow rain grooves, some three or four feet deep, the edges of which slipped away when we endeavoured to cross them. The deep radial valleys which trench the hill sides gradually pass into shallow, wide depressions when traced up to this level, and the oft-quoted comparison of an eroded volcanic cone to be a partially opened umbrella, was very applicable to the Soufrière. The greater steepness of the upper slopes showed also that the mountain possesses the typical profile of ash cones, though this was by no means very evident in a distant view owing to the great erosion, which produced an appearance of rugged irregularity.

This ash on the summit of the cone was mostly a fine black powder, smelling strongly of sulphuretted hydrogen, but in it there was a very large number of ejected blocks and bombs, many of them on the surface, but apparently still more were embedded in its mass, as if the last material to gather on the slopes had contained proportionately fewer of the coarse ingredients. The ejected blocks were often four or five feet in diameter, and the spongy andesitic bombs not seldom two or three feet. Many of these last seemed to have been hot and plastic when they fell and to have stuck together, or, at any rate, the later had moulded themselves on the surfaces of the earlier. Though the fragments of the old lavas and ash beds which had been torn from the walls of the crater showed in their brittle condition the effects of having been intensely heated and suddenly chilled, they were never fused on their surfaces, and presented no resemblance to the true bombs. Occasionally pieces of much charred wood entombed in the ash were to be seen in the sides of the rain-rills. On the windward side the proportion of large fragments in the ash deposit at this level was especially high, and where much of the finer dust had been washed away, great accumulations of stones remained. That the lower slopes were so bare, while near the summit fine ash remained in considerable sheets, was due to the deeper erosion features at lower levels. The sides of the ravines showed angles of about 40°, the winding knife-edges of the spurs had an average inclination of less than 10°, the summit cone sloped at about 25° to 30°. The amount of erosion of the new ashes was in direct proportion to the steepness of the slope in each case. It must also be remembered that originally the depth of the deposit was greatest immediately around the crater; in some of the shallow valleys it was at least 12 feet, and may have been 20 feet in places. On the valley sides the large blocks and bombs could not rest; they rolled down the steep slopes till they rested in the bottom of the ravines; but on the edge of the crater they had accumulated, partly because more fell there and partly also because the surface slanted at angles sufficiently low to enable them to lodge.

The Crater.

In the month of June it is seldom that the Soufrière is not capped with cloud, and one may consider himself fortunate if, after climbing the hill, he obtains a clear view of the crater. Our first ascent—from the leeward side—was made on a very favourable day, and the first of the party to reach the edge of the crater could see the bottom for a few minutes. Then the mist closed in, and only once again did it lift sufficiently to enable us to discern the lakes in the floor of the depression. Heavy rain followed soon after, and we had to beat a hurried retreat. From the windward side we twice essayed the ascent, and were both times baffled by the mist. Once we persevered and reached the edge of the cliff, but it was impossible to see for more than 30 yards in any direction, and the interior of the crater was a sea of vapour. For 10 days we waited in Georgetown, making daily excursions, but ready to start for the summit at any time when the conditions might seem propitious; but we never had a clear view of the upper part of the hill, and we were informed by the inhabitants that the month of June of this year (1902) had been more than usually unfavourable for our purpose.

The first party to ascend the hill was led by Mr. T. M. McDonald, of Chateaubelair, and included Professor Jaggar, Mr. E. O. Hovey, and Mr. Curtis. They had a very fine day (31st May), and were able to secure photographs of the north wall of the crater. Professor Jaggar was so good as to give us full descriptions of what he saw. Mr. McDonald also conducted our first ascent, and placed all his information at our disposal. Lieutenant ROBINSON, R.E., who was accompanied by the Rev. Mr. HUCKERBY, climbed the hill on the 3rd June, and from him we obtained a valuable report* as to the state of matters on that date. On the 5th June, Mr. BIDDICK made an ascent. We followed on the 12th June, and since then several parties have reached the edge of the crater. We are indebted to Mr. ARTHUR DARRELL, of Kingstown, for notes made on the appearance of the old and new craters on the 27th June; and in the 'Sentry' (of Kingstown), dated 15th August, a few notes are published on the condition of the crater on the 12th August by Messrs. A., I., and F. RICHARDS, of Kingstown. These ascents were all from Wallibu on the leeward side.

On the windward side ascents have been made by Mr. ANTOINE; Mr. BEACH, Professor JAGGAR,† Mr. HOVEY, Mr. CURTIS, Mr. TAYLOR, and Mr. WILSON, of Kingstown; by Mr. HOVEY and Mr. CURTIS; and by us.

The great convulsions of the spring of this year have effected little alteration in the general outline of the two craters. Both remain somewhat modified indeed, but the changes in them, according to the opinion of those who knew them before, have not been very extensive. Exact measurements could not be made under the circumstances; it is doubtful whether a careful survey was ever executed. Mr. POWELL, Mr. T. M. McDONALD, and Mr. DARRELL consider that the shape of the main crater is more elliptical—it is broader from east to west than it was before, and that on the whole it is larger. This agrees with the statement of inhabitants of Chateaubelair that, as seen from that place, the lip of the crater is slightly lower and somewhat different in profile, even if we allow for the effect of the disappearance of the vegetation which covered it. The small crater has not disappeared, neither is it much enlarged. Apparently it took no part in this eruption; its walls are now bare, and it is reported—we believe by Mr. HOVEY‡—that it contained a slight deposit of black ash in its bottom. The saddle between it and the large crater still stands, though not quite so high as before, and several observers have seen landslides taking place on it, the material tumbling down into the large crater.

When the first party ascended the mountain, they found a little water in the bottom of the main crater. It was boiling vigorously and giving out clouds of steam, especially at the south-east corner, close to the walls.§ Lieutenant ROBINSON, R.E., on the 6th June, reports as follows:—

* Published among the papers in the Blue Book "On the Volcanic Eruptions in St. Vincent and Martinique in May, 1902," p. 89.

† T. A. JAGGAR, "Field Notes of a Geologist on Martinique and St. Vincent," 'Popular Science Monthly,' August 1902, p. 366.

‡ E. O. HOVEY, "Martinique and St. Vincent: a Preliminary Report upon the Eruptions of 1902," 'Bull. Amer. Museum Nat. Hist.,' vol. 16, p. 338.

§ E. O. HOVEY, *loc. cit.*, plate 37, figs. 1 and 2.

The crater was completely filled with a cloud of smoke or steam. After some minutes this cleared away, and the bottom and sides of the crater were distinctly visible. The clearing and filling of the crater with steam was repeated at intervals of about ten minutes. The bottom of the crater contained three small lakes, two of which were of very yellow looking mud, with a low wall of mud and boulders separating them. They were quite quiescent. To the right was a very large mound of earth and stones, which divided them from the third. This third pool was the cause of the steam alluded to above, for by walking some distance to the west along the edge of the crater, it was seen to be bubbling up with excessive fury, and throwing up liquid mud amidst the steam. I estimated these pools to be 1800 feet below the lip of the crater."

When we saw it, matters were in very much the same condition as on the 6th June. Three irregular lakes of greenish, turbid opalescent water occupied the floor of the crater. The two on the west side were not boiling; only a narrow isthmus separated them. In the south-east corner was another lake, the whole of which could not be seen from where we stood. It was boiling vigorously with a hissing noise, and throwing up jets of mud and steam. The steam rose in curling wreaths along the high south-eastern wall. Water was flowing gently from one of the other lakes into this one. The floor of the crater was bare and stony, and on its northern side lay a huge pile of broken rock, which had evidently fallen from the vertical cliff behind it This mound separated the lake which was boiling from the other two.

Of the dimensions and depth of the crater it was very difficult to form an opinion; the mists trailing over the hill prevented us from obtaining a clear view, and we had only a brief glimpse of the base of the opposite wall. Its summit we did not see. Formerly the southern lip was about 1100 feet above the surface of the lake, and it is now generally agreed that the cavity is deeper than before by several hundred feet. Some good judges consider it to be 2000 feet, others will not admit that it is more than 1400. Probably from 1600 to 1800 feet would be a fair average of the estimates formed. The cliff, which on the north side overlooks the lakes of water, must be over 2000 feet high.*

The south-western wall, on which we stood, sloped downwards at its upper part for perhaps half its whole height. The angle of declivity varied from 40° to 44°, and a layer of wet black ash, deeply furrowed with grooves eroded by the rains, covered the surface. The lower part of this wall was steeper, probably vertical; we could not see it from where we were. We tried to work round the lip of the crater to the windward side, but in the thick wet mud, in which we sank to the knees, walking was very difficult, and as a storm of wind and rain sprung up, we had to give up the attempt.

Professor JAGGAR's photographs show that the north-eastern wall is vertical, a precipice of bare rock. From it great landslides and falls of rock frequently tumble on the floor of the crater with a loud noise.† They have been seen by more than one

* Further modifications have since taken place, owing to the eruptions of September and October, 1902.

† E. O. HOVEY, "Martinique and St. Vincent: a Preliminary Report upon the Eruptions of May 1902," 'Bull. Amer. Museum Nat. Hist.,' vol. 16, p. 337, 1902.

observer. When we ascended from the windward side we reached the edge of this precipice. Our guide had been there with Mr. HOVEY, and he told us that since his previous visit the outline of the cliff had considerably altered. We saw great cracks some yards back from the edge, running parallel to it, and before we descended a large slice of the face broke away and slid down into the abyss. When he ascended with us, Mr. McDONALD remarked that since his previous visit much rock had fallen, and lay at the foot of this great cliff.

Lieutenant ROBINSON found that the southern lip of the crater was 2450 feet above sea level.* We made it at three different places 2690, 2630, 2700. These measurements are by aneroid, and are sufficient to show that on this side the lip is lower than before by at least 300 feet. At the spot where we reached the edge of the crater from the windward side, our aneroid recorded a height of 3050 feet, where formerly the altitude must have been not less than 3400 feet. There can be no doubt that a considerable mass of the crater walls has been blown into the air by the great explosions of the 7th May, and that the crater is somewhat larger, and its rim distinctly lower in consequence.

The amount of water in the crater continually increased during the months of June, July, and August, 1902. When first visited, it contained only one small lake. A few days later Lieutenant ROBINSON found that there were three—as was also the case when we were there.

Mr. ARTHUR L. DARRELL, along with a party from Kingstown and Chateaubelair, ascended the mountain on the 27th June. He has sent us a description of the crater, from which we extract the following:—

"We remained on the summit about three-quarters of an hour, carefully inspecting the localities. I knew both of the craters, the old and the new—as they are popularly called—that were such objects of interest to tourists before the eruption, having visited them as late as last Easter Monday, March 30.

"I noticed that the old crater was changed in shape. Before the eruption it was nearly circular, to-day it is an irregular oval, the extension being towards the Morne Ronde side on the north-west, and on the south-east where the Rest House formely stood. The hill on which the Rest House formerly stood has been blown away. The northern and eastern sides of the crater are more precipitous than they were. The south-eastern side is not so steep, but shelves from the top to the bottom. In some places the sides are very rugged, being covered with large angular rocks, and in other places with smoother and finer material. The southern edge of the crater is lower than it was before the eruption. As I stood on the south-west edge of the cone, and looked across to the north-east, I noticed that the 'saddle' or division ridge between the two craters seemed lower than it was formerly, for I could see over it to the furthermost side of what was known as the 'New Crater,' which appeared to be more precipitous than formerly, and which presented a dark brick red appearance. Before the eruption, no one standing where I stood, on the edge of the old crater—now lower than before—could see the new crater beyond the 'saddle.' I therefore infer that the crest of the 'saddle' is considerably lower than it was; otherwise I could not have seen the red-faced further side of the 'New Crater.'

* Report by Lieutenant ALICK C. ROBINSON, R.E., Blue Book, 'Correspondence relating to the Volcanic Eruptions in St. Vincent and Martinique in May, 1902,' p. 90.

"At the bottom of the old crater, I saw three lakelets. The bottom of the crater consists of broken rock and sand. The depth from the edge of the cone to the surfaces of the lakelets does not seem to be much greater than was the depth from the edge of the old crater before the eruption to the surface of the old lake. The water in the three lakelets is not of the same colour. The northernmost one is of a dark olive-green colour, that of the central one is of a light sea-green colour, and that of the most southerly one is black and muddy. This lakelet is constantly bubbling and boiling, emitting steam with a hissing noise, the vapour rising, at the time of my visit, considerably above the crater's mouth. The side of the crater, at the base of which this black boiling lake lies, is very steep. This bubbling pool cannot be seen by looking over the side of the crater, at the base of which it lies. I had to walk at least a hundred yards to the western edge before I could get a clear view of it. Large stones were seen and heard falling into the boiling lake, which is separated from the middle lakelet by material, from which an apparently ashen-coloured smoke seemed to ascend. In addition to these three lakelets there is a small pool of yellowish mud resting on the top of a mound that lies close to the base of the eastern side of the crater.

"I was anxious to complete my inspection of the mountain by visiting the New Crater so-called, but I was unable to do so owing to the great difficulty of passing to the other side of the crater—the guide being unacquainted with that part of the mountain."

It would seem that during the three weeks which had elapsed since we were there, no considerable change had taken place in the appearance of the crater and of its lakes of water.

The latest account which we have received is one which is given in 'The Sentry,' on 15th August, 1902, in the form of an interview with Messrs. ADOLPHUS RICHARDS, IVAN RICHARDS, and FRASER RICHARDS, of Kingstown. From this it would appear that there was then only one lake, which was about one-third the extent of that which occupied the crater before the eruptions. They state that steam and pebbles were being intermittently thrown up with a hissing noise from a small opening on the lip of the crater. This looks as if the activity were increasing. Two weeks later another eruption broke out.

The Evidence for the Hot Blast and the Avalanche of Dust.

The statements of the survivors in the Carib Country and of those observers who were in Chateaubelair, place beyond doubt the existence of a great black cloud which swept from the crater down the flanks of the mountain on the fatal afternoon of the 7th May. It remains for us to discuss the bearings of our observations on the deposits of ash and other associated phenomena in the devastated country on the peculiar features which are exhibited by eruptions of this remarkable type. These establish, we believe, the presence also of an avalanche of dust, sand and stones, and of a hot blast, and that they are intimately connected with one another and with the great black cloud.

The Avalanche of Dust, Sand, and Stones.

The distribution of the materials emitted during this eruption on the Soufrière and in the valley at its base, cannot fail to be regarded as very remarkable, and cannot be accounted for on the theory that the ash was simply rained down from above and gathered where it fell. A rain of ashes certainly took place. It lasted for hours on Wednesday afternoon and night. Hot stones falling from the sky struck many people in the Carib Country who were running from one house to another in the gloom, seeking for their friends, and the noise of the ash clattering on the roofs was at times almost deafening. In this way a sheet of deposit must have been laid down all round the volcano, which thinned out gradually as it was traced further and further from the crater. Over Chateaubelair and Georgetown the black cloud did not pass, and the thickness of the ash is a measure of the violence of the shower. Since 18 inches accumulated in Georgetown, it does not seem unlikely that the 3 feet or more of deposit in the Carib Country, and the 5 feet on the Mahoe, above Lot 14, should be due almost entirely to the hailstorm of sand and scoria which lasted through the night. Over the Carib Country the great black cloud rolled, but we cannot believe that it piled up any considerable sheet of ashes, though we know it was laden with dust, as some of the survivors state that on the floor of the huts a thickness of 1 or 2 inches gathered during the passage of the wave of heat which killed so many people. Similarly, we may allow that the ash which lay on the ridges and slopes of the spurs, on the mountain and on the edge of the crater, which had originally varied in depth from a few feet up to 10 or 12 feet, might have been entirely deposited during the rain of ashes. But this will not account for the extraordinary manner in which the ravines were choked with hot sand. The very high temperature of these masses shows that they did not gradually accumulate, but must have been practically instantaneously piled up in the valleys. So fine is the dust that it would have fallen very slowly had it been projected vertically upwards from the crater, and should in that case have been nearly cold before it reached the surface of the ground. It would probably also have shown traces of stratification, as after each outburst the coarse stones would first fall and the finer material would settle slowly afterwards. But on the banks of the Wallibu and Rabaka Dry River it was rare to see sections of the new ash which exhibited any pronounced stratification. The whole mass—sand, stones, scoria, and burnt timber—seemed to have reached its present position practically simultaneously.

The distribution of the heaped-up ash is also significant. It is principally on the south side of the mountain, as if it had risen in the crater and welled over the lower southern lip. It is found in the Rozeau and Larikai Valleys on the east side, though not in very great quantity. On the west side it lies only in the Rabaka Valley, there being hardly any in the gorges above Orange Hill, Overland Village, and Sandy Bay. Very little was able to surmount the great Somma rampart and reach the valleys above Fancy and Grand Baleine.

Moreover, it did not gather on the slopes and ridges of the spurs that descend to the Wallibu and Rabaka Dry River. Nor did it rest in the upper part of the ravine between the spurs. It is only when it reached the flatter ground below that its velocity was checked and it could accumulate. Nine-tenths of the mass seemed to have been launched into the upper part of the two valleys above-mentioned, and there it was met by the opposing face of the Morne Garu. It could not ascend the slopes, but was split into two currents, one following the Wallibu and Wallibu Dry Rivers, the other the Rabaka Dry River. Into these it poured, and on the leeward side it coursed along till it reached the shore, for sections of the round-backed mounds it formed are to be seen in the sea cliffs (see Plate 24, fig. 1). In the Rabaka Dry River the great tide of sand came down the main valley, rapidly slowing down, and it had come to rest before it had reached the lowest part of the channel, which begins about a mile above the sea. This contained none of the thick banks of hot sand which obstructed the stream above that point. The deluge of dust and stones had poured down the main valley like a flood, and, gathering there, had obstructed the mouths of all the lateral gorges. It clearly did not drain off the whole surface and down all the stream channels like a fall of rain, but in one well-defined torrent it coursed along the ravine of the Rabaka Dry River. The trees growing on the slopes of the mountain and in the wooded gorges were overwhelmed, caught up, charred, reduced to shapeless fragments, and swept along by the avalanche. How much erosion had been effected by the moving mass we could not tell. There was no very striking evidence of its action, and in the upper parts of the mountain it seems likely that no great changes had been produced. But the surface was plastered with mud where it was not washed and scoured by the tropical rains, and, as we had no knowledge of its configuration before the eruption, it was not easy to form an opinion as to the effects of the avalanche. Further down the sheets of sand covered over and obliterated all traces of the havoc they had wrought as they swept down the valleys.

The geological evidence was not sufficient to demonstrate what form the discharge took, what was its path, and how great was its velocity when it left the crater; but by the time it reached the valleys below it was a rushing torrent of sand, stones, and hot gases, which coursed along the valley bottoms, adapting itself readily to all changes in their configuration, too heavy to surmount any great height, but sweeping over the surface of the minor ridges, and coming gradually to rest in the deep ravines behind them. In the valleys of the Wallibu and Rabaka Dry River it filled the whole channel, and when its energy was spent it lay in banks, with irregular rounded upper surfaces, like glaciers of black sand.* In the more shallow and open valley of the Wallibu Dry River it had not been confined to a narrow and steep-sided channel, but had been free to spread out laterally, and there it took the form of a broad sheet of sand with round-backed ridges, like wreaths of snow, pointing down the valley and diverging with a slightly fan-shaped arrangement.

* The likeness to a glacier is remarked also by Mr. E. O. HOVEY, "St. Vincent and Martinique: a Preliminary Report upon the Eruptions of 1902," 'Bull. Amer. Museum Nat. Hist.,' vol. 16, p. 343, and Plate 39, fig. 1.

The Hot Blast.

Few in St. Vincent saw the avalanche and none survived, but many were struck by the hot blast, and of these a certain number have lived to tell the tale. Its force was nearly spent before it reached the low grounds of the Carib Country, where stood the most populous estates, but there and in Fancy the men who were holding the doors or windows felt the shock, and in one or two cases were knocked down by the impulse of the blast. The houses are built so as to freely admit the air, and the labourers' huts cannot be effectively shut up. Several of the survivors in Overland Village and Orange Hill told us that the sudden rush of the hot gases was like a powerful puff of wind. It is only, however, further up the mountain that it was sufficiently vigorous to leave behind unmistakable effects. At Richmond and at Rabaka it was travelling at perhaps 30 miles an hour, a strong breeze, but not sufficient to do much damage. The trees were broken by the falling stones, and the weight of ash which gathered on the branches and the withered leaves was often sufficient to weigh them down to the ground or tear them off the stems. It was not the violence of the blast which injured the vegetation.

The varying effects of the blast, the rate at which it travelled, and the changes in its velocity as it swept down the hill-sides, are best studied in that tract of flat land above Lot 14, over which the path to the summit passes before it takes to the knife-edges of the spurs (see Plate 31, fig. 2). There the configuration of the surface is comparatively simple; elsewhere the irregularities presented by the ridges and ravines, and their influence in shielding or exposing the standing timber, must constantly be kept in mind, for sometimes in a valley which everywhere else was swept bare of all vegetation, a solitary tree would be left standing behind some ridge, or in a little lateral gully, where it had been sheltered and preserved. But the changes were essentially of the same character on all parts of the hill, though local conditions had had an influence in modifying their intensity.

At Lot 14 the trees were still standing, but had lost many of their branches, and principally those which were on the side towards the crater. This was also to be seen on the lower slopes on the leeward side and on the ridge behind Wallibu (see Plate 26). The trees were erect for the most part, but all branches facing the blast had been stripped; a few of those pointing towards the opposite quarter still remained. The smaller and weaker trees were often bent over and inclined away from the crater. A glance at these leafless twisted stems was sufficient to show that over them a blast had swept, tearing off everything that directly obstructed its path (see Plate 27, fig. 2).

Further up the hill, on both sides, the effects were still more noticeable. Many of the trees were overturned; others still stood, mere trunks without leaves or branches. All that had fallen lay parallel, and pointed down the valleys and the slopes. The smaller branches had disappeared, broken off and swept away, or burnt up by the heat of the gases. At the upper limit of this flat ground, above Lot 14, few trees were still standing; practically all were broken off at the base, their prostrate stems pointed down the slopes, their leaves and smaller branches had disappeared. Only the stoutest remained erect, mere columnar broken trunks without a branch. Here the destruction was quite as great as that of the most powerful tornado, the forest had been mown down as if by a mighty sickle (see Plate 35). The sides of the branches and trunks towards the crater were charred and eroded by the hot sand carried by the blast. The timber was green and had not been set on fire, but the bark and wood had been carried away on the weather side to depths of $\frac{1}{4}$ or $\frac{1}{2}$ an inch or more, while on the lee side the parched dry bark still adhered and flaked away readily when touched with the finger nail.

At a higher level still, about 1500 feet, as a rule, everything was overturned, cut down or uprooted, only the trunks—blackened and half destroyed by the consuming blast, lay scattered on the slopes; a single tree here and there had miraculously escaped. Even the large "cotton trees," 8 to 10 feet in diameter, had been overwhelmed; nothing could resist the violence of the blast (see Plate 34, fig. 2).

Nearer the summit all that was left of the rich forest that had clothed the hill with green, was the scattered, shapless fragments of burnt wood buried in the stinking black mud which covered all the higher slopes. The destruction was so complete that it could not be said whether it was to be ascribed to the heat of that tide of incandescent ash and superheated gases, or to the velocity with which it swept along the ground. The mud lay thick on these parts of the hill, and it was not often that the old surface could be seen in the bottom of the rain gullies. The buried wood appeared to have been in every case uprooted, but we could not be certain whether the shapeless fragments we saw were the bases of the stems with the roots, or pieces of the trunks broken off. One thing was clear,—that blast of sand-laden gases must have been at least bright red-hot when it welled over the lip of the crater, so completely had everything combustible been reduced to charcoal, when it had escaped entire destruction. And it is also certain that the passage of so enormous a volume of sand and stones over the surface must have wiped out all vegetation, cut down everything standing, and swept up all that could be carried away in its own moving mass.

One of the most interesting features of the hot blast was the rapidity with which its velocity diminished as it swept from the higher slopes down upon the plain. At Lot 14 no buildings were damaged by its force, and the trees had not suffered more than if they had been exposed to an ordinary gale, if we allow for the high temperature of the blast and the dust it carried with it. At a point a mile and a half further up the hill, the destruction was more complete than that effected by a hurricane or tornado, and in so short a distance the velocity must have changed from perhaps 100 miles an hour to 30 or 40 miles an hour. There are many reasons why this should have been the case. One of the most obvious is the change of gradient, another is the great weight of sand and dust which was kept in suspension by the gases, still another the cooling by expansion of the steam and by contact with the cold surface of the ground, but these will be discussed more fully when we have considered also the evidence afforded by the eruptions of Pelée.

The area over which the hot blast spread was enormously greater than that traversed by the avalanche. The latter poured down the south side of the hill, and along the streams that drain these slopes, but the blast covered the whole hillside and ascended the shoulders of Morne Garu. The trees were broken down on all the higher parts of the mountain, though least on the northern side and above Fancy and Owia. From Point Espagnol to Langley Park the whole upper part of the Carib Country, and the ridges and spurs higher up, were ruined by the blast, the timber for the most part fallen, and the prostrate trunks pointin goutward from the crater and down the deep radial valleys. This is true also of the leeward side from Windsor Forest to Richmond Estate.

In short, the effects of the hot blast were shown by all the area over which the great black cloud had swept in the first part of its course, and the correspondence between the region of broken forest and the country covered by the black cloud before it reached the lower grounds is too close to be accidental. When the dust in the cloud was hot and when the velocity of the gases was still very great, the forest had been cut down and the wood charred, eroded and destroyed. When the hot sand had cooled and was subsiding, the hot blast effects diminished and finally disappeared, though still the cloud of dust and asphyxiating gases crept along the ground, and where it passed over the estates on the windward shore, though no longer able to cut down or overturn the trees and structures in its path, brought injury or death to their living occupants. To those who saw it from outside it was a black cloud, or even a purplish and reddish cloud, but those who were overtaken by it felt it a hot blast laden with sand and dust. This was near the shore, or on the sea; only there did any who were caught survive. No one in St. Vincent was in the region of its fiercest energy, but in the city of St. Pierre a similar blast wrought desolation with a completeness and a murderous violence which are now a matter of history.

But the blast is not merely a phase of the great black cloud, it has also a very close relationship to the avalanche of sand. In it the gases greatly preponderated; it had a mobility, a power of surmounting obstacles, a tendency to spread laterally which the avalanche does not seem to have possessed. We may say that the hot blast coursed over the ground like a current of heavy gas; the avalanche resembled a viscous heavy fluid. The blast which swept down into the valleys at the south side of the Soufrière was too heavy to climb vertically the steep face of the Morne Garu. It split into two parts, one of which ascended obliquely over each shoulder of the mountain, mowing down the forest and strewing the trunks of the trees before it in such a way as to mark the direction of its path. The avalanche, on the other hand, when it reached these valleys turned almost at a right angle to its previous course and flowed along them, clinging to the ravines, but did not ascend the opposing slopes. Except in this case there is little evidence that the blast had any power of climbing; it seems, in fact, to have been so heavy, so weighted down with dust that it flowed along the depressions of the hill sides almost like a torrent of water. This is shown by the evidence of those who saw the black cloud pouring in an inky mass down the gorges on the leeward side of the hill. The Carib Country is too level and open to modify in any way the course of this current, but at Chateaubelair there are several well-marked ridges between the village and Wallibu, and these certainly directed and deflected the path of the blast. At the north side of Richmond Vale Estate there is a spur, some 500 or 600 feet high, running down to the sea, and on the side of this ridge next the crater the destruction of vegetation has been very great; on the south side, a week or two after the eruption, everything was as green as before. It is in every way probable that these ridges saved the village, and a careful examination of the difference in the appearances presented by the country to the north and to the south side of each of them convinced us that they had intercepted the violence of the blast, and protected the region behind them. The moving mass of sand and gases was too heavy to rise freely in the air when it passed over Richmond, but clung to the surface of the ground, and lost much of its energy and dropped most of its solid matter before it could surmount an obstruction. The blast was, in fact, only the lighter and upper portion of the avalanche of dust.

The rampart of the Somma wall, which faces the crater on its northern side, undoubtedly protected the country behind it, for the denser portion of the cloud was too much loaded with dust to climb this ridge. Its main force poured over the lower south lip of the crater with the avalanche of sand. On the north side the deposits are comparatively thin, and it seems that most of the material that emerged from the crater was deflected by the Somma and lodged in the valley of the Larikai. A black cloud certainly descended on Grand Baleine, but in surmounting the intervening summit ridge of the hill it had lost by far the greater part of its burden of ash and therewith most of its violence.

The Subsidence at Wallibu and Morne Ronde.

More than one-half of the ash which gathered on the slopes of the Soufrière has already been washed into the sea. When this rainy season is over little will remain on the higher ground, and the underlying soil will be in large measure also removed. So rapid is erosion under the conditions that prevail on the mountain, that when the eruptions cease it will soon be difficult to find traces of the new ash deposits on the higher grounds, and when tropical nature again spreads a thick mantle of vegetation over the naked surface, it will cover over and obliterate most of the effects of the eruptions of this year. The thick ash deposits in the valleys will long remain, but even these will disappear at last before the persistent, restless action of the streams.

On the devastated estates a new soil will form, and agriculture will go on as before. The changes in the crater will remain, but they are not of great magnitude, and should the volcano sink into repose, a new lake may gather not unlike the old one, and the rocky walls will be again covered with green forest.

In addition to the widening of the crater and the obstruction of the valleys, the only important alteration in the geography of St. Vincent which has been occasioned by this eruption is the disappearance of a narrow strip of land along the leeward coast. It extends from Wallibu to Morne Ronde, and had a maximum breadth or perhaps 200 yards. Between these two points there formerly stretched a low flat beach on which ran the public road. Two villages stood on this beach, one at Wallibu, the other at Morne Ronde, and both have totally disappeared. The road is gone, and the bluff which stood behind it has now receded for several yards, and presents a clean-cut section to the sea. At first the water washed its base, but the soft loose ash is constantly tumbling down, and a narrow beach had formed when we were there. It was not safe to explore this cliff very closely, for the hot dry ash above was frequently slipping every here and there, and masses of many tons were being precipitated on the shore (see Plate 25, fig. 1).

Mr. ROBERTSON, of Wallibu, told us that 64 acres of that estate which lay between the bluff and the sea have vanished, and the chimney of the works, formerly about 200 yards from the shore, is now quite near the edge of the cliffs. The subsidence runs all along the coast to a little south of Morne Ronde Point, a distance of nearly a mile, and although the face of the cliff has been somewhat modified by slipping and by the erosive action of the rivers and the sea before we arrived, it is clear that originally it was a nearly straight line.

There can be no doubt that the low beach below the bluff was mostly a talus of material fallen from the cliffs or brought down by the rivers and spread along the shore. The submarine slopes off Wallibu are very steep, depths of 120 fathoms being found in less than half a mile from the land. This means an angle of 16°, and as at Morne Ronde and along this shore the earthquakes attendant on the eruptions were more severe than anywhere else in the island, it is probable that this loose talus slid down into deeper water. Then the cliff behind the beach, being composed of soft, incoherent ash, would crumble away and break down, as it was doing when we were there.*

At the mouths of several of the streams further north along this shore there were, before the eruption, little patches of flat ground on which, in some cases, stood the houses of peasant cultivators. These consisted of matter brought down by the torrents which flow in the deep ravines on this side of the mountain, and deposited in the shape of alluvial fans when the current of the streams was checked on reaching the sea.

* See also T. A. JAGGAR, "Field Notes of a Geologist in Martinique and St. Vincent," 'Popular Science Monthly,' vol. 61, p. 363, August, 1902.

Mr. T. M. McDONALD, who knows every feature of this coast intimately, pointed out to us that in most cases they had disappeared with the houses which were planted on them. The rocky cliffs behind them still stand, bearing the remains of the trees which previously grew there. Only the wedged-shaped deltas have vanished. There is no trace of any fracture or dislocation, and the marks cut by the tide on this shore show that there has been no change of level, or, at any rate, none of more than a few inches. Everything points to the slipping of loose, gravelly and sandy deposits piled on the steep submarine slope which characterises this coast.

There is no difficulty in believing that a similar process has gone on at Wallibu and Morne Ronde, and this will explain most of the facts observed. Mr. ROBERTSON, of Wallibu, left for Chateaubelair on Wednesday, the 7th May, about 12.30 P.M. As he went down from his house to the boat on the sea shore he noticed that the flat beach was sinking, "dropping down like stuff from a cart," and the bluff behind was tumbling down on the flat below. The impression formed on his mind was that the soft, incoherent accumulations were settling down under the concussions and earthquakes produced by the eruptions. No one saw this part of the shore again till several days had elapsed, and then it was in essentially the same condition as when we visited it, except that there was no beach below the cliff.

Allowance must also be made for the effects of the blast which rushed out from the valleys of the Wallibu and Wallibu Dry Rivers. It was strong enough to blow down many of the trees on the ridge above Wallibu, and must have raised the sea in powerful waves. Captain FREEMAN, of the "Roddam," states that in St. Pierre harbour the waves occasioned by the blast were tempestuous.* But here the wind was off the shore, and may have really produced very little effect.

There is, however, a certain amount of evidence which points to the conclusion that the inner boundary of this depressed tract may be a fault line. It certainly has a very straight trend, and, looking at it on the map, one is at once struck with this peculiarity. In this respect it differs entirely from the smaller subsidences at the mouths of the streams at Larikai and Trois Loups. Another fact of great interest is the rapidity with which the water deepens off the new shore. Mr. P. FOSTER HUGGINS,† of Chateaubelair, found that at 50 feet from the beach the depth is $7\frac{1}{2}$ fathoms, at 100 feet 18 fathoms, a submarine slope of 45°. This is a gradient much higher than is usual along this side of the island, and may be due to the presence of a fracture, on the seaward side of which there has been depression.

Formerly, this coast was known as Hot Waters, because the water obtained by digging pits in the sand was warm. This may indicate the existence of a fissure up which hot water rose, but all the inhabitants of the villages on the beach whom we

* Captain FREEMAN, "The Awful Doom of St. Pierre." See 'Pearson's Magazine,' September, 1902, p. 316.

† "An Account of the Eruptions of the St. Vincent Soufrière," p. 17. By P. FOSTER HUGGINS, St. Vincent, 1902.

cross-questioned said there were no hot springs, and that the warm water was merely surface water.

There is no evidence of any submarine cliff, and had there been any at first, it must now have been masked by the material dislodged by landslides, or eroded by the sea from the cliffs and the vast quantities of new ash which have been deposited all along this coast by the rivers which flow down the mountain. At present, we can only say that the existence of a fault along the shore from Wallibu to Morne Ronde remains an open question.

PREVIOUS ERUPTIONS OF THE SOUFRIÈRE.

The Eruption of 1718.

The earliest historical account of an eruption in St. Vincent is that which appears in the 'Weekly Journal,'* or 'Saturday's Post' (otherwise known as 'Mist's Journal'), of July 5, 1718. It occupies the principal place in that number, and was considered so important that the usual letters from correspondents were crowded out to make room for it.

It begins as follows :—

"We have a piece of public news this time of such consequence, and so necessary for all our readers to be fully acquainted with it, that our friends who have written several letters to us, which otherwise deserve publishing, must excuse us for this week.

"This relates to the entire desolation of the Island of St. Vincent, in the West Indies, by the immediate hand of Nature, directed by Providence, and in a manner astonishing to all the world, the like of which never happened since the creation, or, at least not since the destruction of the earth by the water in the general deluge.

"Our accounts of this comes from so many hands, and several places, that it would be impossible to bring the letters all separately into this journal; and when we had done so, or attempted to do so, would have the story confused, and the world not perfectly informed. We have therefore thought it better to give the substance of this amazing accident in one collection, making together as full and as distinct account of the whole, as we believe is possible to come at by any intelligence whatsoever; and at the close of this account we shall give some probable guesses at the natural cause of so terrible an operation. The relation is as follows, viz. :—

"An account of the island of St. Vincent, in the West Indies, and of its entire destruction on the 26th March last, with some rational suggestions concerning the causes and manner of it.

"The island of St. Vincent is the most populous of any possessed by the Carribeans, its altitude is 16 degrees north from the line. Those who have seen the island Ferre or Fietre, one of the Canaries, affirm that this is much of the same figure. It may be about 8 leagues in length and 6 in breadth. There are in it several high mountains and very fruitful plains, if they were cultivated. The Carribeans have many fair villages, where they live pleasantly, and without any disturbance; and though they have a jealousy of the strangers, yet do they not deny them the bread of the country, which is cassava,

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* Reprinted in 'Daniel Defoe : his Life, and recently discovered Miscellaneous Writings.' By WILLIAM LEE. Vol. 2, p. 52. 1869.

water, fruits, and all other provisions growing in their country, if they want them, taking in exchange wedges, hooks, and other implements of iron, which they much esteem.

"On the 24th March a French sloop arrived at Martinico, that passed by the island of St. Vincent the 22nd, that, as the master reported, he bought some fish of some of the savages who inhabited there, and who came off to him in their canoes. He says that all was safe, and in very good condition there, for anything he perceived, only that some of his seamen report that since the disaster, that one of the Indians told them that they had been terribly frightened with earthquakes for some time, and with flashes of fire like lightning, which did not come out of the clouds as usual, but out of the earth, and that they had felt these earthquakes for a month past, to their very great amazement.

"On the 27th in the morning the air was darkened in a dreadful manner, which darkness by all accounts seems to have extended over all the colonies and islands which were within 100 miles of the place, but was perceived to be more or less dark as those islands were further or nearer from the place.

"But that which is most remarkable of all is, that at some of the islands, and at Martinico in particular, a dreadful flash of lightning, as they called it, was seen on the 26th about 11 o'clock at night. This flash, which they called lightning, we shall account for in the following part of the relation.

"It is to be observed in the next place, that as there were several ships, or other vessels at sea, in several ports among the islands, some of these had a more terrible sight of this thing than others; particularly they write that in one sloop which is come into Martinico, the men are so terrified still, and were so amazed at what they saw and heard, that they appeared perfectly stupified, and gave little or no account. Others are come into other ports so horribly frightened, that they scarce retain their senses; others give confused accounts, and so more or less distinct as they were nearer or farther from the place. The sum of what may be gathered from them all is this:

"That they saw in the night that terrible flash of fire, that after that they heard innumerable clashes of thunder; some say it was thunder they heard, others that it were cannon only, that the noise was a thousand times as loud as thunder or cannon, considering that it appeared to be at a great distance from them.

"That the next morning, when the day began to break, the air looked dismally, viz., all overhead was a deep impenetrable darkness, but below, all around the edge of the horizon it looked as if the heavens were all on fire.* As the day came on still the darkness increased till it was far darker than it had been in any part of the night before, and as they thought the cloud descended upon them, the darkness still increased after this, viz., in the afternoon they were surprised with the falling of something upon them as thick as smoke, but fine as dust, and yet solid as sand; this fell thicker and faster as they were nearer or farther off, some ships had it 9 inches, others a foot thick upon their decks; the island of Martinico is covered with it at about 1 to 9 inches thick; at Barbados it is frightful, even to St. Christophers it exceeded 4 inches; it is fallen over the whole extent of the Island of Hispaniola, and there is no doubt but it has been seen on the continent of New Spain, about the point of Guiana, and the mouth of the River Orinoco, all of which will perhaps be accounted for in some measure in the following narrative.

"This continued falling for two or three days and nights successively, and it was impossible for any man to find out or so much as guess at the meaning of it, or of any natural cause to produce it, till the whole came to discover itself, but all people stood amazed at the cause, and several letters were sent to England of it, from Barbados in particular, as of a strange, miraculous shower of sand, of which we gave an account in our Journal of the 20th past. The first news that was given of the whole thing was by some vessels that were under sail on the night of the 26th, belonging to Martinico, by which we had the following particulars: that on the said 26th, about midnight, the whole island of St. Vincent rose up into the air with a most dreadful eruption of fire from underneath the earth, and an inconceivable noise in

* Compare with this the descriptions of the appearance of the sky immediately before the fall of dust in Barbados on the 7th of May, 1902, as given on p. 408 and p. 409.

the air at its rising up; that it was not only blown up, but blown out of the very sea with a dreadful force, as it were torn up by the roots, or blown up from the foundations of the earth.

"That the terror was inexpressible, and cannot be represented by words; that the noise of the bursting of the earth at first is not possible to be described, that the force of the blow or blast is such, and the whole body of the island was raised so furiously that the earth was entirely separated into small particles like dust; and as it rose to an immense height so it spread itself to an incredible distance, and fell light and gradually, like a small but thick mist. This part, we suppose, must be occasioned by the force of the blow, effectually separating the parts, otherwise they would have fallen with a violence of motion proportioned to the weight of the whole, the particles pressing one another, whereas now every grain was loose and independent in the air, and fell no faster than it was pressed by its own weight, as in a shower of snow or rain.

"The more solid parts of this land, which were lifted up by this blast, and supposed to be of stone, slate, or clay, or such solid matter as would not dissipate or separate in the air like the rest, being lifted also to an immense height, and their plunging by a mighty force received by their own weight into the sea, must of necessity make a noise or blow equal to that of the loudest cannon, and perhaps to thunder itself; and these we think to be the several reports or blows which were heard even to St. Christopher's Island (which is a vast distance from that of St. Vincent), and of which the people in these islands, as well as in the ships, heard about a thousand or twelve hundred distinct blows or reports, and supposed it to be the noise of guns.

"As soon as it was understood by the inhabitants in the other islands what it was, *that is to say*, that it was an eruption of the earth at the island of St. Vincent or thereabouts, sloops, barks, and other small vessels came from all parts to see how it was, to enquire into the damage suffered, and to get an account of the particulars; but how astonished must these enquirers be, when meeting from all parts upon the same errand, they may be supposed to go cruising about to find the island; some examining up their books to cast up the length they had sailed, some blaming their own negligence for not keeping a right reckoning, some their men for mistaking their distance, others taking observations to know the latitude they were in; at last all concluding, as it really was, to their great confusion, that the said island was no more, that there appeared no remains except three little rocks, no, not any tokens that such an island had been there, but that, on the contrary, in the place of it the sea was excessive deep, and no bottom to found at 200 fathoms.

"As this is an event so wonderful as no history can give us an account of the like, so it cannot be unpleasant to our readers to consider briefly some natural causes which may be assigned for it."

The writer then proceeds to discuss the possible theoretical explanations of this remarkable phenomenon. He rejects the suggestion that it was due to an earthquake, owing to the fact that the island was blown into the air. Two other causes are considered, the sudden admission of air through cracks produced by earthquakes to vast bodies of sulphurous and nitrous gases in the caverns and hollows of the earth, producing a violent explosion, and the ingress of water through fissures to the subterranean fires. He is rather inclined to adopt the latter hypothesis.

The writer of this article was probably no other than DANIEL DEFOE, the author of "Robinson Crusoe," who was at that time editor of this Journal, and the hand of that master of romance may be traced in the paragraph which suggests that "sloops, barques, and other vessels came from all parts to see how it was," and joined in a futile search for the remains of the island which was now sunk "full-fathom deep." This embellishment of the narrative apparently evoked protest* and contra-

* 'Daniel Defoe: his Life and Miscellaneous Writings.' By WILLIAM LEE, vol. 1, p. 280.

diction, for in the same Journal of August 2, 1718, he returns to the subject and says: "They pretend to tell us a strange story, viz., that the island of St. Vincent is found again, and is turned into a volcano, or burning mountain, but we must acknowledge, we do not believe one word of it."

On account of its obvious exaggeration this record has been received by many with incredulity. SHEPHARD, in his "History of St. Vincent," does not mention it, and it is generally held that the eruption of 1812 is the first of which there is historical evidence. Mr. HUGGINS, in his "Account of the Eruptions of the St. Vincent Soufrière," discredits the story altogether.*

'It is supposed by some that St. Vincent was the scene of an eruption in the year 1718, which produced what is called the old crater of the Soufrière, and, because some seamen that year heard and saw signs of volcanic disturbance having taken place somewhere in these seas, it has been concluded that St. Vincent was the place. This, however, is doubtful, and it is certain from the researches of Major PATRICK CRICHTON, of this island, that the Caribs did not even possess a tradition of such an occurrence, and their language, I believe, did not contain any word expressive of such an event, which, it must be supposed, would have left some trace behind, uneffaceable within a century. The Caribs, it is true, looked upon the mountain with dread, but only as the abode of a vengeful spirit hiding himself in the clouds."

The reasons he advances, however, are somewhat discounted by Mr. ANDERSON'S statement in 1784.†

"The most remarkable of these mountains is one that terminates the north-west end of the island and the highest in it, and has always been mentioned to have had volcanic eruptions in it. The traditions of the oldest inhabitants in the island, and the ravines at the bottom, seem to me to vindicate the assertion."

It was well known, he says, to be a volcano, and this was the main reason which led him to make the ascent.

If an eruption took place in 1718, there must have been persons living in St. Vincent in 1784 who had witnessed it. But it is not mentioned by Mr. ANDERSON, and apparently he was in ignorance of its occurrence. This is in itself strange, but it is not inexplicable.

In 1718 the island was practically entirely in the hands of the Caribs, who, according to DEFOE'S account, were not unwilling to trade with passing vessels, but resented the intrusion of white settlers. SHEPHARD‡ states in his history that St. Vincent was first colonised in 1719 by a party from Martinique, who had been invited to take up land by one of the two tribes into which the Caribs were divided. In 1723 the DUKE OF MONTAGUE sent an English expedition to take possession of the island, but they found the natives hostile and the French colonists already in possession, and in consequence they gave up the attempt. Gradually, however, the English established themselves alongside of the French settlers, and for a time the

* P. FOSTER HUGGINS, 'An Account of the Eruptions of the St. Vincent Soufrière,' 1902, p. 3.

† "An Account of Morne Garou, a Mountain in the Island of St. Vincent, with a Description of the Volcano on its Summit." By Mr. JAMES ANDERSON ('Phil. Trans.,' vol. 75, p. 16, 1785).

‡ 'An Historical Account of the Island of St. Vincent.' By CHARLES SHEPHARD, p. 23.

island was neutral or debateable ground; but in 1779 the French, with the aid of the Caribs, obtained the supremacy. In terms of the Peace of Versailles in 1783, the island was handed over to the British on the 1st January, 1784. Mr. ANDERSON'S ascent of the Soufrière took place in March of that year, and it is evident that at that time the Caribs still maintained their hostile attitude, for one of the dangers to which he considered himself exposed was the possibility of being cut off by some of their roving bands. In 1793 war broke out again between the Caribs and the English, and lasted for several years.

Mr. ANDERSON seems to have never met the Caribs of the north end of the island, and relied principally on the planters, who had not long been settled in that quarter, as it was considered a reserve for the natives. His porters were negro slaves. He may never have heard of the eruption of 1718, or if he did so, may have considered the evidence for it unsatisfactory.

The anonymous writer of the account of the eruption of 1812 distinctly refers to a previous eruption in the words, "A century had now elapsed since the last convulsion of the mountain" (see p. 463).

The internal evidence, also, is very strongly in favour of DEFOE'S narrative having been founded on fact. The first news to reach England was that in Barbados the startling phenomenon of a rain of ashes had caused great alarm, and it had been preceded by sounds like distant cannonading. Similar noises were heard all over the Caribbean Sea from Antigua to Trinidad. The rain of dust had been heaviest near St. Vincent and in Barbados. Around the Soufrière the inhabitants had for a month previously been terrified by the frequency of the earthquakes. Then the mountain burst with a tremendous noise, hot stones and sand rained down for hours, and there was complete darkness. Those who were in ships off the island saw a flash of fire, followed by loud crashing noises. The eruption was sudden in its outburst, and lasted only for a day or two.

These are, in fact, the distinctive features of the eruptions of 1812 and 1902, as observed by those at some distance from the volcano, and the whole account resembles in many respects very closely some of the narratives which were published in the spring of this year. If DEFOE was able so exactly to predict the circumstances of future eruptions of the Soufrière, he must have had even more of the creative spirit of imagination than he has hitherto been credited with.

HUMBOLDT made several references to this eruption, though it is not exactly known from what sources he drew his information. He seems to have had no doubt of its having occurred.*

If the statements regarding the area over which ash fell, from Hispaniola (Hayti) to the mouth of the Orinoco, and the depth of the layer in Barbados and Martinique, are even approximately true, this was the greatest and most violent of all

* HUMBOLDT, 'Personal Narrative,' English Translation by Mrs. WILLIAMS, vol. 4, p. 26.

the eruptions of the Soufrière since the colonisation of the West Indies. We should hesitate, however, to place much reliance on them.

The Condition of the Crater in 1784.

In the 'Philosophical Transactions of the Royal Society' for the year 1785 there is an account of what was apparently the first visit made by any white man to the crater of the Soufrière. At that time the name "Morne Garu" was applied also to this mountain; only after it was known that at the summit there was a cone emitting sulphurous vapours was it replaced by its present name "La Soufrière." In the early part of the 19th century the volcano was often referred to under both names, or under either. At present it seems that only the term Soufrière is used. Morne Garu is now the name of the mountain mass which lies immediately to the south. Mr. ANDERSON* in his ascent met with enormous difficulties, and had to hew a path through the forest for most of the way. For three days he was baffled, but on the fourth, with Mr. FRASER and some negro slaves, he reached the crater's rim, and, descending into the interior, explored it thoroughly. Probably, had he had Carib guides, he would have been shown a much easier way.

"March 4 being the day I had fixed to finish my excursion, about 4 in the morning I left the house of Mr. FRASER, who, out of curiosity, agreed to accompany me, of which I was very glad, as he was a sensible young man, and with the assistance of two negroes we pursued our journey. We found very little obstruction in our way up until we got to the place where I returned, and there, for about a quarter of a mile, we had considerable difficulty to clear our way through grass and ferns. After we came within a quarter of a mile from the top, we found ourselves in another climate all at once, the air very cold, and the vegetable productions changed; here was nothing but barrenness over the whole summit of the mountain. On the confines of the grassy region and the barren I found some beautiful plants. Moss grows here in such plenty that I frequently sunk up to my knees in it. This is the only place in the West Indies that produced any moss that I have seen. About noon we gained the top of the peak I had directed my course to before, when, in an instant, we were surprised with one of the grandest and most awful scenes I had ever beheld. I was struck with it amazingly, as I could not have conceived such a very large and so singularly-formed an excavation. It is situated on the centre of the mountain, and where the various ridges unite. Its diameter is something more than a mile, and its circumference to appearance a perfect circle. Its depth from the surrounding margin is above a quarter of a mile, and it narrows a little, but very regularly, to the bottom. Its sides are very smooth, and for the most part covered with short moss, except towards the mouth, where there are a number of small holes and rents. This is the only place where it is possible to go down to the bottom; it is exceedingly dangerous, owing to the numberless small chasms. On the west side is a section of red rock like granite, cut very smooth, and of the same declivity with the other parts. All the rest of the surrounding sides seems to be composed of sand, that looks to have undergone the action of intense fire. It has a crust, quite smooth, of about an inch thick, and hard almost as rock, after breaking through which, you find nothing but loose sand. In the centre of the bottom is a burning mountain, of about a mile in

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* "An Account of Morne Garou, a Mountain in the Island of St. Vincent, with a Description of the Volcano on its Summit." By Mr. JAMES ANDERSON ('Phil. Trans.,' vol. 75, p. 16, 1785).

circumference, of a conic form, but quite level. On the summit, out of the centre of the top, arises another mount, eight or ten feet high, a perfect cone; from its apex issues a column of smoke. It is composed of large masses of red *granite-like* rock of various sizes and shapes, which appear to have been split into their present magnitudes by some terrible convulsion of nature, and are piled up very regular. From most parts of the mountain issue great quantities of smoke, especially on the north side, which appears to be burning from top to bottom, and the heat is so intense, that it is impossible to go upon it. Going round the base is very dangerous, as large masses of rock are constantly splitting with the heat and tumbling to the bottom. At the bottom, on the north side, is a very large rock split in two; each of these halves, which are separated to a considerable distance from each other, is rent in all directions, and, from the crevices, issue efflorescences of a glossy appearance, which taste like vitriol, and also beautiful crystallisations of sulphur. On all parts of the mountain are great quantities of sulphur in all states; also alum, vitriol, and other minerals. From the external appearance of this mountain, I imagine it has only begun to burn lately, as on several parts of it I saw small shrubs and grass, which looked as if they had been scorched and burnt. There are several holes on the south, from which issues smoke, seemingly broken out lately, as the bushes round are but lately burnt. On two opposite sides of the burning mountain, east and west, reaching from its base to that of the side of the crater, are two lakes of water, about a stone's throw in breadth; they appear to be deep in the middle, their bottom to be covered with a clay-like substance. The water seems pleasant to the taste, and is of a chalybeate nature. I suppose these lakes receive great increase if they are not entirely supported by the rain that tumbles down the side of the crater. I observed on the north side of the bottom traces of beds of rivers, that to appearance run great quantities of water at times to both these lakes. By the stones at their edges, I could perceive that either absorption or evaporation, or perhaps both, go on fast. The greater part of the bottom of the crater, except the mountain and two lakes, is very level. On the south part are several shrubs and small trees. There are many stones in it that seem to be impregnated with minerals. I saw several pieces of pumice-stone. I also found many stones about the size of a man's fist, rough, on one side blue, which appearance, I imagine, they have got from heat and being in contact with some mineral. These stones are scattered over the whole mountain; one or two I have sent you, with some others.

"After I had got up from the bottom of the crater, I could not help viewing it with admiration, from its wonderful structure and regularity. Here I found an excavation cut through the mountain and rocks to an amazing depth, and with as much regularity and proportion of its constituent parts as if it had been planned by the hand of the most skilful mathematician. I wished much to remain on the mountain all night, to examine its several ridges with more attention next day; but I could not prevail on my companion to stay, and therefore thought it advisable to accompany him."

From this description it will be seen that in 1784 the volcano was in a solfataric condition, emitting much steam and sulphuretted hydrogen. Its crater contained only two small lakes, and had a low interior cone. The depth of the cavity is given as a quarter of a mile, but this must be exaggerated, for the next account of it, in 1812, states that it is only 500 feet deep, yet, apparently, not a single important alteration had taken place during the years that intervened.

The Eruption of 1812.

Many accounts of the eruption of the year 1812 have appeared in works on the West Indies, and in treatises on volcanology. They appear to be for the most part abridged from the original papers which, on May 7th, 1813, were ordered by the House of Commons to be printed, and appeared subsequently as an official paper. They have this year been reprinted as an appendix to the Blue Book on the volcanic eruptions in St. Vincent and Martinique, in May, 1902, where they will be found in full.

Of these papers the most important is an anonymous account which was published in the 'Evening News,' June 30th, 1812.

As it is the only contemporary history of the disaster, we reproduce it *in extenso*:—

"*Description of the Eruption of the Soufrière Mountain, on Thursday night, April 30th,* 1812, *in the Island of St. Vincent.*

"The Soufrière Mountain, the most northerly of the lofty chain running through the centre of this island, and the highest of the whole, as computed by the most accurate survey that has yet been taken, had for some time past indicated much disquietude; and from the extraordinary frequency and violence of earthquakes, which are calculated to have exceeded 200 within the last year, portended some great movement or eruption. The apprehension, however, was not so immediate as to restrain curiosity, or to prevent repeated visits to the crater, which of late had been more numerous than at any former period, even up to Sunday last, April 26th, when some gentlemen ascended it, and remained there for some time. Nothing unusual was then remarked, or any external difference observed, except rather a stronger emission of smoke from the interstices of the conical hill, at the bottom of the crater. To those who have not visited this romantic and wonderful spot, a slight description of it, as it lately stood, is previously necessary and indispensable to form any conception of it, and to the better understanding the account which follows; for no one living can expect to see it again in the perfection and beauty in which it was on Sunday, the 26th instant.

"About 2,000 feet from the level of the sea (calculating from conjecture), on the south side of the mountain, and rather more than two-thirds of its height, opens an immense circular chasm, somewhat exceeding half a mile in diameter, and between 400 and 500 feet in depth. Exactly in the centre of this capacious bowl rose a conical hill, about 250 or 300 feet in height, and about 200 in diameter, richly covered and variegated with shrubs, brushwood, and vines above half-way up, and for the remainder powdered over with virgin sulphur to the top. From the fissures in the cone and interstices of the rocks a thin, white smoke was constantly emitted, occasionally tinged with a slight, bluish flame. The precipitous sides of this magnificent amphitheatre were fringed with various evergreens and aromatic shrubs, flowers, and many alpine plants. On the north and south sides of the base of the cone were two pieces of water, one perfectly pure and tasteless, the other strongly impregnated with sulphur and alum. This lonely and beautiful spot was rendered more enchanting by the singularly melodious notes of a bird, an inhabitant of these upper solitudes, and altogether unknown to the other parts of the island; hence principally called or supposed to be invisible; though it certainly has been seen, and is a species of the merle.

"A century has now elapsed since the last convulsion of the mountain, or since any other element had disturbed the serenity of this wilderness than those which are common to the tropical tempest; it apparently slumbered in primeval solitude and tranquillity, and from the luxuriant vegetation and growth of the forest, which covered its sides from the base nearly to the summit, seemed to discountenance the fact and falsify the records of the ancient volcano. Such was the majestic, peaceful Soufrière on April 27th, but we trod on '*ignem repositum cineri doloso*,'* and our imaginary safety was soon to be confounded by the sudden danger of devastation. Just as the plantation bells rang 12 at noon on Monday, the 27th, an abrupt and dreadful crash from the mountain, with a severe concussion of the earth and tremulous noise in the air, alarmed all around it. The resurrection of this fiery furnace was proclaimed in a moment by a vast column of thick, black, ropey smoke, like that of an immense glass-house, bursting forth at once, and

* "*Ignes suppositos cineri doloso.*"—HORACE, II, Od. I, 7.

mounting to the sky, showering down sand, with gritty calcined particles of earth and favilla mixed, on all below. This driven before the wind towards Wallibu and Morne Ronde, darkened the air like a cataract of rain, and covered the ridges, woods, and cane pieces with light grey-coloured ashes, resembling snow when a little sublimed by dust. As the eruption increased this continual shower expanded, destroying every appearance of vegetation. At night a very considerable degree of ignition was observed on the lips of the crater, but it was not asserted that there was as yet any visible ascension of flame. The same awful scene presented itself on Tuesday, the fall of favilla and calcined pebbles still increasing, and the compact, pitchy column from the crater rising perpendicularly to an immense height, with a noise at intervals like the muttering of distant thunder. On Wednesday, the 29th, all these menacing symptoms of horror and combustion still gathered more thick and terrific for miles around the dismal and half obscured mountain. The prodigious column shot up with quicker motion, dilating as it rose, like a balloon. The sun appeared in total eclipse, and shed a meridian twilight over us that aggravated the wintry gloom of the scene, now completely powdered over with falling particles. It was evident that the crisis was as yet to come; that the burning fluid was struggling for a vent, and labouring to throw off the superincumbent strata and obstructions which suppressed the ignivomous torrent. At night it was manifest that it had greatly disengaged itself from its burden by the appearance of fire flashing now and then, flaking above the mouth of the crater.

"On Thursday, the memorable April 30th, the reflection of the rising sun on this majestic body of curling vapour was sublime beyond imagination, and comparison of the glaciers of the Andes or Cordilleras with it can but feebly convey an idea of the fleecy whiteness and brilliancy of this awful column of intermingled and wreathed smoke and clouds. It afterwards assumed a more sulphureous cast, like what we call thunder-clouds, and in the course of the day a ferruginous and sanguine appearance, with much livelier action in the ascent, a more extensive dilation, as if almost freed from every obstruction. After noon the noise was incessant, and resembled the approach of thunder still nearer and nearer, with a vibration that affected the feelings and hearing; as yet there was no convulsive motion or sensible earthquake. Terror and consternation now seized all beholders; the Charraibs settled at Morne Ronde, at the foot of the Soufrière, abandoned their houses with their live stock and everything they possessed, and fled precipitately towards town; the negroes became confused, forsook their work, looked up to the mountain and, as it shook, trembled with the dread of what they could neither understand nor describe. The birds fell to the ground overpowered with showers of favilla, unable to keep themselves on the wing; the cattle were starving for want of food, as not a blade of grass or a leaf was now to be found. The sea was much discoloured, but in nowise uncommonly agitated; it is remarkable that throughout the whole of this violent disturbance of the earth, it continued quite passive, and did not at any time sympathise with the agitation of the land. About 4 o'clock P.M. the noise became more alarming, and just before sunset the clouds reflected a bright copper colour, suffused with fire. Scarcely had the day closed, when the flame burst at length pyramidically from the crater through the mass of smoke; the rolling of the thunder became more awful and deafening; electric flashes quickly succeeded, attended with loud claps, and now, indeed, the hurly-burly began. Those only who have witnessed such a sight can form any idea of the magnificence and variety of the lightning and electric flashes: some forked zig-zag, playing across the perpendicular column from the crater; others shooting upwards from the mouth, like rockets of the most dazzling lustre; others like shells, with their trailing fires flying in different parabolas, with the most vivid scintillations from the dark, sanguine column, which now seemed inflexible and immovable by the wind. Shortly after 7 P.M. the mighty cauldron was seen to simmer, and the ebullition of lava to break out on the north-west side. This, immediately after boiling over the orifice and flowing a short way, was opposed by the activity of a higher point of land, over which it was impelled by the immense tide of liquefied fire that drove it on, forming the figure of V in grand illumination. Sometimes when the ebullition slackened, or was insufficient to urge it over the obstructing hill, it recoiled back, like a refluent billow from the rock, and then again rushed forward, impelled by fresh supplies, and scaling every obstacle, carrying rocks and woods together in its course down the slope of the mountain, until it precipitated itself down some vast ravine, concealed from our sight by the intervening ridges of Morne Ronde. Vast globular bodies of fire were seen projected from the fiery furnace, and bursting, fell back into it, or over it on the surrounding bushes, which were instantly set in flames. About four hours from the lava boiling over the crater it reached the sea, as we could observe from the reflection of the fire and the electric flashes attending it. About half-past one another stream of lava was seen descending to the eastward towards Rabaka. The thundering noise of the mountain, and the vibration of sound that had been so formidable hitherto, now mingled in the sullen, monotonous roar of the rolling lava, became so terrible that dismay was almost turned into despair. At this time the first earthquake was felt; this was followed by showers of cinders, that fell with the hissing noise of hail, during two hours; at 3 o'clock a rolling on the roofs of the houses indicated a fall of stones, which soon thickened, and at length descended in a rain of intermingled fire that threatened at once the fate of Pompeii or Herculaneum. The crackling and coruscations from the crater at this period exceeded all that had yet passed; the eyes were struck with momentary blindness, and the ears stunned with the glomeration of sounds. People sought shelter in cellars, under rocks, or anywhere, for everywhere was nearly the same; and the miserable negroes, flying from their huts, were knocked down or wounded, many killed in the open air. Several houses were set on fire; the estates situated in the immediate vicinity seemed doomed to destruction. Had the stones that fell been proportionately heavy to their size, not a living creature could have escaped without death; these having undergone a thorough fusion, they were divested of their natural gravity and fell almost as light as *pumex*, though in some places as large as a man's head. This dreadful rain of stones and fire lasted upwards of an hour, and was again succeeded by cinders from 3 till 6 o'clock in the morning; earthquake followed earthquake almost momentarily, or rather the whole of this part of the island was in a state of continued oscillation, not agitated by shocks, vertical or horizontal, but undulated like water shaken in a bowl.

"The break of day, if such it could be called, was truly terrific. Darkness was only visible at 8 o'clock, and the birth of May dawned like the Day of Judgment. A chaotic gloom enveloped the mountain, and an impenetrable haze hung over the sea, with black, sulphurous clouds of a sulphurous cast. The whole island was covered with favilla, cinders, scoriæ, and broken masses of volcanic matter. It was not until the afternoon the muttering noise of the mountain sunk gradually into a solemn yet suspicious silence. Such were the particulars of this sublime and tremendous scene, from commencement to catastrophe: to describe the effects is, if possible, a more difficult and truly most distressing task."

In SHEPHARD'S 'Historical Account of the Island of St. Vincent' (London, 1831) there is an account of this eruption, which is obviously very largely extracted from that given above. It is valuable, however, in that it gives some further particulars as to the subsequent history of the mountain, and the distribution and amount of the damage incurred :—

"The volcano still, however, burned, and on June 9th it again gave alarming signs of activity, but nothing more occurred than the throwing up of a quantity of stones and ashes, which fell back into the abyss from whence they came. All the former beauty of the Soufrière was, of course, destroyed; the conical mount disappeared, and an extensive lake of yellow-coloured water, whose agitated waves perpetually threw up vast quantities of black sand, supplied its place. A new crater was formed on the north-east of the original one, and the face of the mountain was entirely changed. Many of the adjoining ravines were filled up, particularly Wallibu and Duvallie's. In the former the river was absorbed for some years, but the gradual accumulation of water burst through the sandy barrier, and carried away many negro houses in its progress; 32 slaves, belonging to Wallibu estate, were washed into the sea by the torrent. At Duvallie's, the former settlement of the Carib chief, a sugar plantation had been established by Messrs.

Thesiger and Calvelly; the works, situated in a valley, were entirely covered by the sand and ashes, and some hogsheads of sugar remain there at present calcined to a cinder. The Rabaka River was also filled up, and its stream seldom reaches the sea except in cases of heavy rains. It was at first feared that the island would be rendered barren by the ashes, which lay on its surface to a considerable depth, but they did not prove so injurious as was supposed. The great danger was famine; but the neighbouring colonies of Barbados, Demerara, and Dominica, with a generous promptitude, hastened to supply the island with provisions, and a Committee was appointed by the Council and Assembly for the purpose of purchasing supplies. An investigation of the losses sustained was also made, and a petition presented to the Prince Regent praying for relief, which was most favourably received, and, on the case being laid before Parliament, the sum of £25,000 was voted for the relief of the sufferers. It is a wonderful circumstance, although the air was perfectly calm during the eruption, that Barbados, which is 80 miles to the windward, was covered several inches deep with the ashes, and the inhabitants, on the last day of the eruption, were terrified by the approach of utter darkness, which continued for four hours and a half, and then slowly decreased. There also, and in several other islands, the troops were under arms, supposing, from the continued noise, that the hostile fleets were engaging."

SHEPHARD was for some years resident in St. Vincent, and must have been acquainted with many who had witnessed the eruption. To MONTGOMERY MARTIN'S 'History of the West Indies' he contributed an account of this eruption, with much other matter regarding the island of St. Vincent.

In the Blue Book * there appear also several letters and other papers which, as they were written within a short time after the outburst, give valuable particulars as to its history and consequences.

It would appear that immediately before the eruption of 1812 the crater was in practically the same condition as when seen by Mr. ANDERSON in 1784. The interior cone was still standing, and at its base were the two small lakes of water—one bitter and sulphurous, the other fresh. From apertures in this cone gases were still being emitted. It was a "Soufrière" giving out steam and sulphuretted hydrogen, like many others in the Caribbees, and from the action of the sulphurous vapours no vegetation grew on the upper part of this cone, but its base and the encircling walls of the crater were covered with low bush. On this inner cone a coating of sulphur had been deposited, and the acids generated by the oxidation of the sulphurous vapours had attacked the rocks, giving rise to aluminous salts which, with the precipitated sulphur, contaminated the water of one of the lakes.

The eruption began about noon on April 27th with the emission of a great cloud of black smoke, accompanied by a trembling of the earth and a loud noise. For three days steam continued to ascend in a great column from the crater, and fine dust with lapilli and scoriæ rained down on the slopes of the mountain, covering everything with a deposit of grey ash, and injuring all the vegetation, but causing no loss of life. One is irresistibly reminded of the earlier stages of the eruption of Pelée in May, 1902,

* Blue Book: 'Correspondence relating to the Volcanic Eruptions in St. Vincent and Martinique in May, 1902,' pp. 91 *et seq.*

when for several days steam rose from the mountain, and the streets of St. Pierre were powdered over with light grey ashes.

On the morning of April 30th the violence of the eruption was obviously increasing, and the Caribs of Morne Ronde deserted their houses. The volume of steam was becoming larger and larger, and in the afternoon the noises from the mountain became louder and louder, but as yet earthquakes had not occurred in any number. As night fell the climax was at hand, and the "lava" welled over the edge of the crater, one stream flowing down to the north-west—probably from the new crater—while another was seen shortly afterwards to descend into the valleys of the Wallibu and Rabaka. The noises from the crater were now deafening, and a rain of cinders followed, which lasted, with intermissions, till 6 o'clock next morning. The earthquakes were numerous and violent, but the sea remained calm all night, and there were no tidal waves.

The account first published in the 'Evening News' states clearly that lava was seen to flow down to the north of Morne Ronde, and took four hours to reach the sea, but there is much reason to believe that in this case historical accuracy has been sacrificed to literary effect, and that many of the graphic touches in the picture are to be ascribed to the action of a powerful imagination. According to SHEPHARD another smaller outburst followed on June 8th, but did no damage.

The extent of country devastated by this eruption is sufficiently indicated by the List of Estates, to which a share of the money voted by Parliament was assigned :—

Appropriation of the Sum of £25,000 granted to the Sufferers by the Volcanic Eruption by 53rd Geo. III, cap. 136.

	Estimated Loss.			Paid.		
	£	s.	d.	£	s.	d.
Robert Sutherland for Rabaka	19,378	0	0	5,300	0	0
John and Lewis Grant for Wallibu	8,261	0	0	3,900	0	0
Charles Thesiger for Duvallie's	7,800	0	0	3,750	0	0
John Cruickshank for Langley Park	8,064	0	0	2,400	0	0
Alex. Cruickshank and A. Cuming—Lot 14	6,974	0	0	2,100	0	0
Thomas Browne for Grand Sable	7,392	0	0	1,580	0	0
John Smith and Alex. Cuming for Rabaka	4,780	0	0	1,200	0	0
William McKenzie for Turama	4,006	0	0	1,140	0	0
Robert Brown for Mount Bentinck	3,718	10	0	793	0	0
Thomas Fraser for Fraser's	1,262	0	0	700	0	0
James Cruickshank for Richmond	3,528	0	0	654	0	0
John Low	378	10	0	200	0	0
Thomas Dickson	577	0	0	200	0	0
Jane Dermot	508	0	0	200	0	0
Jno. W. Carmichael	820	0	0	180	0	0
Henry Haffey	1,100	5	0	166	0	0
Fanny Cruickshank	150	0	0	60	0	0
Thomas Riddock	75	0	0	57	0	0
Alexander Clunes	250	0	0	50	0	0
Henry Charles	103	0	0	50	0	0
				24,680	7	0
Treasury Charges and Commissions				319	13	0
	£79,125	5	0	£25,000	0	0

It would seem that all the leeward side of St. Vincent, from Richmond to Windsor Forest, had suffered severely, and the Carib Country, from Grand Sable to Turema, was covered with 6 to 10 inches of ashes. At Fancy and Owia, on the northern shore, there was a certain amount of damage, but it is quite probable that, as in this eruption, they suffered only to a comparatively slight extent. The list of ruined estates is practically the same as that of May, 1902, and in particular we may note that, while the country around Georgetown was much damaged, no injury was done at Chateaubelair. The depth of ashes which fell on the Windward Estates was only 10 inches, as compared with 3 to 5 feet on this last occasion, and this leads to the belief that on the whole the eruption of 1812 was the less violent of the two.

The agricultural value of the land in the Carib country was hardly affected, as the eruption took place when the crop was over; and the same amount of sugar and rum was manufactured there in 1813 as in 1812.* Duvallie's was completely destroyed; Fraser's (north of Wallibu) recovered only in 1814; and Wallibu in 1814 or 1815.†

The loss of life was also small, and singularly little mention is made of it, as nearly all those killed appear to have been negro slaves, and their value was no doubt reckoned up in the grand total of losses. As at that time the sugar estates were highly prosperous there must have been a large population, so we may safely conclude that a hot asphyxiating blast did not pass over the villages. The injuries are ascribed to hot falling stones, and to the collapse of the roofs of the huts on their occupants. It is said that the number of lives lost was 56.‡ By the collapse of the roof of the Grand Sable house "a gentleman of the name of PHILLIPS" was killed. According to a letter from WILLIAM MACKENZIE, of Turema, very few lives were lost in the Carib Country.§ Nine perished at Duvallie's.||

In a letter from ALEXANDER CRUICKSHANKS, who was part proprietor of Lot 14,¶ we have some further particulars which are of great importance:—"The Rabaka River and the Wallibu have totally disappeared, not one drop of water being left in the channels of the Rabaka. The lava is 50 to 60 feet, and in some 80 feet, above the bed of the river, and in some places on the other side of the island the lava is about 130 feet, covering completely a fall in the Wallibu River, which was 70 feet high, not only to the top, but 50 or 60 feet above the top of it, from which the water formerly fell."

It is also repeatedly stated, in the correspondence printed in the Blue Book, that the Rivers Rabaka and Wallibu have completely dried up, and this was of

* Blue Book, p. 88; also p. 98.

† Blue Book 'On the Eruptions in St. Vincent and Martinique in May, 1902,' p. 87.

‡ P. FOSTER HUGGINS, 'Account of the Eruptions of the St. Vincent Soufrière,' p. 7.

§ Blue Book 'On the Eruptions of St. Vincent and Martinique in May, 1902,' p. 92.

|| Blue Book, p. 95.

¶ Blue Book, p. 92.

great importance, as affecting the supply of water to the sugar works and rum distilleries.

The material which filled up these valleys is called "lava," but there can be no doubt it was sand and ashes. SHEPHARD expressly states that the Wallibu was dammed up with sand, and that some years afterwards "the gradual accumulation of water burst through the sandy barrier and carried away many negro houses in its progress; 32 slaves belonging to Wallibu Estate were washed into the sea by the torrent."

In short, it is clear that after the eruption of 1812 the upper parts of the Wallibu and Rabaka Valleys were in very much the same condition as at present, filled with deep deposits of sand, which obstructed the lateral valleys and caused lakes of water and of mud to collect there. Obviously, on the night of April 30th, in the height of the eruption, an avalanche of sand swept down the mountain and lodged in the ravines on the south side of it. With it there must have been a black cloud and a hot blast, only the eruption was less violent than that of this year, and the black cloud had lost its burden of hot ash, and lifted off the surface of the ground before it reached the Carib Country, so that it mounted into the air over the heads of the inhabitants, and they narrowly escaped a sudden and painful death.

The avalanche of dust must have welled over the southern lip of the main crater, and we learn, from SHEPHARD and other sources, that after the eruption the interior cone had vanished. Major CRICHTON is said to have visited the crater three days after the eruption,* and to have found in it a lake of water. It was then in very much the same condition as before the eruption of this year—that is to say, its depth had increased to about 1600 feet, and it had a highly concave, basin-shaped floor.

It is, of course, possible to argue that this discharge of sand took the form of a mud lava, and not of a dry hot avalanche, but this explanation will not meet the exigencies of the case when we consider the phenomena on the north and west sides of the mountain. About midnight on April 30th, when the epoch of maximum activity supervened, a great outburst was noticed on the north-west side. This marked apparently the formation of the new crater. A current of red-hot matter discharged from it, passed down the valley of Larikai to the north of Morne Ronde. It is also stated (*see* p. 464) that the lava,† "immediately after boiling over the orifice and flowing a short way, was opposed by the activity of a higher point of land, over which it was impelled by the immense tide of liquefied fire that drove it on, forming the figure of V in grand illumination. Sometimes, when the ebullition slackened, or was insufficient to urge it over the obstructing hill, it recoiled back, like a refluent billow, from the rock, and then again rushed forward, impelled by fresh supplies, and, scaling every obstacle, carrying rocks and woods together in its course down the slope of the mountain, until it precipitated itself down some vast ravine concealed

* P. FOSTER HUGGINS, 'An Account of the Eruptions of the St. Vincent Soufrière,' p. 94.

† Blue Book, p. 94.

from our sight by the intervening ridges of Morne Ronde. Vast globular bodies of fire were seen projected from the fiery furnace, and bursting fell back into it, or over it on the surrounding bushes, which were instantly set in flames. About four hours from the lava boiling over the crater it reached the sea, as we could observe from the reflection of the fire and the electric flashes attending it."

Now this looks very circumstantial, but the fact remains that when we were at the mouth of the Larikai this summer we saw no lava in the bed of the stream there. This torrent flows down a tremendous gorge, cut in the old lavas and tuffs of this part of the mountain. On the shore below there had been a small alluvial fan, but, as already mentioned (p. 454), it had slid away and disappeared during the eruption of this year. In the mouth of the gorge there was a low cliff, some 50 feet high or more, capped by a few feet of the new, hot sand. The cliff consisted of a material so exactly similar to the ash that overlay it that, if it had not been for the old burnt soil, it would have been hardly possible to find a line of demarcation between the two deposits. We were at once struck with the similarity, and came to the conclusion that here was the evidence of a dust avalanche eruption previous to that of this year. We could not land, as the bare cliff of volcanic sand was tumbling in frequent landslips into the sea, but we rowed quite close in, and could make out all the more important features of the deposit. It was almost unstratified, and had a few stones scattered through it, but for the most part was a yellow or brownish incoherent sand. It could not possibly have been an alluvial deposit, as it showed so little stratification, and such a torrent as the Larikai could not be supposed to lay down 50 feet of sand in any part of the precipitous ravine. Further up we could see where it had been rolling down enormous boulders during the recent heavy rains. This was the last deposit in the Larikai, and it bore all the marks of a dust avalanche. It lay in the old eroded gorge behind a bend, where a projecting mass of rock had protected it from erosion.

On the north-west corner of the Soufrière lay the estate of Duvallie's (De Volet's), also known as Windsor Forest.* This was at that time a sugar estate, but is now devoted to grazing and cocoa. It is stated to have been "entirely covered with the matter thrown out by the volcano; the sugar works totally covered and not discernible; nine negroes killed, the rest escaped over the mountains and came to town much cut and bruised." †

According to SHEPHARD it was "entirely covered with sand and ashes." This may have been the work of a mud lava, but it is more probable that from the position of the new crater that its emissions were directed principally towards the north side of the hill, and that the black cloud which descended there was even more destructive than in the present year, when most of the valleys in this quarter

* P. FOSTER HUGGINS, 'An Account of the Eruptions of the St. Vincent Soufrière, 1902,' p. 7.

† Blue Book: 'Correspondence relating to the Volcanic Eruptions in St. Vincent and Martinique in May, 1902,' p. 95.

contained deposits of ashes which for some days prevented the flow of the streams. The estate was thereafter abandoned for a number of years.

It is universally believed in St. Vincent that the ejecta of this eruption which gathered in the valley of the Rabaka Dry River greatly modified the volume of the water in this stream and the regularity of its flow, which has hitherto been more or less continuous, like that of the majority of the rivers in the island. Thenceforward it was a "dry river"—that is to say, its capacious channel contained no water except immediately after rain. The bed of the stream is probably 200 yards in width, and was usually occupied only by black sand, mud, and boulders, so that it could be crossed dry shod, but at times it was suddenly filled from bank to bank with a rushing torrent which could not be forded, and, as there was no bridge, the north end of the island on the windward side was then cut off from communication with the rest. So mysterious and unaccountable did those periodical floods seem, that many believed they were due to some strange outflow from the crater lake by means of subterranean passages.*

The explanation usually accepted was of a more simple character †:—

"The Windward slopes of this portion of the range are drained by a channel called the Dry River, which runs through the Carib Country, and which from its peculiarity deserves notice. Before the eruption of 1812, a stream of average size filled this now dry watercourse, and emptied itself into the sea. During the eruption, the channel of the stream was completely filled and choked with scoriæ, rocks, and gravel, underneath which the water now, in ordinary times, disappears some distance before it reaches the coast and finds its way to the sea. In floods, however, the water comes down with singular force and volume, filling the rocky bed, which is 200 yards across (where the highway passes it), from bank to bank. The water is described as advancing in huge waves, like the bore of a tideway. On these occasions it is very destructive, and it has already washed away many acres of cane land from the estate of Langley Park, situated on its bank."

Before we reached St. Vincent the conditions had again been entirely altered by the eruption of this year. It is not possible now for us to be certain exactly what were the causes which so modified the behaviour of this stream about the year 1812. The explanation offered—viz., that the valley above was choked with sand and scoria—is, at any rate, credible, as if these materials were dry and porous they might absorb much of the water before it could reach the lower levels. It also strongly confirms SHEPHARD'S statement, that the Rabaka River was filled with sand, and strengthens the evidence in favour of the eruption of 1812 having been characterised by the emission of an avalanche of dust.

For the last mile of its course, before reaching the sea, the Rabaka Dry River flows through what is known as the "lava bed." In this it has cut a wide channel, and on each side it is flanked by two or three well-marked terraces, the traces of former

* P. FOSTER HUGGINS, 'An Account of the Eruptions of the St. Vincent Soufrière,' p. 9.

† 'Historical and Descriptive Sketch of the Colony of St. Vincent, W.I.' (Compiled under the direction of the Commissioner for the Windward Islands, 1891.) By T. B. C. MUSGRAVE, p. 3.

levels at which the stream flowed as it gradually eroded the mass which had obstructed its older and still wider bed. The "lava bed" is composed of black mud, sand, and stones, in which there is also a considerable amount of charred timber. It is essentially a recent formation, which has filled up and obliterated the course of the stream at no very distant date, as it differs considerably in appearance from the rocks of the Carib Country, in which the primitive valley of the Rabaka River had been carved, and has altogether a much newer aspect than the weathered tuffs exposed on the sea cliffs and in the higher slopes and ravines. Many believe that it is a product of the eruption of 1812, but we could find no very conclusive evidence of this, and there is no inherent reason why it may not have been due to some earlier eruption.

It faces the river in low, vertical banks from 6 feet to 20 feet high; its upper surface is perfectly terraced, and shows two or three benches several feet apart. Only two explanations suggest themselves to account for its presence there. It may have been a hot sand avalanche, and, if so, it cannot have accumulated during the eruption of 1812, for when so great a mass of débris was projected into the lower part of the Rabaka Valley the accompanying hot blast must have been tremendous, and would have annihilated every living thing for miles around. But it does not look like a sand avalanche; in the stream sections it too often shows a well-marked bedding, and it contains many rounded blocks of lava, which certainly appeared to be water-worn boulders, such as are common in the valleys. Everything pointed rather to its having been a great mud lava, which had swept down the upper parts of the river's course with a high velocity, and had caught up and incorporated the gravel and boulders over which it passed. Then, when it reached the flat country at the lower end of the valley, it had been unable to flow further, and had come to rest, a great glacier of black mud and stones, which filled up the broad but shallow channel into which it had flowed. Such floods of mud followed the eruption of 1812, and may possibly occur in the near future as a consequence of the eruption of this year, and the discharge of such mud lakes as are forming in some of the higher streams would furnish most of the conditions necessary for the obstruction of the rivers in their lower parts by masses of stony mud exactly resembling the "lava bed."

The "May Dust" in Barbados, 1812.

Early in the morning of May 1st, 1812, sounds as of distant cannonading were heard in Barbados, and it was generally believed that a naval engagement was taking place somewhere off the coast. The garrison prepared to repel any attack. At Rozeau, in Dominica, similar noises were heard a little after midnight, and the regular forces were placed under arms and the militia called out. In Barbados dust began to fall about half past 1 o'clock, and there was intense darkness, but in Dominica there was no darkness and no fall of dust. For several days afterwards there was great excitement, as ship after ship came in reporting that they had had the same experience, only varying in degree, and no explanation was obtained till word came from St. Vincent that the Soufrière had erupted.

Sir ROBERT SCHOMBURGK, in his history of Barbados, gives the diary of a gentleman residing in St. Peter's parish in the island, containing his observations on the unusual occurrence * :—

"At half-past 12 A.M. on May 1st, 1812, a heavy, dark cloud obscured the heavens completely, hanging so low as apparently to touch the ground, except in the south and north-east, where there was a fine, light blue tint, which closed in at half-past 1 A.M., when darkness visibly overspread this part of the island. At this period a sandy grit began to fall in small quantities. At 2 A.M. explosions heard to the southward and westward, resembling two frigates exchanging broadsides, to the amount of 18 or 20; went to the top of the house, but could perceive no flashes, though the sound seemed sufficiently near, light being perceptible at a much greater distance than sound can be heard, the sandy grit, converted into ashes, silently falling. From 2 to 6 A.M. low, murmuring, hollow distant thunder, but no lightning seen, except the vivid flashes which preceded two nearer peals. Between these periods smart squalls with rain and ashes mixed from the eastward, which seldom lasted above 40 seconds, the ashes bearing a greater proportion than the rain in this composition. At half-past 5 A.M. a small glimmering in the south and south-east resembling the appearance of daylight, but did not last 10 minutes before the atmosphere was completely obscured again, and the darkness more intense, if that was possible. At half-past 6 A.M. heavy fall of ashes, with light breezes and a hollow, low, undulating noise to the northward; expecting an earthquake, quitted the house and retired to a wattled negro hut. From 6 to 8 A.M. light breezes, with squalls of ashes and rain of the same description and duration as mentioned before. During these last two hours meteors resembling globes of fire, about the size of a 13-inch shell, appeared in the north-east and north-north-east, to the amount of 10 or 12, crossing each other in every direction, occasionally appearing and disappearing for the space of an hour and a half; so incessant a falling of ashes as to render it impossible to face the eastward. At 9 A.M. the sky to the northward assumed a purple torrid appearance, greatly resembling a vast town at a distance on fire, accompanied by a tremulous motion resembling the Aurora Borealis. The horrid glare of this sky made the surrounding darkness more awfully dreadful; the sky to the southward, in the direction towards Bridgetown, had occasionally the same colour, only the tinge much fainter, attended with no motion. The sky never approached in any direction by my calculation nearer than 7 miles; as I have no data to go on this is a mere matter of conjecture. From 9 A.M. to 12 at noon light breezes and constant and heavy fall of ashes. At 10 A.M. a large flight of birds passed over the hut, flying so very low that the fluttering of their wings was distinctly heard; the notes of these birds resembled the yelping of puppies. When daylight took place they proved to be marine birds, called men-of-war and cobblers, so loaded with ashes they could scarcely raise themselves from the ground. At a quarter past 12 daylight appeared immediately over our heads; half-past 12 the form of the sun, obscured in clouds in the same place. At 1 P.M. daylight; returned to my own house. From 1 A.M. to half-past 12 P.M. the wind east to east-north-east; 1 A.M. light gentle breezes never varying above two points, but fluctuating between both, the wind dying away nearly to calm, but never perfectly a calm. This may be said to be the state of the weather during the whole 12 hours of total darkness, except when interrupted by the momentary squall of sand and ashes. The darkness was so impenetrable that, with the exception of the light that was visible in the south and south-east at 5 A.M., at no period could anything be discerned even within reach. From three admeasurements taken in the lowest places the fall of ashes was an inch and a half. When I left the house the thermometer was 70°, when I returned at 70°; as I left the instrument behind I know not what variation might have taken place in my absence. The other

* 'The History of Barbados,' by Sir ROBERT H. SCHOMBURGK, 1848, p. 72.

observations were made with my own eyes, and the watch in my hand. It will be observed the first two hours the sand was small in quantity and coarse in its nature, but the last 10 hours were ashes, reduced to an impalpable powder, and sublimated to the highest degree. That it is a calcined matter strongly impregnated with nitre and ferruginous particles does not admit of a doubt, if examined through a good microscope; and that it has come from the *eastward* may be supposed from its involving in its mass the men-of-war birds, which are generally found about 60 miles to the east end of the island, seldom approaching nearer. From 1 P.M. to 6 the fall of the ashes began to decrease; at 6 P.M. ceased altogether. At no period of the day did the light amount to more than a dull twilight, and at 5 P.M. the day closed altogether, and darkness succeeded until the morning."

According to the contemporary account already quoted (p. 464), it was shortly after 7 P.M. that the "lava" overflowed the north-west side of the crater, and about that time the noises from the mountain were very loud. These reports, apparently, were not heard at Barbados, or, if heard, were mistaken for thunder. About half-past one another overflow took place on the south side, towards the valleys of the Rabaka and Wallibu, and the detonations which attended this outburst were heard in Barbados at two in the morning, according to the diary. Ashes were falling in small quantity between 2 o'clock and 6 o'clock; there was much lightning, but it was not very dark. When the day broke there was a thick mist of falling dust, and at half-past six there was a considerable increase in the rain of ashes. This means, probably, that the material ejected by the great outburst at 2 A.M. had taken four hours and a half to reach Barbados, a distance of 99 miles. This year the main explosion was approximately at two in the afternoon, and the dust was falling freely in Barbados at half-past five, having taken only three and a half hours on its journey.

In 1812 ash began to fall "between 2 A.M. and 6 A.M.," fell freely from 6 A.M. to 1 P.M., and ceased altogether about 6 P.M., a duration of somewhat over 12 hours. In 1902 ash began to fall about 5 o'clock, and continued till daybreak next day, or approximately 12 hours also. In 1812 it fell mostly in the day; this time mostly through the night. The weather was dry this year, and the dust formed a fine, dry powder easily blown about by the wind; in 1812 there were frequent heavy showers, and much of the ash fell wet. Otherwise the two records are as similar as could well have been expected.

Another account of the rain of ashes in Barbados in May, 1812, has come down to us in the form of a private letter from a gentleman of St. George's parish to a correspondent in Great Britain. It is less precise and full of details than that just quoted, and was printed in TULLOCH's 'Philosophical Magazine' of the year 1812 (p. 71).

In the morning at half-past six, when it should have been bright daylight and the sun above the horizon, he was astonished to find that it was still so dark that he could only compare it to moonlight on a night when the moon is at times clear and at times obscured by cloud. He had not heard the detonations about 2 o'clock in the morning, though they had led to a general opinion that an engagement between British and French ships of war had taken place somewhere in the neighbouring seas, and preparations had been made among the troops to repel attack. Thick clouds covered the sky except near the southern horizon, where a bright light shone through a thin cloud-veil. The morning was still and calm, and the appearance of sky and air so unusual that he was apprehensive of an impending catastrophe, and hastened to the house of some friends. By 7 o'clock it was much darker, at half-past seven candles were required; by eight it was pitch dark—"so dark that we could not perceive our hands when held up before our faces at two feet distance." This continued till 12.25 P.M., when the light returned and rapidly increased till near objects could accurately be perceived. About 3 or 4 o'clock the light was fairly good, but the air hazy. Fine ashes fell all day till 8 o'clock at night.

"In order to ascertain the quantity which had fallen, Mr. H. last night took up that which lay upon a foot square, when it measured three pints somewhat pressed into the measure, and weighed $1\frac{3}{4}$ lb.

"This morning another square foot, where the surface was hard and level, gave, in $\frac{5}{8}$ inch and $\frac{1}{2}$ inch in depth, three pints loosely filled up in measure, and 1 lb. $7\frac{1}{2}$ ozs. in weight.

"Against the bottoms of windows, doors, and walls it was considerably deeper. But assuming the product of my experiment as the medium quantity which fell on a foot square throughout the island, and estimating from our best maps the quantity of land in the island at 106,470 acres, the total quantity of this extraneous substance which is now on its surface, independent of that which is on the trees, could not be less than 1,739,187,750 gallons wine measure, or 6,811,817,512 lb. avoirdupois."

According to this estimate, a total of about 3,000,000 tons fell on the surface of Barbados, which is nearly twice that estimated to have fallen this year. Although both accounts differ somewhat in respect of this point, they agree in making the fall of ashes greater than it was in May, 1902, but it is very doubtful if the old estimates are anything like as accurate as the modern ones.

Further Activity in 1814 *and in* 1880.

It is generally supposed that in 1812 the Soufrière had relapsed into repose, and that the lake which has occupied its crater since the last great eruption has been undisturbed by volcanic emissions till the beginning of this year. But there is good evidence that this is not altogether the case, and we are indebted to Dr. NICHOLLS, C.M.G., of Dominica, a gentleman who has done much for the advance of scientific knowledge regarding the Caribbean Islands, for bringing to our notice a most interesting correspondence which appeared in the 'Trinidad Chronicle' in 1880. Had his quick eye not detected its importance at the time, and had he not carefully preserved it, we should certainly have missed it altogether. Inquiries made at the Colonial Office showed that there was no mention of volcanic activity, on the dates mentioned, in the official papers and despatches.

It seems that in September, 1880, reports reached Trinidad that apprehension was being felt in St. Vincent regarding the state of the Soufrière, and that an eruption was feared. On September 28th the following letter was printed in the 'Trinidad Chronicle':—

" *The Soufrière at St. Vincent.*

" To the Editor,

" 'Trinidad Chronicle.'

" DEAR SIR,

" I observe that, in noticing what the fears of those who dwell in the vicinity of the Soufrière in St. Vincent lead them to regard as possible signs of a coming eruption, you state that the volcano has been quiescent since the great eruption in 1812. This is not quite correct. There was the small eruption of 1814, of which I have a manuscript account by an eye-witness. This has never been published. I think a few extracts from it may not be uninteresting to your readers :—

" 'On Sunday, January 9th, 1814, about 1 o'clock P.M., I observed a cloud of smoke issuing from the Soufrière. A part appeared to roll down the side of the mountain towards Wallibu ; and a large column shot upright to a great height. It continued to rise for upwards of half an hour, when it was detached from the mountain and proceeded in a compact body in a direction nearly opposite to that of the (lower stratum of) wind at the time. At about 5 o'clock it had reached the horizon, and before six had entirely disappeared. During its passage overhead the heat was excessive, but I had no thermometer to ascertain its degree.

" 'The eruption was preceded by loud noises . . . . like the discharge of distant artillery. . . . . It was preceded by a severe earthquake. Dr.   , who was in a favourable position for observing the craters, not only remarked an intense light to issue from them, but saw rocks thrown to a great height, which seemed to fall back into them. All appearing quiet on Monday and Tuesday, the craters were visited on Wednesday. The eruption proved to have been from the old crater. Large rocks had been ejected to considerable distances, some having been found a quarter of a mile from the edge of the crater, which is strewed with them. There is little alteration in the appearance of the crater, but the water in it is boiling with great violence. The new crater remains unaltered. The rocks around are shattered in several places. One of these fractures is very large. . . . . Many of the pieces which have been ejected . . . . are entirely unaltered by fire . . . . but many have been evidently acted upon and altered by fire, but none retained any heat. . . . . Amongst others was a curious specimen of what I observed after the great eruption. It has the colour and somewhat the appearance of dry sponge, but is very friable, and seems principally composed of slender glass-like filaments, slightly connected, and enclosing numerous pieces of spar and other mineral substances.'

" I may mention that a correspondent of mine states, in addition to the particulars which you quote from your correspondent's letter, that all the beautiful vegetation, which for 60 years has adorned the sloping sides of the old crater, and has always been such a remarkable feature in the scene, has been destroyed, burnt up as if by fire, it is supposed by volumes of gas, which have rolled round the crater and overlapping its edge have rolled some way down the leeward side of the mountain and there, likewise, destroyed the vegetation. Mountain pigeons and some other birds are commonly seen on the heights—these seem to have forsaken the dangerous neighbourhood, and the melodious notes of the mysterious, and as popularly believed invisible, Soufrière bird are no longer heard.

" (Signed) H.

" *September 28th*, 1880."

The notes by an eye-witness of the eruption of 1814, contained in this letter, are so explicit and carefully worded that there can be little doubt that they describe a real occurrence, and not merely those deceitful shapes assumed by the drifting trade-wind cloud which frequently mislead superficial observers, and start the propagation of baseless rumours of eruptions. But it is quite improbable that any considerable disturbance took place, or that any great activity was manifested. We note especially the absence of the premonitory symptoms which invariably at the Soufrière have preceded any resumption of volcanic action, and as the crater had then been quiescent for eighteen months (since June, 1812), it is unlikely that any violent eruption should have broken out without giving warning beforehand. It is a rule, to which we know of no exceptions, that the longer the period of quiescence at the Soufrière, the more marked are the disturbances and earthquakes which are observed before an eruption. The outburst of May 18th this year gave apparently no warning, though of this we cannot be quite certain, as it took place after dark; before all the others, earthquakes have been numerous, violent, and continued.

It is said that a steam column shot upwards from the crater and, reaching the higher currents of the air, floated away on the anti-trades. It spread out to form a cloud which, as the emission was brief, was soon separated from its parent stem and, having become detached, was borne away to the horizon. There is no description of any rain of ashes, but a few days afterwards large stones were found lying around the old crater, some of them several hundred yards from the rim. As by that time a covering of green vegetation had probably formed in some part of the upper slopes, which had been devastated two years before—though Mr. ANDERSON, in 1784, describes them as quite barren and stony—and as the observer was resident near and well acquainted with the volcano, there is not much chance of his having been in error on this point. Their distribution led to the belief that it was from the old crater the steam arose, which is quite likely, as undoubtedly that crater had taken the chief part in the eruption of 1812, and had discharged the great masses of sand which blocked the Wallibu and Rabaka Valleys, and were accompanied by the loud detonations that awakened alarm in Barbados.

This description of the steam cloud, "part of which rolled down the side of the mountain," is curiously reminiscent of the behaviour of the great black cloud. But it is in no way probable that this phenomenon appeared on this occasion. It has never been known, except in the major eruptions, and had an avalanche of dust rolled down the hillside it would have left traces visible when the mountain was again visited three days afterwards, and too obvious to have been overlooked. Moreover, we are told that the water was still left in the crater, and little change was to be perceived in the aspect of the interior. Now the great black cloud never appears till after the crater lakes are emptied, and the ascending column of lava has forced its way to the surface.

In all probability this was merely an exacerbation of solfataric activity, such as has been experienced by more than one of the Soufrières of the Windward Islands, and after the emission of a great mass of vapour and sulphurous gases the short-lived eruption came to an end. Such an emission would carry with it many stones from the bottom of the crater lake, would blast any vegetation growing within the crater, produce minor changes in some part of the crater walls, and project into the air a column of mud and dense muddy vapours which would fall partly outside the lip and flow for a short distance down the slopes, giving rise to clouds of steam as it coursed over the surface. The discharge of steam thereafter for some time would keep the crater lake in a state of furious ebullition.

Apparently again, in 1880, a considerably increased production of sulphuretted hydrogen had killed the growing bush within the crater. This is a not uncommon phenomenon around the Soufrières of Dominica and St. Lucia, where every increase or diminution in the amount of the poisonous gases emitted is attended by a widening or contraction of the surrounding region in which the vegetation has been killed, and the blackened, blasted stems of trees scattered through the green forest are the standing witnesses of epochs during which the noxious fumes were able to increase the area over which they had control, but which they were unable permanently to dominate.

THE SOUFRIÈRE AND MONTAGNE PELÉE.

Their Resemblances and their Differences.

It is not possible at the present juncture for us to give more than the main points of similarity and of difference in these two mountains, and the features of their activity. Our own visit to Martinique was short, and was brought to an unexpected termination by the eruption of July 9th. Smaller outbursts followed during the next two days, and neither was it safe to work on the mountain slopes, nor could porters be obtained in Carbet, which had been deserted on the night of July 9th, who would undertake the ascent. We had, indeed, planned an excursion to the southern lip of the crater on the day after the eruption (July 10th), but all the arrangements we had made were nullified by the sudden increase of volcanic activity on the previous evening, and without much delay it would have been impossible to make an examination of the upper slopes that face St. Pierre. We had, however, spent two days in the ruined city, and examined the desolation wrought in the historic catastrophe which overwhelmed it, and had made a more or less cursory inspection of the lower fringes of the volcano and the fields and bluffs around the town. But there were many points of great importance into which we had not had time to enter. To Professor LACROIX, of the Scientific Expedition sent by the Académie des Sciences of Paris, we are indebted for much valuable information, and for his kind offices with the officials and others in the island of Martinique. His preliminary account of the results of his first visit to the scenes of the eruption* has furnished us with additional details. In Fort de France we had the privilege of renewing our friendship with Professor JAGGAR, of Harvard, whom we had previously met in Barbados, and he and Mr. ROST, photographer to the United States Geological Survey, discussed with us most frankly the results of their observations, and the conclusions to which they had been led.

Much has already been written on the great eruption of Pelée, and the havoc it wrought in St. Pierre, but mostly from a popular point of view, and without reference

* 'Comptes Rendus,' vols. cxxxiv. and cxxxv.

to the causes which underlie the phenomena. Articles of more permanent value have appeared also in certain magazines and scientific periodicals, but perhaps we are right in saying that the geological history of that catastrophe has yet to be penned, and as more than one party of scientific men have addressed themselves to the task, there should be available, in no great lapse of time, the results of careful and thorough examination of all the effects of the eruption, with a judicious and critical digest of the evidence of what actually took place on the fatal morning of May 8th. We are well aware that much of what has been published is quite untrustworthy, and unsuited for scientific discussion, and we will rely mostly on the results of our own observation, and on information given us by Professor LACROIX and Professor JAGGAR, but we have also made more or less use of the articles which have appeared in the newspapers of Guadeloupe, Martinique, Barbados, Trinidad, and in the English journals, and ot the reports by Professor R. T. HILL and Professor ISRAEL RUSSELL to the National Geographic Society of the United States, and their articles in the 'Century Magazine.' *

The resemblance between Pelée and the Soufrière in their geological relationships is so striking that it cannot fail to impress the most casual observer. Each stands at the northern end of its respective island, an isolated volcanic cone, bearing a summit crater or craters, and with its skirts descending to the sea on all sides except the south. Here in each case there is a broad, flat depression, more marked in St. Vincent than in Martinique, on the south side of which rises another volcano, or group of volcanoes, extinct, highly eroded, but still bearing in its internal structure, and less obviously in its external configuration, the proofs of its origin. The Piton de Carbet, which lies to the south of Pelée, has not been in eruption since the European colonisation of Martinique; but its crater, though partly destroyed, is not yet completely effaced by erosion, and like its analogue, the Morne Garu at St. Vincent, it seems to have been the last volcano in the island which has died out and become extinct.

In both islands the older volcanic piles lie in the south end, which consists mainly of lavas and agglomerates emitted from foci which have long since passed into repose. The lavas are andesitic, and alternate with vast sheets of coarse agglomerate, which testify to the frequency and violence with which explosive action took place when activity was at its maximum along the Caribbean chain. The epeirogenetic movements which have affected this border ridge between two oceans have left their marks in the raised beaches which are found along the shores of both islands, and the same conditions of accumulation and uplift, with intense and rapid erosion on steep slopes attacked by tropical climates and tropical rainfall, have in each case resulted in deep sculpturing by the agencies of subaerial denudation. The ravines of Pelée have

* R. T. HILL, "A Study of Pelée," 'Century Magazine,' September, 1902, vol. lxiv., p. 764. ISRAEL C. RUSSELL, "Phases of the West Indian Eruptions," 'Century Magazine,' September, 1902, vol. lxiv., p. 786.

all the depth and picturesqueness of those of the Soufrière, and where the volcanic blasts have withered up and swept away the vegetation, the same general resemblance to the rugged, naked cañons of the western American desert country is seen in both cases.* Vertical cliffs of lava alternate with sloping taluses of ash; every variation in the underground structure is reflected in the contours of the surface, and where the rich Antillean forest clothes the eroded surface, the beauty of the landscapes and the variety of colour lend a striking charm to the distant hills and the highly-cultivated shores.

In both mountains the conical volcanic form is well exhibited, though scored with deep radial ravines. Pelée is 4428 feet high, while the Somma rim of the Soufrière is 4050, but had the latter mountain not lost by some great explosion the upper part of its cone, it would probably have been somewhat the more lofty of the two. In each case the diameter of the cone at sea level is almost 8 miles, and the restless action of the waves has eaten back the land, and formed ranges of lofty cliffs which face the ocean.

At the summit of the Soufrière we have a concentric structure—a crater within a crater. The great convulsion during which the huge Somma crater † of the mountain was produced, antedates authentic history. The lower lip of this great "caldera" must have been the southern, near which the main crater of the present day stands, and this in turn bears on its north-east side another smaller parasitic vent (that of 1812). Pelée had at its apex a single small crater surrounded by a serrate range of cliffs some 200 feet high or less, and in the bowl-shaped depression lay a little lake, the Lac des Palmistes, 150 metres in circumference. But on Pelée were numerous lateral orifices, the parent sources of "soufrières" and hot springs, one of which, at Ajoupa Bouillon, has since attained notoriety as the focus of a minor eruption on September 3rd, 1902. Another lay near the gorge of the Rivière Sèche to the south of the summit; it emitted steam and sulphuretted hydrogen, and around it the rocks were decomposed by acids and often crusted over with sulphur. This was surrounded by high cliffs, and was very rarely visited, but from near the top of the mountain a view might sometimes be obtained of its interior. It lay apparently on one side of the cañon, and from the descriptions of it which we have received must have closely resembled many of the soufrières of Dominica.

This Soufrière has now assumed a new importance, for, according to some accounts, it was from it that rose the cloud of suffocating gases and red-hot dust which laid the fair city on the shore below in ruin and ashes. When we were at St. Pierre great towering balloon-shaped steam clouds would frequently ascend from the neigh-

* TEMPEST ANDERSON and JOHN S. FLETT, "Preliminary Report on the Recent Eruption of the Soufrière in St. Vincent," 'Proc. Roy. Soc.,' vol. lxx., p. 11, 1902.

† Mr. R. C. HILL suggests ('National Geographic Magazine,' vol. xiii., p. 233) that the upper part of the mountain was blown away in the eruption of 1718. Mr. Anderson's description of the crater as it was in 1784 disproves this.

bourhood of the fissure in this gorge, and, as will be seen later, it had still not lost its virulence and destructive energy.

The Lac des Palmistes is now filled with hot stones and sand to within a few feet of the lip, and the present crater lies to the south-west of it, apparently on the site of the former Soufrière, which has been much enlarged, and a great fissure has been opened on its southern lip.

The Eruptions of Pelée.

The only previous eruption of Pelée of which there is historic record is that of 1851, which appears to have been brief and abortive. A few mud-flows in the rivers, a discharge of steam and a fine ashy dust, and the volcano relapsed into quiescence for another 50 years. The earlier stages of the eruption of this year were of a precisely similar character, and this was one of the causes which lulled the suspicions of the inhabitants of St. Pierre, and inspired them with a fatal feeling of security. The premonitory earthquakes, so frequent always at the Soufrière, where they have heralded the outburst of every eruption, and prepared the minds of the inhabitants for the approaching paroxysm, were apparently practically absent in Martinique, and although there are records of a few small shocks, we are not aware that they were numerous or disquieting. But at Pelée there was a long preliminary phase leading up to the crisis. Steam was seen to ascend from the crater about April 23rd, or a fortnight before the culmination of the eruption. At first the activity was so gentle that it awakened only curiosity, and several people made ascents and reported that both the upper and the lower Étangs were boiling and giving out much steam. But day by day the violence increased, and by May 2nd a good deal of apprehension was felt in St. Pierre, and some were meditating flight. That night there was great activity in the craters, loud noises were heard, and over the mountain top a bright glare was visible. The ashes were wafted by the wind over St. Pierre and Prêcheur, and next morning these were covered with a layer of light grey dust. The crops were blighted, the cattle starving for want of water and of food; the people from the country began to flock into town. The noises and the rain of cinders and of dust continued more or less intermittently from that time onward.

The rivers descending to the south-west from the summit had already become muddy on more than one occasion, but on the 5th a great flow of hot mud poured down the Rivière Blanche with great rapidity and overwhelmed the Usine Guérin, killing many people. At the same time there was a small sea wave which did no damage. This mud-flow was apparently the waters in the Étang Sec which had escaped through some fissure on the south side of the peak, driven out by the ascending column of lava and the constantly increasing pressure of the gases within the volcano. Next day the streams were still torrents of mud, and the harbour of St. Pierre was covered with floating trees and the wreckage of bridges and other structures swept away by the floods. No better instance could be cited of the difference between Pelée and the Soufrière in the rapidity with which the crisis of the eruption came than this :—in Martinique the discharge of the crater lake took place four days before the climax arrived; at St. Vincent the first overflows were seen only three hours before the avalanche of dust swept down the mountain slopes.

From May 2nd onwards, no doubt remained that the volcano had resumed activity, and as each day passed the outlook became more threatening, the discharges of steam more violent, the detonations louder, and the rains of ashes more frequent and heavier. On the 4th the cloud of dust was so thick over the leeward side of the mountain that the steamer "Topaze" could not call at Prêcheur. The ash was very fine and light grey, resembling cement or flour, and covered the trees and shrubs as if there had been a light fall of snow. Animals were dying of thirst and hunger; birds, overcome by the fumes, or weighted down by the dust on their plumage, were lying dead by the sides of the paths; the crops were withering, and the outlying districts already abandoned and deserted. On the 6th, and again on the 7th, loud noises rose from the crater, and the red glare was visible in the steam cloud. But as yet no earthquakes; even though a rift could now be seen to have opened at the base of Morne Lacroix.

Wednesday, May 7th, the day of the great eruption of the Soufrière, was not marked by any special features in Martinique.* That day the mountain was, in fact, rather less violent than it had been on the 6th; but on the following morning, at 7.50, the great convulsion came, and with it the end of all things for St. Pierre.

So deadly was the blast that swept the city, so awful in its completeness the destruction that it wrought, that few survived who saw the great black cloud descending from the mountain, but of those few there are some who have placed on record what they saw, and it is clear from their descriptions that in Martinique there was a repetition of what had happened in St. Vincent on the previous afternoon. The mountain burst open and a great cloud appeared near its summit. It arose with a loud, growling noise, and some say that in it they saw a bright red glare. Like an avalanche it poured upon the city, covering the distance in a few minutes, and enveloping all in total darkness. It passed almost as rapidly as it had come, and when the darkness lifted a little, it was seen from the ships lying in the harbour that the city was razed, and fierce fires had broken out in many places. The north end of the town was practically wiped out in an instant: nothing was left but blazing ruins, the inhabitants perished where they stood. But in the south end the devastation was not so complete, the walls were left standing in many of the houses, and the

* In the 'Report of the Commissioners of the Academy of Sciences' it is remarked that a tidal wave was observed on the 7th May both in Martinique and Guadeloupe, and that it did not correspond to any eruption (of Pelée); needless to say that was the day of the great eruption in St. Vincent. MM. A. LACROIX, ROLLET DE L'ISLE & GIRAUD, "L'Eruption de la Martinique," 'Comptes Rendus,' vol. cxxxv., p. 390.

living occupants rushed into the streets, yelling with pain and terror, terribly injured, throwing themselves into the sea to mitigate the agony of their burns. It was no earthquake that levelled the town, neither was it lightning nor the weight of ashes. All who saw that calamity and have survived agree that a mighty blast came with the cloud and mowed down everything in its path. The origin of the conflagration is not quite so clear, and there may have been more than one cause. Lightning may have ignited some structures, and the fires in some of the houses may have played a part in setting the ruins ablaze. But the cloud was filled with hot ashes, and we have no doubt that, especially in the north end of the town, the temperature of the dust was sufficiently high to ignite combustible substances.

Captain FREEMAN, of the "Roddam," has described his fearful experiences in language so terse and vigorous that it is well suited to the occasion*:—

"At about 8.15 he was in the chart room; a good many of the sailors were leaning over the side of the vessel watching the distant mountain, which was emitting dense clouds of smoke and occasional flashes of light. Mr. CAMPBELL was talking to Mr. PLISSONNEAU on the deck. On a sudden he (the Captain) heard a tremendous noise, as though the entire land had parted asunder. Simultaneous with the noise there was a great rush of wind, which immediately agitated the sea, and tossed the shipping to and fro; he rushed out of the chart room, and looking over the town and across the hills he saw a sight he cannot describe. He remembers calling out to Mr. CAMPBELL, and saying: 'Look!'—then an avalanche of lava was upon them. It immediately caught the town afire as it passed over it, likewise the shipping. It struck his ship with the force of a mighty hammer, and the lava rained upon the deck. Everyone, as far as he could see, sought shelter at once, but the heat was so great, and the air so suffocating, that Mr. CAMPBELL and many of the crew, among whom was the chief mate, threw themselves in despair overboard. Some crawled from where they had hidden themselves on to the deck to obtain a breath of air, and were roasted upon the fiery hot ashes. He did not lose his head, his first thought was to try and save his ship and such of his crew as were still alive. He rang the bell for full speed astern, and the heroes below turned on the steam. He had time to slip his anchor, and he was off. As his steering gear was rather difficult to manage he once or twice nearly ran foul of the steamship 'Roraima,' which was on fire. He saw two still figures standing on the bridge with arms folded heroically awaiting their end. One of them waved a good-bye to him. There were a good many passengers on board, these were rushing up and down in anguish. When he was steaming out of port he looked down at the burning city. A pall had enveloped it, but through it he could plainly see the skeletons of burning houses, and the shadowy figures of men and women running hither and thither in their terror, and above the loud din of the falling cinders, the roar of the raging sea, he heard the agonised cries of 30,000 voices."

The cloud was red hot when it emerged, or, at any rate, a red glare was seen in the fissure from which it leaped. As it swept down it was black to those who saw it coming, and lightnings scintillated in its front. With it came the mighty wind which capsized the "Grappler," ruined the town, and laid the "Roraima" and the "Roddam" on their beam-ends till the water poured in through the lee ports. The dust cloud followed in an instant. The sea raged as in a storm. Its surface hissed with the hot dust, and must have been nearly boiling. Even late that night the engineer of the R.M.S. "Esk" found the temperature of the water of the bay five

* Blue Book 'On the Volcanic Eruptions in St. Vincent and Martinique in May, 1902,' p. 45.

degrees above the normal for the time of year. The wood deck of the "Roraima" was set on fire; the "Roddam" had iron decks, and was lying further to the south, in the quarantine station. Some of the crew of the "Tereso Lobico" also escaped. The rigging of the ships, where it was not cut away by the blast, was charred or set on fire by the heat of the dust.

It does not appear that the smell of burning sulphur was overpowering as in the black cloud at St. Vincent. There it was noticed by all; but in Martinique comparatively few of the survivors mentioned it. The hot dust entered nose, and mouth, and throat, and some stuffed their caps in their mouths to prevent getting burnt in the respiratory passages. They had great difficulty in breathing, and felt choked; some noticed a gentle return current, which brought fresh air and relief to the suffering. The burns on the bodies of those least severely injured were often beneath their clothes, which had not been ignited or destroyed. In the north end of the town the corpses were superficially charred; their clothing had often entirely disappeared. It is probable that in many cases death was instantaneous, though many of the stories which were printed in the papers as to the attitudes in which the bodies were found are not worthy of credit.

The Effects of the Eruptions on St. Pierre and its Vicinity.

We visited St. Pierre in the beginning of July, 1902, and are able to confirm from our own observations the majority of the facts already described by Mr. Hill, Professor Russell, and the French Commissioners. Before we arrived much time had elapsed, and the eruptions of May 20th, 28th, and June 6th had added their quota to the sum of destruction. Moreover, the city had for 36 hours after the first eruption been the scene of a gigantic conflagration. The piles of coal on the wharves still smoked when we were there. No good evidence is yet available of its condition when the first blast had finished its deadly work, except, perhaps, the reports furnished by the relief party, who went from Barbados under Mr. Newton, the Colonial Secretary.* We have also some photographs taken on May 14th by Mr. Poyer, of Barbados. These show that the eruption of the 20th had finished the destruction of the cathedral and demolished many houses, weakened as they must have been by the fire which consumed the city. In the north end of the city, across the Rivière Roxelane, all houses were levelled with the ground, except where they stood below the bluff which forms the river's bank and faces the sea. Everything was burnt up, all vegetation gone, but the copper telephone wires were not fused, and objects of metal were little affected by the direct heat of the blast. Those, of course, which were within the houses showed more alteration, but nothing that might not reasonably have been attributed to the action of the conflagration.

* Blue Book: 'Correspondence relating to the Volcanic Eruptions in St. Vincent and Martinique in May, 1902,' p. 47.

The blast had crossed the shallow valley of the Roxelane, had twisted the iron stanchions of the bridge over the stream, and planed off the upper parts of the houses which stood in the shelter of the steep northern bank. On the south side of the river the destruction was less, and it rapidly decreased as it was traced southwards, though still the desolation was so striking that it seemed as if no more utter ruin had ever

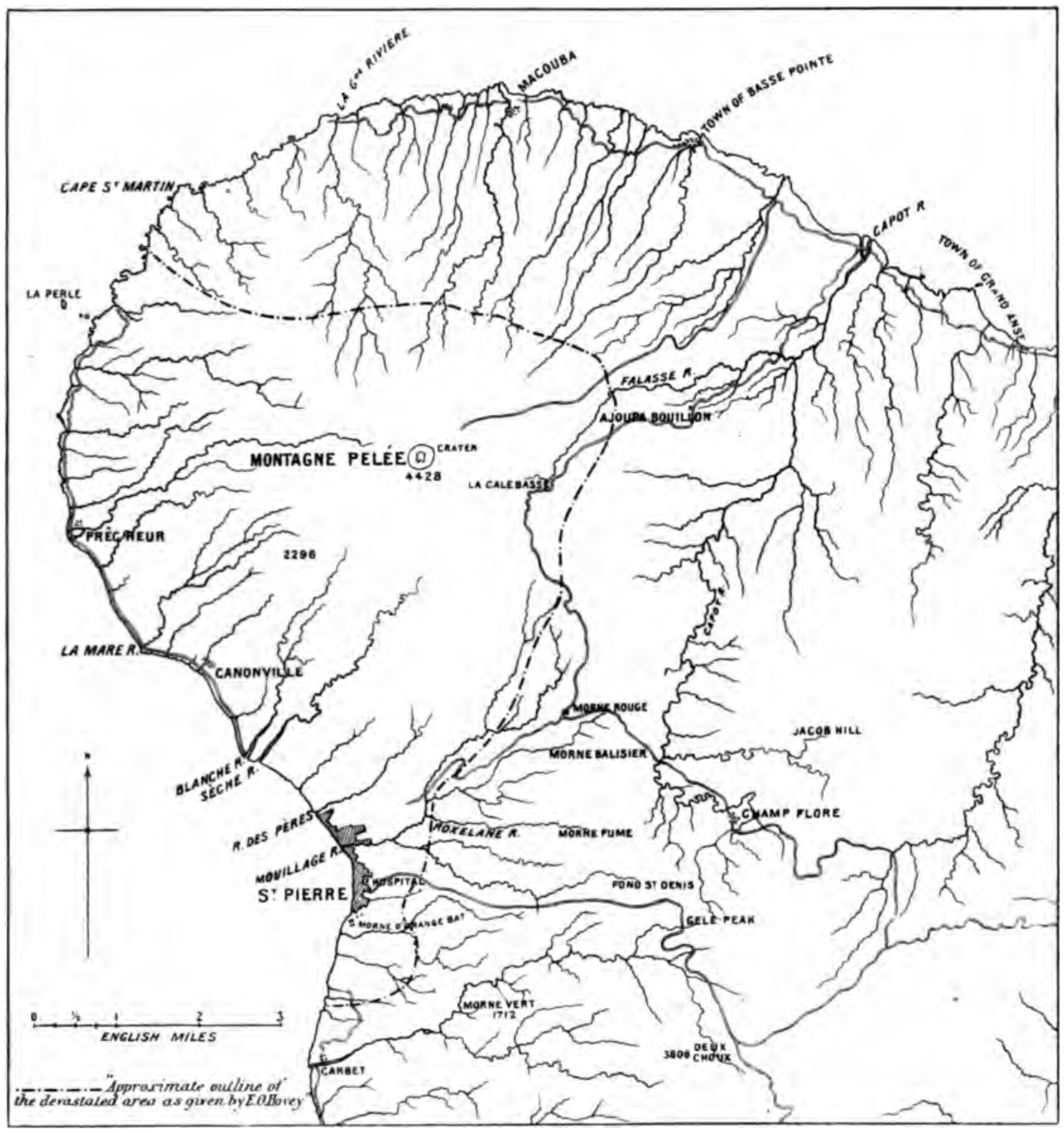

FIG. 2.—Sketch Map of the North End of Martinique.

overwhelmed a town. The streets were full of piles of stones, the remains of the walls which had been overturned. In many cases the walls running east and west were levelled, as they had faced the force of the blast, while those which ran north and south had offered their ends to it and successfully resisted its violence. It was curious to note how different in consequence was the aspect of the town when looked at from the north of the Rivière Roxelane, and from the anchorage in the bay. From the one side it seemed entirely razed, hardly one stone left upon another; from the sea it was possible to make out where the streets had been by the long walls which had formed the frontages and were still standing. The houses were burnt out, and filled with blackened timber, ashes, and mud, much of which had apparently been washed down by the rains from the slopes behind the town. These were now nearly bare, though a little green vegetation was again showing itself, and evidently rivers of mud had flowed along the streets and come to rest on the flat ground on which the city had been built. It was in turn being washed out of the houses by every shower, and fresh heaps of skeletons were in this way daily being exposed to view.

The violence of this blast must have been terrific. The prostrate walls, the twisted ironwork of the verandahs, the ruined cathedral, the uprooted and dismembered trees, all spoke eloquently of this. The cannon in the fort near the south end of the town had been overthrown (they stood side on to the blast). The gigantic statue of the Virgin, which was planted on the edge of the bluff near the southern fort, was torn from its pedestal. This was not in itself wonderful, as the statue was fastened to the pedestal only by four or five iron bolts which had given way, but it was marvellous to see how it had been carried 40 feet away, and lay prone with its head pointing directly to the crater. Near it a low, stone wall, about 18 inches thick, had been broken from its foundations and forced southwards for several inches.

The conflagration, too, had left its mark. Nothing that was combustible had been preserved. Everything was more or less completely burnt, except some unsigned notes, which lay in a box in the strong room of the Banque Coloniale. We were told that robbers had rifled the houses of everything of value, but we saw very little—it was difficult even to obtain a curio to remind one of the visit. The iron safes of the business houses were there, most of them broken open; the books they contained were more or less charred. Coins found in the houses and shops were shown us, most of them blackened, and often sticking together as if they had been partially fused. The shops were empty, except those which had contained china, glass, or iron. The china was often superficially fused, the glass in some cases melted into lumps. The iron beams of one large building were curved and twisted like reeds.

From our point of view the condition of the trees was of special interest, as giving us data on which to base a comparison with what we had seen in St. Vincent.

To the north of the city they had vanished, and on the south side of the Roxelane they were overturned—even the largest charred and sand-blasted. But on the extreme south end, though many had fallen, some stood, and behind the town a banana was putting out its oar-shaped leaves of fresh green amid the desolation of ashes and death. The trees in the streets may have been partially protected by the surrounding houses. It is not wise to push the comparison too far, but in general the south end of St. Pierre was in much the same condition as St. Vincent on the windward side, about a mile above Lot 14, so far as the condition of vegetation in the city was concerned. There were no houses, of course, in that region in St. Vincent.

In St. Pierre, as in St. Vincent, the blast was heavy and crept along the ground. At any rate, when it reached the lower slopes it flowed along, and was deflected by prominent ridges in its path. The bluff behind St. Pierre directed it along the coast, where it swept the shore to Carbet, killing or scorching all the cocoa-nut palms on the low beach, and singeing the face of the steep bank, but unable to mount the heights and devastate the country behind. This when we saw it was green; it had, perhaps, been covered with a thin sheet of ashes, but the crops, the trees, and even the buildings were little damaged, and nowhere was the line between the blasted, desolate, fire-swept area and that which had been injured, but not beyond the power of rapid recovery, so perfectly sharp and definite. In the length of one garden, near the statue of the Virgin on the cliff top, we could find every transition, from utter destruction at one end to very fair preservation at the other.* The edge of the dust cloud had been as well defined between St. Pierre and Carbet as in any part of St. Vincent.†

The depth of the layer of ashes was quite inconsiderable when compared with that on the south side of the Soufrière. On the cane fields at the north end of the town it had been originally perhaps a foot, but near the sea-shore, behind the rum distilleries, and near the mouth of the Rivière des Pères, perhaps 3 feet or more. In the town itself so largely had the deposit been re-arranged by water that it was not safe to deduce its original thickness, and everywhere the heavy rains had scoured away the loose, ashy sand, and only indirectly could we infer how much had once been there. The upper surface was wonderfully smooth, but Professor LACROIX and his colleagues‡ describe ridges "like sand dunes," which resemble the hog-backed mounds on the Wallibu Dry River. There did not appear to have been any great deposits in the valleys, which were mostly open and shallow, not deep, narrow ravines, but there was more in such situations than on the flat, and it was obvious that much of what had originally obstructed the stream courses had been cut out by running water and carried to the sea. In the Rivière Blanche we believe there is some depth of hot sand, which, as described by Professor HEILPRIN and Professor LACROIX, is slipping into the water and giving out gushes of steam, recalling on a smaller scale the explosions on the Wallibu. The sand was distinctly lighter in colour than that of the Soufrière, as may be inferred from the descriptions of its mineralogical and

* Mr. HOVEY states that "in many places the line of demarcation passed through single trees, leaving one side scorched and brown, while the other side remained as green as if no eruption had occurred." E. O. Hovey, "Martinique and St. Vincent: a Preliminary Report," 'Bull. Amer. Museum Nat. Hist.,' vol. xvi., 1902, p. 347.

† MM. A. LACROIX, ROLLET DE L'ISLE & GIRAUD, "Sur l'Éruption de la Martinique," 'Comptes Rendus,' vol. cxxxv., p. 382, 1902.

‡ MM. A. LACROIX, ROLLET DE L'ISLE & GIRAUD, "Sur l'Éruption de la Martinique," 'Comptes Rendus,' vol. cxxxv., p. 421, 1902.

chemical composition already published. It was astonishingly uniformly fine-grained; small lapilli were present, spongy, brownish-grey, and porphyritic, and were most numerous where the finer stuff had been removed by the rains, but large bombs are rare, except on the slopes around the crater, and we saw none near the city of St. Pierre. There were a few ejected blocks, so few that most of them already bore the marks of the hammers of the French and American geologists, who had been there before us. They were brittle, and flaked off on the surface like those already described as found on the Soufrière. All that we saw were old and somewhat decomposed porphyritic andesites.

The products of the magma of Pelée were distinctly more acid than those of the Soufrière, and more of the dust consisted of felspar, which gave it a pale grey colour. It is less rich in the ferro-magnesian silicates, especially augite, but contains a fair amount of hypersthene and some hornblende. No olivine has been reported. Mixed with the broken and entire crystals of these minerals are the remains of a base or ground-mass, which is often filled with fine microlites of hypersthene,* and this material of the later period of consolidation is, on the whole, more abundant than in the dust of the Soufrière. The felspars are also more rich in the albite molecule, and contain less of anorthite.

The area of devastation in Martinique is not only sharply defined, it is small, much smaller than that of St. Vincent, and occupies only a segment of the volcanic cone. Its base stretches along the coast from Carbet to Roche La Perle; its apex is a little to the north of the summit of Pelée; its boundaries are fairly straight, but are apt to be deflected by the irregularities of the surface and the obstruction offered by the projecting ridges to the outward flow of the black cloud near its margin Within this region the desolation varies almost directly with the proximity to the crater. It is complete and total on the upper slopes and in the north end of St. Pierre, but decreases rapidly as traced southwards through the city and along the coast to Carbet. On the west side, Prêcheur is covered with ashes, but it was not swept by the awful blast. The wind constantly floats the fine ash projected from the crater with the rising steam clouds in this direction. The trees are powdered over, the vegetation blighted, the streets paved with dust, but much of this is due, not to the great eruption, but to the subsequent activity of the volcano.

Only about a third part of the mountain has been ravaged by the blast. The north and east sides have hardly suffered, or at any rate the deposit of ash on them was so thin that when we were in Martinique it had mostly been washed away, and the beautiful verdure which characterises that lovely island flourished to all appearance as if no eruption had ever taken place.

The area affected is rather more than one half that which has been blasted in St. Vincent, and the total mass of material ejected by Pelée, may be, perhaps,

* A. LACROIX, "Sur les Roches rejetées par l'Éruption actuelle de la Montagne Pelée," 'Comptes Rendus,' vol. cxxv., p. 453, 1902.

one-tenth of that which the Soufrière has furnished. The great avalanches of dust which fill the Rabaka and Wallibu valleys enormously surpass in magnitude any deposits of the same kind in Martinique, and the general sheet of deposit over the Soufrière is not only larger but probably also five times as deep as that which can be found on Pelée. The dust from the Soufrière fell in Barbados (1,700,000 tons), and all over the sea for 700 miles to the south-east of this.

The cloud which surged from the crater of Pelée had only one outlet. On north and east it was hemmed in by walls of rock; only to the south-west could it find a fissure of escape, and through this it rushed and swept down the slopes on the plain beneath and on the devoted city. It spread out somewhat, and the area it covered is fan-shaped, but all its violence was concentrated in that small space, and the havoc it wrought was fearful in consequence. Probably the force of the hot blast was as great in Martinique as in St. Vincent at equal distances from the point of origin. But in St. Vincent the total energy expended during the great explosion was vastly greater than in Martinique, for the avalanche poured over the whole lip of the great circular crater, though mostly over the notch on the south-west side, and radiated out in all directions from the centre. Still, that the blast in Pelée was so violent, while the amount of material ejected was so small, is one of the most interesting features of the eruptions, and calls for special discussion when we come to consider the mechanism of these discharges.

In St. Vincent no fissures are known to have opened on the hill-sides, no flows of hot mud lava have welled out of the mountain, and there is a complete absence of fumaroles or minor steam emissions, except from the boiling lake within the crater. But in Martinique early in the eruption the rivers began to flow full of muddy water, and on May 5th the Étang Sec broke through its barriers and, discharging into the Rivière Blanche, sent down a torrent of hot mud which buried the Usine Guérin. Fissure formation and hot mud-flows did not end here, they are one of the dominant features of the eruption of Pelée, and some interesting facts regarding them are contained in the Preliminary Report of the French Commissioners.* Along the course of the Rivière Sèche, and in the district between that and the Rivière Blanche, numerous fumaroles have appeared which indicate the presence of a series of fissures in that quarter. They are probably radial in direction, and may be crossed by another series (tangential) on which lie certain fumaroles near the sea-shore. On the north-west side of Montagne Pelée there is, at Ajoupa Bouillon, a fumarole which has poured out large quantities of muddy water, and this may lie on a prolongation of the radial fissures on the south-east side of the crater. They are not characterised by gaping cracks, but rise through the old or new ash deposits, and give evidence of their presence by emanations of steam and sulphuretted hydrogen. Some of them are at a temperature sufficiently high to melt pieces of lead inserted into the orifice.

* MM. A. Lacroix, Rollet de l'Isle & Giraud, "Sur l'Éruption de la Martinique," 'Comptes Rendus,' vol. cxxxv., p. 381, 1902.

Their maximum activity does not coincide closely with the outburst of steam clouds from the crater.

When these fumaroles lie in the course of a stream or in the sea, the water flows into the open tube in periods of quiescence; when, on the other hand, the activity resumes, it is discharged as an overflow of hot mud, alternating with steam puffs and jets of muddy water. To this is due the sudden variations in the volume and the temperature of the streams. As in St. Vincent, the banks of hot ash overlooking the current are subject to frequent landslide, which give rise to ascending steam clouds when they meet the water; and this must not be confounded with the open fumaroles from which steam is also emitted. Professor LACROIX and his colleagues also remark that the large number of dead fishes cast ashore on some days in the Bay of St. Pierre may have been killed by the action of similar fumaroles beneath the sea, along a prolongation of the same fissures, and that the telegraph cable was broken apparently where it crossed this line, and when recovered its insulating material was found to have been melted.

On the north-western side of the mountain also, mud-flows have taken place on a large scale. One has covered the village of Basse Pointe, another flows down to Macouba. Even before the great eruption there were mud currents in some of the streams, and though they may be in part due to the washing action of rains on the ash covered soil, and consequently similar to the muddy rivers of St. Vincent, yet they cannot all be explained in this way. Some are due to the discharge of the crater lakes through fissures, others no doubt to the re-emergence of water which has been engulfed into fumaroles and open cracks, but for a fuller discussion and explanation of their origin and nature we must wait till the detailed reports of the French Commissioners are to hand.

The long preliminary stage of the eruption at Pelée, the scarcity of earthquakes, the development of fissures and of fumaroles, and the extensive flows of mud, together with the more acid nature and more uniform fineness of the ejecta, and the greater strength of the blast in proportion to the small amount of dust deposited, are the main differences which we find in making a comparison of the great eruptions of St. Vincent and Martinique. In all their principal features the two outbursts are parallel, and belong to a clearly-defined and highly-destructive type of volcanic action. These volcanoes are of the explosive class, and in their dust avalanches exhibit one of the most remarkable effects of the expansive power of the superheated steam in an igneous magma. Their fatal violence is owing rather to the physical processes at work and to the form their ejecta assume than to the magnitude of the eruptions themselves, for while that of the Soufrière was really a considerable eruption, and produced notable geological consequences, that of Pelée was comparatively small, and its geological effects are of no great importance, and most of them will disappear within a few months of the cessation of the explosions.

Another and a striking difference between the Soufrière and Pelée is in the manner of their behaviour during the time that has elapsed since their first outburst early in May this year. The Soufrière soon ceased to emit its column of vapour and of ashes, and between the successive eruptions periods of complete tranquillity (except for rumblings and slight earth tremors) have intervened. But Pelée, according to the accounts given us by many who have visited the mountain since the first great outbreak, has never quite discontinued to send out towering steam clouds at more or less regular intervals. When we were in St. Pierre in the early part of July this year, the great gaping rent on the south-west side of the mountain-top would every now and then discharge great puffs of steam which, rising in the air, would expand and become balloon-shaped, their surfaces covered with rounded, swelling convolutions, which rapidly multiplied and incessantly changed their form. They were very similar in appearance to the puffs which rose from the Wallibu in St. Vincent, and as they were sudden, and formed in a second or two, their upper parts soon separated from the stem, and floated off before the steady east-north-east trade wind. As they drifted across the face of the mountain the fine ash fell from them like a thick mist, which veiled the features of slope and scar and ravine. We often compared them to cauliflowers, or to bunches of grapes, and very similar effects may occasionally be noticed where a large locomotive sends one great blast of steam straight up from its funnel. When they leaped into the air, a low, dull rumble might often be heard. They ascended to heights of 4000 or 5000 feet above sea-level before their upward velocity was spent, and their graceful beauty of form, and the play of light and shade on their surfaces, as they ceaselessly expanded and their convolutions swelled and melted into the flattened drifting clouds, which the wind bore with it to leeward, were objects of continual interest and admiration to us. We did not see them carry up stones of any size, nor did they condense as they floated away, for the ash which fell was dry, and there was actually a lack of rain in Prêcheur, in which the falling dust had covered everything with an ashen pall.

One of these clouds would rise every 10 or 20 minutes, for hours at a time, then for an hour or more there would be none, and when the trade-wind cloud which always capped the mountain would lift and clear for a little, we could see with our binoculars the great V-shaped cleft which faces St. Pierre, and out of which welled the deadly blast that razed the city. A sloping scree of enormous angular blocks of rock lay in this gulch. At night a dull red glow is sometimes seen given out by these boulders, for they are intensely hot; and little landslides occasionally took place in them, the material being probably set in motion by the tremors which accompanied the rise of the steam jets.

This talus of great stones was formed, apparently, around the crater, where the ejecta which had been cast up, but had not sufficient velocity to surmount the summit and land on the windward side or in the apical lake (the Étang des Palmistes), would necessarily accumulate. Its formation was plainly due to the greater eruptions, for the smaller jets of steam could add but little to the piles of rock which gathered there. The large size of the boulders showed that most of the finer dust had soared high in the air and travelled far before alighting, and little whiffs of steam rose sometimes from between these stones, and wafted away whatever finer stuff had temporarily landed among them.

These club-shaped steam columns which towered into the air have been seen by all visitors to St. Pierre, and when unusually large, have occasioned much trepidation, and given rise to many baseless rumours of eruptions. According to Professor JAGGAR, they had been visible every day he saw the mountain from that side, but varied a good deal in frequency and in size. They were quite harmless, even to those who were accidentally involved in their edges, and consisted of dry steam, dust, and a little sulphurous acid.

The Eruption of July 9th, 1902.

The night of July 9th was marked by one of the major eruptions of Pelée, and we had the exceptional good fortune to be in St. Pierre that day, and to have a magnificent view of the eruption, while we escaped entirely unscathed.

The morning had been exceedingly fine, and we spent it in St. Pierre examining the ruined city and the cane-fields on the banks of the Rivière des Pères. During the forenoon the mountain was in a state of almost complete quiescence. Hardly a single steam cloud rose from fissures in the Rivière Blanche, and at times the summit of the mountain could be made out rising above the great cleft near the top. To the west it formed a broken cliff, with extraordinary ruggedness, overlooking the old crater of the Lac des Palmistes. As mid-day passed the familiar steam jets appeared again, and in the clear air they were so beautiful, so large, so perfectly formed, that we perforce had to halt in our wanderings through the city and gaze on their varied transformations. Similar clouds of larger size we had seen previously, but never any so uniformly perfect in all their proportions. We had with us a small sail-boat, the "Minerva," of Grenada, of 10 tons register or less, which served as a base for our expedition, and in the afternoon we went aboard and cruised about the bay, sailing down along the coast to Prêcheur, taking photographs of the hill and of the steam clouds, which continued to rise at regular short intervals. Off Prêcheur we put about and stood back close-hauled across the bay. For a time the breeze fell away, but as we drew out from the land the fresh trade wind met us and bore us along to the south end of the anchorage. The perfect afternoon light showed up in deep relief the naked, scarred, and riven surface of the great volcano. As we were half-way across the bay of St. Pierre, about half-past five in the afternoon, the steam clouds, which hitherto had followed one another at short intervals sufficient to allow each to exhibit its perfect form and to pass through the various stages of ascent and expansion before another followed it, began to rise with greater frequency, so that one interfered with the isolated development of that which went before.

We ran down to Carbet, about $1\frac{1}{2}$ miles south of St. Pierre, where we came to anchor on a sandbank a little north of the village. One of us went ashore to make the final arrangements with the porters who were to come on board before dawn next day, and to ascend the hill with us. After purchasing some food he returned, and now the sun was setting behind a dense pall of ashes which hung over the leeward side of the mountain like a dark fog, and over the sea to the westward for a distance of several miles from the mountain. From the fissure in the volcano, clouds of pale slaty vapour rose constantly, and, spreading out, they floated away before the trade wind. We could see that puff followed puff; each could be distinguished, though they followed one another at intervals so brief that as each expanded it melted more or less completely into the streaming cloud mass which swept across the hill. The sun behind this cloud became a pale yellowish or greenish-white disc, easily observable with the naked eye long before it touched the rim of the horizon.

In the rapidly-falling twilight we sat on deck intently watching the activity of the volcano, and calculating the chances of an ascent next morning, when our attention was suddenly attracted to a cloud which was not exactly like any of the steam "cauliflowers" we had hitherto seen. It was globular, with a bulging, nodular surface; at first glance not unlike an ordinary steam jet, but darker in colour, being dark slate approaching black. But in its shape there was nothing very distinctive. Its behaviour, however, was unique. It did not rise in the air, but rested there, poised on the lip of the fissure, for quite a while as it seemed, and retained its shape so long that we could not suppose it to be a mere steam cloud. Evidently it had been emitted with sufficient violence to raise it over the lip of the crater, but it was too heavy to soar up in the air like a mass of vapour, and it lay rolling and spouting on the slopes of the hill. The wind had no power over it, fresh protuberances spurted out from its surface, but it did not drift to leeward any more than if it had been a gigantic boulder. For a little time we stood watching it, and slowly we realised that the cloud was not at rest but was rolling straight down the hill, gradually increasing in size as it came nearer and nearer. We consulted together; it seemed so strange and so unaccountable, but in a minute or two suspicion gave place to certainty. It seemed that the farther the cloud travelled the faster it came, and when we took our eyes off it for a second and then looked back it was nearer and still nearer than before. There was no room for doubt any longer. It was a "black cloud," a dust cloud, and was making directly for us. So with one accord we prepared to get out of its path. We helped the sailors to raise the anchor and, setting the head sails, we slipped away before the wind. By the time the mainsail was hoisted we had time to look back, but now there was a startling change. The cloud had cleared the slopes of the hill. It was immensely larger, but still rounded, globular, with boiling, pillowy surface, pitch black, and through it little streaks of lightning scintillated. It had now reached the north side of the bay, and along its base, where the black mass rested on the water, there was a line of sparkling lightnings that played incessantly.

Soon, however, it seemed to lose its velocity; its surface became less agitated, it formed a great black pall, with larger, less vigorous, more globular, bulging convolutions. Evidently its violence was spent, and it was not to strike us; it lay almost like a dead mass on the surface of the sea.

At first the wind was east and very gentle, a slight tide drew us southward and, as we slipped past Carbet, the church tower shone in the pale moonlight (the moon was in its first quarter and high in the heavens to the south-west), and there was still light to enable us to see the figures of men fleeing south along the cliffs, and we could hear their shouts of terror.

The black cloud rose from the fissure about 20 minutes to 8 o'clock. It took very little time for us to get the sails set, and for 20 or 30 minutes we sailed along with a gentle breeze from the east, every sail drawing, and the houses of Carbet lessening gradually as we sped south. Then the wind fell away, and it was practically a dead calm. In the deepening darkness we kept a close watch on the mountain, and soon the black cloud seemed to clear, for again we could see dimly the distant cloud-capped mass of Pelée, with a faint red glare above the fissure from which the cloud had come. This glare, however, had been seen once or twice during the previous month by various observers. But it slowly increased, and we could see bright, glowing masses describing parabolic paths through the air and then landing on the mountain slopes and rolling down the hill. These were clearly red-hot stones, and they must have been projected about a mile from the crater. The sailors had been often in St. Pierre during the previous three weeks, but they had never seen anything like this before, and it was apparent that the volcanic activity was unusually great.

Suddenly a great yellow or reddish glare lit up the whole cloud mass which veiled the summit. It was like the lights of a great city on the horizon, or the glare over large iron furnaces, as seen from a distance on a dark night reflected from an overhanging mist, but brighter and more yellow. Then from the mountain burst a prolonged angry growl, not a sharp detonation or a series of detonations, such as we had heard just before when the hot stones were launched from the crater, but a long, low, rumbling sound, like the sullen growl of an angry wild beast. It seems strange that this sound should have been heard as far as Barbados, for what struck us about it was not its loudness, but its snarling character.

Then in an instant a red-hot avalanche rose from the cleft in the hillside, and poured over the mountain slopes right down to the sea. It was dull red, and in it were brighter streaks, which we thought were large stones, as they seemed to give off tails of yellow sparks. They bowled along, apparently rebounding when they struck the surface of the ground, but never rising high in the air. The main mass of the avalanche was a darker red, and its surface was billowy like a cascade in a mountain brook. Its velocity was tremendous. The mist and steam on the mountain top did not allow us to see very clearly how the fiery avalanche arose, but we had a perfect view of its course over the lower flanks of the hill, and its glowing undulating surface was clearly seen. Its similarity to an Alpine snow avalanche was complete in all respects, except the temperature of the respective masses. The red glow faded in a minute or two, and in its place we now saw, rushing forward over the sea, a great rounded, boiling cloud, black, and filled with lightnings. It came straight out of the avalanche, of which it was clearly only the lighter and cooler surface, and as it advanced it visibly swelled, getting larger and larger every minute. The moonlight shining on its face showed up the details of its surface. It was a fear-inspiring sight, coming straight over the water directly for us, where we lay with the sails flapping idly as the boat gently rolled on the waves of the sea.

The cloud was black, dense, solid, and opaque, absolutely impenetrable, like a mass of ink. It was globular as seen end on, very perfectly rounded, but covered with innumerable minor excrescences, rounded, and filled with terrific energy. They shot out, swelled, and multiplied till the whole surface seemed boiling; one had hardly time to form before another sprung up at its side; but they were directed mostly to the front and fewer at the margins, so that their effect was that the cloud drove onward without expanding laterally to any great extent. On the whole the resemblance to the rising towering cauliflowers of steam, which soared up from the fissure, was quite striking, only here the cloud lay on the water and sped on horizontally, and its ebony mass was a great contrast to the pale, pearly, ascending steam jets.

The display of lightning in the cloud was marvellous. In rapid flashes, so short that they often seemed mere points, and in larger, branching, crooked lines it continually flickered and scintillated through the whole vast mass. It was often greenish, perhaps, when seen through some slight depth of the dust cloud, at other times yellowish, and always rapid, short-lived—a mere succession of flashing points in the great black wall of cloud. Many of the flashes were horizontal, others shot obliquely from one lobe to another, while along the base, where the black cloud rested on the steel-grey sea, there was a line of sparkling lights, constantly changing, varying in amount but never disappearing. This feature was so pronounced and so apparent at the first glance, that we were at once reminded of the narratives given us by survivors in St. Vincent, in which it was stated that when the black cloud rolled down upon the sea it was filled with fire.

Nearer and nearer it came to where our little boat lay becalmed, right in the path of its murderous violence. We sat and gazed, mute with astonishment and wonder, overwhelmed by the magnificence of the spectacle, which we had heard so much about, and had never hoped to see. In our minds there was little room for terror, so absorbed were we in the terrible grandeur of the scene. But our sailors were in a frenzy of fear, they seized their oars and rowed for their lives, howling with dread every time they looked over their shoulders at the rushing cloud behind us. Their exertions did little good, as the boat was too heavy to row, and fear gave place to despair. But in a minute a slight puff of wind came from the south-east, very gentle, but enough to ripple the water and fill the sails. We had drifted out from the shore, so we gave our boatmen instructions to keep the boat close-hauled, and draw in to the land, as the cloud was passing more to the westward. Then, when we looked at the cloud again; it was changed, it showed no more the boiling, spouting, furious vigour, but the various rounded lobes in its point swelled slowly and to greater size, while fresh ones did not shoot forward, and the mass had a more reposeful and less violent appearance. In the moonlight it was difficult to say how far away it was, but judging by our distance from the shore, we thought it was a mile off, or rather more.

It now lay before us nearly immobile, a gigantic wall, curiously reflecting the moonlight like a pall of black velvet. Its surface was strangely still after the turmoil it had exhibited before, and great black rounded folds hung vertically like those of an enormous curtain. This lasted a few minutes, and the folds became flatter and less convex, and a strange shimmering and change of colour began to steal through the great murky wall, like a transformation scene. It became brownish in places, and in others grey, or even white on the edges of the folds, and through the whole vast face of the cloud these changes gradually spread. Soon it was evident that the base was darker, and the paler summit was rising in the air and soaring obliquely upwards and forwards. The dust was sinking, and the pale steam set free from entanglement with the heavier solid particles, was following its own natural tendency to ascend, while still impelled forwards by the great onward impetus it had received.

The steam cloud crept southward, and was soon directly over our mast-head, travelling with a velocity of perhaps 20 miles an hour. It was grey and tongue-shaped, with a blunt, rounded apex, and at its sides and beneath it there were bars of fleecy white where the moonlight fell upon its thin edges and the lobes which hung beneath it. The mass of the cloud was slaty-grey, and as we looked up at its slightly rounded under surface we could see that still through it the expansive energy of the vapours was working everywhere, and many rounded convolutions were forming especially on its front, though no longer with the rapidity that they had formerly exhibited.

The lightnings were now reduced in number and frequency, but still, in branching tortuous lines, threaded the dark mass in every direction. A low rumbling noise was given out as the cloud worked its way across the clear, starry sky. In a little while it obscured the moon, and the night became very dark. It spread and spread, broadening and elongating till in a great, flattened, rounded mass it covered the whole sky, and in an hour or two only a narrow crescentic belt of stars could be seen away down on the southern horizon. The low rumbling noise continued, and the lightnings, though less numerous, were visible for a long time almost continuously flashing.

As the cloud reached the zenith a hail of pebbles fell in the sea and on our decks. We picked up the first that fell. It was about the size of a chestnut, and was cold to the touch, so we knew that we were safe. Then smaller pellets rattled on our decks, like a rain of peas or small shot. A little afterward the fine grey ash came in little globules moist and adherent, noiselessly sinking through the air and sticking to everything on which they landed. They were not warm, and there was a slight but noticeable smell of sulphurous acid. After a few minutes the ash took the form of a dry powder, which got into our eyes and felt gritty between our fingers.

We had now a little wind, which rose gradually to a fresh breeze, and with many tacks we beat up towards Fort de France, with the lightning flickering still in the sheet of cloud overhead, and the fine ashes on everything that we touched or tasted. It covered the decks, and fell from the sails and the rigging overhead, but there was not much of it. A thin layer, perhaps one-sixteenth of an inch thick, was all we found when daylight broke, and we could ascertain its exact amount. That night dust fell on Fort de France and the whole south end of Martinique, but only in very small quantity.

As we beat up through the darkness to the harbour lights of Fort de France there were loud claps of thunder and bright flashes of lightning in the northern sky. They were quite distinct from the growl of the mountain, the short stabbing lightnings of the black cloud, and the low rumble we had noticed as it passed overhead. We watched them carefully, and thought they were only atmospheric, and the thunderstorm was certainly not all to the north of us, but partly also to the north-east, where there was no possibility it could have been mistaken for an eruption of Pelée. There is a good deal of evidence, however, connecting sudden thunderstorms with eruptions of Pelée and the Soufrière, and we cannot be sure that all the noises were thunder, or that the storm was not in part due to the atmospheric disturbances attendant on the explosion. The thunderstorm broke out about midnight, and by that time the lightnings in the ash-laden cloud overhead were practically over.

The avalanche of hot sand was discharged about 8.20 P.M. In a couple of minutes it had reached the sea, and was over. The second black cloud, which was all that remained of it when the heavier dust had subsided, travelled about 5 miles in six minutes, and very rapidly slowed down, coming to rest and rising from the sea in less than a quarter of an hour. The tongue-shaped steam and dust cloud was over our boat by 8.40. A few minutes after that the ash was falling on our decks.

The second black cloud did not differ in appearance from the first, except that it was larger, had a far greater velocity, and swept out at least twice as far across the sea. It was black from the first moment when we saw its boiling surface in the moonlight. Both travelled very rapidly over the lower part of the mountain, but slowed down after reaching the sea, and came to rest comparatively suddenly. The lightnings on the two clouds were similar in all respects.

No blast struck us—in fact, we were becalmed—and it seemed that when the black cloud ceased the blast was also over. Nor did the sea rage around us as some have described who were overtaken by the dust storm. When the cloud was passing overhead there was a slight rolling sea, but as the breeze freshened the boat steadied, and there was no unusual disturbance. We watched carefully for a strong indraught, such as was described by more than one observer, but the wind that rose from the south-east was very gentle, and increased gradually to a full-sail breeze. There were no reef points in our sails, which were all set, and the boat carried them quite easily.

In the cloud there was a dull, low rumble, but we heard no detonations, and saw no sheet of flame, so that we both agreed that there had been no sudden ignition of quantities of explosive gases. The lights in the cloud, in our opinion, were lightning and nothing else.

No wave was noticed by us other than the slight roll already mentioned. Yet we learned in the morning that a sudden rise of the sea had been observed at Fort de France, and Professor LACROIX * states that on July 9th, as on May 8th, May 20th, May 26th, and June 6th, the dates of the greater eruptions of Pelée up till that time, the sea level oscillated in sympathy with the volcanic outbursts. It was not to be expected that any such disturbance would be very evident on board a boat on the open sea.

On the morning of July 11th we were strolling through the streets of Fort de France photographing the picturesque inhabitants of Martinique and the changing scenes of a tropical city, when a low rumbling sound fell on our ears. We paid little attention to it: it might have been the noise of a heavily-laden cart, or a military wagon passing along the roads, but in a minute or two we noticed that the people were gathering in clusters on the pavement, gazing up in the northern sky and exclaiming, "La montagne! La montagne!" We raised our eyes, and there against the background of blue sky a long, narrow, tongue-shaped cloud, fleecy white, with rolling, boiling, globular protuberances continually forming at its apex, was working its way upwards and southwards in the clear morning air.

That morning on Pelée a small outburst had taken place, following the larger eruption of July 9th after the lapse of a period of about 36 hours, just as in St. Vincent the small eruption of the morning of May 9th followed the great explosion of the afternoon of the 7th. For some days thereafter the mountain was in a restless, unquiet condition, and on the morning of Sunday, the 13th, there was a fall of very fine grey dust in Dominica after another eruption, which must have occurred about midnight on the previous night. About 6 A.M. a very fine powdery matter could be seen floating on the air and resting on the glossy leaves of the plants in the gardens. When gathered and examined microscopically it proved to be undoubtedly dust from Pelée. We made inquiries, and learned that an explosion had taken place in Martinique about six hours before. The path the dust had followed had been a very indirect one. It had been projected southward as usual, had risen into the anti-trade region and been floated away to the east-north-east, then sinking into the lower strata of the air had been borne northward to Dominica

* MM. A. LACROIX, ROLLET DE L'ISLE & GIRAUD, "Sur l'Éruption de la Martinique," 'Comptes Rendus,' vol. cxxv., p. 390, 1902.

by a gentle south-east brease which was blowing that morning, so that in making the journey from St. Pierre to Rozeau, which are only 20 miles apart in a direct line, it must have travelled at least thrice as far through the air, and had taken about six hours to cover the distance.

We left Fort de France on the afternoon of July 11th, and on our way to Dominica we had a good opportunity of seeing the general effects of the eruptions of the 9th and of the 11th. Captain BARRETT, of the R.M.S. "Yare," most kindly took his ship right up into St. Pierre Bay, and round the shore as close as was possible. Evidently the avalanche had come down approximately along the line of the Rivière Sèche, for all over that part of the mountain there was a layer of fresh, pale-grey dust covering the black surface of the older ash. The effect was not unlike that of a fall of snow, but, of course, the country was treeless and perfectly bare. The grey dust was blowing over the surface in little clouds, stirred up by the wind, and the rivers were flowing down through their channels hot and steaming. We thought that there was more ash in the valleys than had been there on the afternoon of the 9th, when last we sailed along that shore, but as we had never landed there it was not possible for us to be certain. Evidently the total amount of matter ejected had not been large, only sufficient to add a thin additional layer to the older deposits, but not enough to dam up the valleys or make any essential difference in the surface features.

A COMPARATIVE STUDY OF THE PELÉAN TYPE OF ERUPTION.

The attention of mankind has this year been powerfully directed to the effects produced by eruptions of a type which hitherto has not been known to exist, and which differs from other more customary kinds of volcanic action in several important respects. As the catastrophe by which, in the month of May, 1902, the city of St. Pierre was erased from the map of the world will remain to all time a witness to the violence with which these eruptions are attended, we propose to adopt the term "A Peléan Eruption" to designate this group of phenomena. The earliest historic instance of such eruptions is that of St. Vincent, in 1812, which, as we have already shown, was clearly accompanied by the discharge of vast masses of hot sand and stones into the valleys of Wallibu, Larikai, and Rabaka. It is probable, but it is not certain, that the eruption of the same volcano in 1718 was also of this nature.

Eruptions of the Peléan type are distinguished by the occurrence of one or more discharges of incandescent sand, which rush down the slopes of the mountain in the form of a hot-sand avalanche, accompanied by a great black cloud of gases charged with hot dust, which sweeps over the country with a very high velocity, mowing down everything in its path. All living beings within the zone nearest the crater are killed; all plants reduced to charred and broken stumps. At greater distances men and animals are scorched by hot sand or mud; plants are burnt, eroded, and stripped of leaves and branches; but beyond the limits covered by the great black cloud no effects are produced, other than those consequent on the rain of ashes which precedes or follows the avalanche. Except for the dust avalanche, there is nothing unusual about these eruptions. They have, indeed, many points in common with those of volcanoes of the ordinary explosive type, to a sub-group of which they evidently belong.

It is possible for us at the present time only to compare the history of the different outbursts of Pelée and the Soufrière in order to ascertain what features they have in common which are distinct from those of other eruptions, and to form a general idea as to what are the stages of their action, and what variations are possible in the type they represent. Even for this purpose the data are not yet so full and exact as we hope they ultimately will be, when the various scientific men who are engaged in the study of these volcanoes at this moment have completed their labours, and given the world the results of their investigations. But sufficient is known already to enable us to formulate certain preliminary conclusions and working hypotheses.

We will avail ourselves, in the first place, of the results of our own observations in St. Vincent and Martinique, and of our experiences during the eruption of Pelée on July 9th, 1902. But the Reports of the Commissioners appointed by the French Academy of Sciences, and of the various parties of American scientific men, already quoted by us, have furnished many additional facts of importance, and not a few theoretical suggestions, which we shall be able in some cases to adopt as in accordance with the opinions we have been led to form by our own investigations. It is only by the collection of a large body of facts from authentic sources, well and carefully sifted, that this new branch of the science of volcanology will ultimately be established on a secure basis, and its results and conclusions entitled to the confidence of scientific men.

The Stages of the Eruptions.

We have in a Peléan eruption certain distinct stages to recognise and describe. They may be classified as follows:—

1. The premonitory symptoms which herald the volcanic outbreak, but are attended by no actual emissions from the volcano.
2. The preliminary stages, in which activity has been resumed and discharges are produced from the crater. Their violence increases more or less rapidly, and they lead up to—
3. The climax ot the eruption, which is manifested by the appearance of the avalanche of incandescent sand and the passage of the great black cloud.
4. The concluding stages, during which the volcano sinks into more or less complete repose.

These stages must be admitted to be more or less artificial and arbitrary. In some of the eruptions they can all be recognised as distinct, in others there is a tendency for one or more to become inconspicuous or disappear, while occasionally the preliminary stages of one eruption are continuous with the closing stages of another. We have adopted them as convenient rather than as necessary, and as affording merely an easy and simple method of classifying the observed facts.

1. The premonitory symptoms of the eruptions have been very noticeable at St. Vincent, and much less obvious in Martinique. They consist of numerous earthquakes, not so violent as to damage houses, but so frequent as to awaken apprehension. They have on more than one occasion been observed for a year before the outbreak. That was the case before the eruption of 1902, and also, according to HUMBOLDT, before that of 1812.* Before the eruption of 1718,† earthquakes were frequent during the previous month. They have invariably been most violent around the base of the volcanic cone, especially on the west and east sides, and have never been conspicuous in Chateaubelair and Georgetown. They are not known to have taken place before the eruption of May 18th, but in that case the area over which they are felt had been completely evacuated. When the throat of the crater has been recently cleared by a previous eruption they are never so violent as after a long period of quiescence, when the passages are occupied by masses of solid rock.

At Martinique the first indications of activity in April, 1902, were the increased action at the Soufrière, the emission of steam from the summit crater, the formation of lakes of boiling mud, and the fall of fine ashes on the surrounding country. Since the first great eruption that destroyed St. Pierre the subsequent outbursts have given little or no warning. Earthquakes have not been at all numerous in Martinique, either before or during these eruptions.

2. *The Preliminary Stages.*—In their duration, their violence, and the constancy of their occurrence, these vary as much as do the premonitory symptoms. They consist of the emission of steam in increasing volumes from the crater, with fine, ashy dust, small lapilli, and fragments of rock from the crater walls, the discharge of the crater lakes as torrents of water or of hot mud, with loud detonating noises, and in some cases numerous earthquakes accompanying the explosions. In Martinique the earthquakes were few and attracted little attention, but fissures were opened in the flanks of the volcano, and through these the crater lakes discharged, steam arose from many fumaroles, and the rivers were augmented by flows of boiling mud. In St. Vincent no fumaroles and no fissures are recorded, there was apparently no change in the temperature or volume of the springs, the crater lakes were driven over the lip of the depression, and the fall of ashes around the volcano was quite inconsiderable. In Martinique the preliminary stages of the great eruption were prolonged over a period of two weeks. Ash fell steadily on the leeward slopes of the mountain during that time. In St. Vincent, in 1812, the preliminary stages occupied

* HUMBOLDT'S 'Personal Narrative,' English translation by WILLIAMS, vol. ii., p. 226. See also anonymous narrative cited above, p. 463.

† DEFOE'S 'Narrative,' cited above, p. 456.

three or four days, and were on the whole similar to those witnessed on Pelée during the present year, except that fissures were not formed, and no flows of hot mud are spoken of in the accounts. This year the preliminary stages of the eruption of the Soufrière lasted only for a little more than 24 hours.

When one eruption follows another after a brief lapse of time the preliminary symptoms may be indistinguishable from the closing phases of the previous outbreak. This was the case on the Soufrière on May 9th, and on Pelée on July 9th there was nothing, except a slight increase in the amount of steam discharged, to give warning of the approaching outburst of the avalanche of incandescent dust. Equally sudden was the eruption of May 18th at the Soufrière, of which no symptoms were visible at nightfall—about 7 o'clock—yet at 8.30 an immense cloud of steam suddenly towered into the air, with vivid lightnings and loud detonations.

The only danger during these preliminary stages is the suddenness of the mud lavas that may flow down the valleys, burying the houses on their banks, as happened at the Usine Guérin near St. Pierre this year. Even the vegetation of the hill, though covered with fine dust, suffers very slightly, and a few showers of rain will remove all the ashes and restore the beauty of the foliage. In Martinique, and also in St. Vincent, it is possible that heavy falls of rain took place on the higher parts of that mountain during the earlier outbursts of steam, but these were local and did no real damage.

3. *The Climax and Descent of the Black Cloud.*—The preliminary stages gradually or suddenly pass into the culminating phases of the eruption. The great black cloud wells out of the crater and rushes down the slopes, obliterating all trace of vegetation, annihilating every living thing in its path, and leaving behind it a desert of ashes. Its appearance is usually terribly sudden; a few minutes previously the volcano may have been emitting only a little steam and fine dust, perhaps more than usual, but not enough to awaken any general alarm.

On the morning of May 8th the "Roddam" had just dropped her anchor; the sailors were leaning against the bulwarks, watching the great column of grey smoke which rose from the volcano, while the fine dust was gently falling on city and harbour. "Then came a sudden roar that shook the earth and the sea. The mountain uplifted, blew out, was rent in twain from top to bottom. From the vast chasm there belched up high into the sky a column of belching flame, and a great black pillar of cloud. That was all—just the one big roar of the shattering explosion, one flare, and then the cloud, shooting out from the rent, rushing down the mountain side on to the doomed city." *

It will be seen that in Martinique little warning was given, and the residents in St. Pierre were uneasy, but not madly excited. Things looked no worse than they had done often during the previous five days. It was the feast of the Ascension, and many were hurrying to church. So sudden, so unexpected, was the great

* Captain FREEMAN, "The Doom of St. Pierre," 'Pearson's Magazine,' September, 1902, p 316.

catastrophe, that death overtook most of the inhabitants before they knew what had happened.

It was otherwise in St. Vincent on the previous afternoon. For an hour or more the mountain had laboured and groaned, quivering in the throes of the eruption, great explosions followed one another at comparatively short intervals, the enormous steam cloud got larger and larger, the violence of its ascent more and more terrible, the lightnings flashed, and loud crashing noises burst on the ears of the observers. Yet after all the climax came suddenly. There was an "enormously increased activity over the whole area," * and with a terrific noise the great black cloud surged from the crater, and in one torrent poured down upon the valleys and right out to sea.

Captain CALDER was of opinion that the cloud ascended in the air and then curled over and came down the mountain slopes exactly in the same way as some have described the fatal blast in Martinique:—"As the top of the stupendous cloud bent over toward our little village the weird fascination gave place to a feeling of impending doom. It was vividly apparent that in a very short space of time this dust-charged pall of sulphurous smoke must envelop the district for miles."†

The eruption of Pelée on May 24th was seen by Professor HILL. He describes it in the following words‡:—

"Stepping out of the door I saw before me a perfect tropical night. Not a cloud obscured the starlit firmament. Suddenly, to the north and above Pelée, there was a dim flare of light like the sheet-lightning of a summer storm. This was the reflection of the incandescent molten mass within. Following this a great spherical cloud, with hundreds of boiling and seething convolutions, slowly rose above the vent. It had hardly appeared before it was followed by a blinding flash of light, like a great gun flash, from the mouth of the crater, accompanied by long, deep-pitched detonations from the bosom of the mountain. Over the crater's rim followed a fountain shower of incandescent pumice, which looked like molten fire. Hardly had the cloud-ball reached the air when around and through it flashed a thousand lightning-like streaks, with here and there great balls of fire. While standing in mute amazement observing this phenomenon at the apparently safe distance of some 3 miles, I was horrified to see the cloud fall suddenly, flatten, and float out horizontally into the sky like an aerial river directly toward and above me—a ribbon of inky blackness, and coming slowly, yet so fast that it was easy for me to see that it was not to be escaped by running."

According to Professor HILL's statements it would appear that the black cloud floated out horizontally in the air. If so it cannot have been of the same nature as those we saw on July 9th or that of May 8th, for these flowed along the ground. But in this case also it came suddenly with a loud noise and a bright light from the crater. The "fountain shower of incandescent pumice" was the avalanche of red-hot ashes, which, as a rule, is visible only after dark.

* Mr. T. M. McDONALD'S Diary, 'Sentry' Newspaper, Kingstown, St. Vincent, May, 1902.

† 'Century Magazine,' vol. lxiv., p. 636, 1902.

‡ 'Century Magazine,' September, 1902, vol. lxiv., p. 778.

On July 9th, when we were off Carbet, there were two black clouds. It was obvious before the first emerged that activity was increasing, but not in our opinion to a dangerous degree. The first cloud welled out quietly in the twilight, and was quite a small affair. It was black from the first—a surging, foaming, boiling mass. Slowly it gathered speed, and came rushing along. The second was much larger, and in the darkness we could see that with it there was a glowing avalanche of red-hot dust. It came down with far higher velocity, but, like the other, slowed down rapidly when it reached the sea. With the first we heard no noise, with the second there was a loud angry growl. Both were full of lightnings, and in the features of their surface so like that no essential difference could be distinguished between them.

It is in all cases difficult to learn what happens after the great black cloud has passed. Not many survive that experience, and the terrible shock they receive unfits them, as a rule, for making exact observations of what is going on around them. But there are a few both in St. Vincent and in Martinique who have passed through that ordeal of fire, and their recollections of what followed are interesting, and at any rate worth placing on record.

In the Carib Country of St. Vincent, as already described, the hot wave lasted a few minutes, perhaps at most two or three. The darkness was absolute at first, but cleared slowly till it was possible to make one's way about in the open air, but not within the homes. The mountain continued to thunder and roar; hot stones fell through the air; there was a strong smell of sulphurous acid, and the fine, dry dust irritated the eyes and throat. Apparently there was no rain, and no second visitation by the dread and deadly cloud, but great explosions of steam were taking place within the crater, and forcing into the air quantities of dust, stones, scoria, and bombs, which fell in a continuous hail on all the country round. The mountain was veiled in clouds of ashes and vapour, and no one on the island could see what was taking place there till the morning of the next day. But the noises, the rocking of the ground, the continuous fall of stones and ashes, exactly resemble the features of eruptions of the usual type in which the explosive violence of the steam within the magma acts mostly in an upward direction.

This is also true of the later eruptions of the Soufrière during May of this year. For hours the mountain roared, and stones and dust fell through the air, landing with great force. But there was no second outburst of the black cloud, and nothing which can be regarded as in any way unusual in an explosive volcano. Having delivered itself of the avalanche of dust, the volcano settles down to spout its gigantic column of vapour into the air, sending up with it great quantities of fine dust and hot stones, and this goes on till the subterranean forces are exhausted, and a period of quiescence, or, at least greatly reduced activity, ensues.

At St. Pierre hardly one was left to tell the tale of destruction, and those whose lives were spared were so busy in taking measures to relieve pain and escape from the fatal harbour that they had little time to attend to the scientific phenomena. But from the narratives of Captain FREEMAN and Mr. ELLERY SCOTT, we can glean a few particulars as to what happened during the time they spent before the city. The great cloud passed in a few minutes, and the air cleared sufficiently to enable them to see the burning streets and the inhabitants fleeing hither and thither, stricken to death with wounds and burns. No second incursion of that destroying cloud swept over them. The air was thick with dust, hot stones were falling freely, and the mountain boomed in the distance. At times the darkness lifted a little, till they could make out more clearly the details of the awful scene on shore.* Working backward and forward to free his steering gear from the dust with which it was jammed, the captain of the "Roddam" had still light to see the land and to avoid collision with the wrecked and burning ships which strewed the bay. The "Roraima" was ablaze; most of the crew and passengers were dead; she lay a helpless, burning hulk, but those who were alive took steps to put out the flames, and were at least able to keep them in check till 3 o'clock in the afternoon, when the French cruiser "Suchet" came in and took them off. This was about seven hours after the great explosion, and it seems that at Pelée the period of comparative quiescence followed much sooner than at St. Vincent, where the noises and the rain of stones continued for 12 or 15 hours.

The later stages of the eruption of May 26th are not recorded by Professor HILL, and on July 9th we could not say exactly what followed the descent of the red-hot avalanche and the black cloud, for the mountain was concealed in a mass of dust and vapours, and we were gradually increasing our distance from it. But we believe that on that night the activity was short-lived, and soon came to an end.

4. *The Concluding Stages.*—The concluding phases of these eruptions are in most respects similar to the preliminary stages, except that the activity is now constantly decreasing. Steam rises from the crater in rolling, expanding clouds, densely charged with fine dust, which gives them a slaty-grey colour. The Soufrière relapsed into complete inactivity in seven or eight days, to break out again after a week's repose. Montagne Pelée has continued, between the greater outbursts, to send out, more or less frequently, the cauliflower steam clouds which well from the fissure in its side. In other respects the two mountains have behaved in much the same way when the period of waning violence arrived. Each day they have been less active than on the previous one, with occasional rare and temporary exceptions, on which the discharges increased for a few hours to again diminish more rapidly than before.

In St. Vincent the eruption of May 7th was followed by that of the 9th, without any intervening cessation; between that of the 9th and that of the 18th there was a considerable pause. After the eruption of the 8th at Pelée came that of the 20th, and then that of May 26th. On June 6th another took place, and thereafter for a

* Professor LACROIX and his colleagues state that the sky cleared in one hour after the passage of the black cloud. "Sur l'Éruption de la Martinique," 'Comptes Rendus,' vol. cxxxv., p. 425.

month there was no great outburst. It is true that several have been recorded both from St. Vincent and from Martinique on other dates, but in the former case they were false, and in the latter we have good reason for believing they were trivial, or did not occur at all. So excitable is the population after the terrible events of this spring, and so willing are the newspapers to publish sensational news without inquiring as to its veracity, that many eruptions have been reported which never happened. On Pelée there was an outbreak on July 9th, and two minor ones on the 11th and the 13th, and between these dates the smaller steam clouds were frequently emitted, though for hours at a time none might be seen, and as on the afternoon of the 11th, when we passed along the base of the mountain, there might be nothing to indicate its deadly virulence except the hot water in the streams, and the thin coating of fine, pale-grey ashes which had been scattered over its surface that very morning.

The Avalanche of Sand and the great Black Cloud.

A synthetic study of the features of these remarkable discharges, so far as they are known to us from our own observations and those of eye-witnesses on whom we can rely, involves the discussion of many matters which are more or less theoretical; and we have, in consequence, thought it best to separate this part of our Report from the previous chapters in which we describe what we and others have seen, referring only indirectly to the underlying causes.

All witnesses agree that the great black cloud consists of dust, stones, and gases at a very high temperature, and moving with a great rapidity. But as yet it is impossible to give a complete description of its properties, though sufficient evidence is available to enable us to consider its outstanding features and to justify an attempt to explain them.

The Beginning of the Blast.—We have ourselves observed one of the black clouds emerge from the crater and come rushing down the hill, and have already described what we saw on that occasion. The evening of July 9th was perfectly clear, and the mouth of the fissure, on the south-west side of Pelée, was clearly visible from where we were anchored, a little north of Carbet. The little black cloud ball rose from the crater and rested on the lip, tumbling and seething; it lay there for a little time, then began to travel down the hill, at first slowly, then faster and faster, till it rushed down the lower slopes with a velocity which must have approached 100 miles an hour.

Others have seen the black cloud rise from the fissure, but their descriptions do not entirely agree with ours. Several describe it as rising in the air a considerable distance and then curving downwards as if it overbalanced itself. It is probable that in the larger outbursts a considerable mass of dust is projected up into the air; and as this black cloud is too heavy to ascend or to be wafted away by the wind, when its upward energy is spent it sinks to the ground, owing to its own weight, and then flows down the hill. But if we consider the great eruption of the Soufrière and the enormous amount of hot dust which was then shot into the valleys, it seems quite unlikely that more than a small fraction of this was elevated to any great height above the crater. The bulk of the material must have swept down in a river of hot sand, though over it a lighter cloud would form, consisting mostly of hot gases densely charged with dust.

All witnesses, however, agree that the outburst appears in the form of a cloud, which rises to a certain height, and then flows over the surface of the ground. None have seen it in the form of a fluid molten lava. Professor HILL describes the black cloud of May 26th as floating out horizontally in the air, but in this respect that eruption differs entirely from all the others.

The mixture of dust and gases is so heavy that it courses down the slopes like a torrent in a river, clinging to all the valley bottoms, ever availing itself of the steepest descents, and deflected by the projections and irregularities of the ground. That it does so we are convinced, not only from our own observations of its effects on the Soufrière and in St. Pierre, but also from what we saw on the night of July 9th. The black cloud poured down the hill like a torrent of inky water, except that it spread out, expanded, and its upper surface rose slowly in the air as it advanced. This explains also why the great mass of the ejecta at the Soufrière came down the south side of the hill, where the crater rim is lowest, while the north side was spared, as the Somma wall protected it.

That a mixture of gases and dust should behave in this way is certainly remarkable, but similar phenomena are to be observed in connection with even the minor steam jets emitted by Montagne Pelée. Professor LACROIX and his colleagues describe: * "Waves of dense vapour, heavy, dark coloured, often coppery, which roll over the external taluses of the crater, and down to the bottom of the fissures in the region of the Rivière Blanche. They are probably puffs of gas and steam very richly charged with ashes." It is, moreover, not uncommon, when a steam cloud larger than usual has been ejected, to see its lower part dark, heavy, and laden with dust, rolling over the surface of the ground, while its summit of pure white steam steadily mounts into the air.

In considering this property of perfect fluidity, which the black cloud possesses, we must remember its origin. Within the crater it was a molten magma, in which a considerable number of small crystals floated in a liquid which contained enormous quantities of occluded steam. As it rose in the throat of the volcano the relief of pressure allowed the gases to expand, and to free themselves from the liquid in which they were held. Sooner or later the cohesion of the liquid was overcome, and from a spongy froth the mass changed to a cloud of particles, mostly solid, but, perhaps, in

* MM. A. LACROIX, ROLLET DE L'ISLE & GIRAUD, "Sur l'Éruption de la Martinique," 'Comptes Rendus,' vol. cxxxv., p. 380. *See* also vol. cxxxv., p. 426.

some part liquid, each surrounded on all sides by films of expanding gases, and thus the mixture of the ingredients from the first was perfect. Around each grain of dust there was a film of gases ready to expand enormously when the mass reached the upper air.

The amount of expansion of which these gases are capable is so great as to be almost incredible. The small black ball of cloud, which we saw emerge on July 9th, in a few minutes was a great black mass, which covered more than a square mile, and the white steam, which shoots upwards in the air when the cloud is dead, is still actively expanding at a great rate. This leads us to wonder whether, when the cloud emerges, it may not be partly at least composed of molten droplets, which, when they cool and pass into the solid condition as the cloud rolls on, give out gases which, till then, had been physically occluded or absorbed in the liquid. The mere pressure within the crater would almost seem insufficient to compress so great a volume of gas into so small a space, especially when we remember the very high temperature of the mass.

As this turbulent mixture of expanding gases and fine dust pours down the surface of the mountain, the small, solid grains are unable, at first, to rest on the ground, even when they may have sunk to the base of the cloud, and they are swept up again, and borne along till they reach some sheltered hollow, or the violence of the expansive forces lessens and the turmoil diminishes.

As noted by Professor LACROIX and his colleagues,* the cloud cools more rapidly when it passes over the sea than over the land, as witness the more complete destruction of the south end of St. Pierre than of the "Roraima" and other ships, which were lying off the shore. The explanation is simple: when the hot dust falls on the sea it can rise no more. The sea also, owing to its higher specific heat, rises more slowly in temperature than the land surface, and, though it may be raised to boiling point, it cannot exceed this. There is no such limit to the possible temperature of dry, bare earth. By the trapping of the dust and the cooling of the gases in contact with the water the cloud soon loses its heat, and with that its power of buoying up the solid matter it contains.

The temperature of the magma, when it rises within the crater, can be fixed within certain limits, though these are not very precise. We know that it was bright red hot, for all who have seen it at night have described it as incandescent. When the cloud struck the north end of St. Pierre the dust was hot enough to set fire to combustible articles, but did not fuse the copper wires of the telephone apparatus, or melt objects of brass or tin. And in the liquid within the crater were floating crystals of hypersthene and plagioclase felspar in great abundance, and in such perfection of crystalline form as to indicate that they had formed by crystallization out of a cooling molten mass. Professor JOLY gives the melting point of labradorite

* "Sur l'Éruption de la Martinique," 'Comptes Rendus,' vol. cxxxv., p. 424.

as 1229° C.,* but this, of course, is in the dry condition and under atmospheric pressure, not in a magma saturated with steam.

The velocity of the black cloud is different in different parts of its course. So far as our observations go it is comparatively low at first, and increases as it sweeps down the hill till it is probably at a maximum just before it reaches the plains beneath, or the sea. Then it again diminishes, and rapidly slows down, as is well seen in St. Vincent by its effects on the trees. We have compared its violence to that of a hurricane or tornado, but in many ways the comparison does not hold good. For equal velocities the destructive effects of the dust cloud must have been considerably greater than that of any wind, for the weight of the mass, or rather its momentum, is high, owing to the density of the mixture of gases and of dust. This is much heavier than air, and flows along the ground, but lighter than water, on which it always floats.

There are a few facts which seem to show that the mere weight of the cloud did much damage, as, for example, that the hatches of the "Roraima" were stove in.† We looked in St. Vincent for similar effects, but found none, even on Lot 14, which was nearest the crater. The roofs had in some cases collapsed, probably with the weight of ashes which gathered through the night. Many windows were broken, apparently by falling stones, as in Georgetown. There was no evidence that a great aerial shock, such as follows an explosion or the discharge of large guns, had broken the windows, though, as it was about mid-day, they were probably open, and may have escaped in consequence.

Professor LACROIX and his colleagues‡ consider that the blast which destroyed St. Pierre covered a distance of 8 kilometres in three minutes. No very good evidence is available on which to base exact estimates. When the blast passed over the north end of the town it was travelling with a velocity certainly over 100 miles an hour, but before it got to the Morne d'Orange, at the south end, it had considerably slowed.

The fundamental question remains to be discussed—What is the source of the energy which drives the cloud along? To this we believe there is only one answer—The motive power is supplied by the weight of the mass. It is in a condition comparable to that of a heavy and mobile fluid which has been elevated by the volcanic forces and poised on the edge of the crater, and proceeds to flow downward in obedience to the law of gravitation. This is, to our minds, the only conceivable explanation of what we saw on the evening of July 9th. The little black cloud rose from the crater exactly like a puff of steam, but lower and more globular. It did not

* The melting point of hypersthene has not been ascertained, but that of enstatite, a less ferriferous rhombic pyroxene, is given as 1295° C. The melting point of different kinds of monoclinic pyroxenes ranges between 1187° C. and 1300° C.

† 'Cosmopolitan,' July, 1902, p. 250.

‡ "Sur l'Éruption de la Martinique," 'Comptes Rendus,' vol. cxxxv., p. 425, 1902.

start its rush down the slopes at once, but rolled and tumbled, squirted and seethed, for quite a perceptible time. Then it began to move with greater and greater speed down the hillside. Faster and faster it came till it struck the sea, when its velocity began to diminish, at first slowly, then more and more rapidly. It was like a toboggan on a snow slide. It was not the blast of a gun, it was the rush of an avalanche. Gravity did the work and supplied the energy. There was no explosion; had there been any, we would certainly have seen it. The lightnings were visible only when the cloud came near.

Like an avalanche, it drives the air before it and parts it on each side. In the statements of Captain FREEMAN and Mr. SCOTT there is the clearest evidence that the blast struck the vessels and heeled them over before the hot dust began to fall*:—"On a sudden he (Captain FREEMAN) heard a tremendous noise, as though the entire land had parted asunder. Simultaneous with the noise there was a great rush of wind, which immediately agitated the sea, and tossed the shipping to and fro. He rushed out of the chart-room, and, looking over the town and across the hills, he saw a sight he cannot describe. He remembers calling out to Mr. Campbell and saying, 'Look!'—and then an avalanche of lava was upon them."

But these discharges are not mere avalanches; they are more, for they have properties unlike those of avalanches, and by means of which they approach more closely to blasts. In an ordinary avalanche the gases are more or less accidentally involved, and form only a small part of the whole mass. They are compressed by the weight of the moving solid mass, and when that pressure is relieved they expand again.

But here their presence is essential; they are an original part of the mass, and without them there would be no flow. They are expanding, surging of their own inherent energy, and lift the dust and sweep it along, while the dust in turn fetters them and compels them to keep to the surface of the ground.

The dust avalanches, or blasts emitted by these two volcanoes during the recent eruptions, though essentially similar, show minor points of difference. The first discharges have been in both cases those which contained most solid matter. In particular, the great avalanche which blocked the Wallibu and Rabaka Valleys in St. Vincent on May 7th must have consisted to so great an extent of red-hot sand that it may best be pictured as rivers of dust and stones flowing down from the crater. But before the main avalanche, and on each side of it, a great black cloud swept over the country; it consisted mostly of gases, though laden with hot dust, and resembled a hot blast far more than an avalanche.

On Montagne Pelée also the first eruption probably sent out more solid matter than any of the others, and was consequently more like an avalanche than those which succeeded it.

* Blue Book: "Correspondence relating to the Volcanic Eruptions in St. Vincent and Martinique in May, 1902," p. 45.

It will be understood also that, as a rule, the greater the mass of material ejected the farther the avalanche travels, and the greater is the black cloud which accompanies it. On July 9th the first black cloud was small, and soon came to rest; the second was much larger, and nearly overwhelmed us. Of course, we could not say what was the absolute velocity of either at any point in its course, but certainly the second rushed out twice as far as the first across the bay.

Probably the mass is never homogeneous throughout at any point after it has left the crater. The heavier solid ingredients must gradually sink to the bottom and flow over the ground, while the lighter gases will tend to rise to the surface and to dilate laterally. Thus from an early period in its history the cloud will have a heavy base, in which the solid particles preponderate, and an upper part lighter, and relatively richer in gases. The black cloud covers and envelopes a hot avalanche. The surface and sides of the mass are in contact with the air, mix with it, and are cooled. Hence those towards whom the cloud is coming may see a black advancing front, while when encircled by it they find it incandescent and red hot. That must have been the case with the unfortunate inhabitants of the north end of St. Pierre.

When we keep in mind the composite nature of these discharges, it becomes possible for us in some measure to understand the peculiar properties they possess at different points in their course and in different stages of their development. When they rise from the crater the gases are in a condition of indescribable turmoil, and buoy up the vast quantity of hot sand they bear with them. Each solid particle is cushioned on gases violently expanding, and the temperature of the whole mass is exceedingly high. Hence it seems quite probable that the black cloud rushes upwards, and may even shoot some distance into the air and fall back upon the slopes of the mountain when its first impulse is spent and its first heat has cooled. We may, at any rate, believe that the whole mass has then a mobility which it no longer possesses, when, by the expansion of the gases, by mixture with the air and by contact with the ground, its temperature has been lowered, and the solid matter is beginning to segregate from the gaseous, each taking its own course.

Some such explanation is required to account for the manner in which the upper part of the black cloud of May 7th surged over the Somma wall which overlooks the crater of the Soufrière, and poured down the north side of the mountain. The same cloud in the lower part of the valleys of the Wallibu and Rabaka Rivers was deflected by even comparatively slight ridges, and clung helplessly to the bottoms of the ravines—that is to say, its lower and heavier part flowed over the ground, for there is good evidence that above this there was an enormous mass of black, dust-laden vapours which filled the whole mountain valley between the Soufrière and Morne Garu, cutting down and sand-blasting the growing trees, though the mass of sand it left behind was comparatively small.

We have said that the blast which levelled the walls of the stone-built houses of St. Pierre was about as vigorous as that of the Soufrière at equal distances from the crater, while the amount of solid matter discharged was very much smaller. Several possible explanations of this offer themselves. It may be that the velocity of the blast is greatest at that point where the slope of the hill gives place to the plain beneath, and the city stood exactly in that situation. It is more probable, however, that the avalanches of Pelée are of a more mobile and fluid character than those of the Soufrière, and hence acquire a greater velocity, and this must be a consequence of the slightly different proportions of gaseous and of solid matter which they contain. To judge by the crystalline state of the dust, as revealed by the microscope, there can have been no very great difference in the temperatures of the two magmas at the time when they were shivered into dust. That of Pelée contains rather more amorphous, glassy matter, and may have been slightly the hotter of the two, but not to any great degree. We may suppose that the percentage of gases in the dust cloud of Pelée was greater than in that of the Soufrière, the temperature at least equally high, the interfusion and admixture of the components equally perfect. The one may be compared to a heavy fluid, extremely mobile, the other to one still heavier, but more viscous. It would seem that in these circumstances, as the slopes down which they sped were about equally steep, the former would acquire a greater velocity after a certain specified period, or after covering a certain distance from the crater. It must also be kept in mind that the avalanche emitted by Montagne Pelée on May 8th was confined to a very limited space, and that the north end of St. Pierre stands, apparently, not far from the centre of its path.

This brings into prominence one property in which these discharges differ from ordinary avalanches. They have, in virtue of the expanding gases with which they are permeated, the power of moving down slopes much gentler than those on which an avalanche could start. The sides of Pelée and the Soufrière have an average inclination of 12 to 15 degrees, if we neglect the deep, steep-sided ravines with which they are seamed, and no avalanche, even of fine snow, would move on such gentle gradients. Had the hot sand been piled up there it would have rested peaceably; without the surging gases intermingled with the solid particles there would have been no motion. It is not correct to regard these cataracts of sand as mere avalanches; the idea of a blast is also essential, if we are to form a proper conception of the mechanism in operation.

Several other explanations have been advanced to account for the manner in which the deadly cloud of the Peléan eruption sweeps over the ground, but does not ascend in the air like the ordinary steam clouds with which all geologists are familiar in volcanic outbursts. One of these we may call the hypothesis of oblique discharges, the other the explosion hypothesis. It has also been hinted that electricity is responsible in some way or other for the devastation, but we are not aware that anyone has as yet formulated any workable hypothesis on this basis.

The great V-shaped fissure which looks down on St. Pierre from near the summit of Pelée is undoubtedly responsible, by its disposition and conformation, for the course which the discharges take as they sweep down the mountain. The avalanche of dust rises in this cleft, it tumbles out on its lower or southern lip, where it is hemmed in by walls of rock on all sides but one. We can easily see that these are powerful factors in determining the path along which the blast will travel. But it has also been stated* that on the north side of the crater there are visible passages descending obliquely through the rocks of the mountain, and it is from these the avalanche of sand is launched in a direction which is nearly horizontal. That may be so, but even in that case it is not stated that these fissures are above the southern lip, or that they can emit blasts inclining downward at an angle of 12 to 20 degrees from the horizontal. And if from these fissures the dust-cloud is shot obliquely *upwards* so as to graze the southern rim of the fissure, it still remains to be explained why the cloud sinks down again and flows over the surface of the ground, refusing to rise in the air and float away as an ordinary cloud would certainly do. This, in fact, merely postpones the difficulties, and does not settle them. Moreover, if such an explanation were possible at Pelée, it would have no bearing whatever on the eruptions of the Soufrière, as there the crater is a vast bowl about half as deep as it is broad; the black cloud could never have been shot obliquely from the bottom of this, down the mountain side, but must have risen nearly vertically into the air.

The explanation proposed by Professor JAGGAR† is of a different kind: "These horizontal blasts are not hard to account for, and do not require a horizontal nozzle to project them. They are simply the effect of the down blast after the heavy gravel has begun to fall, acting against the upblast from the throat of the volcano, and both together deflected and thrown into terrific whirls or tornadoes by the prevailing wind, which on Mont Pelée is north-east." He would, in fact, account for them by the resistance which the sand and lapilli falling through the air offered to the ascent of subsequent discharges. Mr. E. O. HOVEY‡ has adopted this hypothesis without essential modification.

But, in our opinion, this is quite incompetent to explain the behaviour of the black clouds we saw on the night of the 9th of July. Before the first black cloud arose no very great amount of dust had been projected into the air, and the steam clouds were drifting steadily westwards before the trade wind towards Prêcheur. Before and after the appearance of the black cloud the steam ascended freely and apparently without hindrance. The black cloud took a different path, and once it had rolled a short way down to the mountain there was nothing above it to prevent it rising in the air; but it hugged the surface of the ground so closely that the conclusion was inevitable that it flowed down merely because it was too heavy to ascend.

* 'American Journal of Science,' Series IV., vol. xiv., p. 73, 1902.

† T. A. JAGGAR, "Field Notes of a Geologist in St. Vincent and Martinique," 'Popular Science Monthly,' vol. lxi., p. 366, 1902.

‡ E. O. HOVEY, "Martinique and St. Vincent: a Preliminary Report," 'Bull. Amer. Museum Nat. Hist.,' vol. xvi., p. 341.

The theory of explosions has also won a certain number of adherents, among whom are several distinguished American geologists. That there was an explosion —a steam explosion—is, of course, admitted by all. But some hold that there were also explosions of combustible gases attended by sheets of flame, and that these took place either during or shortly after the outburst from the crater. Our objection to these theories is that they have no sufficient basis of observed facts on which to stand. Neither what we know about the gases in the cloud, nor the recorded observations of eye-witnesses of the eruptions, make it in any way probable that such explosions took place except on a minor scale, or that they had an essential part in the propulsion of the discharges.

Many, of course, who saw the great black cloud emerge from Pelée or the Soufrière describe it as welling out of the hill with sheets of flame. But students of volcanic phenomena are too well acquainted with such descriptions to place any great reliance upon them. The popular mind is not careful to distinguish between a mere incandescent discharge, or the glow of the red-hot surface of the lava reflected from overhanging clouds, and true sheets of flame. The belief in burning mountains dies hard.

On two separate occasions we have witnessed the black cloud which rises from the fissure of Pelée, and on neither did we see any flame. Through the face of the cloud lights flickered and scintillated, but they were only lightnings. We have cross-examined many careful and accurate observers who have seen more than one eruption of the Soufrière, and not one of them described them as attended by flames. Neither were the noises they heard like the detonations of aerial explosions, they came from within the mountain. It is no doubt possible to obtain declarations from eye-witnesses, stating that great flames were visible, but they either break down altogether on careful cross-questioning, or are advanced by persons too uneducated, too excited, and often too inaccurate, to give evidence of any value in matters of this sort.

The Gases of the Cloud.—This raises the question—What were the gases in the cloud, and what were their properties? Unfortunately, this is a subject at present imperfectly known. We can only approach the question by indirect methods; no one has bottled a sample of the great black cloud. But what evidence is available is singularly consistent, and makes it highly improbable that great explosions due to chemical combinations between the gases of the cloud, or between these gases and those of the atmosphere, played any conspicuous part in the mechanism of the eruptions.

The gases of the cloud were the gases of the andesitic magma. The great black mass cleaved the air, driving it aside in virtue of its weight and the expansive forces within it. The atmosphere was passive, inert; it could not penetrate to the interior of the rushing inky torrent; only at the margins, where the cloud sent out curling wreaths of dusty vapour, was there any mingling between it and the air.

Even after the dust had settled down, and the steam mounted from the sea and forced a path obliquely upwards through the air, the white cloud cut its own way, maintaining its separate identity for a prolonged period.

Of these gases the most abundant was certainly steam. At first it was dry, invisible, superheated; afterwards condensation set in, and it formed a fleecy cloud of mist. All the symptoms of the injured are in harmony with the theory that steam and hot dust were the deadly agencies at work. The feeling of suffocation experienced by the survivors, and the exhaustion of the air so that it did not support respiration, are all explicable in this way. The falls of moist ash and of hot mud, which were more or less local, but were observed by many, are natural consequences of the abundance of superheated water vapour.

Next in abundance, in St. Vincent at any rate, was sulphurous acid. All the survivors agree in this; they describe it as the smell of burning matches. Most of the medical men who attended to the injured in St. Vincent considered that dry, hot steam and hot dust were the principal components of the cloud, and that sulphurous acid was very abundant, so abundant that it might have even caused some deaths, and have been responsible for some cases of bronchial catarrh and pharyngitis, though it was not possible to separate its action from that of the other constituents, which would have been, on the whole, similar. On account of its smell, the sulphur dioxide was very conspicuous, but it did not leave any very startling effects. We did not learn of any cases of bleaching or discoloration, or of the formation of crusts of sulphite or sulphate, on any objects of metal.

In St. Vincent sulphuretted hydrogen was also present to some extent. It was recognised by several competent observers. The silver ornaments on the arms of some of the coolie women turned black in a minute or two. Months afterwards the mud around the crater stank of sulphuretted hydrogen till on a hot day it gave one a headache. But the medical men did not attribute any deaths to it; symptoms of poisoning by its action were not observed; asphyxiation, burns, and shock were the chief causes of death.

It may be that in reality not sulphuretted hydrogen but metallic sulphides (such as calcium sulphide) were originally present, and that in presence of moisture they were decomposed at a certain temperature, and hydrogen sulphide produced. This is the most probable explanation of the abundance of that gas in the month of June in the wet mud near the summit of the hill.

As has been remarked by Professor LACROIX and his colleagues, there was comparatively little sulphur in the magma of Pelée, and analyses show that it is certainly more abundant in the ejecta of the Soufrière. But for weeks before the fatal May 8th there was a strong smell of sulphuretted hydrogen in the streets of St. Pierre, and the old name Soufrière, given to the Étang Sec, is an enduring witness to the presence of that gas. All the Caribbean volcanoes emit it; it has given a name to many a crater and fumarole in the various islands. It was certainly present in the great black clouds in Martinique, and on the night of July 9th the wet ash which fell upon our decks smelt of sulphurous acid, though not strongly. Sulphuretted hydrogen is, of course, combustible, but would occasion no bright flame, and its presence cannot be blamed for the devastating forces which levelled the town.

We may also be certain that other gases were there, some of them highly inflammable, but it is impossible to believe that they were present in relatively large amount. In this line of inquiry the classic researches of FOUQUÉ on the gases of the andesitic magma of Santorin are the best guides. Hydrogen and various compounds of hydrogen and carbon were ascertained by him to be present in that case, and there is every probability that they were here also, but there are no data to enable us to judge what were their composition, proportions, and abundance. They may probably have occasioned trivial explosions, but could only have ignited when mixed with air—that is to say, on the outer fringes of the cloud. They were not its motive force, and could not have supplied the energy which launched it on its errand of destruction.

Hydrochloric acid has been mentioned by some as having been observed in connection with certain of the eruptions. No doubt it was there, but as it has left no visible effects, so far as we know, we cannot suppose it to have been plentiful. Nitrogen is another probable component, and so also is carbon dioxide, which accompanies practically all volcanic outbursts; but at the present moment little can be said about these, for, though we may admit that they were present, the evidence respecting them is altogether of a negative kind. There is nothing to show that they played any important part in the mechanism of the eruptions.

It has been suggested by Professor VERRILL* that the dissociation of steam within the volcano produced an explosive mixture of hydrogen and oxygen which combined with violence on emerging from the mouth of the crater, and that this explosion explains the disastrous force which razed the city of St. Pierre. That such dissociation takes place to a certain extent is made probable by the researches of FOUQUÉ,† but, owing to the enormous pressures, this could have affected only a small part of the water in the magma, which, moreover, was at a temperature not very much higher than that at which steam begins to be dissociated at atmospheric pressure.

The crystalline minerals which were floating in the magma before eruption show that it was at a temperature of less than 1200° C., and this renders it probable that the amount of dissociation produced would be quite inconsiderable. The magma of Santorin, to judge by the nature of the products, is considerably hotter than that of Pelée at the moment of effusion. It is also certain that when the lava broke forth, cooling would be continuous and not instantaneous, and the gases would

* 'American Journal of Science,' 4th Series, vol. xiv., p. 72 (July, 1902); also by Professor ISRAEL C. RUSSELL, 'Century Magazine,' vol. lxiv., p. 790, September, 1902.

† 'Santorin et ses Eruptions,' p. 232.

combine gradually and quietly, as the temperature fell, without occasioning any explosion whatever. Some, however, of the products of dissociation would escape combination, and these might, if not too much diluted with other ingredients, be ignited by lightning flashes at a later period, though we are not inclined to regard this process as having taken place on any but a very small scale.

Others, of whom Professor HEILPRIN * is one, hold that the cloud was highly charged with mephitic carbon gases. This theory is interesting, though we cannot endorse it :—

> "What the exact constitution of this death-dealing cloud was will never perhaps be known, but its associations with the mud discharges, its heavy specific gravity, and the mephitic or oily odour of the products emitted by both the lower and upper craters, lend reasonable certainty to the belief that this glowing cloud was mainly composed of one of the heavier carbon gases brought under pressure to a condition of extreme incandescence, and whose liberation and contact with the oxygen of the atmosphere, assisted by electric discharges, wrought the explosion, or series of explosions, that developed the catastrophe.
>
> "To the enquiry as to what was the source of this carbon gas—to my mind the main factor of the catastrophe—the geologist points to those vast bituminous deposits, like those of Venezuela and the island of Trinidad, which lie but little out of the line of the connected series of volcanoes, of which the Soufrière of St. Vincent, and Pelée of Martinique, are a part. He also points to the limestone deposits, with their enormous masses of locked-up carbon, forming the foundation on which these same volcanoes are implanted, which indicate a source of energy far greater than was required for the catastrophe of Pelée."

When we were in St. Vincent we made most careful inquiries, both of the survivors and of the medical men who had attended the injured, as to the occurrence of poisoning by carbon dioxide, carbon monoxide, or poisonous hydrocarbons. We failed to find any evidence whatever of symptoms such as would have indicated that much of these gases was present, and the medical men were all convinced that they were not responsible for the fatal effects of the great black cloud. This seems to us all the more remarkable, as such gases must have been present in the cloud which, on May 7th, did such deadly havoc in the Carib Country, and this for a reason which has apparently escaped the American professor.

That afternoon, as the darkness was closing in around the north end of St. Vincent, the richly-wooded slopes were still covered with all their wealth of tropical forest up to the moment of the climax, when the great dust avalanche arose. In an instant all was changed. The hot sand which now fills the valleys is mingled with innumerable fragments of charred, broken trees, caught up, destroyed, and swept along in that burning flood. The great hot blast which radiated outwards mowed down the standing trees, scorched them, eroded them, consumed their leaves, twigs, and smaller branches. The amount of vegetable matter carbonised or semi-carbonised in that brief space was enormous. The charcoal in the valleys is washed out and floats on the sea, supplying the inhabitants with fuel for months to come. Never

* 'Fortnightly Review,' September, 1902, pp. 477 and 478.

was a fairy landscape changed to a blighted desert in a shorter space of time. What came of all the carbon compounds produced by the destructive distillation? They must have been incorporated in the great black cloud. This was in itself one of the most startling and marvellous features of that strange eruption.

What form the products took, what was their relative amount and the changes they passed through, we can only guess. There was little or no oxygen in the cloud, and the vegetable matters were practically distilled in presence of dry steam. Any oxygen which had not already combined with the hydrogen or hydrogen sulphide would unite with the carbon of the wood to form carbon monoxide or carbon dioxide, and the vast number of volatile organic compounds produced by the charring of wood in the absence of oxygen must all have been there in greater or less abundance. Many of these substances must have been capable of producing explosions when mixed with air or oxygen in suitable proportions, and we may believe that the black cloud at one stage of its history was entirely deprived of oxygen and filled with carbon gases. It is probable that the temperature fell too rapidly, and the process of mixture with the air was too slow to allow of any considerable part of these gases being burnt in the cloud. Before the oxygen could reach them they were too cold and too much diluted with steam to ignite. We may in this way explain why the ash which fell in Kingstown on the afternoon of May 7th had an odour of organic matters. Mr. POWELL described it to us as strongly resembling that of guano. The ash was moist, and the water mixed with it may have absorbed some of the more soluble organic products of the great black cloud.

Even when we were in St. Vincent in the month of June, after a few hours of dry weather and sunshine, wreaths of blue smoke would be seen curling up into the air from the banks of hot sand where pieces of carbonised wood lay partly exposed to the atmosphere. The air then smelt strongly of burning wood, and specimens of tar have since been sent us, which were brought down by the streams when the ashes were washed away by the rains in the Rabaka Valley. This tar is a product of the distillation of the wood as it lies embedded in the hot ashes.

No other eruption was attended by these circumstances; no second black cloud involved in its mass the forest growth which for 90 years had clothed the surface of the mountain. It had vanished like a fall of snow, and in its place was now a waste of ashes. Carbonic acid and carbon gases there may be in the later outbursts, but these are from the magma, original and not accidental ingredients. We may, in fact, be certain that they are there, but we may be equally certain that they are not the principal gaseous components, and that neither does their density determine the behaviour of the heavy cloud, nor does their potential energy furnish the motive force which impels it.

The gases emitted by volcanoes have been the subject of much study, though they are still less known than any of the other products. In the interests of science it is desirable that some day we may be able to obtain samples of the gaseous emanations of Pelée and the Soufrière. It is to be hoped that the investigations of the French Commissioners will greatly advance our knowledge in this respect, for the gases of the Caribbean volcanoes may be supposed to present important points of difference from those which accompany less violent and more continuous activity. We regret that the results of our own inquiries are so purely negative in character, but St. Vincent does not offer the conditions necessary for the investigation.

The Physical Condition of the Magma.—Accounts have already appeared of the composition and structure of the dust which fell on Barbados on May 7th,* and of the earlier falls of ashes in St. Pierre and Fort de France.† It has not yet been possible for us to find time to make a comparative study of all the specimens which we have collected during our visit to the West Indies, or have been sent us by correspondents residing there. But there are certain general conclusions regarding the composition and structure of the materials emitted which we may draw from the facts at present before us, which throw some light on the causes which determined the magma to assume the form of a dust cloud.

All the samples, and notably the Barbados dust, contain a very large proportion of crystalline fragments of volcanic minerals, often broken, but frequently showing perfect crystalline form. Volcanic glass is present also, in fine threads and broken splinters and in thin pellicles, coating the surface of the crystals. The same material occasionally forms little rounded pellets, in which small microliths may be seen embedded in the glassy matrix. That the Barbados dust should be so largely of a crystalline nature has awakened general astonishment, especially when it is compared with the fine air-borne dust of Krakatoa and Cotopaxi. The glassy fragments are of lower specific gravity than the minerals, and while the latter frequently are sub-cubical in form, the former are highly irregular, and have a very large surface in comparison with their volume and weight. In consequence, the splinters of glass should fall through the air more slowly, and should be carried by the wind to greater distances before subsiding, than the heavier and more compact minerals. The ash which fell on ships some 200 or 300 miles to the east of Barbados

* JOHN S. FLETT and W. POLLARD, 'Quarterly Journal Geological Society,' vol. lviii., p. 368. J. S. DILLER, "Volcanic Rocks of Martinique and St. Vincent," 'National Geographic Magazine,' vol. xiii., p. 285. W. F. HILDEBRAND, "Chemical Discussion of Analyses of Volcanic Ejecta from Martinique and St. Vincent," 'National Geographic Magazine,' vol. xiii., p. 296. JOHN D. FALCONER, 'Nature,' vol. lxvi., p. 132. Professor CARMODY, Blue Book on "Volcanic Eruptions in St. Vincent and Martinique in May, 1902," p. 83. LONGFIELD SMITH, Blue Book on "Volcanic Eruptions in St. Vincent and Martinique in May, 1902," p. 79. T. C. PORTER, 'Nature,' vol. lxvi., p. 131.

† MICHEL LEVY, "Sur la Composition des Cendres Projetées, le 3 Mai, 1902, par la Montagne Pelée," 'Comptes Rendus,' 134, p. 1123. MM. A. LACROIX, ROLLET DE L'ISLE & GIRAUD, "Sur l'Éruption de la Martinique," 'Comptes Rendus,' vol. cxxxv., p. 377. A. LACROIX, "Sur les Roches rejetées par l'Éruption actuelle de la Montagne Pelée," 'Comptes Rendus,' vol. cxxxv., p. 451. T. G. BONNEY, 'Quarterly Journal Geological Society,' vol. lviii., p. 86, 1902.

contained a higher percentage of glassy matter than that which was gathered on the island.* From their freshness, their idiomorphism, and other characters, the crystals were clearly formed in a fluid magma, and the glass may be taken to represent the still liquid material at the moment of eruption. If so, it seems clear that such a rock could never have formed a pumice. It is too highly crystalline, and contains too little glass. When the steam separated out in little bubbles, which expanded and expanded as the retaining pressures diminished, a time arrived when the fluid part of the magma had passed into a spongy froth, in which innumerable crystals occupied the walls between the vesicles, and on further expansion the mass could no longer hold together, but passed into a mist of droplets, most of which held a crystal in their centre, while some consisted mostly of the glassy material.

Such a magma, with its high percentage of solid inextensible crystals and its small proportion of fluid rock, when the steam within it began to expand, very soon passed beyond its limits of cohesion, and was rent into separate particles, each of which was in most cases a crystal surrounded by a film of glass. The crystals themselves were not only incapable of extension, they were also anhydrous, and acted as passive ingredients; only the liquid magma contained imprisoned water, and the immense amount of steam developed in the explosions is all the more remarkable when we reflect on the relatively small proportion of the substances which held it in solution.

We may infer from its highly crystalline condition that the magma was also at a comparatively low temperature. The minerals have the characteristics found in those of volcanic rocks, and were not formed at very great depths or under such pressures as determine the production of rocks with plutonic structures. The molten mass was lying in the conduits of the volcano, cooling gradually there, and the separation of the first crop of crystals proceeded no doubt for a considerable period and under exceptionally favourable circumstances. Had not the subterranean pressures increased and driven the mass upwards, and the temperatures at greater depths been so high as to render the ascending forces irrepressible, the upper part of the lava column might in a short time have completely solidified.

In all probability crystallization was more advanced near the surface than in the deeper parts, and the lower portion of the magma was more completely fluid than that which was ejected as the great black cloud. In this regard it is important to remember that the dust avalanche is always the first product of the crowning stage of the eruption. As soon as the obstruction in the orifices of the volcano has been overcome the cloud wells forth. It is the upper part of the ascending column of molten rock. We may almost say that the great black cloud is the froth that is blown off the surface of the subterranean reservoirs. When it is once over everything, so far as we know, goes on in the usual manner. Bubbles of steam arise, burst, and

* J. S. DILLER, 'National Geographic Magazine,' vol. xiii., p. 293.

project showers of hot bombs and dust into the air. The later stages of the Peléan eruptions do not essentially differ from those of the eruptions of other volcanoes.

There is, in fact, a considerable amount of evidence to show that that part of the magma which gave rise to the great black cloud was not in a state of complete fusion, but that even the matrix separating the individual crystals was semi-solid and partially crystallized.* The glassy fragments in the dust of Pelée contain many microliths. According to the descriptions of Mr. J. S. DILLER,† "at least half the mass (of the dust which fell on the 'Roddam,' in St. Pierre on May 8th) is dark microlithic, more or less felty, but not vesicular ground-mass, often enclosing or clinging to crystals, and appears identical with the ground-mass of the lavas of Mount Pelée antedating the last eruption."

Professor LACROIX,* describing the ashes which fell in St. Pierre on May 2nd and 3rd, 1902, says:—"The examination of the glassy matter which plays an important part in these ashes is not without interest; it is compact, with few cavities, or at most enclosing a few minute vesicles; it contains very few microliths of felspar, but a pretty large number of opaque globulites, and occasionally some crystallites of hypersthene. It is not in reality a pumice composed of vesicular, filamentous glass, like that which characterised the great explosion of Krakatoa, and that which in pre-historic time blew out the bay of Santorin."

From these descriptions it is clear that a second generation of crystals had begun to form in the magma within the mountain, or at least in the upper part of it before it was forced to the surface and blown into dust by the expansion of the gases it contained. Mr. DILLER, indeed, advances the view that these glassy fragments belong to the older rocks of the mountain:—"It appears certain that the greater portion of the material which fell on the deck of the 'Roddam' was derived from the pulverisation of solid rock about the volcanic vent of Mont Pelée, and only a small portion from the molten magma which was the seat of the eruption." He arrives at the same conclusion as a result of his examination of the dust which fell in Kingstown, St. Vincent, on May 7th, 1902:—"The larger particles are of dusty glass, rarely clear, and colourless, and full of bubbles. Others contained a multitude of minute crystals. Those filled with these microlites are of pulverised older rock, while the dirty vesicular glass ones, like the ground-mass of the pumice, represent the molten magma of the eruption."‡

This theory, that much of the dust was due to the comminution of the older rocks of the hill, was suggested to us by Professor JAGGAR, whom we met in Barbados

* Professor ISRAEL C. RUSSELL also is of opinion that the magma had partly consolidated. Century Magazine,' vol. lxiv., p. 795, September, 1902.

† "Volcanic Rocks of Martinique and St. Vincent," 'National Geographic Magazine,' vol. xiii., p. 290.

‡ 'National Geographic Magazine,' vol. xiii., p. 290.

before we arrived in St. Vincent, and we directed a considerable amount of attention to the evidence in favour of it and against it while engaged in our work on the Soufrière. It cannot be denied that, especially in St. Vincent, an enormous amount of the pre-existing rock around the crater has been blown into the air, and this is sufficiently attested by the changes in the conformation of the crater-walls and the increased depth of its floor. Angular fragments of the old ashes and lavas, often several feet in diameter, are very numerous, and are easily distinguished by their form, appearance, and structure from the bombs which originated from this eruption. No doubt, also, fine dust of this nature mingled with the cloud, but we saw no evidence that any considerable part of the mountain had been shattered to minute, almost impalpable, powder, and disseminated through the air by the explosions. It seemed rather that the older igneous masses had yielded fragments usually of some considerable size, and that a breccia, and not a dust cloud, would have been produced in this way.

The presence of glassy fragments, some of which are full of crystallites, while others are practically free from them, may be explained in more than one way. It may be that the partly devitrified material was that which formed the surface and the sides of the column of molten lava, the more vitreous substance its centre and deeper parts. But we should also be prepared to admit that the magma was not entirely homogeneous, and that parts may have been more liquid, or less crystalline, than others. This would have given rise to a banded structure, such as is so common in the vitreous lavas, had the mass poured out in a coulée and rapidly solidified to form an andesitic lava flow.

It is also possible that the gases may not have been quite equally abundant throughout, and to these two causes, conjointly or separately, we may ascribe the presence of a considerable number of small vesicular lapilli, and even occasionally of rounded pieces of pumice mixed with the dust. There was very little pumice in St. Vincent, but many scoriaceous lapilli with embedded crystals, while at Pelée pumice was more abundant, though still not in sufficient quantity to form a considerable proportion of the ejecta.

In this connection we may remark that in Martinique the eruption of July 9th * ejected more vesicular pumiceous glass than any of the previous outbursts, and we have received information from St. Vincent that pumice is more abundant in the ashes of September 3rd. It looks as if the magma in these volcanoes was undergoing some change in its physical condition, and that the highly crystalline and comparatively cold condition of the material at first ejected was not quite so pronounced in the later stages. What effect this may have on the future phases of the volcanic activity we can only guess at present, but it is a problem of much interest, and well worthy of careful attention.

* MM. LACROIX, ROLLET DE L'ISLE & GIRAUD, "Sur les Roches rejetées par l'Éruption actuelle de la Montagne Pelée," 'Comptes Rendus,' vol. cxxv., p. 452.

We have seen that the magma of these Antillean volcanoes, or at least the uppermost part of it which gave rise to the great black cloud, was to a large extent crystallized, contained comparatively little fluid matter, and that it was accordingly near the temperature of consolidation, or may even in part have solidified already. These may all have been powerful factors in determining it to assume the form of a dust cloud as soon as the retaining pressures were relieved, and the vast quantities of steam and other gases it contained were free to expand.

But the chemical aspects of the problem must not be neglected; they may be of even greater importance than the physical. Both magmas are andesitic, but the analyses and microscopic investigations which have already been published make it certain that they are not exactly the same, so that it does not appear likely that the dust-avalanche type of eruption is a consequence merely of the presence of a magma with a certain narrowly-restricted chemical composition.

On the other hand, it is a significant fact that many of the most terrible instances of disastrous and sudden volcanic explosions have been furnished by volcanoes emitting hypersthene andesite. Krakatoa and Bandaisan are two examples of quite recent date. This group of rocks is, of course, a very diverse one, and includes many important variations; but as contrasted with the basalts, which in so many cases give rise to floods of liquid lava quietly welling out of craters or fissures, they seem predisposed to violent and disruptive activity. The rarity of dykes in St. Vincent, and the abundance and thickness of the sheets of coarse agglomerate, point to the same conclusion.

What influence the nature of the gases present in such quantities may exert is a problem equally interesting and obscure. Till we know more of what these gases are, and in what proportions they exist in the magma, it is premature to enter into a discussion of the part they play in the origination of the great black cloud. Any conditions whatever, whether chemical or otherwise, which diminish the cohesion of the magma in which the gases were absorbed will, *primâ facie*, facilitate the conversion of the mass from a spongy froth into a cloud of liquid droplets.

The Cause of the Deaths.

Owing to the exigencies of the case, it was impossible to perform autopsies on the bodies of the dead in St. Vincent, and however much we may regret this from a scientific point of view, we must recognise that the first call on the energies of the medical men was to attend to the wounded, and give them what assistance they could. At first the number of doctors in the island was too small to enable them to cope with the sudden emergency, but help was rapidly provided from the adjacent British islands, and the final results were brilliant. It was several days before the state of the volcano warranted the exploration of the devastated country on an extensive scale, and when the bodies were finally all discovered and interred, they were very often in a condition which left little hope of obtaining any important information by means of *post-mortem* examinations. Fortunately, the evidence as to the lethal agencies at work is fairly clear and conclusive, and the opinions formed by the doctors who had care of the survivors are entirely in accordance with the geological facts regarding the nature of the catastrophe. From Dr. C. W. BRANCH, Dr. DUNBAR HUGHES, and Dr. AUSTIN, of St. Vincent, and from Major WILLS, R.A.M.C., and Dr. HUTSON, of Barbados, we obtained most of the information on which we have based our conclusions. We had also an opportunity of examining many survivors who had passed the afternoon and night of May 7th in the Carib Country. Some of these had completely recovered, others were in the hospital in Kingstown; many were very unwilling to retail the horrors of that afternoon when their friends, relatives, and families had perished at their side.

Without doubt steam laden with hot dust was the principal cause of the fatalities. When the hot wave struck the houses all the occupants felt a sudden pain in their mouths and throats. This was principally due to the fine hot dust, which was intensely irritant. Many stuck their caps into their mouths, and this relieved the burning feeling, thus proving that it was due to the fine particles floating in the air. It produced intense pain in the eyes, and among the wounded not a few had their faces nearly unburnt about the eyelids and the temples, while their brows and the backs of their hands were severely scorched. When struck with the hot blast they had covered their eyes with their hands in order to protect them. The mucous membranes of the nose and mouth were scorched, and subsequently in some cases desquamated,* and the hot dust gathered on the beards of the men and singed the skin beneath. Those parts of the body which were covered with the clothes, as a rule, escaped injury, or were only slightly burnt. As the black labourers wear thin cotton garments, this must have been because the hot dust was unable to pass through the cloth, and the gases were not at so high a temperature as to do much injury. It is in every way probable that when the black cloud swept over the lower grounds in St. Vincent the dust it contained was hotter than the gases, for these latter were actively expanding, and were cooled in consequence, while the solid matters were merely passive, and being also bad conductors, would only slowly part with their heat to the surrounding medium; but, owing to the small size of the particles, such differences in temperature may have been inconsiderable.

After a minute or so the feeling of pain in nose, mouth, and throat, and on the exposed parts of the body, was oppressive, and many who survived complained that they also felt a burning sensation in their breasts and abdomens—the result probably of their having inhaled the hot dust into their bronchi or swallowed it, and thus scorched their throats, or perhaps also their stomachs. It is clear that it acted as an intense irritant on all parts with which it came in contact. Very rapidly, also,

* *See* also Professor ISRAEL C. RUSSELL, 'Century Magazine,' vol. lxiv., p. 798, September, 1902.

a sense of suffocation supervened. The sufferers gasped and cried for breath, but soon their cries were stilled by the approach of asphyxiation. They felt as if someone was powerfully compressing their throats, and at the same time their thirst was excessive. They complained also of the choking smell of burning sulphur, and in St. Vincent it is clear that in the blast there was much sulphurous acid, though in St. Pierre it was not conspicuous, at least on May 8th, when so many perished. Some of the doctors were inclined to ascribe many of the fatal consequences of the cloud to its presence; others merely regarded it as a subordinate factor, and this seems most probable, in view of what happened in Martinique.

The duration of the fatal wave of hot gases and dust was certainly brief, probably not more than three minutes, but it seems clear that death was not instantaneous in St. Vincent, or at any rate on the estates in the lower part of the Carib Country, as it probably was in the north end of St. Pierre, for all the survivors gave a distinct and consistent account of the gradual though rapid onset of the symptoms. At the same time it must be remarked that apparently after a minute or two the conditions had a lethal effect on the great majority of those subjected to them. The cries were succeeded by silence and inarticulate groans, and death followed almost at once. We were told that in some of the houses where the dead were heaped upon the floor, as in Sutherland's shop in Overland Village, where 87 perished in a little room, the bodies lay regularly piled on one another—the whole mass, living and dead, had fallen at once. It is not possible to separate the effects of the hot gases and the dust. They acted together, and probably neither alone would have produced all the effects. The dust was irritant, and cauterised the epidermal surfaces; the steam, sulphurous acid and other gases in the cloud, especially as they were not mixed with oxygen, produced the suffocation and finished the deadly work.

Only those survived who had shut themselves up in cellars and rooms with tightly-closed windows. We have already given some instances which prove how important it was to avoid direct contact with the cloud. In the cellar at Orange Hill 40 survived; but 30 who were in the passage leading into it died. In Turema all who had escaped had taken refuge in tightly shut-up rooms. At Rabaka many were saved in the same way. All human beings and animals which were in the open air perished. In some cases one or two occupants of a house were spared, while all the others died. This was not the case at Lot 14, or on the leeward side—that is to say, in those parts where the blast was hottest; but in the Carib Country there were not a few of these miraculous escapes. Similarly, on the "Roddam" and "Roraima," at St. Pierre, some were little injured, though apparently as much exposed as others who died. In all probability accidental circumstances, which can now no longer be brought to light, were the determining causes. We cannot say, for example, why in some cases one survived in a room where all the others, to the number of 10 or more, died almost at once.

In Overland Village, and a few other places, the first ash brought in the blast was wet, and stuck to the walls of the houses. This was the case also in Fancy and in St. Pierre. This wet mud occasioned severe burns, as it adhered to the naked skin, and many of the sufferers had extensive burns, from which the skin was peeling. But in most cases the dust was dry, and clung principally to those parts which were moist, like the lips, or were covered with short hairs, like the backs of the forearms. In the hospital in St. Vincent one patient had a cake of dust, one-eighth of an inch thick, adherent to the scalp, which was slowly healing beneath it.

Probably not less than nine-tenths of the fatalities were produced by the causes above enumerated, but there were others which certainly were in operation, though we cannot now establish exactly to what extent any of them swelled the list.

Many of the injured lay among the dead bodies on the floor, covered with a thin film of ashes, groaning, with parched throats, unable to raise themselves and search for water, waiting for death. Most of these died within an hour or two, others dragged on for a couple of days; one case was taken to hospital, and died three days after the eruption. The direct cause of death was shock and exhaustion.

Others were removed and died under treatment, partly from the shock of their burns and the terrible experiences through which they had passed, partly from the other secondary effects of their injuries. Fortunately, they were comparatively few; only 70 deaths from burns and other causes occurred in the hospitals.*

Some also were killed by lightning—how many it is impossible to say. One woman was seen to fall dead during a bright flash of lightning in the yard at Orange Hill. Probably others met a similar death, but this could have affected practically only those who were fleeing from one house to another after the blast had passed.

Many of the roofs of the huts, and even of the more substantially-built stores, collapsed through the night under the weight of ashes, and beneath them the searchers found, in some cases, heaps of dead bodies. Had any within these huts been spared by the fatal blast, they must have been suffocated by the roofs falling with their weight of hot sand.

Similarly, many houses were ignited by incandescent stones or by lightning, and any wounded they contained must have been burned to death, but it is not certainly known that there were any such fatalities.

Undoubtedly some were killed by falling stones. Dr. HUTSON, of Barbados, told us he saw three cases of fractured skulls, and Captain CALDER narrates that when 8 miles from the volcano he was struck and almost rendered unconscious by a piece of rock. There are no statistics, however, to show whether such cases were frequent. No one in Chateaubelair, so far as we know, was injured in this way; one little girl in Georgetown was wounded by a stone in the afternoon of May 7th.

* Sir R. LLEWELYN, Blue Book: 'Correspondence relating to the Volcanic Eruptions in St. Vincent and Martinique in May, 1902,' p. 65.

Probably, if careful inquiries had been made at the time, many similar cases would have been brought to light.*

At least one party suffered death by drowning. They were in a boat, coming from Campobello southwards along the east coast, and were never seen again after the cloud had passed.

We inquired carefully of the doctors whether they had reason to believe that carbonic dioxide, carbon monoxide, or poisonous hydrocarbon gases could be considered to have produced any of the fatal effects, and whether sulphuretted hydrogen was present in such quantities as to have contributed in any way, but they all were of opinion that steam, hot dust, and sulphurous acid were the only important lethal components of the cloud, and though other gases may have been there they were in small quantities, and left no visible consequences.

The Air Waves.

All the greater eruptions of Pelée and the Soufrière during the months of May, June, and July, 1902, have probably been accompanied by both air waves and sea waves. The observations and records in our hands are far from complete or satisfactory, and we do not intend to attempt a final discussion of the phenomena in this paper, but we have given the evidence relating to the eruptions of the Soufrière, and our statements are corroborated by those of the French Commissioners.† The number and form of these waves, their dimensions, velocity of dispersion and range can be fully investigated only when all the data are to hand, and in particular when the various barographic records obtained at meteorological stations around the Caribbean Sea are available. The best records are those of the recording barometers used in the stations of the American Weather Bureau scattered through the islands, and those of the French Government in Martinique, and no doubt they will be fully discussed in all their bearings in the reports of the French and American scientists.

The study of these waves is of importance not only from the hydrographic and the meteorological point of view, they also give very valuable information to the volcanologist. They may help us to fix the exact time of the outburst of the black clouds. It is probable that they will also indicate the relative magnitude of the various eruptions, and in some measure enable us to compare those of the Soufrière with those of Montagne Pelée.

The origin of the air waves is not far to seek. They are due to the sudden and localised increase of pressure occasioned by the outburst of large quantities of steam and other gases into the air. The waves must travel outwards radially, in all directions, from the centre. Their amplitude depends principally on the magnitude

* Professor ISRAEL C. RUSSELL met with certain cases of injuries of this nature, 'Century Magazine,' vol. lxiv., p. 798, September, 1902.

† "Sur l'Eruption de la Martinique," 'Comptes Rendus,' vol. cxxxv., p. 389.

of the explosion. According to the investigations of Lord RAYLEIGH, quoted in the Krakatoa report to the Royal Society,* it diminishes in proportion to the square of the distance from the focus, and Lieutenant-General STRACHEY, R.E., calculates that the initial velocity of the air waves generated by that eruption was about 713 miles an hour. The great explosion at the Soufrière should, in consequence, have affected the barometric column in Barbados in less than 10 minutes. So far as we know at present, the eruption in St. Vincent on May 18th did not leave any record on the barograms, either in Barbados or in Martinique.

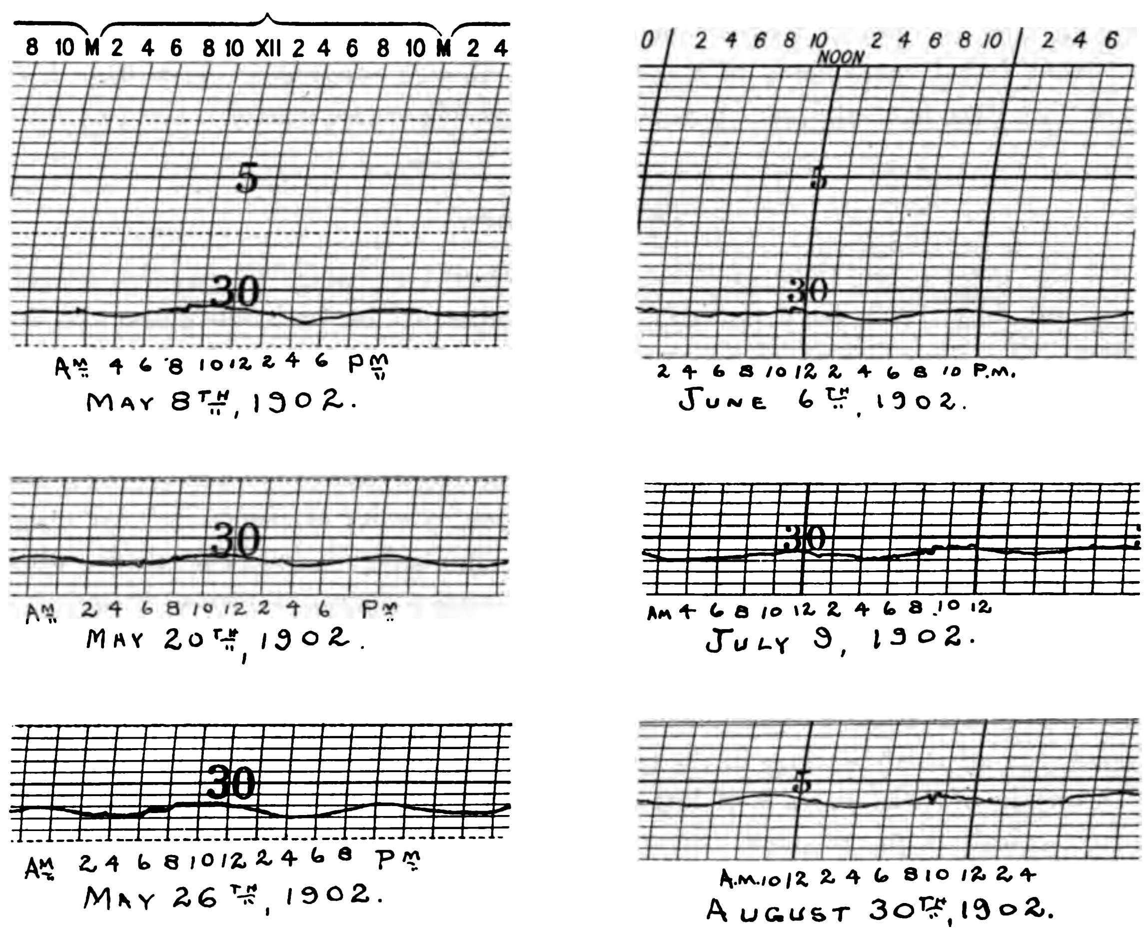

FIG. 3.—Barographic tracings, showing the air waves generated by the eruptions of Montagne Pelée. Taken in the station of the American Weather Bureau, Rozeau, Dominica.

The form of the wave tracing is precisely that given by sudden and violent explosions. We have obtained from Mr. PORTER, of Rozeau, in Dominica, photographic copies of the barograms yielded by his recording barometer at that station (through the kindness of Mr. HOBBS, of the American Weather Bureau, St. Kitts). (Fig. 3.) The characteristics of the waves have already been emphasised by Professor LACROIX

* "The Eruption of Krakatoa," 'Royal Society's Report,' p. 64, 1888.

and his colleagues.* It is the presence of a considerable, short, sharp depression, in advance of an elevation, which is more continued, and may last for a quarter of an hour or more. With these we reproduce also, by the kindness of the Meteorological Council, the trace left by the explosion of 12 tons of gunpowder on board the ship "Lottie Sleigh," lying in Liverpool Harbour, on the recording barograph at Liverpool Observatory, on January 15th, 1864. (Fig. 4.) The similarity between these waves is very striking: in each we have the initial, short, rapid fall, followed by an almost equally sudden rise, which lasts for a longer period, and is then succeeded in the Liverpool record by a second depression, not so great as the first.

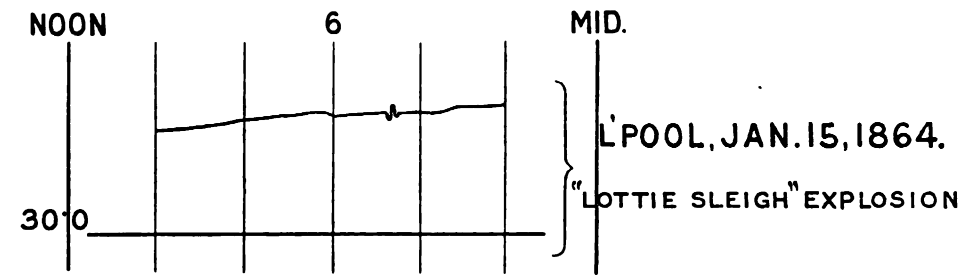

Fig. 4.—Barographic tracing of the King's barograph at the Liverpool Observatory, showing the effect of the explosion of twelve tons of gunpowder on board the "Lottie Sleigh," three miles distant.

(*Reproduced from the 'Proceedings of the Royal Society*,' vol. xxxvi., Pl. I.)

In the air waves which were produced by the eruption of Krakatoa these features were by no means so marked, and, in fact, Lieutenant-General STRACHEY was led to the conclusion, partly from his studies of the actual barographic tracings, and partly from the theoretical researches of Lord RAYLEIGH, that "the rise of the barometer indicating a sudden increase of pressure was the first and direct result of the explosion, and that the succeeding fall of the barometer . . . required some considerable time for its development."

The Sea Waves.

We have already detailed the observations regarding sea waves occasioned by the great eruption of St. Vincent on May 7th in Barbados, Bequia, St. Lucia, Martinique, and Guadeloupe. (*See* p. 406 and p. 410.) In Barbados and in Bequia its amplitude was $2\frac{1}{2}$ feet, in Martinique about 1 foot. Assuming that it originated in St. Vincent, and was synchronous with the great explosion and discharge of the avalanche of dust about 2 o'clock in the afternoon, we find that it took 70 minutes to cross the channel between that island and Barbados, where the first crest arrived at 3.10 P.M., and had a velocity of about 90 miles an hour.

According to the preliminary report of the French Commissioners, sea waves have been observed in Fort de France on the occasion of all the more important eruptions

* 'Comptes Rendus,' vol. cxxxv., p. 390.

of Montagne Pelée. On May 8th the first phenomenon observed at Fort de France was a recession of the sea; it was followed by a considerable rise, and at intervals of several minutes minor oscillations succeeded the principal one to the number of five or six. In St. Pierre and in Carbet these waves have invaded the land and done considerable damage, especially on the morning of the great eruption (8th May), when the wave at Carbet was estimated to have an amplitude of nearly 7 feet (2 metres). This wave was not observed at Guadeloupe, though that of the previous afternoon, attendant on the eruption of the Soufrière, was clearly visible there.*

The most remarkable feature of these sea waves is that they have never been observed in St. Vincent, even on the afternoon of May 7th, when many people along the leeward coast of the island were embarking in boats or landing on the shore at the moment of the climax of the eruption. They cannot certainly have taken place on so large a scale as at St. Pierre, as in Chateaubelair many huts stand on the low beach but little above high-water mark, and none of them was destroyed or damaged. Yet the wave originated by this outburst was felt in Guadeloupe and in Barbados.

To some extent these waves may have been caused by the sudden increase in atmospheric pressure which started the air wave, but this cannot have been a very important factor in their production, as there is no reason to believe that the rise of the barometer was in any case more than a quarter of an inch.

They may also be partly a result of the concussion or shock which was occasioned by the great explosion, and may in this way partake of the nature of "earthquake waves."

Our knowledge of the extent and magnitude of the changes which have taken place on the sea bottom around the Windward Islands is at present unsatisfactory. It may be regarded as highly probable that the loose material lying on the steep submarine slopes on both sides of the islands has been set in motion, and has slipped downwards over considerable areas. The subsidence at Wallibu can hardly be the only case in which this has occurred. Interesting evidence on this point is given in a letter by Mr. C. B. CRUICKSHANK to Professor JOHN MILNE, F.R.S., from which we take the following :—

"I regret exceedingly that the amount of information which I can give you as to changes in ocean depths off Martinique and St. Vincent is practically nil.

"During the time I was out in the West Indies after the eruptions we did not attempt to tackle any repairs off Martinique. The greater part of the time was occupied with cables off St. Vincent, and the first cable we tackled was one which was laid in 1898. As no soundings were taken in this line before the laying of the cable, and this was the first break that had occurred, it is difficult to say whether or not the depths were changed.

"As to the other cable, the one between St. Lucia and St. Vincent, we found no great alteration in the soundings, and what little difference we did find may have been due to errors in taking the soundings, for we had very strong currents to contend with, making accurate sounding difficult.

* 'Comptes Rendus,' vol. cxxxv., p. 390.

"It might be interesting, however, for you to know in what state we found the former of these two cables—viz., the one between St. Lucia and Grenada. This cable passes off the island of St. Vincent, running in an almost north by east and south by west direction, and passing off the Soufrière at its nearest point to the centre of the crater at a distance of about 16 miles. The cable was hooked about 24 miles in a direct line from the crater (towards St. Lucia), and a remnant picked up towards Grenada, after buoying St. Lucia side, about a mile in length. The first part of this came up in a good condition, but the balance came up in variable condition, in some places almost all the sheathing wires being cut through, as if by the sharp edge of a heavy rock coming down on it, and in lots of places twisted and knotted in a very similar manner to that shown in Fig. 8 of your paper on 'Suboceanic Changes.'

"For a considerable distance from this break the cable seems to have been either buried or carried away out of position; at all events, we failed to hook it or feel any signs of it till we were down almost due west of Grand Bonhomme. In grappling, the grapnels were found to have been ploughing deep in soft grey mud, lots of which came up on the teeth, with occasional particles of a bright red colour."

We may reasonably expect that if there has been extensive and sudden displacement of the sediments on the sea floor, as is indicated apparently by the condition of the cables, they would have been attended by sea waves of greater or less importance.

It is interesting in this connection to note that on the 5th May, when the crater lake of the Étang Sec burst, and a deluge of mud poured down the Rivière Blanche and buried the Usine Guérin, there was a distinct sea wave which did some damage at the mouth of the stream.* As no black cloud was emitted in this case, this wave cannot have been caused by its action, but, as stated by the French Commissioners, a line of fissures has formed almost exactly along this radius of the mountain, and submarine movement may have taken place and given rise to a sea wave.

But these causes are not sufficient in themselves to account for all the phenomena, and in particular for the great disparity in magnitude between the waves observed in St. Pierre and Chateaubelair. Some additional and local factor must be in operation, and this is, in all probability, the direct action of the great black cloud on the surface of the sea. The avalanches of dust and gases which are emitted by Pelée roll right down the slopes of the mountain upon the bay beneath, driving back its waters by their weight and momentum. So great a mass of matter sweeping downwards with so high a velocity must certainly have a considerable effect in disturbing the hydrostatic equilibrium of the sea surface, and must start a local wave which travels outwards in all directions.†

In St. Vincent the avalanche of dust is discharged over the southern lip of the crater, and rolls down into the broad valley between the Soufrière and Morne Garu. Its onward course is obstructed by the latter mountain, and its current is split into two parts, one taking the direction of the Rabaka Valley to windward, the other

* LACROIX, ROLLET DE L'ISLE, & GIRAUD, "Sur l'Éruption de la Martinique," 'Comptes Rendus,' vol. cxxxv., p. 390.

† We find that this suggestion has previously been made by Professor ISRAEL C. RUSSELL, 'Century Magazine,' vol. lxiv., p. 800, September, 1902.

passing to leeward by Wallibu. Before they reach the coast most of their energy is spent, and their velocity so greatly diminished that the black cloud, when it flowed out over Richmond Village, was travelling at the rate of only 30 miles an hour, and did not produce any great disturbance in the level of the sea surface, while that which passed over the mouth of the Rivière des Pères at St. Pierre had a velocity of at least 100 miles an hour. Under the circumstances it is not difficult to believe that the one may have had very much greater effect upon the level of the waters than the other.

Magnetic Disturbances.

We understand from the reports of Professor LACROIX and his colleagues, and of Professor HILL,* that at several observatories magnetic disturbances have been noted corresponding in time to certain of the eruptions of this spring. As we are not in possession of any special information regarding these observations, it is not possible for us to discuss them in this Report.

THE GENERAL SEQUENCE OF VOLCANIC PHENOMENA IN THE ANTILLES AND CENTRAL AMERICA IN THE EARLY PART OF 1902.

The disturbances in St. Vincent which culminated in the eruptions of Pelée and the Soufrière can be traced back for more than a year. They began at least as early as February, 1901, at which time the Caribs were alarmed by the numerous earthquakes around the Soufrière. After a temporary quiescence they resumed in March and April, 1902. Montagne Pelée began to emit steam about April 23rd, though, according to Professor JAGGAR, who has made a special study of the premonitory symptoms, the water in the crater lake was noticed to be warm in January.† On April 28th the violence of the earthquakes in St. Vincent was startling.

On April 18th—that is to say, just before actual volcanic action was observed at Martinique—a powerful earthquake shook Guatemala, and destroyed the town of Ruez-Altenango.

On May 5th the crater lake of Pelée burst, and the Usine Guérin was destroyed. On the 7th the great eruption occurred in St. Vincent. On the 8th the city of St. Pierre was destroyed. It was not till the 15th that the Soufrière of St. Vincent passed into a state of temporary quiescence.

The second important eruption of the Soufrière was on the 18th. (There had been a minor outburst on the 9th.) That of Montagne Pelée followed on the 20th.

In Martinique further outbursts took place on May 26th and June 6th. There was no corresponding activity in St. Vincent.

* 'Comptes Rendus,' vol. cxxxv., p. 391; 'National Geographic Magazine,' vol. xiii., p. 255, July, 1902.

† 'Popular Science Monthly,' 1902, p. 363.

On July 9th, at 8.20 P.M., Montagne Pelée broke again into activity. That afternoon there were several earthquakes in St. Vincent, so severe as to cause great apprehension.

In the end of August there was renewed activity at Pelée, and on the 15th, 28th, and 30th of that month and September 3rd there were eruptions. On September 1st and September 3rd the Soufrière was active, the latter especially being one of the greater eruptions of this year.

These facts are sufficient to show that a distinct connection exists between the outbursts of these two mountains during the present year. The eruptions of the Soufrière have sometimes followed, sometimes preceded, those in Martinique, but, as a rule, the greater eruptions of the one volcano have been accompanied by eruptions at the other within a period of one or two days. The outbursts of Pelée have been more numerous than those of the Soufrière. In particular, those of the end of May, of June, and of July had no corresponding eruptions in the sister island, but though more frequent they have been of less magnitude, and have produced less widespread effects. Pelée has also been more constantly in action of a subordinate kind during the intervals between the major eruptions.

Some general cause underlying the volcanic activity is required to explain the synchronism in the superficial phenomena. It is to be found in the existence of internal pressures and stresses in that part of the earth's crust, of which the Caribbean fold is one of the dominant ridges. The volcanic chain of the Windward Islands occupies the summit of one of the great earth folds of this region.

Great earth movements have taken place around the Caribbean Sea in Tertiary times, and are still in progress. It is in consequence one of the great earthquake centres of the globe,* and the connection which subsists between volcanic activity in the volcanoes of the Lesser Antilles and earthquakes in the surrounding region has been emphasised by HUMBOLDT and by many subsequent writers.

Although there is apparently no record of great earthquakes having attended the eruption of the Soufrière in 1718, that of April 24th, 1812, was preceded by a most violent earthquake in Venezuela on March 26th of that year. The city of Caracas was levelled with the ground, and it is estimated that 10,000 of its inhabitants perished.† The disturbances had begun about three months previously (in December, 1811), and were not confined to Venezuela, but affected also a wide area of Central and North America. In the valleys of the Mississippi and the Ohio there were numerous earthquakes from December 16th, 1811, onwards. In St. Vincent over 200 shocks were counted during the twelve months before the eruption.‡

* *See* Professor J. MILNE'S Seismic Map of the Globe, 'Geographical Journal,' January, 1903.

† HUMBOLDT, 'Personal Narrative of Travels to the Equinoctial Regions of the New Continent,' English translation by Mrs. WILLIAMS, vol. iv., chap. 1.

‡ HUMBOLDT, *op. cit.*, vol. ii., p. 231.

In 1880 there were symptoms of activity at the Soufrière of St. Vincent, and an outburst occurred in Dominica on January 4th.* Many earthquakes were felt about that time along the chain of the Greater Antilles. On January 22nd there were several shocks in Havana; others were felt in Cienfuegos, San Diego, and Santiago, and the town of San Cristobal was almost destroyed.† From December 21st, 1879, to January 10th, 1880, there was seismic disturbance in San Salvador, and on February 5th several earthquakes were reported from Mexico.‡

The eruption of Montagne Pelée in 1851 was perhaps connected with the great earthquake which shook Chili on April 2nd of that year.§

HUMBOLDT has given many interesting facts to confirm his hypothesis that earthquakes and volcanic activity in this region go hand in hand. In 1692 Port Royal, in Jamaica, was destroyed, and the volcano of St. Kitts was in eruption. In 1766 there was a violent earthquake in Cumana, Venezuela, and many shocks were felt in Jamaica, Trinidad, and the Lesser Antilles. Qualibou, in St. Lucia, burst into activity. In 1796 there was a tremendous earthquake in Quito. On December 14th, 1797, the town of Cumana (Venezuela) was razed by a terrible shock. On September 27th, 1796, an eruption took place in Guadeloupe. In 1800, 1801, and 1802 many earthquakes were felt in Maracaibo, Porto Cabello, and Caracas, and in February, 1802, volcanic activity broke out in Guadeloupe.‖

The connection between earthquakes and volcanic activity is further emphasised by the fact that in Guatemala a violent earthquake took place on April 18th, 1902, just before Montagne Pelée began to emit steam. This earthquake was recorded on the seismographs in the Isle of Wight.¶ It was most severe in western Guatemala, but affected also Salvador and Honduras. Quezaltenango was destroyed, and about 500 lives were lost, and extensive damage was done to the coffee and sugar plantations in all the surrounding district.**

Further earthquakes, attended by eruptions, followed in October, and the exceptionally long duration of the disturbances in Martinique and St. Vincent during this year—to which there is no parallel in the history of the Antilles—is to be ascribed to the continuance of crustal adjustments affecting the whole borders of the Caribbean Sea.

* H. ALFORD NICHOLLS, 'Nature,' vol. xxi., 1880, p. 372.

† 'Nature,' vol. xxi., 1880, pp. 306 and 357.

‡ 'Nature,' vol. xxi., 1880, p. 452.

§ J. MILNE, "Seismological Observations and Earth Physics," 'Geographical Journal,' January, 1903, vol. xxi., p. 14.

‖ HUMBOLDT, 'Personal Narrative of Travels to the Equinoctial Regions of the New Continent,' vol. iv., chap. i. English Translation by Mrs. WILLIAMS. *See also* Professor MILNE, as above, 'Geographical Journal,' vol. xxi., pp. 12–15, January, 1903.

¶ Professor J. MILNE, 'Nature,' vol. lxvi., p. 57.

** EDWIN ROCKSTROH, 'Nature,' vol. lxvi., p. 150; KARL SAPPER, Petermann's 'Mitteilungen,' vol. xlviii., p. 193.

The minor earthquakes are local, and more probably due to the changes beneath the volcano before an outburst takes place. It is significant in this respect that on July 9th, though there was no discharge from the crater of the Soufrière, that mountain showed its sympathy with the eruption in Martinique by means of strong earthquake shocks.

No earthquakes of great violence have been experienced this year in Martinique, St. Vincent, and St. Lucia, though small shocks were frequent. In Trinidad the Milne seismograph in the Botanic Gardens has shown none but small disturbances.*

In Montserrat, since the year 1896, earthquakes have been very frequent; in fact, it is said that they have been of almost daily occurrence, and in some cases as many as 100 have been counted in one day.†

It is apparently a matter of indifference which of the volcanoes of the chain is in operation; one appears to be able to function in place of the others. The previous eruptions of the Soufrière and Montagne Pelée did not coincide in point of time, and that both have this year been in violent action further proves the unusual magnitude of the changes in progress in that part of the earth's crust.

Nowhere along the Caribbean islands have changes of level been proved to have taken place upon the coasts. Sensational paragraphs have been published regarding alterations in the soundings, but they are probably unreliable. The frequent ruptures of the submarine cables, however, are sufficient to prove that there has been disturbance on the sea bottom.

Concomitant Activity in the Adjacent Islands.

In the other islands of the Lesser Antilles there has been remarkably little disturbance. In St. Lucia, which lies between Martinique and St. Vincent, and which contains a volcano—Qualibou—which is said to have been erupted in 1776, nothing unusual has been noted, except a slightly increased activity at the Soufrière in the south end of the island.

It is possible also, as will be seen from the following report by Major HODDER, R.E., that some submarine activity has taken place off Castries. He writes:—

"On Friday, the 9th instant, about 12 noon, I observed two large white patches on the sea, bearing about 294° from the Garrison Office at Morne Fortuné. They were at a distance (estimated by various persons) of 8,000 to 10,000 yards. These patches remained in the same position in sight till about 1.30 P.M., when they disappeared. At first I considered they were floating pumice-stone, but soon came to a different conclusion when I saw they did not shift their position to any extent; besides, they gave the appearance of bubbling. The patches were irregular in shape, but approximating to oval. The large patch was perhaps 150 yards long and 100 in diameter; the smaller one, say 100 long and 60 in diameter. They were distant from each other by about half a mile.

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* Botanical Department, Trinidad, 'Bulletin of Miscellaneous Information,' July, 1902, p. 450.

† EMIL DECKERT, "Die Westindische Vulkankatastrophe und ihre Schauplätze," 'Zeitsch. d. Gesell. für Erdkunde. Berlin,' 1902, p. 420.

"Staff-Sergeant CROWHURST, R.E., states he saw these patches at 8.30 A.M. on the same day, and that they never shifted their position until they disappeared at 1.30 P.M. All this leads me to conclude that a volcanic vent exists in the sea at this point.

"On the following day I think I detected a slight white patch of a similar sort in exactly the same place, but am not certain of this."

Grenada.—It having been reported that the lagoon, a sheet of water connected with the "carenage" or harbour of Grenada, had shown signs of volcanic activity, Dr. ANDERSON, at the request of Sir R. LLEWELYN, the Governor, visited the locality.

The lagoon is a nearly circular sheet of water about a quarter of a mile in diameter and about 25 feet deep in the centre, to the south-east of the carenage, and connected to it by a shallow, narrow channel about an eighth of a mile wide and only a few feet deep. As shown in Plate XVII., fig. 1, it is almost surrounded by hills, arranged in a manner that certainly at first sight suggests a similarity to an old volcanic crater.

They are all composed of beds of volcanic material, chiefly if not entirely scoria and ashes consolidated into tuffs and agglomerates. Closer examination, however, soon showed that the bedding does not follow the slopes of the surface, or even dip with any apparent reference to the centre of the lagoon. Many of the beds can also be traced into the *massif* of other surrounding hills, which obviously owe their present shape to denudation, and not to the mode of deposition of the beds. We therefore conclude that the lagoon and surrounding hills owe their configuration to the same general causes, and are not a crater.

Père LABAT, who visted Grenada in 1705, gives a map in his book, 'Voyage aux Isles d'Amerique,' in which the then town is shown on an isthmus between the carenage and the lagoon. The lagoon at that time appears to have contained only fresh water, and a brook through its isthmus was its only connection with the carenage.

About the middle of the eighteenth century the town was removed to the opposite side of the carenage, and the isthmus became submerged, and remains as a reef. As this was the exact position of the disturbance in May, 1902, referred to below, it seemed desirable to ascertain the particulars of this submergence. The island was at the time in the occupation of the French, and, through the good offices of the Colonial and Foreign Offices, the French Government have caused a search to be made in their archives, but without throwing any light on the subject.

It having been reported to us that some sort of a volcanic eruption took place in the carenage of Grenada about 1867, we asked the authorities at the Colonial Office that search might be made in the records of that office for any entry bearing on the subject. Such search was made, and we were very courteously allowed to inspect the original documents, which were chiefly cuttings from the newspapers of the period. As they are correctly summarised in the following extract from 'The Grenada Handbook for 1897,' it is unnecessary further to particularise them :—

a full view of it (both of whom were eye-witnesses), elicited the fact that on Friday, June 6th, disturbances were noticed more than once in the course of the forenoon in the water about the entrance of the lagoon, the appearances being described as a rippling or bubbling.

Major BAYLY had, in consequence, gone out to the spot that morning, when, by using a thermometer, he ascertained that there was no rise of temperature in the water. He was good enough to convey Dr. ANDERSON in a boat to the exact spot where the rippling had been observed, when it was found to coincide with the shallow bar across the mouth of the lagoon, over which the water had a depth of only $4\frac{1}{2}$ feet, which fact was verified by sounding.

Further inquiries from the chief boatman to the Customs elicited the fact that on the morning in question, which was also that of one of the eruptions of Montagne Pelée, the level of the water in the carenage rose and fell repeatedly, at intervals of about 12 or 15 minutes, to a height of about a foot.

We conclude that there is no reasonable doubt that the currents set up over the bar by this small tidal wave were the cause of the disturbance in question, and that it had no connection with any local volcanic manifestations.

Dominica.—After our visit to Martinique we proceeded to Dominica, where it was reported that anxiety had been felt regarding the condition of the Boiling Lake and the Grand Soufrière. In December, 1901, a young man who was on a tour through the islands and a Dominican boy were killed at the lake. Since then it had been visited several times, and was found to be more active than usual. Mr. C. F. BRANCH, at the kind request of the Administrator, undertook to conduct Dr. FLETT there, as the guides showed some unwillingness to face the journey. Under his energetic and able guidance this was successfully accomplished.

The road from Rozeau is by Laudat, a settlement in the mountains above the town at an elevation of 1585 feet. We left before dawn, and rode along a good though steep and winding path. As the sun rose over the hill-tops and broke through the mists which hovered over the ridges the scene was one of superlative beauty. The river foaming in its deep ravine, the craggy, richly-wooded slopes, the waterfalls over which the mountain rivulets threw themselves into the valley, and the dark, dense, tropical forest which clothed the island, were such as Dominica can show better than any other of the Antilles. Every here and there a puff of steam would rise from among the trees, the sign of a hot spring or Soufrière, of which there are many in Dominica, so many that the atmosphere in Rozeau is often redolent of sulphuretted hydrogen.

After leaving Laudat we struck a path through the woods, and crossed several streams before we emerged on the top of the narrow ridge, in which the central mountain range of the island culminates. Its altitude is 2930 feet. From this we descended into a valley on the eastern side. At the head of this lies the Grand

Soufrière, a cirque bounded on three sides by walls so steep as to be almost precipitous, but open to the north, where a stream, hot and turbid with precipitated sulphur, flows out to make its way to the sea. In Mr. BRANCH's opinion this Soufrière was more active than usual. Half a dozen orifices spouted steam and boiling water into the air with a loud hissing noise, like that of a locomotive. In the bottom of the pit no trees grew, and the naked walls that overlook it showed that the poisonous gases had entirely prevented the growth of vegetation, and had, in addition, attacked the exposed rock surfaces of coarse agglomeratic tuff, which were crumbling away and bleached by the acids in the air. Formerly there were times when these springs were quiescent, or only few of them emitted steam. They were now in vigorous activity, all puffing and casting up little columns of mingled steam and water; the smell was overpowering, and the heat of the steam, with the tropical sun beating down on the bare, rocky walls, made it a place in which one did not desire to loiter.

We then followed the stream down the valley, along a path so seldom used that it was almost obliterated by the dense growth of calumet and razor grasses, through which we waded up to our necks. The whole of this valley contained hot springs charged with sulphurous gases: lateral streams entered the main one—some cool, clear, and potable; others hot, dirty, and laden with sulphur. After walking rather more than half a mile, we turned to the left up a side valley, and, crossing a small ridge, we came to the famous boiling lake.

It is a cup-shaped depression, a bowl nearly circular in outline, perhaps 100 yards across, with high bare walls of weathered tuff surrounding it. At the east and west sides the bowl has two deep notches in its margin. Through these, two small streams enter on the west—one pure and cool, the other sulphurous; and on the east the effluent stream emerges. It is, in fact, an enlargement of part of the channel produced by the action of a powerful soufrière, which has decomposed the rocks around its orifice, and produced a funnel-shaped cavity through which the stream flows, and out of which it washes all the finer mud due to the churning of the water by the uprising steam. The north and south walls are perhaps 50 feet high, and show the effects of the acids generated by the oxidation of the hydrogen sulphide in their crumbling decayed surfaces.

The pool was full of milky, greenish water, boiling furiously towards its centre, where it was seething like a gigantic caldron. The smell was oppressive, especially when the wind blew towards us and carried with it the steam and gases. We found that the only danger was that of being poisoned by the sulphuretted hydrogen, and this could only take place in the bottom of the depression, where there was least chance of the gases being mixed and diluted with air. The deaths which took place here this spring were, in the opinion of Dr. NICHOLLS, occasioned by the visitors having gone down to the edge of the water. They had fallen unconscious, and the guides had been afraid to go to their rescue.

The configuration of the whole valley showed that it had been eroded by running water. It contained no actual structural craters, only "soufrières," rising apparently along some line of fissure which runs from the cirque on the south along the western side of the stream channel. It has been noted that this year the activity is exceptionally great, but no special violence has been seen to accompany the eruptions of Pelée or the Soufrière of St. Vincent.*

According to the observations of Dr. NICHOLLS,† there was in January, 1880, a great outburst from the Grand Soufrière, which projected much steam and fine broken rock into the air. This was carried before the wind, and fell in Rozeau. The trees around the Soufrière were blackened and blasted, and the largest ones were projected to some distance. Since then the bush has never quite recovered its former luxuriance of growth.

It is reported also that in Guadeloupe there have been emissions of steam and fine ashes from the volcano; but as so much that has appeared in the newspapers is unworthy of credit, and as we have had no opportunity of verifying the statements on the spot, wè cannot say of what nature the disturbances have been. This matter will no doubt be fully treated of by the French Commissioners, who have included that island in the range of their inquiries.

In conclusion, we desire to express our indebtednesss to the many residents in the British West Indies and in Martinique, who gave us invaluable assistance in pursuing our investigations. The Scientific Commission was sent out, at the suggestion of the Colonial Office, by the Royal Society of London, who defrayed Dr. FLETT's expenses out of the Government grant for scientific investigations.

Sir ROBERT BAXTER LLEWELYN, K.C.M.G., Governor and Commander-in-Chief of the Windward Islands, and Sir FREDERIC MITCHELL HODGSON, K.C.M.G., Governor of Barbados, gave us every facility for pursuing our work, and Mr. EDWARD JOHN CAMERON, Administrator of St. Vincent, Colonel DALRYMPLE HAY, Administrator of St. Lucia, and Mr. H. HESKETH BELL, Administrator of Dominica, rendered us great service by taking charge of our arrangements in their respective islands.

In St. Vincent much information and assistance was given us by Mr. F. W. GRIFFITHS, Mr. J. H. PRESTON, Lieutenant ROBINSON, R.E., Surgeon-Major WILLS, R.A.M.C., Mr. T. M. McDONALD, Mr. HENRY POWELL, Mr. JAMES E. RICHARDS, the Rev. Mr. DARRELL, Dr. C. W. BRANCH, Dr. DUNBAR HUGHES, Dr. AUSTIN, Mr. PORTER, Mr. KNOWLES, Mr. ROBERTSON, Mrs. KELLY, Mr. ISAACS and the officials in his

* Descriptions of the Grand Soufrière and the Boiling Lake will be found in F. A. OBER, 'Camps in the Caribbees,' 1880; and W. GIFFORD PALGRAVE, 'Ulysses: or, Scenes and Studies in Many Lands,' 1887.

† H. ALFORD NICHOLLS, 'Nature,' vol. xxi. (1880), p. 372

district at Georgetown, Captain CALDER and the members of the police force throughout the island, the Rev. Mr. BELL, the Rev. Mr. LESLIE, and many others whom space will not allow us to mention.

The planters and merchants with whom we came in contact in every case did everything they could to help us, and the numerous replies which we received to our printed schedule of inquiries have very largely been embodied in the text of this report, and acknowledgment made of the sources from which the information was derived. We desire to thank all those who have in this and other ways enabled us to collect the data on which our report is founded.

From St. Lucia, Major HODDER, R.E., has sent us many interesting details of his observations during the whole period of the eruptions.

Dr. MORRIS, head of the Imperial Department of Agriculture for the West Indies, has supplied us with much important scientific information; and the officials of his department, both in Barbados and throughout the islands, have forwarded to us valuable material, and have been of the greatest assistance to us in many ways.

We wish to acknowledge also the information given us by Bishop SWABY, of Barbados, and by the Rev. N. B. WATSON.

In Dominica, Dr. H. ALFORD NICHOLLS, C.M.G., placed at our service his intimate knowledge of the island and the history of its eruptions, and Mr. G. F. BRANCH, at the kind request of the Administrator, made the necessary arrangements for visiting the Boiling Lake. To Mr. PORTER, of the West India and Panama Telegraph Company, we are indebted for the barographic tracings reproduced in the text (Fig. 3). Dr. TEMPEST ANDERSON was hospitably entertained by Mr. DUNCAN NAISH, Picard, and Mr. J. SOWTRAY.

Our best thanks are due to M. L'HUERRE, the Governor of Martinique, who received us with great courtesy, and to Professor A. LACROIX for the kindness with which he explained to us the results of his investigations in the island.

In Grenada Dr. TEMPEST ANDERSON was most hospitably entertained by Sir R. LLEWELYN, and to that gentleman and his family, and Mr. PRESTON, his private secretary, his warmest thanks are due. He desires also to thank Major BAYLY and Mr. RICHARD HEALD for assistance on the spot, and Mr. FRANK ROWNTREE, and Mr. J. BOWES MORRELL, of York, for historical information, also Mr. C. P. LUCAS, C.B., and Mr. WALTER SCOTT, of the Colonial Office, for searching out and verifying the details in the library of that office.

APPENDIX I.

REPLIES to our printed Schedule, asking for information, specimens of volcanic ejecta, or written communications containing facts relative to the eruptions, have been sent us by the following :—

BARBADOS.

Dr. D. Morris, C.M.G.
Bishop Swaby.
Mr. F. J. Newton, C.M.G.
Mr. John R. Bovell.
Rev. N. B. Watson.
Mr. W. G. Freeman.
Mr. Radclyffe Hall.
Dr. Longfield Smith.
Mr. John W. Kirkham.
Mr. J. J. O'Donnell.
Captain Owen.
Mr. Lewis B. Brown.
Mr. H. Maxwell-Lefroy.
Mr. Skeete.

ST. VINCENT.

Mr. E. J. Cameron.
Mr. F. W. Griffiths.
Mr. J. T. Preston.
Mr. Isaacs.
Mr. G. Gentle.
Mr. George Durrant.
Rev. Mr. Darrell.
Mr. Henry Powell.
Mr. T. M. McDonald.
Mr. Robertson.
Mrs. Kelly.
Mr. Charles Knowles.
Mr. Proudfoot.
Dr. C. W. Branch.
Dr. Dunbar Hughes.
Dr. W. Bruce Austin.
Mr. Porter.
Mr. J. C. Wilson.
Mr. Rowland Winn.
Mr. P. Foster Huggins.
Mr. Effingham Dun, Owia.
Mr. E. M. Browne, Belair.
Mr. A. L. Darrell, Kingstown.
Rev. Mr. Bell, Georgetown.
Rev. Mr. Huckerby, Chateaubelair.
Rev. Mr. Leslie, Georgetown.
Captain Calder, Kingstown.
Mr. J. W. Clarke, Georgetown.
Mr. H. A. Allen, Chateaubelair.
Mr. Morgan, Chateaubelair.
Mr. Jos. W. Cubbin, Fancy.
Sergeant Ballantine, Chateaubelair.
Mr. Cyril Inniss, Georgetown.

ST. LUCIA.

Mr. Okell, Castries.
Major Hodder, R.E.
Captain Ford, Harbour-master.
Lieutenant A. C. Robinson, R.E.
Mr. Gerald Devaux, Cul de Sac.

BEQUIA.—The Rev. Mr. Duffus.

MONTSERRAT.—Mr. F. H. Watkins, Commissioner.

ST. KITTS.—Mr. Hermann E. Hobbs. Dr. W. J. Branch.

DEMERARA.—Professor J. B. Harrison.

Jamaica.

Mr. T. Laurence Roxburgh.	Mr. Maxwell Hall.
Mr. William Fawcett.	Mr. S. T. Scharschmidt.
Mr. H. H. Cousins.	Mr. J. F. Brennan.
Mr. John D'Aeth.	

Trinidad.

Mr. S. W. Knaggs.	Mr. H. C. Huggins.
Mr. J. H. Hart, F.L.S.	Mr. W. C. Nock.
Mr. W. M. Gordon.	Mr. J. F. A. Redhead.
Mr. E. R. Smart.	Mr. T. J. Potter, F.L.S.
Mr. J. E. Lickfold.	Mr. J. Haynes.
Mr. H. C. Warner.	

Dominica.

Dr. H. Alford Nicholls, C.M.G.	Mr. Duncan Naish, Picard.
Mr. G. F. Branch.	Mr. J. Sowtray.
Mr. Porter.	Mr. Wm. Jackson.
Mr. Bellot, Soufrière.	Mr. C. S. Kitching.

Antigua.

Mr. J. S. Udal, Chief Justice.	Mr. Francis Watts, F.C.S.

APPENDIX II.

Notes taken by Mr. T. M. McDonald on the Recent Eruption of the Soufrière.

(Reprinted from the 2nd edition of 'The Sentry' newspaper, Kingstown, St. Vincent, May 16th, 1902.)

LANDED at beach of Richmond Vale Estate about 6 P.M. on the 6th instant, and up to this time was sceptical as to any eruption having taken place, as during our approach by sea from Wallilabou nothing unusual in appearance had been noticed, and the summit of the Soufrière was enveloped in the usual white clouds. Within a minute or two of landing, however, someone exclaimed, "Soufrière bursting now," and on looking saw an enormous vertical column of white vapour being ejected—practically noiselessly—and was quite convinced that an eruption had been and was now taking place. People were coming in from the direction of the mountain in an agitated condition.

Went up to Richmond Vale House, from which place the summit of the Soufrière is plainly seen, and invited Mr. MATHES, a German gentleman on a visit to Chateaubelair, to come and stay the night and observe.

The following notes, taken by Mr. MATHES, are inserted here :—

"*Tuesday*, 6*th*, 2.40 P.M.—First appearance of white steam in consequence of a noise like a gunshot. 4 P.M. the people arrived at Chateaubelair who had fled from Richmond, and at 4.30 P.M. people from Morne Ronde came excitedly into Chateaubelair. At 4.35 P.M. the reflection of fire on steam clouds was seen quite distinctly. 5.15 P.M., very thick smoke rising from foot of the Soufrière on the right side New Crater. 5.20 P.M., reflection of fire in the Old Crater, and now for the first time to be seen—also issue of the smoke from the New Crater at top of the mountain. 5.40 P.M., both smoke and steam clouds disappeared, and summit of mountain clear and clean. At 6.05 P.M. there was a new eruption with very thick smoke."

Mr. MCDONALD now continues his notes from Richmond Vale House :—

At about 6.30 P.M. (**6th**) a greater discharge of vapour took place, with flame along the whole rim of the crater, forming a red, sparkling line between base of column of vapour and rim of crater, accompanied by a loud noise. At intervals of about two hours during the night similar discharges to the preceding took place, and at midnight flames were seen from Chateaubelair round the rim of the crater.

No further observation was noted at Richmond Vale House till shortly after 6 A.M. on the **7th**, when a discharge took place with the usual column of thick vapour, but beneath this was a much shorter column of almost dense black, and of a heavier nature, as it quickly subsided back into the crater. This was the first appearance noted of what was probably solid matter being erupted, the white vapour being no doubt vapour of water only. At about 7.4 A.M. an enormous high column of white vapour was ejected, and it may be here mentioned that these tall columns rose in a very short space of time—say, about a minute—to heights of about 30,000 feet and over, by comparison seven or eight times the height of the mountain (nearly 4,000 feet). Outbursts took place now at shorter intervals, and at about 10.30 A.M. the eruption became continuous, enormous volumes of vapour reaching to a very great height.

11.10 A.M.—At this time there was thunder and lightning, showers of black and heavy material could now be seen thrown outwards and falling downwards from the column of whitish vapour, associated with loud noises and more violent outbursts. From the commencement the Old Crater seemed to be the scene of activity, but at times it seemed as though some of the discharges proceeded from what is known as the New Crater, a little north-eastwards from Chateaubelair. The area of the escape of vapour seemed now to be extending in a direction corresponding with Morne Ronde (westward).

11.15 A.M.—Thunder and lightning still continuing, and associated each time with a more violent outburst from crater.

11.35 A.M.—Discharge still violent, and Old Crater apparently the great centre of activity, enormous volumes ascending in curling and whirling waves, those beneath forcing those above higher and still higher; the colour of the vapour now assuming a darker shade—white changing to light grey, and low, rumbling noises audible.

11.40 A.M.—The edge of the old crater was quite distinct, but was belching out over the whole area. Flash and peal were continuous. The contour of the whole mountain was unaltered, and vegetation still remained fresh and green, with one enormous pillar of vapour overhead.

12.25 P.M.—Small vents seemed to be forming on slopes near old road facing Richmond Vale, and jets of vapour emitted from them; then a more violent outburst, which seemed to be extending the crater westward, with dense black upheavals and rumblings.

12.35 P.M.—It seemed as if slope to left of old road up Soufrière had formed into fissure, as vapour was issuing from small vents, and at 12.40 P.M. these fissures were unmistakable, and discharges from crater were extended to windward.

12.50 P.M.—Enormous outburst through vent or front of mountain, as far as could be ascertained, the mountain being largely enveloped in vapour, &c.

1 P.M.—There was tremendous roaring, stones being thrown out to windward thousands of feet high.

1.15 P.M.—Activity seemed shifting to windward and Wallibu River Valley direction, the eruption continuing unabated in violence.

At 1.25 P.M. there was still further extension of activity in the direction of Wallibu River and Morne Garou to right of old road.

1.30 P.M.—Violent action to right, with heavy falls of streams of fine matter and black stones.

1.32 P.M.—Violent to left also, with showers of blackish material. A minute afterwards volumes of vapour covered the whole area.

At 1.50 P.M. there was a black outburst to right, and showers of large and small stones shot eastward and downwards with tails of fine, black matter following. These stones issuing from interior of enormous column of vapour, thousands of feet above the mountain. Some large stones were also seen falling from thousands of feet up on face of column to westward, and some were also seen falling from windward side.

1.55 P.M.—Rumbling. Large black outburst with showers of stones all to windward, and enormously increased activity over the whole area. A terrific huge purplish and reddish curtain advancing up to and over Richmond Estate. At this stage left Richmond Vale House and hurried into and pushed off boat a few minutes after 2 P.M. Saw vapour, as we rowed hard across Chateaubelair Bay, coming down to sea level past Richmond Point. Sea peppered all round with stones, one of which, about a cubic inch, fell inside the boat, in which were 11 persons. The huge curtain referred to was advancing after the racing boat, which never seemed likely to get out of range of it or the falling stones, which latter varied from the size of one's fist downward. All in the boat felt that their end was near, and someone cried out, "We are all done for—head for shore"! This was done, and the boat beached between Petit Bordel and Rosebank. Got on to public road, where streams of people were hurrying along, all anxious to get to some place of safety. The lightning and thunder at this time was terrific, and there were noises inland. Everything seemed to point to a general break-up both on land and on sea. Fortunately, the writer found a stray horse at Rosebank, which he mounted without a saddle and rode slowly along after the rest of the party. On reaching Troumaca Hill the bulk of the party refused to face the descent into the ravine, fearing darkness seen advancing from eastward.

Small stones were coming down all the time in a continuous shower, and Troumaca stream was thick from ashes. At Cumberland a saddle was obtained, and the journey to Wallilabou continued in bodily comfort. Reached the last-named place about 6 P.M., and found everything covered with dust from the eruption nearly one-eighth of an inch thick, and small stones had also reached there. Horses were being despatched to Cumberland to assist Captain CALDER and Dr. HUGHES, who with all others had made a general escape from Chateaubelair about 2 P.M.

8th.—The next morning (8th) the writer returned to Chateaubelair with the two above mentioned, also Mr. MATHES, Mr. ALLEN, and Mr. GENTLE. Slaty-coloured vapours were still being discharged from the old crater, and on the wind blowing from north showers of dust descended, and darkness set in, producing general alarm. At 2.20 P.M. the discharge of slaty-coloured vapours was continuous, but the new new crater, or some point to the right, appeared more active, the volumes being denser and blacker.

9th, 6.50 A.M.—Continuous rumbling noise for about half an hour, and then an increased discharge from crater, and steam and darker vapours appeared in large quantities, evidently from surface of sea, and, as seen from Chateaubelair Police Station, over Richmond Point, it was concluded to be a discharge of lava. In afternoon went in police boat, with Captain CALDER and Dr. HUGHES, along coast towards Wallibu to observe, but could not proceed further than opposite Richmond Estate, nor could a further view be obtained than the spur at which the flat land of "Fraser" terminates. The impression received was that there were about three lava streams issuing from the same number of ravines in sides of the mountain—one at the back of above-mentioned spur, the next at north side of spur on which ran the Soufrière road, and the third flowed through Wallibu Estate. The general level of all the flat land as far as "Fraser's" was much raised—by 40 or 50 feet, more or less—and terminated in abrupt, almost vertical, bluffs at the sea, the fronts of which frequently broke away and fell into the sea. The whole of the Richmond Village was buried deep with lava or ashes (30 feet, more or less), the highest being nearest to north of Wallibu River. Occasionally discharges of vapour would take place from the furthest first-mentioned ravine, and each was accompanied by a flash and peal of lightning and thunder. Slaty-coloured vapours were discharged from the crater continuously the whole day.

10th.—For some time after daylight crater was almost free from discharges.

9.23 A.M.—At this time there was a lofty grey outburst, and these continued with lessened force throughout the day.

11th.—Discharges continuous and of the same slaty colour.

At about 11 A.M. left in police boat with Captain CALDER and others to make further observations. Opposite Wallibu the sea had encroached along a length of shore beginning at Wallibu River to a point beyond Wallibu Works. The hill tops and crests of ridges had a comparatively thin covering of ashes, but the "flats" near the sea and the main river had considerable depths of volcanic matter. Owing to the enveloping vapours, a complete view of the mountain could not be obtained, and it was impossible to know exactly what changes had taken place.

On the **12th** and **13th** the volcano, although very much quieter, still gave signs of agitation at irregular intervals by sluggish discharges of slaty vapours, accompanied by low rumbling noise.

14th.—Dense cloud still over crater, but less lofty. Few small pebbles fell at Richmond Vale. Towards evening the summit was very clear, but distinct discharges of white steam.

15th.—At 9.30 A.M. there was a slight escape of steam, otherwise the mountain remained clear all day.

APPENDIX III.

On account of the discrepancy (*see* p. 396) between the narratives given by Dr. Hovey and in this Report, in respect of what happened in the cellar at Orange Hill on the afternoon of May 7th, we thought it advisable to write to Mr. F. W. Griffiths, Kingstown, to ascertain, if possible, what were the actual facts. We are much indebted to him for making further inquiries, and sending us the following statement:—

Letter from Mr. F. W. Griffiths, Government Office, St. Vincent, December 29th, 1902.

"The constable from Georgetown, who was of the first to visit Orange Hill cellar after the terrible catastrophe, states that he counted 37 dead bodies, and that this was verified afterwards. He further states that 18 people were in the cellar alive when he arrived, but cannot say how many were saved, as they had nearly all come out, and their ideas were so confused, in consequence of the terrible experiences they had passed through, that there were few, if any, able to give coherent accounts of what occurred. He is certain of one thing, however, and that is that the people were killed in consequence of the door being open. Only those at the door were killed.

"A woman to whom I have just spoken was in the cellar. She states that there was a large number of people in there when the outburst occurred—over 150. About 30 were killed; over 100 were saved. Those killed were all standing either just inside or outside the door, which was open. Everyone near the doorway were killed . . . . . She added that if the door had not been open they would have been suffocated, as the windows were all closed, or, at all events, the place was shut in all round."

DESCRIPTION OF PLATES.

PLATE 21, FIG. 1.

Georgetown and the Carib Country, St. Vincent, as seen from the Windward Road, north of Black Point, one mile south of Georgetown.

On the roadside the old tuffs and agglomerates are exposed. Georgetown stands on a sloping plain, which extends for several miles on the east side of Morne Garu and the Soufrière. In the background a spur of the Soufrière is seen, running down towards Overland Village, and behind Georgetown the land rises in a series of steep, rounded bluffs. It will be seen that on the cliffs and the beach south of Georgetown the trees were not destroyed by the eruption.

PLATE 21, FIG. 2.

Chateaubelair from the North.

The view is taken from the ridge which separates the village from Richmond Valley. Sharp spurs are seen running down to the coast, where they form rocky headlands. Traces of old terraces are furnished by the flattening of the profiles just above the cliffs. This country was covered with ashes, but the vegetation rapidly recovered, and in the month of June, 1902, flourished as vigorously as before. The fields behind Chateaubelair are mostly planted with arrowroot.

PLATE 22, FIG. 1.

Section Exposed on the Sea Cliffs on the Leeward Coast, near Cumberland.

To the left are well-bedded tuffs in horizontal layers. These have been cut into by a stream, and a valley has been formed which, at a later stage, has been filled up with water-worn volcanic conglomerate, the bedding of which is discordant with that of the ash which forms the walls of the valley.

PLATE 22, FIG. 2.

Section Exposed in the Roadside near Colonarie, 2½ miles south of Georgetown.

The rocks are weathered to a dark brown earth, which contains stones of various sizes, and in places exhibits a marked bedding. In this case an upper series of inclined strata rests with an apparent unconformity on a lower series which is nearly horizontal.

PLATE 23, FIG. 1.

Explosions of Steam on the Wallibu River after Rains, as seen from Sea View Cottage, near Chateaubelair, at a distance of Two Miles.

The whole valley is filled with steam: one explosion has just taken place, and the cloud is ascending in the air, expanding as it rises; another is floating to leeward. Their height was usually about 2000 feet.

PLATE 23, FIG. 2.

The Mouth of the Wallibu River, St. Vincent.

A gush of boiling mud, several inches deep, is rushing down the stream, and its surface is steaming vigorously. The valley is eroded out of soft well-bedded tuffs. On the left side, several feet of new ashes lie on the old soil. The vegetation is ruined by the eruption. A fan is forming at the mouth of the river, owing to the amount of mud which is being deposited.

PLATE 24, FIG. 1.

Section of the New Ash Deposits on the Sea Shore, a little south of the Mouth of the Wallibu River, St. Vincent.

The ash has gathered here on a low flat beach, which is covered to a depth of 20 to 40 feet. It is black on the surface when wet, but is quite hot in the interior, and is grey in a few spots where it has dried after the rains. Deep rills have been cut in it by the showers. In the background explosions of steam are rising from the river. On the shore lies a charred tree trunk. Richmond Peak is seen on the right-hand.

PLATE 24, FIG. 2.

Scene in Chateaubelair, St. Vincent, showing the Contrast between the Country which has been Spared and that which is Devastated.

PLATE 25, FIG. 1.

Landing below Wallibu Plantation, St. Vincent.

Before the eruptions there was a broad, flat beach at this place, and on it stood a village of labourers' houses beside the public road. That beach has disappeared, and the bluffs which formerly rose behind it now present a vertical face to the sea. Large masses frequently fall from these cliffs, and a narrow new beach has formed at their base. Soft stratified tuffs are exposed in the cliffs, and over them lies a deposit of new ashes from 5 to 10 feet deep. The remains of the chimney of Wallibu Plantation are seen above the boats on the right. The valley of the Wallibu Dry River lies to the left, and in it the new ash forms round-backed mounds. In the background is the Soufrière, with the Somma wall on the left of the crater, the rim of which is seen in the centre of the picture.

PLATE 25, FIG. 2.

Wallibu Plantation Works, Half Buried in Ashes.

The roof has collapsed, but the woodwork is unburnt. The level ground is covered with several feet of ashes, channelled by the rains. The steeper slopes behind have been washed nearly bare. The trees are blasted, but not overturned. In the background the Soufrière rises to the north of the valley of the Wallibu Dry River.

PLATE 26.

The Plantation Grounds of Wallibu, St. Vincent.

The fields are covered with a layer of ash, which is several feet deep on the flat grounds, but less on the slopes behind. The surface is channelled with rain rills, the arrangement of which varies with the slope. The trees are blasted and stripped of their branches on the side looking up the valley, so that the effects of the blast and the direction in which it was travelling are clearly visible.

PLATE 27, FIG. 1.

The Burnt-out Houses of Wallibu, St. Vincent.

These stood on the ridge behind the plantation works (*see* Plate 25, Fig. 2). They are surrounded by ashes, and the trees are overturned, but their branches have not been consumed or torn off the stems. Richmond Peak rises in the background.

PLATE 27, FIG. 2.

The Fields of Wallibu Plantation.

This view is taken further up the valley than Fig. 1 above, and shows an increase in the amount of devastation. In the background is a spur of Richmond Peak, on which the forest is blasted but not entirely overthrown. On the naked side of the valley a lava flow is exposed, capped by thick masses of tuff. At the foot of this slope the Wallibu is flowing through terraced accumulations of new ash.

PLATE 28, FIG. 1.

The Fields of Wallibu Plantation.

This plate shows the remarkable variety of the sculpturing of the new ash by the rain torrents. The trees are blasted, and in some cases overthrown. The direction in which they have fallen indicates the course of the blast.

PLATE 28, FIG. 2.

The Upper Part of the Wallibu Valley, St. Vincent.

The valley is filled with a thick deposit of new ashes, still very hot in the interior. It is somewhat eroded and terraced, but the rolling character of the original surface is still recognisable. In the background is a spur of Richmond Peak, with a thick lava flow dipping down stream. The trees on this slope are blasted, but still erect. In the right foreground stands a small mud crater in the field of ashes.

PLATE 29, FIG. 1.

The Upper Part of the Valley of the Wallibu River, St. Vincent.

The banks of the old valley are seen on the right of the Plate and in the background. New hot ashes now fill the gorge, from which they are being eroded by the stream, and terraces have formed on each side of the river and its main tributaries. After showers, the surface of the ash is cold and dark coloured, and rain may collect in little pools, but the deeper parts of the mass are still intensely hot, and, as the material dries, landslips are constantly taking place in the banks which overlook the terraces.

PLATE 29, FIG. 2.

The River Wallibu, St. Vincent, Eroding the Thick Deposits of Hot Ash.

In the centre the stream, which is nearly dry, is flowing through a deep gorge which it has cut in the ashes. These are dark on the surface when wet, but grey when dry, and quite incoherent, so that landslides are frequent, and the hot, dry sand may be seen tumbling down the cliffs which overlook the channel. These cliffs are 40 to 60 feet high. On the right the rolling character of the original surface can still be traced, and on both sides the old valley walls are seen covered with burnt forest (in the middle distance). In the background a spur of Richmond Peak rises in bare precipices, which consist of lavas and tuffs in alternating series, dipping outwards from the centre of the mountain.

PLATE 30, FIG. 1.

Small Secondary Crater-pit in the Hot Sand Deposits a little north-east of Wallibu Plantation, St. Vincent.

On the left a channel has been cut in the new ashes by a small rivulet, which drains the slopes above. In the foreground a bowl-shaped depression in which a little water has gathered, and, behind this, two others less perfect and dry. These are produced by the explosions of steam which take place when the water of the stream comes in contact with the hot material in the deeper parts of the layer of recent volcanic ash.

PLATE 30, FIG. 2.

One of the Minor Ravines on the South-west Slopes of the Soufrière, St. Vincent.

A deep, narrow gorge has been cut out of the soft tuffs which form this part of the mountain. It has been filled nearly to the top with new volcanic ash, which has been in large measure washed away by the stream, but a considerable thickness still remains. The upper surface shows well-marked terraces. The ridges above have received only a thin covering, most of which has since been removed by the rains.

PLATE 31, FIG. 1.

The ash-covered cane-fields of the Carib Country, with, in the distance, the Rabaka Dry River pouring down in flood after a heavy shower, and sending up great clouds of steam as the water comes in contact with the hot sand which fills the old channel. At this level the bushes have suffered only slightly. The layer of new ash on the level fields is eroded by the rains.

PLATE 31, FIG. 2.

The Upper Part of the Carib Country, above Lot 14, and the Spurs and Ravines at the Base of the Soufrière on the Windward Side.

The undulating surface of the ground is covered with 4 or 5 feet of sand, in which the rain has worked a feather pattern of rills. The trees are erect, but reduced to mere trunks, without leaves or branches. On the mountain behind, the ash on the knife-edges shines in the sun, and the forest has been completely overturned or destroyed.

PLATE 32.

The Upper Part of the Valley of the Rabaka Dry River obstructed by the Avalanche of Sand.

Before the eruption this valley was over 200 feet deep. It is now nearly completely filled up. The new ash has a hummocky, irregular surface, and the stream flowing through it has cut a shallow channel, which in some places is flanked by inconspicuous terraces. Between the showers the flow of water ceases, though the ash, where it is wet, is freely steaming. In the background rise the lower spurs of the Soufrière and Morne Garu.

PLATE 33, FIG. 1.

The Valley of the Rabaka Dry River, St. Vincent.

The view is taken from the north bank, looking south across the surface of the sand avalanche towards Georgetown. In the foreground the dead trees, eroded by the sand blast and stripped of their leaves and branches, are seen on the back of a ridge which separated the main valley from one of its tributaries. Beyond this ridge lie two great semicircular crater-bowls, out of which explosions of steam have been emitted. Around each of them there is a low cone, and the fields of ash are covered with stones thrown out of the craters.

PLATE 33, FIG. 2.

Nearer View of one of the Crater Bowls shown in the previous Figure.

The dark and cold material forming the cone of ejection is sharply defined from the lighter-coloured and hot ash of the avalanche beneath. At both sides of the picture transverse sections of the low cone surrounding the crater-bowl can be seen. The ash fields around are strewn with stones. In the background the irregular surface of the deposit is marked in places by flat-topped terraces. The river is cutting a new gorge in the foreground, and on the side of this the explosion funnels are situated.

PLATE 34, FIG. 1.

Lake of Water occupying one of the Lateral Valleys opening out into the Main Channel of the Rabaka Dry River, St. Vincent.

The rolling surface of the avalanche of sand is seen in the background. On each side of the picture the cane-fields of Lot 14 are covered with several feet of ashes, but, as is apparent from the state of the bushes which project above the surface, the depth of the layer is inconsiderable, when compared with that of the great mass which blocks the valley.

PLATE 34, FIG. 2.

Lake of Mud in One of the Lateral Valleys which Open Out into the Valley of the Rabaka Dry River, St. Vincent.

A deep, narrow gorge has been cut into the soft bedded tuffs which form the southern part of the Soufrière. This gorge is obstructed at its mouth by the sand avalanche in the main valley, and a lake of mud has collected. The rains have stripped the new ash from the slopes, except near their base, but in places the irregular surface of the masses which occupied the valley bottom can still be seen projecting above the surface of the mud. The forest which clothed the mountain is broken down and destroyed. Most of it has vanished, only one stump remains erect. In the background the knife edges of the spurs are shining as the light is reflected from the layer of fine ash which still rests upon them.

PLATE 35.

The Windward Slopes of the Soufrière, St. Vincent.

The mountain is scored with deep ravines, between which lie sharp-backed spurs. On the knife edges the fine sand still remains, forming narrow strips which reflect the sunlight. The flanks of the ridges are almost cleared of the new ash, which can be seen only in scattered patches. The surface of the older tuffs and agglomerates is now exposed. In the bottom of the valley the course of the stream is marked by a layer of shining mud. Hardly a tree remains standing, and the prostrate trunks lie parallel, with their roots towards the crater and their apices pointing down the slopes.

PLATE 36, FIG. 1.

View taken in the Streets of St. Pierre, Martinique, looking South towards the Cathedral.

PLATE 36, FIG. 2.

View taken in the Streets of St. Pierre.

The trees are broken and eroded by the sand blast. The streets are filled with scoria and sand. A stone, which has fallen from the roof of a building on the right, has been caught on the spikes of the iron railing, one of which has entered a hole made for the reception of an iron bar.

PLATE 37, FIG. 1.

Grenada.—The Lagoon and Carenage looking South from Government House.

The lagoon is to the left, the carenage or harbour to the right. The narrow channel between the two is the seat of the disturbance of June 6th, 1902. The Green Hole is situated in the carenage more in the foreground. The vegetation shows the luxuriance of growth usual in the tropics.

PLATE 37, FIG. 2.

The Crater Lake of the Soufrière as it was before the Eruptions of May, 1902. From a Panoramic Photograph by Mr. J. C. Wilson, Kingstown, St. Vincent.

The mists hovering over the mountain-top are reflected from the surface of the water, except in the centre of the lake, where the reflection of clear sky appears. The photograph was taken from the southern lip of the depression.

PLATE 38.

Montagne Pelée, Martinique, as it appeared on the Evening of July 9th, 1902, emitting Great Clouds of Steam and Dust, which Floated away to Leeward.

On the right of the picture the trade-wind cloud is seen covering the summit, and paler in colour than that discharged from the crater. The first black cloud rolled down the slopes a little to the right of the centre of the picture.

PLATE 39

Map of the North End of St. Vincent. Reproduced from the British Admiralty Chart, by permission.

Fig. 1.—Carib Country, with Georgetown.

Fig. 2.—Chateaubelair.

Fig. 1.—Cliff section near Cumberland.

Fig. 2.—Roadside section, Colonarie.

Fig. 1.—Shore section near Wallibu River.

Fig. 2.—Coast scene, Chateaubelair.

Wallibu Plantation grounds.

Fig. 1.—Wallibu, burnt-out houses.

Fig. 2.—Wallibu Plantation fields.

Fig. 1.—Wallibu Plantation fields.

Fig. 2.—Upper Wallibu Valley.

Fig. 1.—Upper Wallibu Valley.

Fig. 2.—Wallibu River, eroded bed.

Fig. 1.—Secondary Crater pit in the ash near Wallibu.

Fig. 2.—Ravine on slopes of Soufrière.

Fig. 1.—Carib Country, cane fields.

Fig. 2.—Higher Carib Country, and base of Soufrière.

Rabaka Dry River, upper valley.

Fig. 1.—Rabaka Dry River Valley, with crater bowls.

Fig. 2.—Nearer view of crater bowls.

Fig. 1.—Rabaka Dry River, lake in side valley.

Fig. 2.—Rabaka Dry River, mud lake in side valley.

Soufrière, windward slopes.

Fig. 1.—St. Pierre, Martinique; view in streets.

Fig. 2.—St. Pierre, view in streets.

Fig. 1.—Grenada, lagoon and carenage.

Fig. 2.—Soufrière crater lake before eruption.

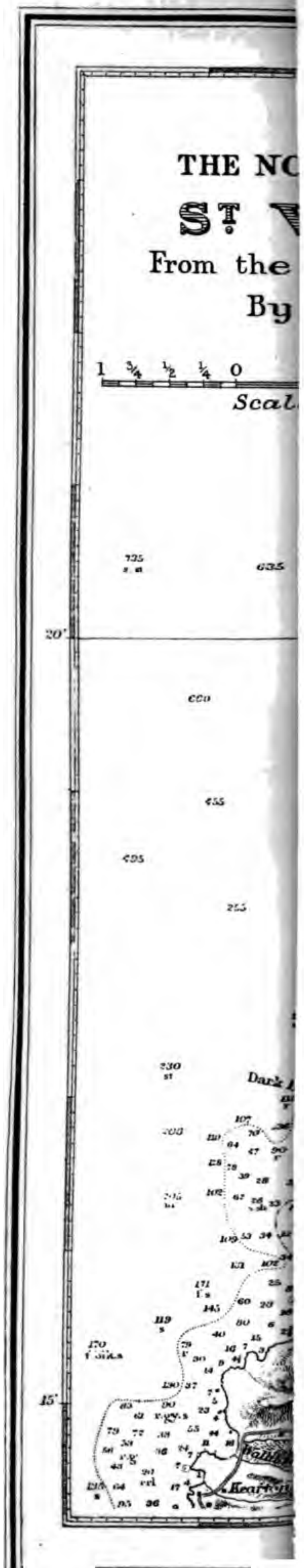
(*Photo. by J. C. Wilson, Kingstown.*)

Fig. 1.—Grenada, lagoon and carenage.

Fig. 2.—Soufrière crater lake before eruption.

(*Photo. by J. C. Wilson, Kingstown.*)

Montagne Pelée, July 9, 1902, evening.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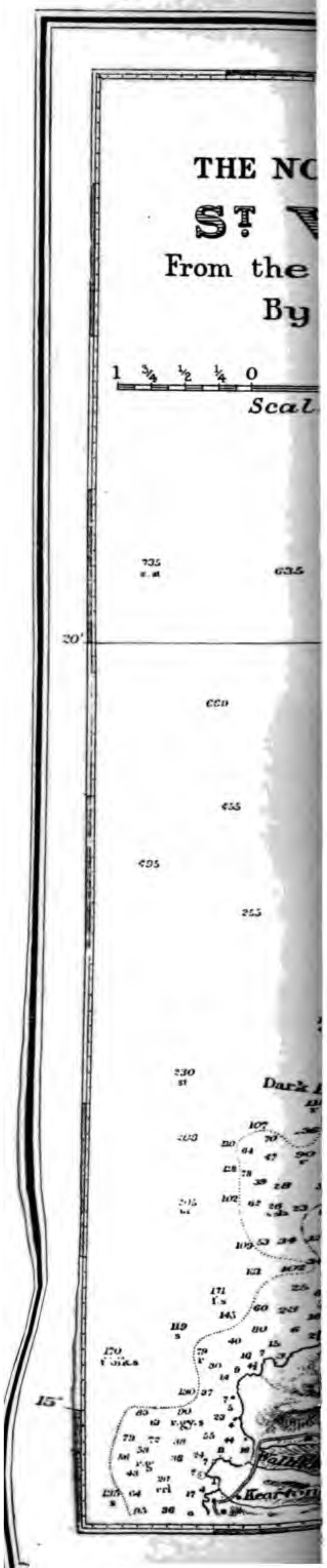
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PHILOSOPHICAL TRANSACTIONS

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SERIES A, VOL. 208, pp. 275–332.

REPORT ON THE ERUPTIONS OF THE SOUFRIÈRE IN ST. VINCENT IN 1902, AND ON A VISIT TO MONTAGNE PELÉE IN MARTINIQUE—PART II. THE CHANGES IN THE DISTRICTS AND THE SUBSEQUENT HISTORY OF THE VOLCANOES. BY TEMPEST ANDERSON, M.D., D.Sc., F.G.S.

PETROGRAPHICAL NOTES ON THE PRODUCTS OF THE ERUPTIONS OF MAY, 1902, AT THE SOUFRIÈRE IN ST. VINCENT. BY JOHN S. FLETT, M.A., D.Sc.

pp. 305–332.

A 433-4.

VII. *Report on the Eruptions of the Soufrière in St. Vincent in* 1902, *and on a Visit to Montagne Pelée in Martinique.*

PART II.

The Changes in the Districts and the Subsequent History of the Volcanoes.

By TEMPEST ANDERSON, *M.D., D.Sc., F.G.S.*

Communicated by Professor T. G. BONNEY, *Sc.D., LL.D., F.R.S.*

Received January 11,—Read January 23, 1908.

[PLATES 9–25.]

IN 1902, Drs. ANDERSON and FLETT had the honour of being commissioned by the Royal Society to visit the volcanoes of the Soufrière of St. Vincent and Montagne Pelée in Martinique, and Part I. of their Report on the eruptions of the volcanoes was published in the Philosophical Transactions for 1903.*

It was intended that Part II. should include an account of the subsequent changes in the deposits of volcanic ejecta observed on that visit, and also on the petrology of the specimens collected in 1902.

In the Spring of 1907, Dr. ANDERSON revisited the West Indies, but Dr. FLETT being unavoidably detained in England by his official duties, Dr. ANDERSON is alone responsible for the field observations on the topography and geology, and also on the return of vegetation in the earlier portion of this Part II., while Dr. FLETT contributes the petrology. (See the following paper.)

By the kind permission of Sir DANIEL MORRIS, K.C.M.G., Mr. W. N. SANDS, of the Botanical Gardens, St. Vincent, was able to accompany Dr. ANDERSON to the Soufrière, and make a collection of the flora which is gradually reappearing on the devastated area. These plants have been identified by him, and also, where necessary, by

* "Report on the Eruptions of the Soufrière in St. Vincent in 1902, and on a visit to Montagne Pelée in Martinique," Part I., by TEMPEST ANDERSON, M.D., B.Sc., F.G.S., and JOHN S. FLETT, M.A., D.Sc., F.R.S.E., 'Phil. Trans.,' A, vol. 200, pp. 353–553, Plates 21–39.

Sir DANIEL MORRIS. Thanks are also due to His Honour E. J. CAMERON, C.M.G., Administrator of St. Vincent, and to DUNCAN MACDONALD, Esq., of Wallilabu, for their kind assistance and hospitality, also to the Rev. T. HUCKERBY, of Chateau Belair, for much help in visiting the Soufrière, and for information regarding the eruptions subsequent to the great outbreak of 1902. The author's special thanks are also due to Professor T. G. BONNEY, F.R.S., and GEORGE YELD, Editor of the "Alpine Journal," for much kind advice and literary assistance.

The map in Part I., Plate 39, shows that the north end of the Island of St. Vincent is formed by the cone of the Soufrière volcano. In the summit of this mountain lies the principal or old crater, nearly a mile in diameter, from which the eruption took place in 1902. There is likewise a much smaller crater, the so-called "new crater," which was active in 1812 and may have been formed in that year. These two craters are surrounded to the north by a large crater-ring of older date, broken down towards the south, which has been referred to as the Somma Ring, since it bears the same relation to the working cone of the Soufrière as Somma does to Vesuvius. The whole mountain group was formerly known as Morne Garu, but the name has now been appropriated to another mountain about three miles to the south, also formed of volcanic material, but of much older date, which is separated from the Soufrière by a deep depression extending right across the island. The part of this depression on the eastern or windward side of the island is occupied by the Rabaka and other smaller streams, and is called the Carib country, while that on the western or leeward side is drained by the Wallibu and other streams, and is here referred to as the Wallibu district. In the 1902 eruption a certain amount of the ejecta overtopped the Somma Ring and descended some of the valleys to the north of it, but by far the greater portion was discharged into the above-mentioned transverse depression. The water from the crater lake was discharged at the beginning of the eruption down the Rabaka and Wallibu Rivers, the former of which it rendered impassable, and thereby cut off escape from the Carib country, where the greater part of the deaths occurred, while the solid and gaseous ejecta in the form of the incandescent avalanches and black clouds* descended to both sides of the island, and the most important geological phenomena were observed in the Wallibu district. These phenomena, including the incandescent avalanche into the Wallibu valley, the partial re-excavation of that valley by the river, the secondary explosions of steam and hot ash, the discharges of boiling mud, and the formations of new fans at the mouths of the rivers, have been fully described in Part I., p. 428, *et seq.*; as has been also the subsidence of part of the coast between the mouths of the Wallibu and Morne Ronde Rivers (Part I., p. 453, *et seq.*). This district was therefore the part to which attention was specially directed in 1907, with a view of observing the further progress of these changes and the return of vegetation.

* Called Nuée Ardente by the French Commission to Martinique, and later Nuée Péléenne. See Note, p. 298.

THE WALLIBU DISTRICT.

The Wallibu valley, like its fellow, the Rabaka, though profoundly modified by denudation, is not primarily a valley of erosion, but a gap left between the mountains of the Soufrière and Morne Garu as they have been built up stage by stage. The slopes of Morne Garu to the south are formed of old tuff and occasionally lava, all dipping away from the centre of that mountain and with their surfaces sloping towards the valley more or less conformably to the dip. This was very evident when the surface was bare of vegetation in 1902 (Part I., Plate 29, fig. 2). The north slopes of the Wallibu district, including in that term the area drained by the smaller parallel rivers of the Wallibu Dry River, Trespé River, Morne Ronde, and others, all to the north of the Wallibu, are composed of a series of beds of a newer date formed by ejecta from the Soufrière. They dip away from the crater of that mountain and abut unconformably against the older beds of Morne Garu. They have been dissected into flat-topped plateaux (Plates 9 and 14) by the above-mentioned rivers, which run in deep gorges with steep and often precipitous sides. These gorges have again been filled in places by ejecta of later eruptions, and re-excavated in different degrees and sometimes not along the old lines, leaving plateaux and terraces of different ages and heights. The lower valley of the Wallibu is a good example of this.* The river as it descends from the mountains in a westerly direction turns abruptly to the south, and then to the west again, after which it flows by a straight course of almost two miles direct into the sea.

The south or proper left bank of this lower portion was before the eruption of 1902, and is now again, moderately sloping and diversified by side gullies, almost deserving the name of valleys, in the old beds of Morne Garu, which show a fairly advanced stage of denudation. The north bank, on the other hand, is cut from a plateau, flat topped in the greater part of its extent, but with a rounded hill at its eastern end, and a moderate slope towards the sea on the west above the sites of the Richmond Estate House and Wallibu Works. Its top slopes gently to the south-west, and there is a terrace on the opposite bank of the river, near the lower end of the valley, which forms a continuation of the same slope, and shows that the plateau was once continuous across the valley which has since been excavated. Unlike the sloping bank opposite, it presents towards the valley a precipitous face in places nearly 200 feet in height. In the 1902 eruption this part of the valley was filled by the incandescent avalanche to a depth of at least 100 feet in the upper part, and to a smaller extent towards the sea, and it was in this deposit of hot ash that the steam explosions, slips of hot ash, flows of boiling mud, and other secondary phenomena took place. They are illustrated in Part I., Plate 29, fig. 2, where a deep channel is in progress of re-excavation on the south side of the valley, while a large plateau of hot ash still occupies its north side.

* Part I., Map, Plate 39; Part II., Plates 9, 10, 11.

In 1907 almost the whole of this ash had been washed away, but a fragment remained in the shape of a terrace about 60 to 80 feet high, which showed the height to which the valley was originally filled (see Plate 10). It is situated on the north side of the valley, just below the abrupt turn to the west above mentioned, and is *in situ* except for a few partial landslides; the ash of which it is formed is unstratified and contains very few ejected blocks or fragments of any kind. The round hill behind it is the same as one shown to the left of the 1902 photograph in the middle distance. It was impossible to get a photograph from exactly the same position as before, since the ash bank on which the camera stood in 1902 has been all washed away, and the Wallibu plateau adjacent, when tried from several directions, proved inaccessible. The camera in 1907 was therefore placed on the floor of the valley in a similar position, but 60 to 80 feet lower. This floor, or more strictly terrace, as mentioned below, is all composed of water-sorted material, chiefly gravel and coarse sand, but with a good many blocks as big as a man's head. They represent ejected blocks and fragments of lava derived partly from the ash of 1902, and partly from older beds, the fine ash in each case having been washed away. The surface of the gravel bed showed marks of quite recent running water, and Mr. DUNCAN MACDONALD, who knows the place intimately, stated that during the last winter, 1906–07, the river ran along the foot of the north bank of the valley. When examined in March, 1907, it ran along the south side of the valley, and had already in those few months excavated a new channel about 30 feet in depth, as shown in Plate 11, which was taken from the top of the valley floor or terrace, the surface of which is shown in the previously mentioned Plate 9. The stratification as exposed in the side of this new valley is very distinct, and the sorting by water, mentioned above, is very evident. This gorge appears to have been excavated when the river was in flood, and as the water subsided and the excavating power became less, its channel in the bottom of the gorge became more tortuous, and it formed small meanders and left small terraces on its sides at different heights. This plate also shows the precipitous and inaccessible character of the north side of the valley where it is formed of the Wallibu plateau till it gets lower as it approaches the sea, and this is a characteristic specimen of the early stages of denudation in these ash beds.

The south side, on the contrary, is sloping, and its outline is characteristic of a more mature stage of denudation. This sloping character has enabled more numerous terraces of the new deposits to survive. Some low down by the side of the river consist solely of water-sorted material, while others show patches of ash in its original condition higher up the slope. In one or two cases it is possible to compare the two in juxtaposition (Plate 12, fig. 1), in which case the lower terrace of water-sorted material stands almost vertical where it has been undermined by the river in two stages; while behind it a mass of ash *in situ* shows most beautifully the marks of rain-water running over and down the surface. Further away again, the slopes of the old valley show denudation in a more mature stage.

Further up the mountain the remains of the avalanche became more abundant in the valley bottoms (Plate 13), and here they were also often better preserved, so that traces of the feather-pattern erosion, so noticeable in 1902,* were still visible on the surface. This was mainly due to the surface of these ash deposits, like those to be presently mentioned on the plateaux and on the ridges, having consolidated into a crust almost like a cement pavement which resists the action of the rain. Another very curious and, it is believed, novel point was observed with regard to these massive ash deposits. Instead of one stream re-establishing itself along the centre of the deposit, the tendency is for a new stream to form on each side at or near the junction of the new ash with the old valley walls, and as these streams deepen themselves, two new valleys are formed where only one previously existed, and the walls of each are composed on the one side of the new ash, and on the other of older tuff with occasional terraces of new ash. Sometimes the two valleys coalesce by the washing away of the central mass, but quite often the two remain distinct, as in the case of the Trespé River† and Wallibu Dry River to be mentioned shortly. The fact of this side formation of streams is clear; it is seen in the ravine just noticed, also in the upper Rozeau, and in several of the plates in Part 1, where, though not noticed at the time owing to its being then in an early stage, it is distinctly visible when looked for, but the cause is not so clear. It appears to be due to the fact that the water from the old slopes in running down into the original valley meets the soft new ash, and at once turns down along the valley and so starts the new stream, and it seems likely that the chief cause of its so turning is that the surface of the deposit tends to be higher along the middle of the valley than at the sides, the shape of the mass somewhat resembling a glacier, which it is well known is usually higher in the middle because of the more rapid motion of that part.

The Wallibu Dry River and Trespé River.—These are two small and short rivers to the north of and parallel with the lower part of the Wallibu valley, and both run in deep gorges in the floor of a wide valley bounded on the south by the Wallibu plateau. In 1902 both these gorges were filled with new ash to the level of the main valley floor, and the process of re-excavation of one of them is shown in Part I., Plate 30, fig. 2. It was noticed that this main valley was wider and more open than the Wallibu valley,‡ but no explanation was forthcoming at the time. Mr. Duncan Macdonald now informs me that before the 1812 eruption the Wallibu River flowed down the Wallibu Dry River, and that its course was changed after that eruption. Mention has already been made of the Wallibu valley making an abrupt turn to the south and turning again to the west round the

* Part I., Plate 26 and Plate 28, fig. 1.

† I heard this river called also Cobrée. The confusion is due to these gorges being liable to be filled up and re-excavated in slightly different positions.

‡ Part I., p. 429.

end of the Wallibu plateau. The line of this upper part of the valley, if prolonged to the sea, passes to the north of the Wallibu plateau down the broad valley of the Wallibu Dry and Trespé Rivers, and is blocked opposite the east end of that plateau by a great deposit of ash, which has deflected the river into its present course (Plate 9). Below this obstruction the broad open valley can still be traced as described above, while its floor is now occupied by the two small river valleys above mentioned, divided by a plateau or ridge often only a few yards wide, and sometimes a mere knife edge. It is formed of ash different from and less consolidated than that composing the walls of the main valley, and its top is considerably lower than the Wallibu plateau. A closer inspection of the Trespé valley (Plate 12, fig. 2), where the narrow gorge has been emptied of the 1902 ash, now shows that the north wall is much higher than the south, and also formed of older and more consolidated tuff. If the sides of the picture were reversed, it might serve as a view in the Wallibu Dry River, the higher bank being in this case the Wallibu plateau to the south. It is thus clear that these two rivers are an example in a more advanced stage of the process which, as described, is now taking place in the ash of 1902 in the ravine above mentioned.

The Wallibu plateau is composed of ash older than that dividing the above two small rivers, but still comparatively new, and its flat top and precipitous sides, both north and south, proclaim it to be in an early stage of denudation, while the south bank of the Wallibu is composed of older tuff and lava, and shows a much more mature type of denudation, viz., sloping hills with rounded or ridged tops, and a good deal weathered into valleys or gullies. The same description would apply to the north face of the plateau, which is precipitous and obviously much less advanced in weathering than the slopes of the Soufrière on the opposite side of the valley to the north. The mass appears to be the remains of an avalanche or succession of avalanches of hot ash poured into the depression between the Soufrière and Morne Garu, on an enormously bigger scale than anything formed by recent eruptions. It would seem that the present bed of the Wallibu to the south, and the broad valley of the Wallibu Dry and Trespé Rivers to the north, are each the enlarged and deeply excavated development of the valleys that were formed at the sides of this prehistoric avalanche.

The Fans and Low Plateaux.—The part of the Wallibu district between the sea and the Wallibu plateau, and others like it, of comparatively old date, consist of a series of low plateaux and fans (Plate 14). These have been formed by a succession of discharges from the Soufrière, which are mostly unstratified, and have been partly or wholly consolidated into tuffs. They are much dissected by ravines cut by the rivers, and the materials brought down by these have formed fans and deltas consisting of water-sorted materials. Sometimes the rivers in the earlier stages of their cutting through the plateaux have deposited water-sorted beds on their surfaces, which are interbedded with those of ash *in situ*, rendering the structure more complex, while the fans laid down in the earlier stages of denudation after an eruption are dissected by the rivers later on, leaving terraces at one or both sides which merge into the plateaux. The plateaux and fans thus pass insensibly one into another, but on the whole it will be convenient in this paper to restrict the term "fan" to the portion over which the river at present habitually flows at intervals, and reserve the term "plateau" for the more completed and generally higher portion over which such a flow no longer generally occurs.

In the eruption of 1902 the incandescent avalanche which came down the Wallibu, as soon as it had passed the deep part of the valley, spread like a fan over the plateaux to the north and south. To the south it turned round the lower end of the Richmond ridge, where it formed, along with water-borne material, a bar at the mouth of the Richmond River. This bar still exists, though much washed away. The river has cut a sinuous channel through it. The shore of the plateau, which in 1902 was sloping,* is now washed away into a steep cliff 30 or 40 feet high. There is only a narrow steep beach at its foot. The plateau at a little distance from the shore is about 50 feet in height, and the older portion further inland about 150 feet, or three times as much.

The fan of the Wallibu in 1902 extended beyond the coast line, and was very steep. Gushes of hot mud came down it,† and tended continually to build it up. In 1907 it scarcely extended beyond the coast line, and both have receded considerably. The fan is no longer steep, but has only a very gentle slope; as shown in Plate 14, which is taken from the plateau just mentioned. The river appears to wander frequently about this fan, as it does further up the valley. In March, 1907, it flowed at the south side of the fan, close under the above-mentioned cliff, and is consequently concealed behind it in the photograph. The avalanche, where it spread north towards the Richmond Estate House below the end of the Wallibu plateau, was of unequal thickness. This, in a good section on the north bank of the Wallibu fan, was from 10 to 20 feet, and, curiously, it was greater nearer the sea coast. The section exposed extended in places to below the old surface, and the line was marked by the vegetation which was returning in the old soil.

The plateaux to the north present similar features in the re-excavated river valleys. They show good sections of soft tuff, with a capping of new ash, generally from 10 to 20, or even more, feet in thickness, and the line of the old surface is here again visible by the return of vegetation. Except about the Wallibu House and Works, their surface is generally bare and consolidated into a crust.

The Wallibu Subsidence.—This took place along the shore north of the Wallibu and south of Larikai Point. The foreshore to a breadth of about 200 yards and a length of above a mile appears to have subsided into deep water by a sort of submarine landslide, a secondary effect of the earthquakes connected with the eruption.

* Part I., Plate 24, fig. 1.
† Part I., Plate 23, fig. 2.

Further slides are reported to have taken place at the times of the eruptions in September, 1902, and March, 1903, but this is not very certain. The cliffs in this part are higher than further south, but present similar structural features, viz. :—tuff capped with new ash (Plate 14). A new beach is forming along the base, the materials of which appear to be furnished partly from the cliffs, partly by that brought down by the rivers. The gorges cut through this plateau are often very narrow, and their steep sides show fine sections of the tuffs and ash beds.*

The Soufrière.

The Upper Slopes.—The upper slopes of the mountain are chiefly formed of beds of tuff like the lower parts, but contain perhaps a larger proportion of ejected blocks which naturally fell in greater abundance nearer the crater. They are much cut up into deep ravines which are separated by the ridges, the slopes of which are often very steep, as described in Part I.† Even in 1902 the new ash, which had never been thick on these slopes, was in great part washed away, and it was only on the ridges and in some of the valley bottoms that any considerable amount of that ash remained, and this process, of course, has gone on ever since.

The ash on the ridges still remains, and its surface is consolidated into a thin but hard crust similar to that on the plateaux. This extends generally only to a width of a few feet, and often not more than one or two. On each side of the ridge where the ash has been washed away the old soil has been exposed, and it would doubtless also have been in a great measure removed if it had not been held together by the roots of plants which, as mentioned below, were in many cases not killed. Even when dead they no doubt held the soil together to a large extent while the new vegetation has been re-establishing itself.

The old Carib track to the summit ran along one of these ridges (Plate 22, fig. 2), and the consolidated ash forms in most parts an excellent footpath along the former lines. It is true that in places the ridge has been carried away by landslides, but a comparatively small amount of labour would suffice to restore it to a perfectly useful condition. The path for a considerable distance overlooks the upper part of the Rozeau valley, which extends nearly to the summit of the mountain, and this is a good example of a high valley in which extensive ash deposits were formed. It was here that Mr. T. M. MACDONALD saw explosions in the earlier stages of the eruption, and these were supposed to proceed from parasitic craters, *i.e.*, side branches of the main chimney. The place was pointed out to me by his brother in 1907. It was impossible to approach it closely except at unjustifiable risk, but an examination from a distance of perhaps 100 yards revealed nothing but a hollow in a bed of ashes, which no doubt was merely the locality of a secondary explosion in the hot ash like those

* Plate 12, fig. 2. In lower Trespé valley.

† Part I., Plate 31, fig. 2, and Plate 35.

described in Part I., p. 438. This body of ash, which is well seen from near the Maroon tree about half way up the mountain, presents one of the best examples of the rounded character of the deposit in its original state, where, as mentioned above, it was higher in the middle than at the edges.

The Crater.—In 1902 we ascended to the lip of the crater twice, from the south-west and south-east sides respectively, by the old Carib track which led from Chateau Belair, *viâ* Wallibu, on the leeward side to lot 14 and Georgetown on the windward side of the Island, but owing to the summit being in cloud on each occasion we saw only rare glimpses of the interior. In 1907 I was more fortunate, and during part of the time I was on the summit the air was perfectly clear, though the clouds came down before I had an opportunity of examining the new crater. The topography of the old crater is still correctly represented on the Admiralty chart. The crater is approximately circular, nearly a mile in diameter at the rim, and with a lake in its bottom (see Plate 15).

The walls in the greater part of their height are nearly vertical, and consist of alternate layers of tuff and compact rock, all dipping outwards from the crater. The latter beds are chiefly lenticular in section and columnar or subcolumnar in structure, the columns being as usual arranged at right angles to the surfaces of cooling. Probably they are chiefly lava flows, but some may be intrusive sheets. It was impossible to get near enough to examine their surfaces of contact with adjacent beds. There is a very prominent dyke to the north-west of the crater and a smaller one to the west of it, which cut through several of the massive beds referred to, so that, as intrusive action has undoubtedly occurred, the results might be horizontal sheets as well as vertical dykes. One of the horizontal beds mentioned above, situated in the north-west wall of the crater, is especially massive. It must be several hundred feet thick and is distinctly columnar. At the foot of the almost vertical cliff is a broad bench or beach, specially well marked on the north and east side of the crater. The Rev. T. HUCKERBY, of Chateau Belair, who has ascended the mountain many times, is quite clear that it was formed by the ejecta of the small eruption of March, 1903. It has suffered much erosion by rain and other agents of subaerial erosion, and a talus is forming on it in places by falls from the cliffs above.

The topography of the crater lake also corresponds with that marked on the Admiralty chart, and the sheet of water appears to be a trifle over half a mile in diameter. Mr. HUCKERBY thinks it is at a somewhat lower level than before the eruption, but Professor KARL SAPPER'S measurements render this doubtful.* The water is of an uniform light green colour and does not boil or steam in any part. The mottled appearance in Plate 15 is due to reflections from the clouds. The lake is not in any way divided, and no secondary cone is visible. If any exists it must be below the water level. There is one spot near the foot of the crater wall on the south side where vapour escapes occasionally in small quantity, and

* See p. 291.

another still less evident on the east. Neither is sufficiently conspicuous to appear on the photographs. Thus all the deeper parts of the crater bear evidence of the severity of the eruption of 1902, since it appears that any loose deposits previously existing there have been entirely blown out, and that the small bench or talus mentioned above is of subsequent formation. The upper parts of the walls of the crater are on the whole less precipitous than those lower down, and are in places, especially on the south and south-west, covered with a deposit of new ash apparently only a few feet thick (Plates 16 and 18). It dips towards the crater at the angle of repose between 30° and 40° and has been much denuded by the rain. There are only a few places, however, where it is sufficiently continuous to obscure the solid beds, and where these are visible ash and tuff predominate over lava, the reverse of which is the case lower down. On the north the wall is considerably higher than on the south, and the precipitous portion extends higher up. The beds of tuff, which are here particularly well developed, contain many large ejected blocks (Plate 17). This abundance of ejected blocks to the north-east of the crater agrees with the observation of Mr. T. M. MACDONALD during the eruption of 1902, that most of the stones thrown out went to windward, so that the direction appears to have remained unchanged from an earlier period. The figure to the right is standing on a lower portion of the rim (Gap A in several plates) near the point where the Carib track begins to descend in a south-easterly direction to the windward side of the island, and through this gap, no doubt, the black cloud and avalanche descended which devastated the Carib country.

This lip of the crater is usually quite narrow, generally only a few feet, occasionally a few yards, wide, as shown in Plate 16. It is mostly composed of a bed of new ashes a few feet thick, almost everywhere consolidated on the surface into a crust, generally less than an inch thick, as in the case of the ridges lower down. Where this crust is entire it has preserved the rest of the bed from erosion, but whenever it has been broken through, the whole of the deposit has generally been washed away, and this is particularly noticeable on the outer slopes, where the beds of new ash lie conformably on the old ones and weather off in successive layers. The lip is by no means regular or uniform in height. It is highest to the north. Besides the gap just mentioned (Gap A), it presents three well-marked gaps, B, C, and D, of which B is shown in Plate 16, and D, the more westerly, in greater detail in Plate 18. B and C are on the south of the crater; of these the more westerly, C, is somewhat the lower, and both are lower than A. It was doubtless through them, and presumably through the lower one especially, that the water of the crater lake and the incandescent avalanche descended into the Wallibu and Rabaka districts.

The other gap, D, Plate 18, occurs more to the west, where the lip of the crater joined the Somma ridge; as the whole of this part of the rim of the crater is much higher than the southern portion, the bottom of the gap, deep as it is, still remains higher than B and C. This gap, D, leads down in the direction of Larikai and Morne Ronde. It was lowered considerably during the eruptions of the autumn of 1902, and this accounts for the greater deposits in the Larikai valley in the later eruptions. The Somma Ring (Plate 18) is seen to consist of beds of lava and tuff dipping outwards from the crater, conformably with the outer slope of the mountain. The whole of the interior of the crater is still quite bare and without any trace of returning vegetation. A few small patches of moss appear on and about the rim, and in somewhat greater abundance on the slopes outside. This is worth notice, for Mr. JAMES ANDERSON, in 1784 (Part I., p. 461), found moss covering the inside of the crater and in great abundance on the cone at the confines of the grassy region and the barren, so that the conditions are presumably becoming similar to those which existed at that time, and the vegetation will eventually be as it was before the eruption of 1902.

The Carib country was not visited*, but as far as could be judged from a distant view from near the top of the Soufrière, vegetation was returning in a manner similar to that in the Wallibu district, and Mr. SANDS, who has since visited the district, assures me that this is the case. He states that there is water in the upper reaches of the Rabaka River, though it all sinks into the ground lower down, so that none reaches the sea. The old bed of the river has become blocked about a mile from the sea and a new course has been formed to the north of it. The restoration of the water supply to the district, by the repair of the old conduit, is under consideration.

The difference between the character of the eruptions of the Soufrière and Montagne Pelée, mentioned in Part I., p. 533, appears to have continued since 1902, the outbursts from the former volcano being generally less frequent but more violent than those from the latter.

THE RETURN OF VEGETATION.

Confining our attention for the present to the Wallibu district, it may be stated generally that the whole of the country north of Morne Garu was devastated in different degrees. The limit of the zone of devastation extended right up to the summit of Morne Garu, and the line followed the main ridge in a westerly direction almost to the sea, before reaching which it diverged so that the Richmond Plantation Works were included, but the south bank of the river was not materially injured (Plate 19). Within this area the bottoms of the valleys, which were covered by the incandescent avalanche, had their vegetation utterly destroyed. In other places, where the hot ash was only deposited in a thin layer, the roots were in many cases not killed outright and are now throwing up new shoots and leaves, though the large trees are almost universally killed, except in a few sheltered situations.

* Arrangements had been made to return by what was then advertised as the last voyage of the Intercolonial Service of the Royal Mail Company.

The localities may now be discussed more in detail. The conditions at the Richmond Plantation Works may be taken as a type of those of all the low ground near the limit of devastation. The incandescent avalanche swept down the Wallibu valley and spread out over the old fan or plateau at its mouth, it then turned south round the lower end of the Richmond ridge and destroyed the Richmond Works and all the vegetation near them. The ash still remains to a depth of two to six feet in different parts, and the old roots are completely buried and thoroughly destroyed, but the avalanche was confined to the bottom of the valley, and none of its effects are visible on either side. The black cloud which accompanied the avalanche either did not keep to the ground beyond the ridge behind the Works or had lost most of its heat, and on this slope there are Gru Gru palms (*Acrocomia sclerocarpa*), which though injured are recovering, and one silk cotton tree (*Eriodendron anfractuosum*) at the Works is still alive (Plate 19). In other places, however, further to the east, some trees are killed, but this appears to be the limit of devastation. The surface of the ash near the Works has not consolidated, but is rapidly breaking up under the influence of plant roots, and humus is being formed. The chief new plants are Castor Oil (*Ricinus communis*), which grows in luxuriant masses along and around the ruins of the Works, and a plant, Cattle Tongue (*Pluchea odorata*), which has already formed flourishing bushes taller than a man (Plate 20, fig. 1). Besides these, Indigo (*Indigofera Anil*), Sensitive Plant (*Mimosa pudica*), Guinea Grass (*Panicum maximum*), *Eupatorium odoratum*, and two grasses (unnamed) were also noticed. On the hill sides, grasses and a few trees, such as Gru Gru palm (*Acrocomia sclerocarpa*) above mentioned, Walnut (*Andira inermis*), Fiddle Wood Tree, and *Ficus* sp. Near the river the Rozeau Grass (*Gynerium saccharoides*) is also growing luxuriantly to a height of 12 or 15 feet (Plate 20, fig. 2).

At the foot of the seaward slope of the Richmond ridge is a fan, or plateau, which was covered several feet thick with the incandescent avalanche, the end of which is mentioned above as extending up the valley as far as the Richmond Works (Plate 21). Here the surface has consolidated into a crust nearly an inch thick, almost like a concrete pavement, and where this crust is perfect no vegetation can spring up; where, however, it is broken up, as along the small water courses, Silver Ferns (*Gymnogramme calomelanos*), grasses and young Plucheas are getting hold and their roots are spreading into the harder parts on each side. In places also the crust is being broken up by the trampling of horses and cattle, and the process of return of vegetation is thereby being hastened. The lower end of Richmond ridge above this fan was only slightly affected.

Further to the north along the coast there are several other plateaux on which the vegetation is making similar progress (Plate 14). They are much cut up by ravines, in the precipitous walls of which, and in the sea cliffs, the old soil is generally exposed at a junction of the old tuff and new ash above it, and this line is often marked by a band of luxuriant growth from the old roots. The Wallibu Plantation (Part 1, Plate 25, fig. 2) was situated on one of these plateaux below the end of the main Wallibu plateau. The vegetation is here more advanced than on the surrounding flats, and it had almost concealed the aqueduct, which is such a conspicuous object in the 1902 plate; Bamboo (*Bambusa vulgaris*) is growing luxuriantly and the other plants are practically the same, and their growth is about as much advanced, as at the Richmond Plantation.

In the Wallibu valley vegetation has made little progress, the floor being composed of ash and gravel which is still liable to re-arrangement by every flood, but on the south slopes leading up to the Morne Garu range the return has been considerable. The surface is still studded with the charred and bleached skeletons of trees, which appear to have been killed universally, with the single exception of a small lateral valley north of the lower part of the Richmond ridge, where a few palm trees in a sheltered position have recovered. The shrubs and herbaceous vegetation, which were all burnt level with the ground, are gradually returning, in many cases from the old roots, since the removal of the thin covering of ashes by the rain. The north wall of the Wallibu valley is precipitous and only recently relieved of its covering formed by the incandescent avalanche, and is still almost bare of vegetation. The top of the Wallibu plateau was entirely devastated. The trees remain only as bleached trunks except a few which have recovered in sheltered positions at the ends and south edge of the plateau (Plates 9, 10, 11). The dead trunks show that the ash was never more than a few feet thick at the most, and the whole is now covered with a luxuriant growth chiefly from the old roots.

In the smaller gorges to the north, such as the Wallibu Dry River and Trespé discussed above, vegetation is making more progress than in the Wallibu. Their precipitous sides are becoming densely covered with Silver Ferns (*Gymnogramme calomelanos*) and creepers such as Ipomœas, besides grasses and herbaceous plants (Plate 22, fig. 1).

Along the slopes of the Soufrière, of which the ridge followed by the old Carib track may be taken as an example, the return of vegetation is very marked. All the trees without exception are killed and their stumps are becoming covered with Ipomœas and other creepers, while, the ash having been much washed away, except along the ridges, the old soil is mostly exposed (Plate 22, fig. 2) and the vegetation is returning chiefly from the old roots and their progeny. In the lower part, as for instance where the track rises steeply out of the Trespé valley, the vegetation is so luxuriant as to form a tropical jungle dense enough in places to require the use of a cutlass to effect a passage through it (Plate 23, fig. 1). At about this height are masses of Rozeau (*Gynerium saccharoides*), *Heliconia Bihai*, Tree Fern (*Cyathea arborea*), a few trees, and a large number of shrubs and herbaceous plants, grasses and creepers (Ipomœas chiefly), and the same flora continues up to the Maroon Tree, which is at a height of about 1000 feet.

At about 800 feet Tree Ferns (*Cyathea arborea*) become very abundant and large sheets of them are common (Plate 23, fig. 2), and generally it may be said that vegetation is luxuriant up to a height of about 1000 feet, abundant up to 1500, and very sparse above that height, with only a few grasses and silver ferns; higher up nothing but mosses and lichens are found.

At the lower lip of the crater and just inside it mosses and lichens only are found. The mosses have been identified at Kew as: *Pogonatum tortile*, P. BEAUV., and *Philonotis tenella*, JAEG., and the lichen as *Stereocaulon* sp.

On the higher slopes of the Carib country vegetation is much the same as on the leeward slopes at about the same elevation.

The coast north of Morne Ronde and Larikai Point was only examined from a canoe, but on this side of the mountain vegetation appeared to be returning in a manner similar to that on the more accessible parts. Most of the plants were the same as at Richmond and Wallibu, and the Trumpet Tree (*Cecropia peltata*) and Bois Flot (*Ochroma lagopus*) were also noticed.*

THE HISTORY OF ERUPTIONS AFTER MAY, 1902.

The Eruption of September 3 *and* 4, 1902.—Through the courtesy of His Honour C. J. CAMERON, Administrator of St. Vincent, and Sir DANIEL MORRIS, of the Imperial Agricultural Department, and other officials, I have been allowed access to reports by Mr. POWELL, of the Botanical Gardens, St. Vincent; Professor RADCLIFFE HALL, Professor LONGFIELD SMITH, and Mr. ALLAN, the Revenue Officer of Chateau Belair. The Rev. T. HUCKERBY, of Chateau Belair, Mr. MACDONALD, and the Rev. JAS. DARRELL have also furnished notes. From these sources the following account is condensed.

After the eruptions of May, 1902, the crater remained quiescent, but earthquakes were noticed at the Botanical Gardens on July 17th and 21st, and by the Rev. T. HUCKERBY at Chateau Belair on the 9th, 19th, 20th, 23rd, 30th, and 31st of the same month. The shock of the 17th occurred at 9.45 a.m., as noted by Mr. POWELL, and was preceded by a noise rather like a bomb exploding. The movement was up and down, and the duration about six or eight seconds; that of the 21st took place at 1.10 a.m. The movement was from north to south, and the duration also six or eight seconds.†

A party who visited the Soufrière on the 12th of August saw small openings (fumaroles) on the lip of the crater from which steam and small pebbles escaped.‡

On September 3, from 6 a.m., a series of explosions commenced, which increased in violence as the day wore on, and at 9 p.m. the detonations became very loud. The

* The return of vegetation on Krakatoa presents many points of similarity. 'Treub. Annal. Jard. Botan. Beutenjorg,' 7, 1887–8.

† Mr. POWELL'S Report, September 12, 1902.

‡ 'Sentry,' August —, 1902.—Some of the newspaper cuttings do not retain the date of issue.

eruption reached its climax about 2 o'clock in the morning of the 4th. A black cloud alive with electric displays stretched itself from the north to the south of the island; at 3 a.m. the detonations had become less regular, and at 3.55 a.m. an earthquake was noticed at Chateau Belair, and also at the Botanical Gardens, where the explosions were considered louder than in May, the "din" being described as terrific. From this time the eruptions became less violent, though slight rumblings continued throughout the day till 5.30 p.m. It was noticed during the eruption that material like mud flowed from the crater down the Larikai valley. There was a heavy fall of ash on the leeward side of the island. Beginning as a thin layer at Barualli, it gradually increased to five to nine inches at Chateau Belair, where several buildings were injured by the heavy fall, which consisted of dust, lapilli, and black stones. Very little ash fell at Georgetown, or the windward side, and the mountains in the middle of the island showed no change in appearance. Mr. POWELL made an official visit to some native allotments on the leeward side of the island, about four miles south of the volcano, in order to estimate the damage. At Rosebank, on the seashore, the thickness of the deposit was about three inches. It consisted of coarse ash and pieces of pumice stone up to three inches in diameter, with solid stones of the size of gravel and occasionally larger. For $1\frac{1}{4}$ miles inland the damage to the native provision grounds was very great, but for the next mile much less. No lives were lost.*

On Sunday, September 21, there was a sharp, but short explosion, very striking in appearance. The people were much frightened, and asserted that there was a greater accompaniment of "fire" than on previous occasions. Part of the red glow, however, may be attributed to the setting sun.†

On September 18 the telegraph cable to the north, which had been repaired only the previous day, was again interrupted.

On Friday, September 22, Mr. HUCKERBY‡ made an ascent of the Soufrière. For some distance, whilst crossing the Wallibu valley, he had to walk ankle deep in mud. On the lower ridges he found a plentiful supply of fine ash. About 400 feet below the summit a large number of newly ejected blocks were lying about in all directions. Great changes had taken place within the crater. He estimated it to be 150 feet deeper than it was immediately after the eruption of the 7th of May. A considerable amount of ash was banked up against the northern wall and part of the eastern side, which had become almost perpendicular, while a large portion of the Larikai (W.) side had been blown away and the lip lowered several feet. A fissure had been formed on the southern lip, from which steam was slowly ascending. The bottom of the crater contained a small lake of stone-coloured liquid, which was constantly boiling up and sending forth clouds of steam.

* Mr. POWELL's Report, September 12, 1902.

† Letter from Mr. MACDONALD, of Wallilabu.

‡ Rev. T. HUCKERBY, in a letter to Dr. ANDERSON.

Mr. HUCKERBY noticed after the eruption that further subsidences had taken place north of the mouth of the Wallibu River, as had happened in the May eruption.

The Eruption of October 13 *and* 14, 1902.—This appears to have been the most severe eruption since May, 1902. Mr. HUCKERBY writes* :—"On the 1st and 13th of October there were electric displays over the crater, and on the night of the 12th a lunar halo was observed. The 13th and 14th were days of intense heat, and several earthquakes were felt at the northern end of the island. At about 8 p.m. on October 14, slight rumblings were heard, and clouds of dust-laden steam were ejected from the crater, but everything passed off very quickly. At midnight the activity recommenced and violent detonations disturbed the people of the district. At 12.30 a.m., what appeared to be a ball of fire presented itself over the crater, followed by a flow of red-hot matter down the Larikai side of the mountain. At the same time a mist-like circle appeared over Chateau Belair. At five minutes to two, stones began to fall in Chateau Belair and continued for about two hours. The electrical displays were terrible to behold, and the thunder cannonaded with a deafening roar. Mud began to fall at 2 o'clock. I noticed four earthquake shocks, the two at 3.22 a.m. and 4 a.m., respectively, being the heaviest and most prolonged. The detonations became irregular between 4 and 5 o'clock and died away gradually. At 8 o'clock in the morning the crater was sending forth volumes of dust-laden vapour, which action continued until the 17th. Stones, some probably two pounds in weight, were picked up at Chateau Belair on the morning of the 15th. Most of the ejecta were carried out E. and N.E. of the island. The Carib country was covered with large stones and coarse material."

The débris fell chiefly upon the windward side of the island. The Carib country, as it had been previously utterly devastated, did not attract much attention, but Mr. POWELL† visited the still inhabited districts and noted the amount of damage. At Kingston there was from $\frac{1}{8}$ to $\frac{1}{4}$ inch of ash. Further north it gradually increased in thickness. At Gregs and Union Estates 2 inches were measured, and at Park Hill 3 to 4 inches, while at Georgetown and Mount Bentinck the depth was 6 to 8 inches. Much damage was done to the provision grounds of the natives in all the localities, which the newspapers describe as utterly ruined. The ash was very hot, but apparently from the heat of the sun. The dust was carried as far as Barbados, where detonations were heard, and samples were collected at the Government Laboratory, and also by the U.S. Weather Bureau, and the Rev. N. B. WATSON, St. Philips. Professor RADCLIFFE HALL gives the amount collected at the Laboratory as follows :—

	Tons per acre.
October 16, from 9 a.m. to 11 a.m., at the rate of	0·48
11 a.m. to 1 p.m. "	2·10
1 p.m. to 3 p.m. "	1·34
Total from 9 a.m. to 3 p.m. "	3·92

* In a letter to Dr. ANDERSON.

† POWELL, Report of October 24, 1902.

He also collected samples at Rosebank and Hastings, where the amount from 8.45 a.m. to 4 p.m. on October 16 was 4·49 tons per acre.*

Mr. POWELL and a party ascended the mountain on October 28, 1902, and found that the old crater was discharging volumes of steam and that numerous cones of ashes were being thrown up to a height of 30 or 40 feet from a fissure close under the southern wall.† The lake was boiling near the centre. The steam as it rose was carried along the south-eastern wall to the eastern edge of the crater, where it became visible to observers in the low country and created the erroneous impression that the new crater was in eruption.

On Wednesday, November 26, 1902,‡ there was a considerable flow of mud down the Rabaka River. The ash avalanches of the May eruptions had completely blocked its bed, and the ejecta of the subsequent eruptions had doubtless contributed their quota. As a result there was no water in the channel, and this in spite of the heavy rainfall of five months. On November 26 the stream at last got vent, and two raging, steaming torrents descended the valley. One of these destroyed the remains of the Rabaka Sugar Works, and for the last mile before reaching the sea the old course has been blocked up and the river now runs in a new channel to the north of the old one. It is supposed that a lake had formed in the higher reaches of the river which at last had got vent, but details are wanting.

Mr. HUCKERBY writes§: "Detonations were heard on the 19th and 22nd of October and on the 6th, 11th, and 24th of November, 1902. On the 26th of November there was a minor eruption and a small quantity of ash and lapilli fell at Georgetown and Chateau Belair. On the 22nd of January, 1903, at 12 noon, there was again a minor eruption with a projection of very dark steam and a little ash. Detonations were heard on the 22nd, 24th, 26th, and 28th of January and on the 6th of February. Steam was emitted from the crater on the 13th, 14th, and 28th of February."

Professor SAPPER, of Tübingen,|| ascended the Soufrière on February 6, 1903, with the Rev. T. HUCKERBY, of Chateau Belair, and paid a visit to both the new and the old craters, this apparently being the first to the new one since the eruption. They found that owing to landslides into the crater the gap above the Larikai valley was deepened. They had considerable difficulty in crossing it, and in order to do this had to descend some distance. Dr. SAPPER made a plan of the crater and found that no material alteration had taken place in its shape from that indicated on the English Admiralty Chart. The diameter in every direction was about 1320 metres (4331 feet),

* 'The Agricultural Reporter,' October 20, 1902.

† 'Sentry,' October 31, 1902.

‡ 'Barbados Advocate,' December 3, 1902.

§ In a letter to Dr. ANDERSON.

|| "Der Krater der Soufrière von St. Vincent," von KARL SAPPER, 'Centralblatt für Mineralogie,' Stuttgart, 1903, pp. 369–373.

but the north wall being higher than the south the plane of measurement was inclined in that direction, so that on a level the shape was really somewhat oval, with the long diameter from the W.N.W. to E.S.E. The lake was also oval, with its diameter in the corresponding direction. Its length on February 6 was 540 metres (1772 feet), its breadth 340 metres (1116 feet), and the height above the sea-level 585 metres (1919 feet),* which agreed almost exactly with that given on the chart (1930 feet). The water was boiling in the centre and also at the south-east corner. The district between the Somma wall and the two craters was deeply covered with ejecta. The new crater was filled up almost flat. It had a small shallow lake (about 70 metres (230 feet) in diameter) towards its eastern side, with water marks which showed that it had been bigger. The saddle, which previously separated the new from the old crater, had disappeared, probably owing to landslides. Fumaroles were found in the crater rim in the gap leading down to the Larikai valley and also one somewhat more to the east above the head of the Rozeau valley.

Professor LACROIX made the ascent along with Madame LACROIX, Ensign DEVILLE, Professor HOVEY, and the Rev. T. HUCKERBY of Chateau Belair, on March 3, 1903, *i.e.*, before the last considerable eruption, and has published his observations in the 'Annales de Géographie.'† The following is an abstract of the parts of his paper which relate to matters that have occurred since the May eruption. He mentions that banks of hot ash and terraces still remain in the Wallibu valley, and that steam explosions still occasionally take place from them.‡ These banks render the river valleys somewhat narrower than before. He saw from his boat, when off the mouth of the Richmond River, an explosion of hot mud take place from the crater of the Soufrière, and he observed the sudden descent of a torrent of mud in the high Rozeau valley, probably caused by a shower. At a height of about 600 metres the ground was covered by large lapilli, the product of the eruption of September, and ejected blocks and bombs were common. They were often partly buried in the lapilli into which they had fallen. He mentions the gap at the head of the Larikai ravine, and was informed by Mr. HUCKERBY that it had been enlarged by the eruption of October, 1902. Avalanches were falling from the walls of the crater, and there was a talus at their base. Large ejected blocks of old rock were more common at the rim of the crater, particularly at the east, than they were lower down. At first, when M. LACROIX gained the edge of the crater, the water of the lake was tranquil, and had the appearance of yellow steaming mud. The least agitation of any part caused it to assume a more grey colour. Suddenly from the centre of the lake there rose a mass of mud of inky blackness, entangling blocks of rock.

* These measurements appear to have been carefully made. HOVEY gives 600 metres; most of the other observers also give figures, but as they are merely estimates I have not quoted them.

† "Les Dernières Éruptions de Saint-Vincent," Mars 1903, A. LACROIX, 'Annales de Géographie,' tome xii., 1903, No. 63 du 15 Mai 1903.

‡ They appear to have ceased about this time.

After some seconds it reached to the level of the edge of the crater, and then rose to a height of several hundred metres. M. LACROIX succeeded in taking a photograph* which shows an outline like sheaves of rockets, mixed with puffs of white vapour, which soon gained predominance and hid the rest from view. The mass of mud, which rose noisily, fell heavily back again with a deafening roar. Then a new column of vapour, larger than the former, rose from the bottom of the crater and filled it.† The party received a heavy shower of mud. Several other explosions of different degrees occurred while the members were on the summit. The explosion was seen from Castries in St. Lucia, and was sufficiently conspicuous to cause inquiries as to its nature to be made by telegraph.

Professor HOVEY was one of the same party who visited the crater on March 3, 1903, and he crossed the mountain to the windward side a few days later. He remarks‡:—"Considerable alterations have taken place since my former visit 8 months previously. The eruptions of May had left the leeward side coated with a deposit of very fine-grained material, which formed a cement-like mud under the influence of the rain; but the deposit on the windward side was of a coarser nature. Now, the surface to leeward is covered with gravel which has more or less completely hardened into a compact surface. This gravel is composed not only of small fragments from a quarter to half an inch in diameter, but also of numberless bombs. These bombs vary in size from that of a pea upwards, the largest observed were between 2 and 3 feet across. On the windward side the gravelly deposit had not been compacted, but is soft to walk upon. Within the district from Richmond to Windsor Forest on the leeward, no vegetation is to be seen except such as has sprung up along the sides of the gullies which cut through the new deposit into the old soil. On the windward side the slopes of the mountain have been much more generally freed from ash than on the leeward, and considerable vegetation is to be seen on the slopes of the ravines and gorges. The crests of the ridges and the lower slopes, however, are still covered with a coating of bare ash." He mentions the rapidity with which erosion has taken place since the eruption, and estimates the amount that has been carried out to sea from the valley of the Wallibu alone at 25,000,000 tons, without counting that from the surrounding slopes.

Eruption, March 21 *to* 30, 1903.—The Rev. T. HUCKERBY writes as follows§:—"From the 15th to the 18th of March the heat was intense. At 5 o'clock of the morning of the 18th three lunar halos were visible. On the morning of the same day a halo circled the sun. At about 9 o'clock the same night we were disturbed by

* LACROIX, 'Montagne Pelée,' pp. 53-54 and 176-7, Plates 21, 22.

† LACROIX, 'Montagne Pelée,' Plate 22.

‡ 'Sentry,' St. Vincent, March 1903. 'American Museum Journal,' July 1903. 'Comptes Rendus,' ix., Congrès Géol. Internat. de Vienne, 1903, "The 1902-3 Eruptions of Mont Pelée, Martinique, and the Soufrière, St. Vincent," by EDMUND OTIS HOVEY.

§ Letter to Dr. ANDERSON.

very loud detonations, the earth trembled severely. I immediately went outside, to see if the Soufrière were showing any signs of an eruption. Everything seemed calm and quiet on the northern end of the island, but looking in the direction of the harbour (Chateau Belair), I noticed three horizontal rings of vapour, one within the other.*

"On the 21st large volumes of steam were emitted from the crater, and early the following morning detonations and rumblings were heard. At 7.25 a.m. the explosive period of the eruption commenced, the usual black cloud, cauliflower in shape and fringed with various colours, rose to a tremendous height and then passed away in all directions. The regular detonations and explosions ceased about 10 o'clock. Occasionally, during the day, noises proceeded from the crater, as if some great monster were in distress. There were three earthquakes between 7 and 8 in the morning, and one at 9 o'clock. After the detonations and explosions had ceased, the crater continued to send forth dust-laden vapour, without cessation, right on to the 30th of March. On the last-named date I visited the coast as far as the Larikai valley. Very little ejecta had fallen at Wallibu. At Morne Ronde there was a depth of 4 inches of new grey dust. At the opening of the Larikai valley there was a fall of $6\frac{3}{4}$ inches. Further along the coast, at the bottom of the Larikai ravine, there was a depth of 20 feet of new ejecta, indicating that there must have been a considerable flow from the western lip of the crater. A bomb, found in a heated condition on the top of a deep layer of ash, proved to be 75 lbs. in weight. Between 8 and 9 o'clock on the night of the same day the whole of the crater seemed as if it was lighted up by electricity. I concluded that the bottom of the crater was in a luminous condition and reflected its glow on everything around and on the cloud above. The light lasted for a few minutes and was followed by the ordinary emissions of dense clouds of steam.

"On the 31st I started on a trip round the island. I found that the material distributed on the windward side of the island was very different from that which had fallen on the leeward side. The deposit on the leeward side, except in the Larikai ravine, was consistently grey dust, while on the windward side, ash, pumice, and large pieces of dull chocolate-coloured material preponderated. The pumice, which I had picked up at Owia, has the appearance of a pink sponge.

"At the beginning of April I again visited the Soufrière. The inside of the crater presented an entirely different appearance, the bottom was filled up to about the old water level, with chocolate-coloured ash. In the centre of this new deposit was a comparatively narrow hole, which I concluded was the mouth of the funnel. The southern lip had been raised by the outflowing dust. A large portion of the north-eastern wall had been blown out and a fair number of fissures, which had formed in the new deposit of the crater, were throwing up a large amount of steam.

* Two such concentric rings were also seen at Chateau Belair on August 30, 1902, before the eruption of September 3.—(Mr. CHASTENET, quoted by Mr. MACDONALD in a letter to Dr. ANDERSON.) See also the eruption of October 13, 14, *supra*.

"I have made many visits to the Soufrière since the occasion mentioned above. The hole in the centre of the new deposit has gradually widened, and, I suppose, will ultimately take up the whole width of the bottom of the crater. Conditions are rapidly becoming normal, and in a few years' time the mountain will once again be covered with verdure and beauty."

Mr. POWELL* reports, on March 24, that the depth of black dust was about half an inch at Park Hill. At Three Rivers and Mount William it was about three-quarters of an inch deep and coarser in grain. It contained many considerable pieces of an inch and upwards in size. The cocoa trees were here a good deal damaged. At the experiment station, near Georgetown, it was coarser still, more cinder-like, and pieces of 3 inches or more in diameter were common. The sugar-canes and other plants were much injured. At Dickson's Village, which is in an exposed position above Georgetown, the ash was 2 to 3 inches deep and larger cinders more abundant still. From Georgetown northward the country "presented one blackened waste." At Turema, about 5 inches of dust were measured. On the whole, there appears to have been a light fall of dust over all the island south of Georgetown and Chateau Belair, a moderate fall on the leeward coast north of this, except in the Larikai ravine, where there was a deposit, in places, 20 feet thick; and a fairly uniform layer of a few inches thick over the Carib country, north of Georgetown. The heat-absorbing properties of the last fall were considered to render it more detrimental than the deposits of the former eruptions.

The dust was carried by the wind to Barbados. On Sunday, the morning was clear till about nine, when a dense black cloud came rolling up from the west, the surface wind being easterly at the time. Dust began to fall about 11.15 and it continued to do so more or less heavily up to about 1 o'clock, after which it slackened and ceased altogether at 5 o'clock. When the gloom was deepest, the day was darker than on either of the previous occasions of a fall, viz., the 7th of May and the 16th of October, 1902. During the midday service lamps were lighted in the various places of worship. The dust appears to have taken about two hours in traversing the distance of 111 miles. The amount as estimated by Mr. LEWTON BRAIN and Mr. R. D. ANSTEAD, of the Imperial Department of Agriculture, from observations made at Bay Mansion, was $2\frac{1}{2}$ tons to the acre. It will be remembered that the total fall on May the 7th was 17·58 tons per acre, and that on October 16 about 3·92 tons per acre. The cloud appeared to be denser towards the north, and at Codrington House, two miles to the north of Bridgetown, the fall was 6·52 tons per acre.† Since this eruption the crater has been practically quiescent.

* Curator to the Commissioner of Agriculture.

† 'Agricultural News,' March 28, 1903, No. 25.

MONTAGNE PELÉE IN MARTINIQUE.

When we visited Martinique in 1902, it was "our intention to make merely such reconnaissances as would enable us in a general way to ascertain the points of difference and of similarity between the outburst of Mont Pelée and that of the Soufrière, and to see what light the phenomena in Martinique threw on the events which had happened in St. Vincent,"* and this being understood, we had the advantage of a friendly conference with Professor LACROIX, the Chief of the French Commission, who most courteously discussed his observations and conclusions with us. These he has since embodied in a monumental volume published by the Academy of Sciences,† and we have already indicated the chief points of difference and similarity between the two volcanoes, both in the preliminary and full report, so that it now only remains to compare the history of the two volcanoes since the great eruption, and to note the changes which, during a visit in March, 1907, I observed to have recently taken place in the crater and the slopes of the mountain, especially the region of the Rivière Blanche, and, since Professor LACROIX's great work is not very accessible to English readers, to draw attention to one or two of the most remarkable phenomena described in it.

The Crater and the Spine.—The great spine which has formed so peculiar and novel a feature in the eruption of Montagne Pelée had no counterpart in the Soufrière of St. Vincent, and this constitutes the most important difference between the outbreaks of the two volcanoes, which in other respects were so remarkably similar. When we visited Martinique in 1902, there was in the upper part of the mountain, at the head of the valley of the Rivière Blanche, a great "triangular fissure,"‡ or V-shaped gap, out of which, on July 9, we saw the descent of an incandescent avalanche, which was the counterpart of that which destroyed St. Pierre. Through that gap, as the trade-wind clouds momentarily dispersed, we caught occasional glimpses of a bank of large loose angular blocks of stone at a high temperature, which rolled down at intervals, accompanied by the discharges of volumes of dust-laden steam. We also saw several times for a few moments a large pointed rock, reaching to a height of perhaps 100 feet, or more, above the top of the dome of stones, but as we were ignorant of the exact topography of the locality, which was not accurately marked on the official maps, we could not ascertain for certain that it was more than an unusually large crag on the further lip of the crater, and accordingly did not particularise it in the report. This uncertainty as to the topography has now been cleared up. The map in Professor LACROIX's book (p. 120) correctly represents the

* Preliminary Report. 'Roy. Soc. Proc.,' vol. LXX., 1902, p. 439; and Part I., p. 478.

† 'La Montagne Pelée et ses Éruptions,' par A. LACROIX, Paris. Masson et Cie., 1904.

‡ Part I., p. 491, called "cleft" in the Preliminary Report, pp. 440, 441, and "Echancreur en V" by LACROIX.

topography as I observed it in March, 1907, and it is now certain that the bank of stones was the surface of a new cone, or dome, which was in process of being built up in the Étang Sec, which, in this eruption at any rate, was the working crater of the volcano.* The dome has never shown any crater of explosion on its summit and appears to be comparable, for instance, to such masses as the Domite Cones of the Auvergne. The pointed rock rose from its summit. It now appears that this rock had been independently seen three days previously, viz., on July 6, by a French party under Professor LACROIX, and by an American party under Professor JAGGAR, and that photographs had been obtained by both, which, though very indistinct, enabled useful diagrams to be drawn.† It is certain that this rock occupied much the same position on the summit of the dome as the spine did later, and one of its surfaces showed "long striated smooth slopes" like the later spine. It does not appear, however, to have been the identical spine, for its smooth surface faced westward instead of eastward, as did the corresponding surface of the latter. JAGGAR thinks it was an early stage of the same phenomenon; LACROIX thinks, on the contrary, that it was part of a "bourgeonnement" (budding) of lava (LACROIX, p. 41) and that its shape was due to the splitting off and falling away of the surrounding portions, and this view is supported by the craggy condition of the summit of the dome shown in photographs taken in October before the upraising of the spine, which commenced in earnest in November.

The French Commission commenced systematic observations from the Morne des Cadets early in October, using first an alidade and then a theodolite, and on November 3 the measured height of the summit was 1343 metres (4406 feet). LACROIX considers that the growth of the spine commenced on the night of the 3rd to 4th November, 1902,‡ and on November 24 it had reached a height of 1575 metres (5167 feet) above sea-level, or a growth of 230 metres in 20 days, *i.e.*, at the average rate of over 10 metres a day. This was the first maximum height; from that time a series of falls gradually reduced the total height till February 6, 1903, when only 1424 metres (4672 feet) were registered, or a net loss of 151 metres (495 feet), and this in spite of a continued rise of the remainder of the spine. From February 7 a new period of growth commenced, though less rapid than the former; on March 25 the former maximum of 1575 metres was again reached and soon surpassed, and from May 10 to 31 and from June 25 to July 6 the height was continuously above 1600 metres (5249 feet). The absolute maximum reached was 1608 metres (5276 feet) on July 4, 1903, or 257 metres above the former summit of the mountain, and

* The other small lake on the summit, the Lac des Palmistes, if a crater at all, was not in action in 1902, and its place is now occupied by a plain of *débris* and ejected blocks, including many bread-crust bombs.

† LACROIX, p. 114. JAGGAR, "The Initial Stages of the Spine on Pelée," 'American Journal of Science,' vol. xvii., January, 1904.

‡ LACROIX, *loc. cit.*, p. 121 *et seq.*

about 600 metres (1969 feet) above the former level of the crater lake of the Étang Sec from which it sprung.*

This cone or dome appears to have been formed of viscous lava partially or wholly solidified in places, and this mixture would be in a condition, by the sudden disengagement of the vapour and the shattering of the partially solidified rock, to give rise to, or at any rate take part along with, other discharges from the chimney in the formation of the incandescent avalanches and other forms of "nuées ardentes"† which have been observed. The avalanche seen by us certainly contained a number of large blocks of a brighter red colour and apparently of a higher temperature than the rest of the material in it, and these presumably had come from the dome. LACROIX considers that the "nuées ardentes" observed by him proceeded from the surface of the dome, and especially from a patch on its south-west flank near the base. They did not issue from any well-marked crater on its summit.

The spine itself seems, as we might have expected, to have been formed of very similar material to the dome. LACROIX speaks of a carapace, or shell, on its surface, which often was detached in flakes (fendillement), disclosing an interior at a high temperature which he describes as consisting of porous matter with driblets (bavure) of molten lava exuding from the intervals and cracks. Portions were frequently detached with the emission of "nuées ardentes." There was no great central passage. The surface of the spine was scratched and grooved by friction against the walls of the volcanic chimney out of which it rose. Its shape at first was angular, but it was almost cylindrical in its later stages, probably because the prominences in the chimney were gradually worn off, and its diameter was estimated by LACROIX at 150 metres. He calculates that if the spine had not undergone any crumbling and falling (ecroulement) between November 3, 1902, and July 4, 1903, it would have attained an altitude of at least 2200 metres (7218 feet), and the total height of the column extruded must have been about 850 metres (2789 feet), or, say, 2800 feet.‡ The careful measurements regularly taken showed that it diminished in height solely by flaking and falling, and that at no time did it sink again into the chimney when it had once risen. It appears clear, therefore, that both the dome and the spine were formed by molten matter, with perhaps some inclusions of blocks torn from the walls of the passage, being forced up from below into the volcanic chimney, that this matter was at first sufficiently plastic to spread out and form the dome, and that as cooling gradually took place, parts solidified and broke up into large blocks, from some of which the vapours escaped

* These estimates depend on earlier measurements, the accuracy of which cannot be depended upon to within a few metres.

† The term "Nuées ardentes," as used by LACROIX, appears to include both the "Incandescent Avalanches" and "Black Clouds" described in Part I. He now prefers the term "Nuée Peléenne" as more general. ('L'Éruption du Vésuve en Avril 1906,' p. 12, par A. LACROIX; 'Revue Générale des Sciences des 30 Octobre et 15 Novembre 1906.') Both Dr. FLETT and I prefer our old terminology as more precise.

‡ LACROIX, 'Montagne Pelée,' p. 132.

quietly, while other parts exploded into minute fragments with sudden escape of vapour and descended the mountain as "nuées ardentes," accompanied often with a mixture of the larger fragments. It is impossible to say exactly the depth to which this breaking up and liberation of the vapours extended. As the whole gradually cooled and became consistent, and as further material was forced up from below, the upper portion no longer spread out into a dome, but was forced up "en masse" as a spine, though it still retained veins of pasty or liquid material spreading through it. This forcing up from below by fluid pressure was clearly the main mechanism of the ascent, but LACROIX thinks that the pressure of the veins of semi-fluid lava might be an accessory cause of the ascent and especially of the lateral swelling and flaking off of the crust. It is impossible to deny the existence of this cause, since it has been postulated that the dome was formed in this way in the early stages of the eruption, but it clearly became much less important later on. Some authors have suggested that the spine was an old plug formed in the chimney, by the materials left there at the close of an earlier eruption. There is no proof whatever of this theory and it does not accord well with the transition from the formation of the dome to that of the spine, nor does it account for the high temperature of the central parts of the spine with its veins of still semi-fluid lava, or for the flaking off of the crust and emission of "nuées ardentes" as the veins of lava came to the surface.

I made two ascents of the mountain in March, 1907, and on the second occasion the cloud lifted for a few moments and enabled me to get a photograph which showed the stump of the spine rising out of a cone of talus surrounding it, and obviously formed of its ruins (Plate 24). At the line of junction of the spine and the talus was a ring of very active fumaroles from which steam and other vapour was escaping with a loud roar, obviously from under considerable pressure. The clouds closed in again before it was possible to complete the examination, but the photograph shows the spine to consist of a sort of volcanic agglomerate of blocks of various sizes, similar to what I imagine the structure of the dome to have been.

The Wall of the Crater.—The talus extended in every direction up to the walls of the crater, and had in a great degree filled it up. On the south-west side was the above-mentioned **V**-shaped gap where the talus had overtopped the former crater ring and extended down to the valley of Rivière Blanche. On the east and south-east the crater was least filled. Its wall continued uncovered from the side of the gap to beyond the remains of Morne Lacroix, to an average depth of probably above 100 feet. It was almost vertical throughout all this extent. The valley formed between it and the talus appeared to extend, but at a decreasing depth, round the north of the dome.

The resemblances between the valleys of the Wallibu in St. Vincent and the Rivière Blanche in Martinique, and the phenomena observed in those valleys respectively, are summed up in Part I., p. 489, and the changes which have since occurred serve chiefly to increase the resemblances and minimise the differences. Thus in March, 1902, there was in the latter valley a number of fumaroles, some of which were active enough to have led to the supposition of their being parasitic craters. Further examination has satisfied Professor LACROIX of their superficial nature, *i.e.*, their origin in the deposits of hot ash, and their consequent similarity to those in the Wallibu.* They are all now cool and extinct except one group, which I had the pleasure of visiting in company with M. GUINOISEAU, Adjutant in charge of the Observatory of Morne des Cadets. They are situated at a height of about 1350 feet above the sea, on the low ridge between the Rivières Blanche and Claire, which here flow down one broad valley apparently much in the same way as two rivers often occupy each one side of a big old valley in St. Vincent. The ridge itself is perhaps 50 feet higher than the valley on each side, and broad in proportion. It consists of fragmentary ejecta of the 1902 eruption, including a good many large blocks. The temperature of the fumaroles had been as high as 300° C. last year, but was gradually decreasing. M. GUINOISEAU found it to be about 230° C. at the time of our visit. This group is the only one about the nature of which any doubt now exists, but it appears most probable that its origin, like that of the others, is superficial.

The differences between the two valleys are not by any means so great as the resemblances, and they appear to be all traceable to two causes, viz., the repeated, or rather, the at one time almost constant, passage of the incandescent avalanches, and the fact that owing to the configuration of the crater these all descend through the V-shaped gap right down the valley on which they spend their whole force. Thus the denudation of the deposits is in a somewhat less advanced stage than in the Wallibu, and the bedding somewhat more complicated owing to an alternation of water-sorted beds with those of fresh ash. Moreover, apparently owing to the very direct course of the valley from the V gap to the sea, and its steep inclination, the number of large ejected blocks even in the lower part of the valley is much greater than in the corresponding part of the Wallibu. This is only what might have been expected when I recall the stones which we saw descending by leaps and bounds in the incandescent avalanche of July, 1902. They were large enough to be visible at a distance of several miles and distinctly a brighter red than the rest of the avalanche material.

In this connection also ought to be mentioned another phenomenon, which though not altogether absent in St. Vincent is much more conspicuous in Martinique, viz., a scoring and grooving of the rocks of the sides of the Blanche valley. The part I specially noticed was a cliff nearly 200 feet high in the ridge between the Blanche and Sèche Rivers and perhaps half a mile nearer the sea than the active fumaroles above mentioned. The valley here is somewhat narrower than higher up, and much narrower than lower down, and it is just the part where the avalanches might be

* LACROIX, p. 400.

expected to attain their greatest speed. The whole rock is scored and grooved in a way recalling glacial scratches, but I have scarcely ever seen any due to that cause so well marked. These scratches, I since find, have been noticed by LACROIX and HOVEY in other parts of the valley.* The rock is a tuff containing many blocks of very hard andesite, so many that it might almost be called an agglomerate. The body of the tuff itself, on the contrary, in which the blocks are embedded though tenacious is soft enough to be cut with a knife, yet the hard stones have been planed off level with the rest of the mass. Nothing could show more vividly the amount of force applied, and the suddenness of its application.

Owing to the cause previously mentioned very few of the upper valleys received any hot ash, but any which did so present a most striking similarity to those in St. Vincent. Thus a photograph of the upper Rozeau valley in St. Vincent is practically indistinguishable from one of the upper Falaise in Martinique. Both were deeply filled with hot ash in the early stages of the eruption, in which explosions were seen to take place that were supposed to proceed from parasitic craters. In both cases what we see are not really true craters, but merely examples of places where secondary steam explosions took place in the hot ash as previously so often mentioned in the Wallibu district. In Martinique the rains, associated with the eruption, swept down such quantities of coarse débris as to form a delta in a few hours (Plate 25, fig. 4).

The Return of Vegetation.—Vegetation has returned in a manner and to an extent strikingly similar to what has taken place in St. Vincent. Thus, at a height of 1500 feet, on the east side of the mountain, where the ascent is usually made from Vivé, practically all the trees are killed and their trunks remain as bare stumps, while a luxuriant vegetation is growing up chiefly from the old roots (Plate 24). Large sheets of ferns are particularly noticeable. The ferns extend considerably higher, viz., to about 2000 feet, where they give way to grasses, while towards the summit only a few mosses and lichens are found. The slopes above Morne Rouge, as far as could be observed from the road, were in a similar condition. At Morne Rouge village the deserted gardens are full of luxuriant tropical growth, so full that most of the gates cannot be opened; partly no doubt in consequence of being embedded in ash, but principally owing to the new plants, which have grown up since the place has been left to run wild.

At St. Pierre the principal street, along which is one of the chief roads in this part of the island, has been cleared of ash and débris. The ruins of the houses on each side are still embedded in ash and covered by a dense jungle of tropical vegetation.

The valley of the Rivière Blanche and the district between it and St. Pierre is the only part which is still bare of vegetation, and this is no doubt due to the passage down it of the repeated "nuées ardentes."

* LACROIX, p. 217; HOVEY, 'Preliminary Report,' p. 363.

The General Sequence of Volcanic Phenomena, etc.*

In addition to the volcanic and seismic occurrences noticed under this heading, mention ought to be made of the great eruption of the volcano of Santa Maria in Guatemala, on October 24, 25, 26, 1902, news of which had scarcely arrived in Europe at the time when Part I. went to press. Owing to the extremely remote and inaccessible position of the volcano the eruption did not attract the notice it deserved, it was not examined at the time by any English or American man of science, although Professor Karl Sapper, of Tübingen, has published an account.†

This eruption was of the same explosive type as those of St. Vincent and Martinique, but much more violent. An entirely new crater about three-quarters of a mile in its longer diameter was formed, and the south side of the volcano (which was supposed to have been extinct) was blown away.

I venture in conclusion to submit the following speculation as to the depth of the volcanic foci beneath St. Vincent and Martinique. The chimneys of the two volcanoes appear to have some connection underground as may be inferred from the following considerations. The eruptions have been repeatedly either simultaneous or so nearly so that the difference in time might be accounted for by the magma being delayed in travelling through a devious and perhaps branching passage or system of passages, blocked in different degrees by various obstructions. The eruptions have been of the same type, viz., explosive without the effusion of lava, and of a rather special variety of that type, the Pelean.‡ The chemical composition of the ejecta is not more different than could be explained by the interaction between the magma at a high temperature and the walls of the passages, supposing them to intersect various strata. It seems, therefore, natural to conclude that the two volcanoes are at the ends of two branches of one common passage, and it is not unreasonable to suppose that these branches divide at an angle not very obtuse and consequently at a great depth. If the two volcanoes were supplied from a comparatively superficial laccolite or intrusive sheet of molten matter extending widely under the whole district at no very great distance below, why did not an eruption also take place in the Island of St. Lucia, which is in a direct line between the two volcanoes and in which there is an active Soufrière, or through the sea bottom, which attains a depth of 10,000 feet both on the Atlantic and Caribbean side of the chain of islands?

* Part I., p. 532.

† Dr. Karl Sapper, 'In den Vulcangebieten Mittelamerikas und Westindiens,' Stuttgart, 1905, and several smaller articles.

† I visited and examined the volcano in January, 1907, and have published an account of this visit in the 'Geographical Journal,' April, 1908.

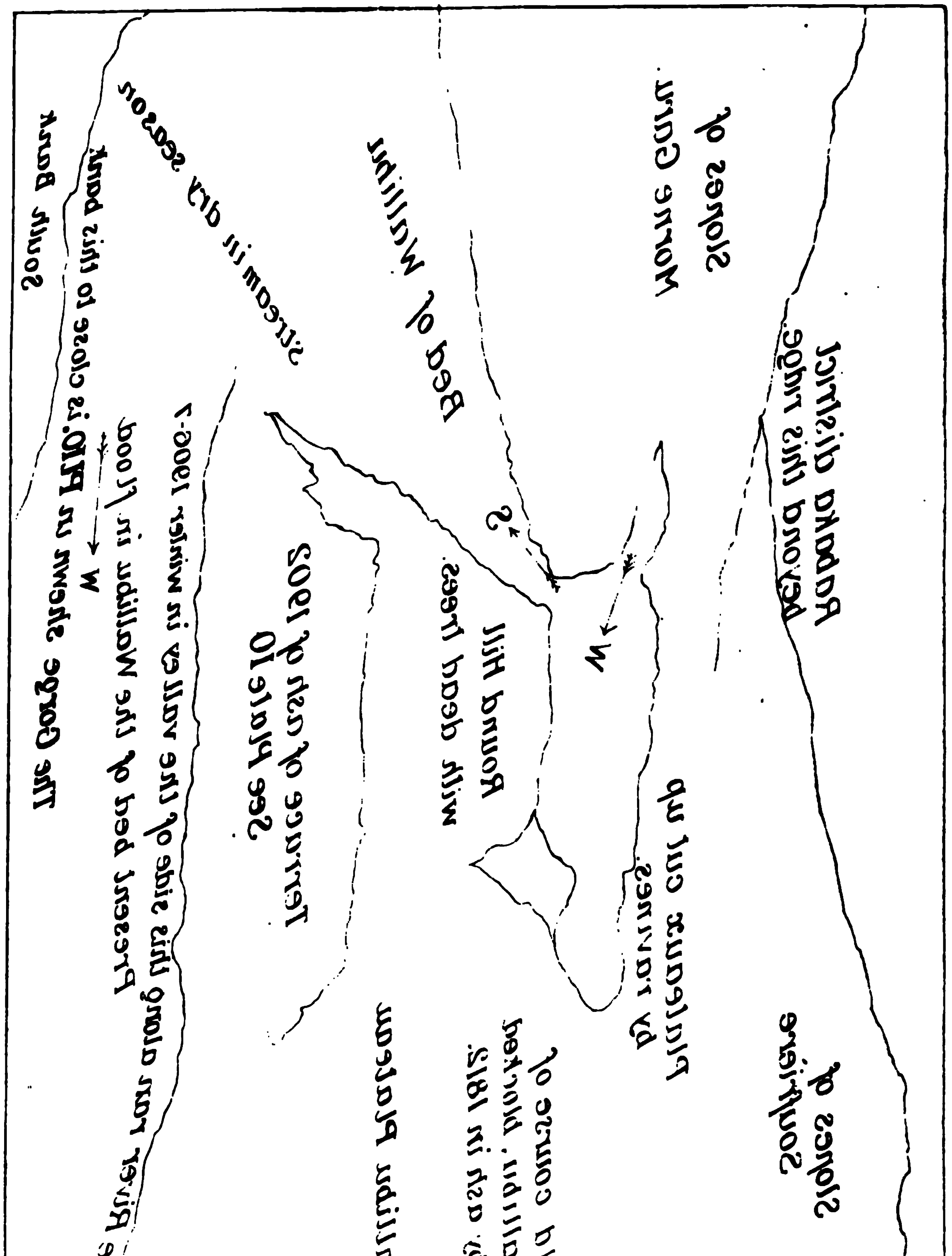
‡ For a discussion of this see Part I., p. 499, and for the details of the coincidence of these eruptions see p. 532.

LIST OF ERRATA

IN PART I. ('PHIL. TRANS.,' A, VOL. 200, p. 353).

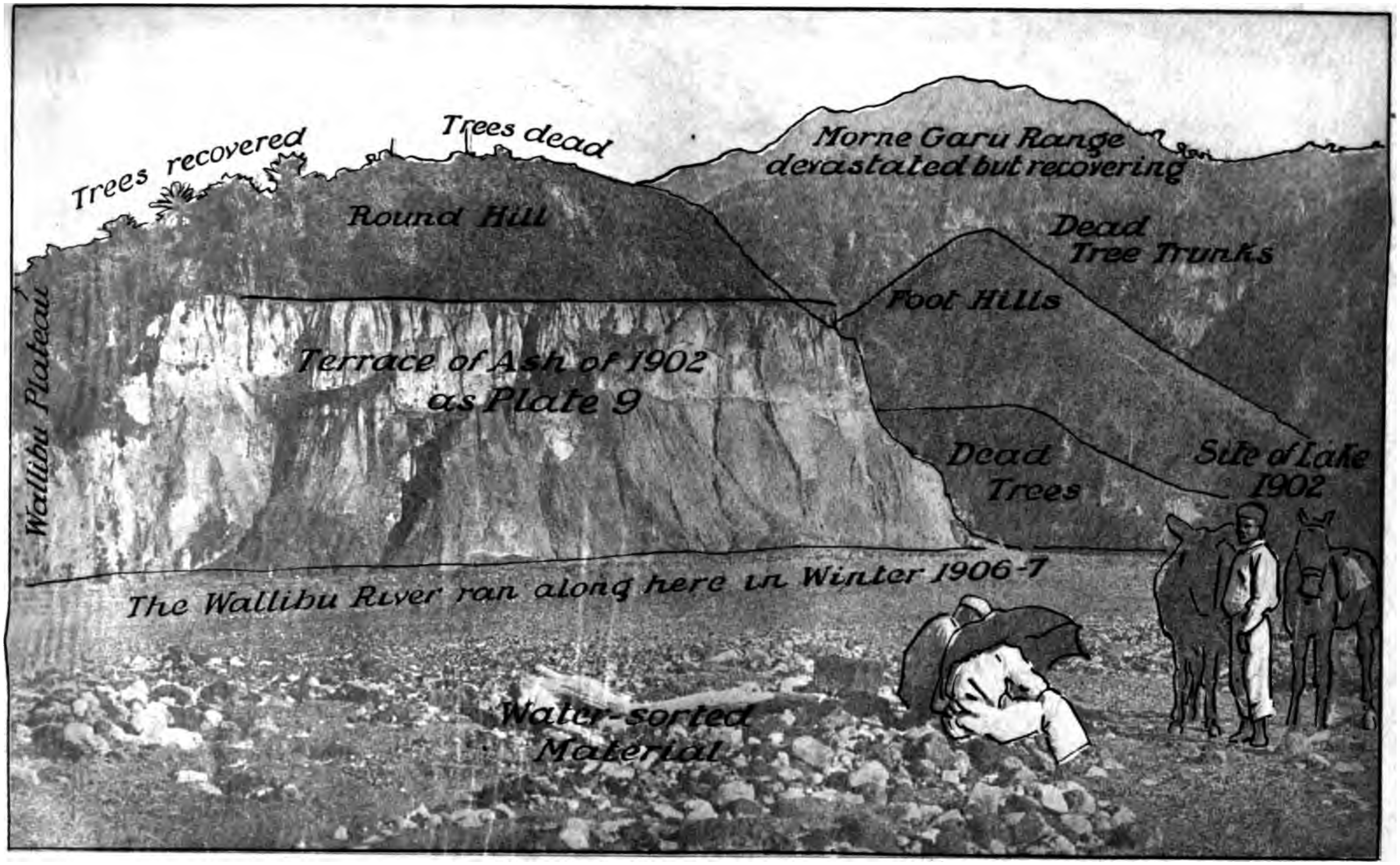
Page 361, line 31, *for* "north" *read* "south"
„ 362, „ 12, „ "indicates" *read* "indicate"
„ 378, „ 26, delete brackets ( )
„ 392, „ 18, *for* "ontburst" *read* "outburst"
„ 393, „ 28, „ "sand," *read* "sand"
„ 400, „ 11, „ "builing" *read* "building"
„ 404, „ 30, „ "Wallibu" *read* "Wallilabu"
„ 406, „ 5, „ "Wallibu," „ "Wallilabu"
„ 407, „ 26, „ "where," *read* "where"
„ 412, „ 11, delete $\delta\gamma-$
„ 414, „ 26, *for* "Wallibu," *read* "Wallilabu"
„ 435, „ 10, „ "Plate 21," *read* "Plate 31"
„ 452, „ 12, „ "pointin goutward" *read* "pointing outward
„ 471, „ 5, „ "has" *read* "had
„ 480, „ 4 from bottom, *for* "p. 11" *read* "Plate II"
„ 497, „ 5 „ „ „ "on" *read* "in"
„ 509, „ 6 „ „ „ "The" *read* "the"
„ 532, „ 9 „ „ „ "Ruez-Altenango" *read* "Quezaltenango"
„ 535, „ 25, *for* "1776" *read* "1766"
„ 543, „ 4 from bottom, *for* "SOWTRAY" *read* "SOWRAY"

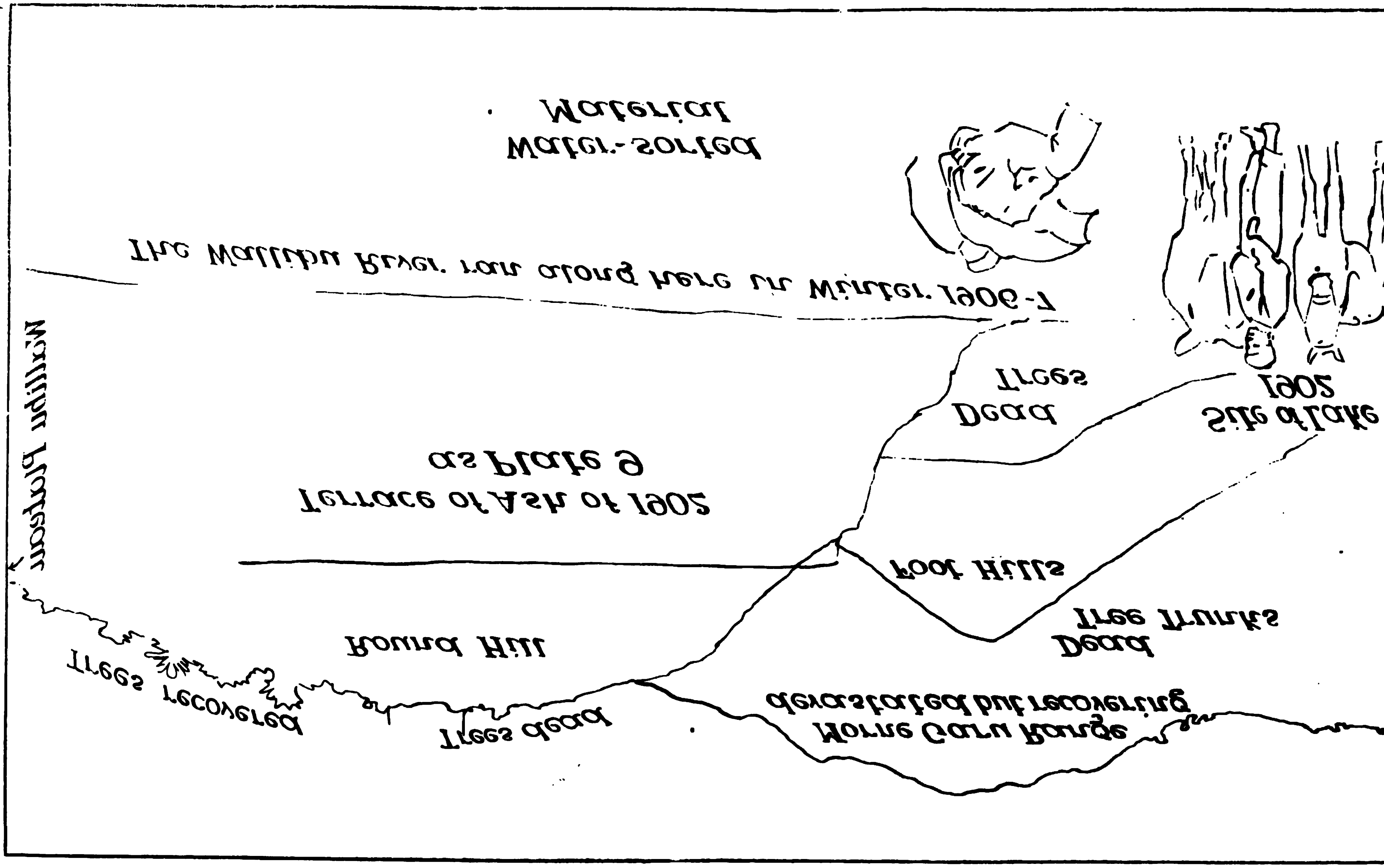
„ 413 is incorrectly numbered 418

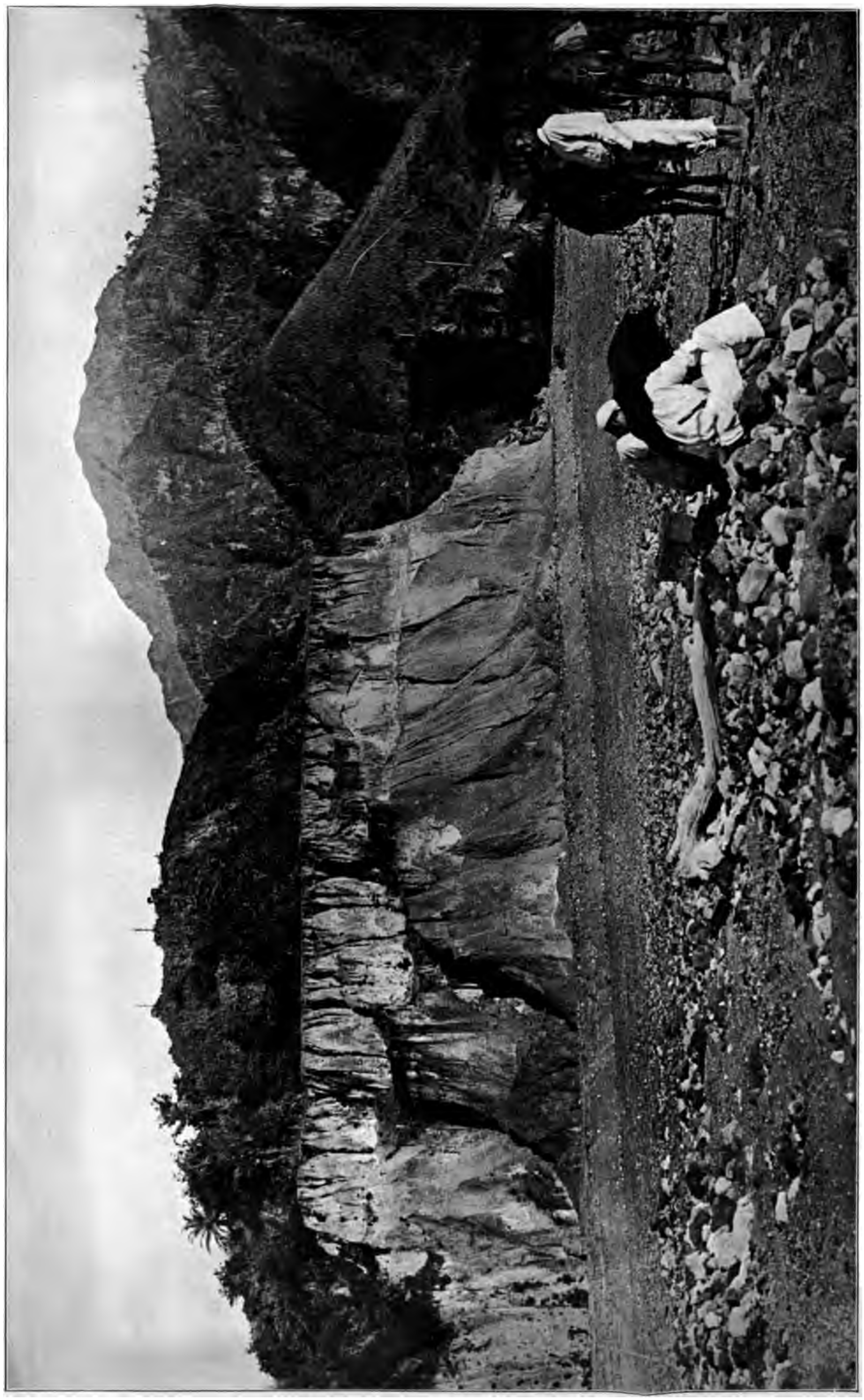


Slopes of Soufriere
Rabaka district beyond this ridge
Slopes of Morne Garu
Plateaux cut up by ravines
Old course of Wallibu, blocked by ash in 1812
Round Hill with dead trees
Bed of Wallibu
Wallibu Plateau
Terrace of ash of 1902 See Plate 10
Stream in dry season
The River ran along this side of the valley in winter 1906-7
Present bed of the Wallibu in flood
The Gorge shewn in Pl.10 is close to this bank
South Bank

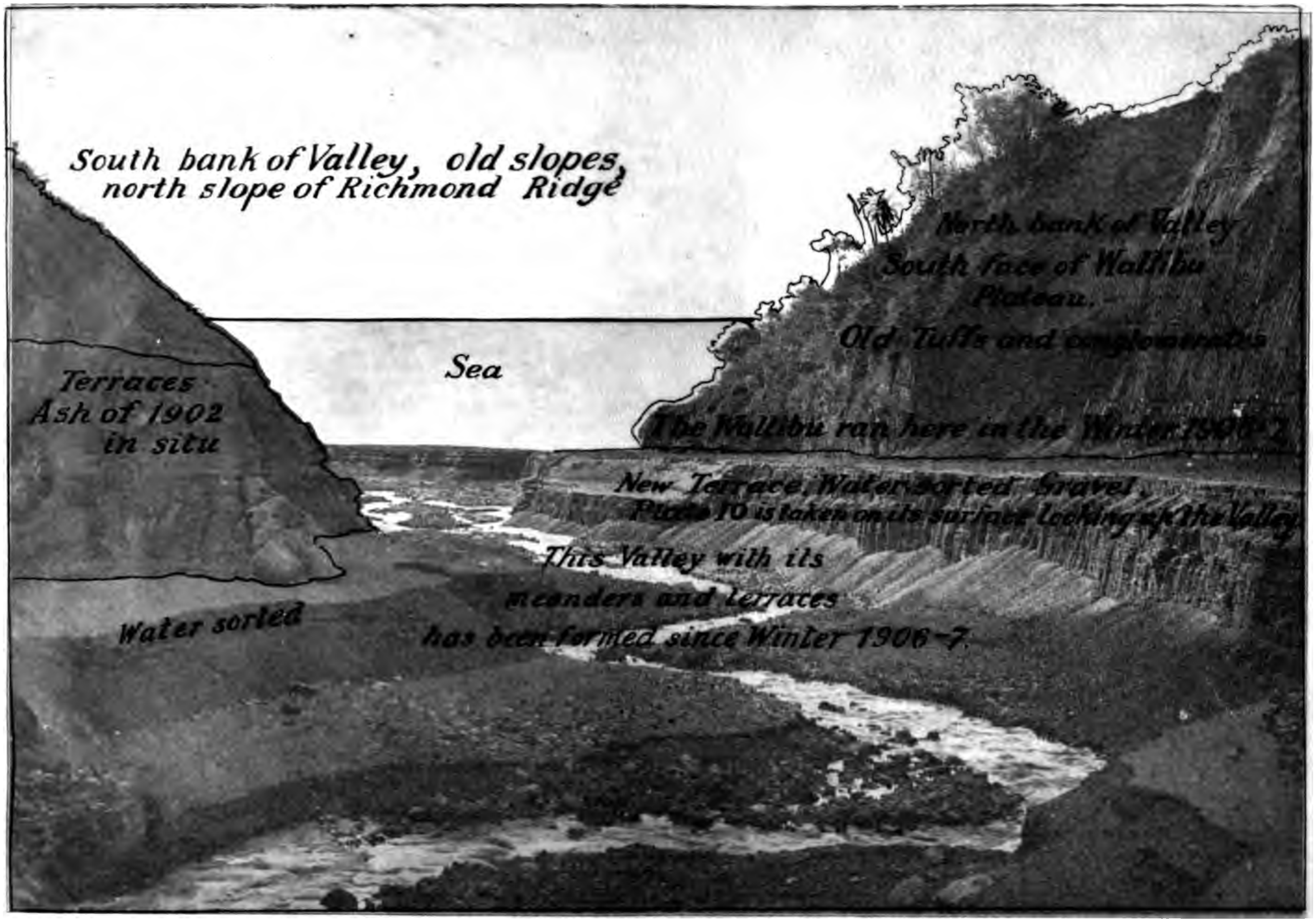
Lower Wallibu district, from Richmond Ridge, near Bunker's Hill.


Trees recovered
Trees dead
Morne Garu Range
devastated but recovering
Round Hill
Dead
Tree Trunks
Foot Hills
Wallibu Plateau
Terrace of Ash of 1902
as Plate 9
Dead
Trees
Site of Lake
1902
The Wallibu River ran along here in Winter 1906-7
Water-sorted
Material

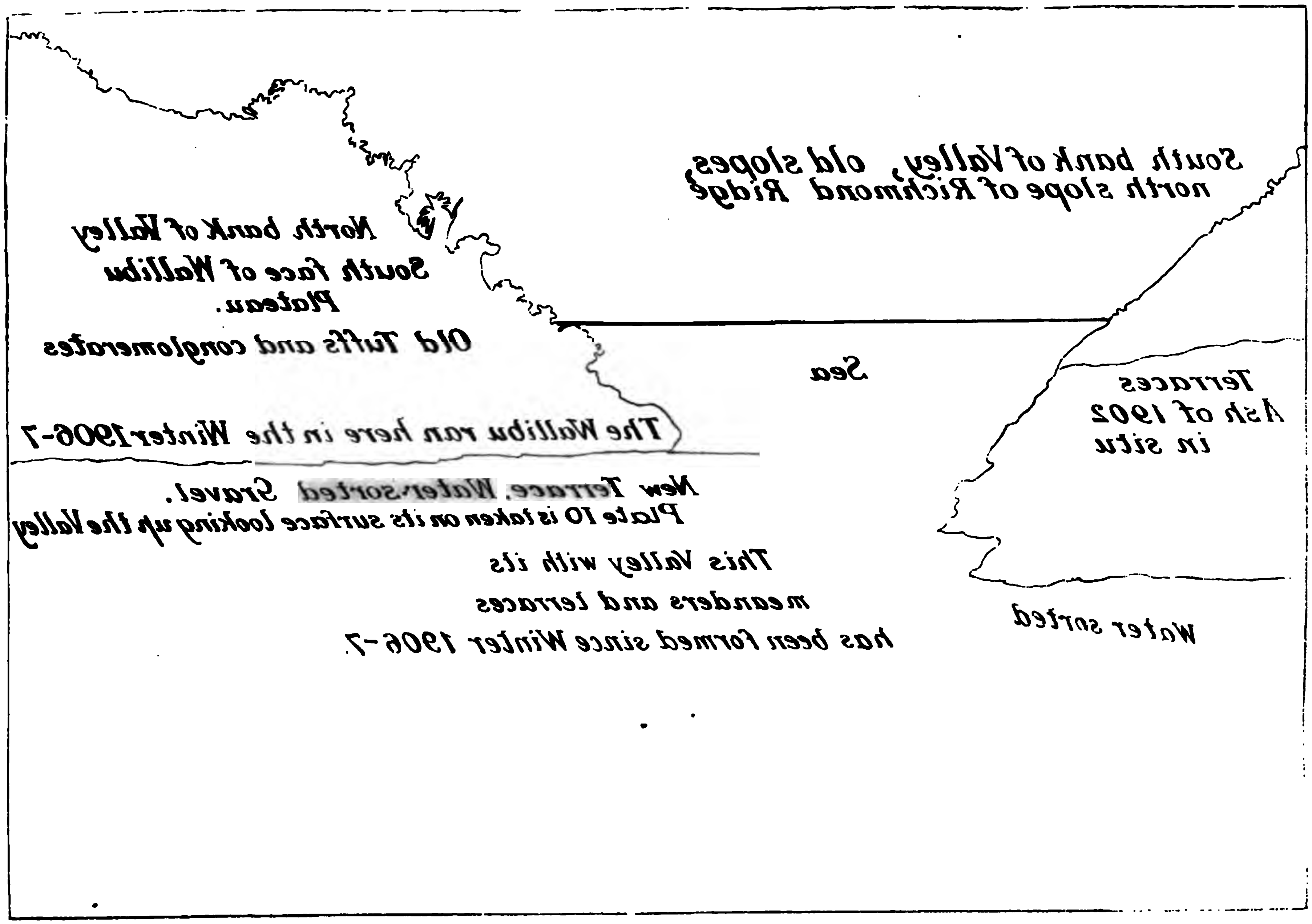

Water-sorted
Material
The Wallibu River ran along here in Winter 1906-7
Site of Lake
1902
Dead
Trees
Terrace of Ash of 1902
as Plate 9
Foot Hills
Dead
Tree Trunks
Round Hill
Wallibu Plateau
Trees recovered
Trees dead
Morne Garu Range
devastated but recovering

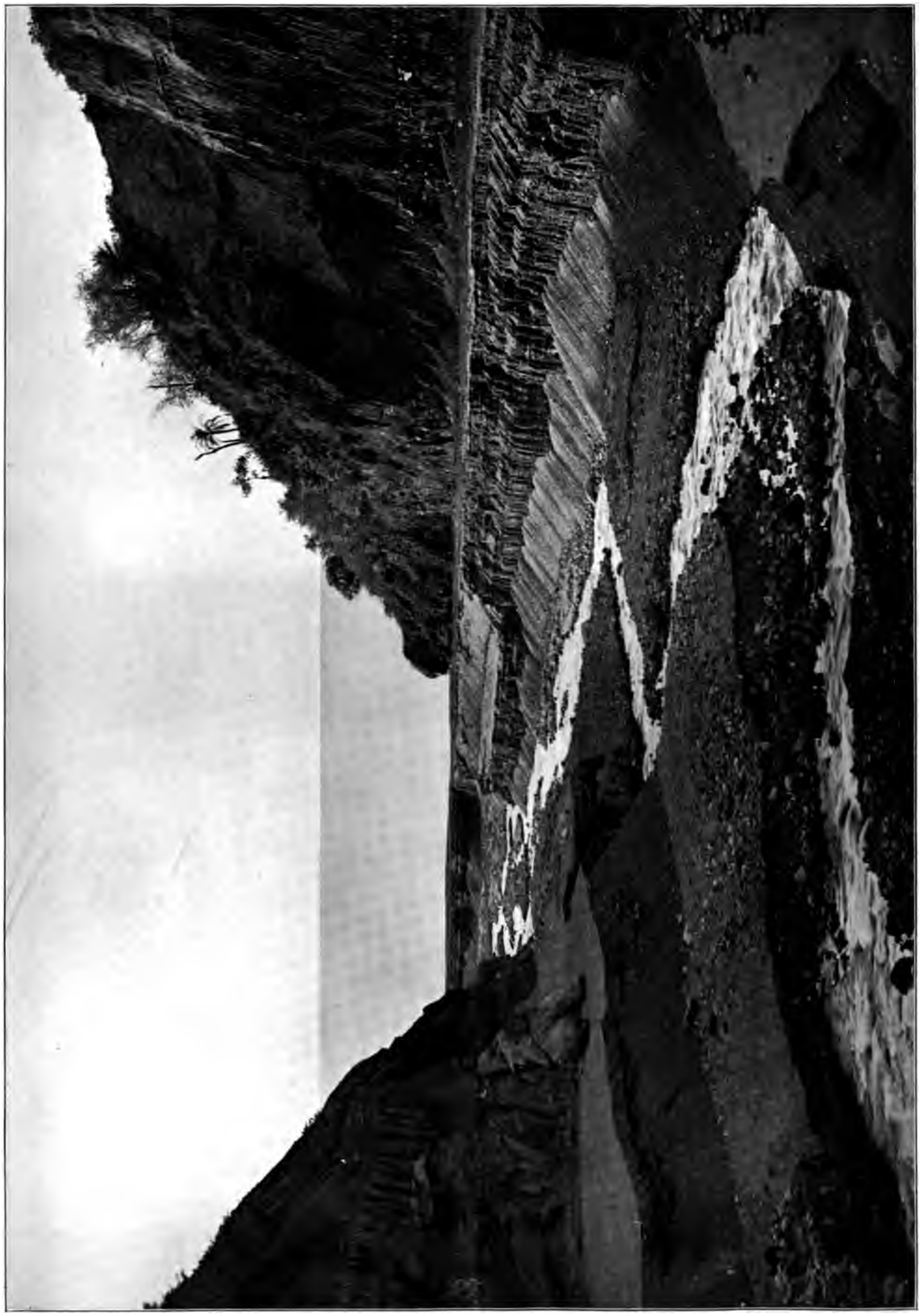


Terrace of new ash, North bank, Lower Wallibu Valley.



Lower Wallibu Valley looking W., towards the sea.


South bank of Valley, old slopes
north slope of Richmond Ridge
North bank of Valley
South face of Wallibu
Plateau.
Old Tuffs and conglomerates
Sea
The Wallibu ran here in the Winter 1906-7
New Terrace. Water-sorted Gravel.
Plate 10 is taken on its surface looking up the Valley
This Valley with its
meanders and terraces
has been formed since Winter 1906-7.
Terraces
Ash of 1902
in situ
Water sorted



Lower Wallibu Valley, looking West, towards the sea.

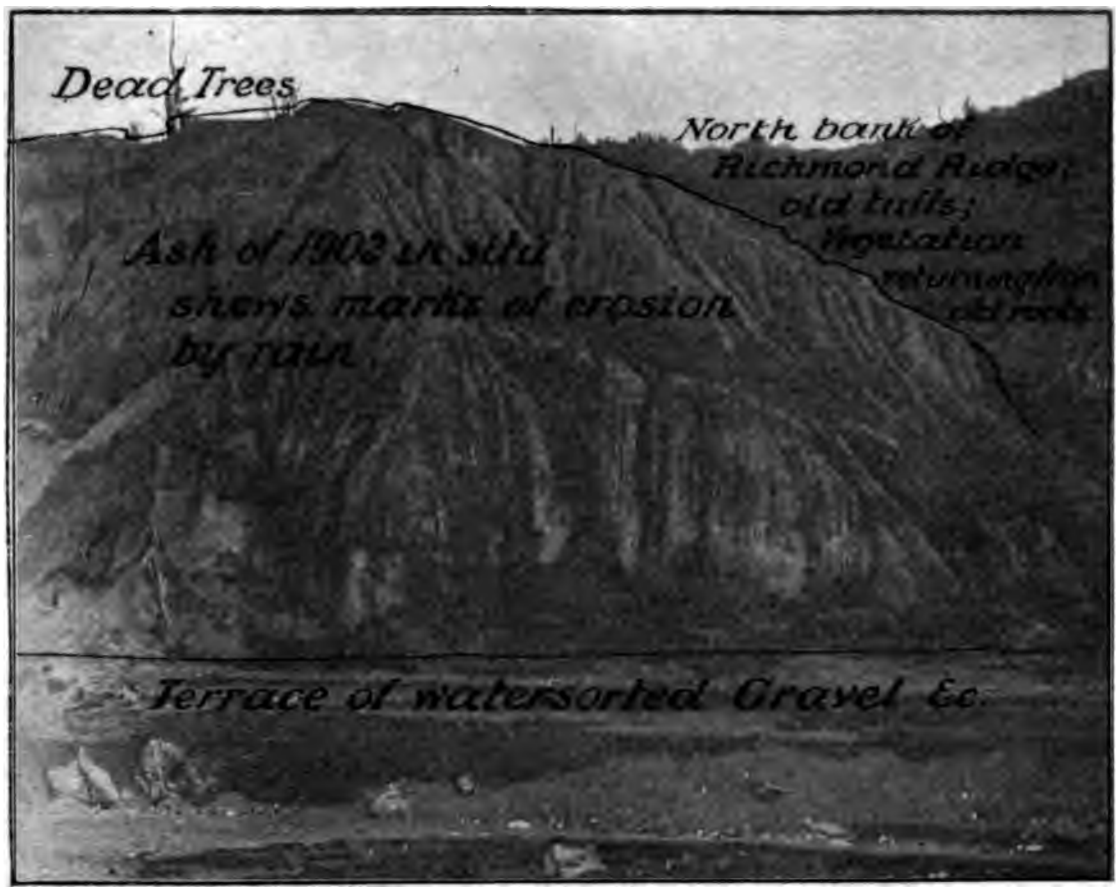


Fig. 1. *Terraces on South bank of Lower Wallibu.*

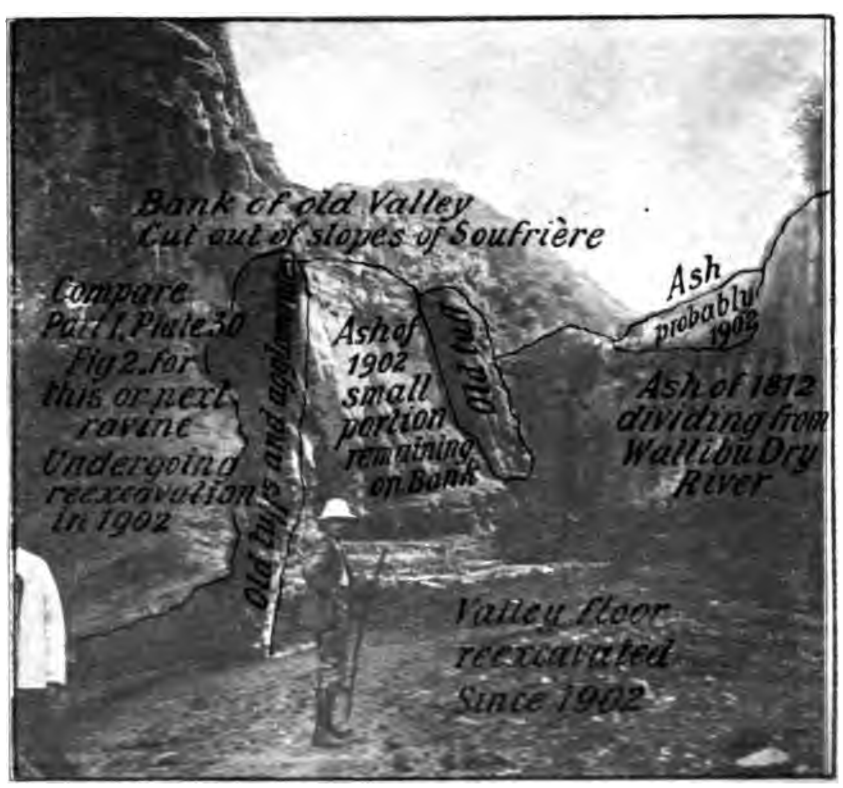
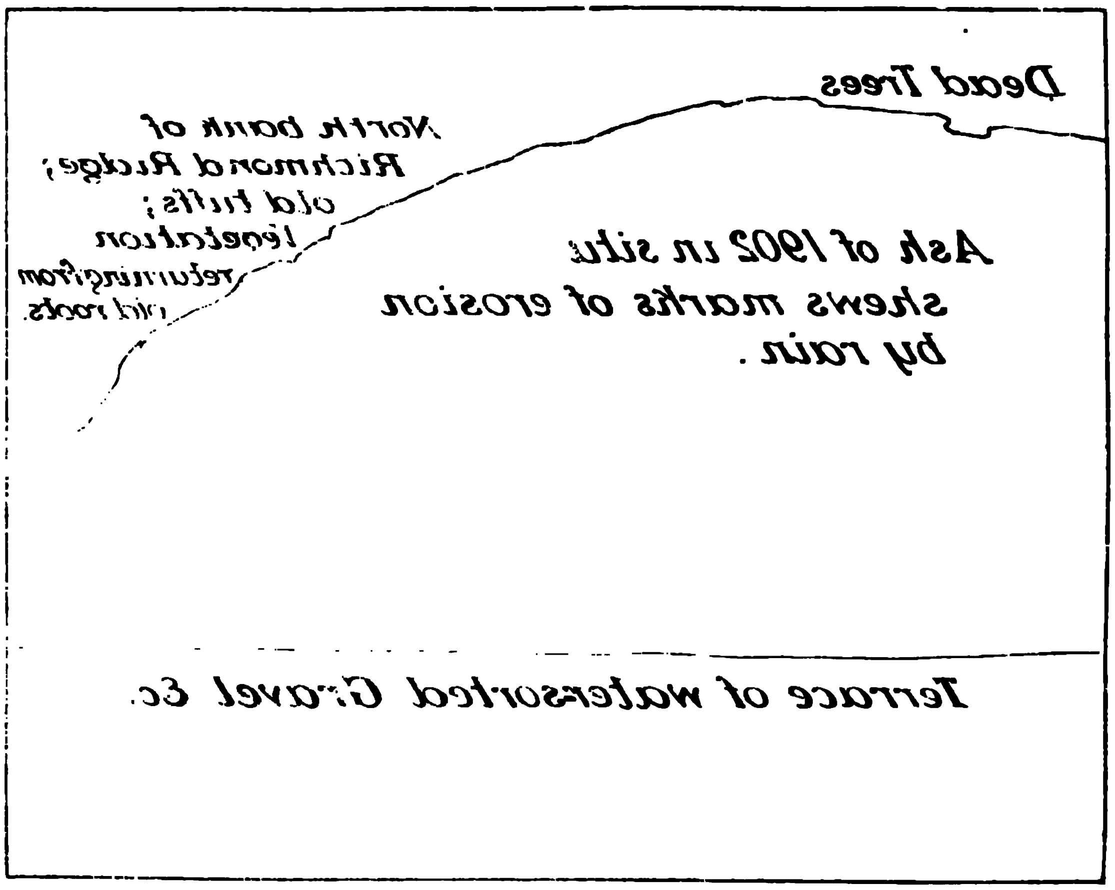


Fig. 2. *Trespé Ravine.*


Dead Trees
North bank of
Richmond Ridge;
old tuffs;
vegetation
returning from
old roots.
Ash of 1902 in situ
shews marks of erosion
by rain.
Terrace of watersorted Gravel &c.

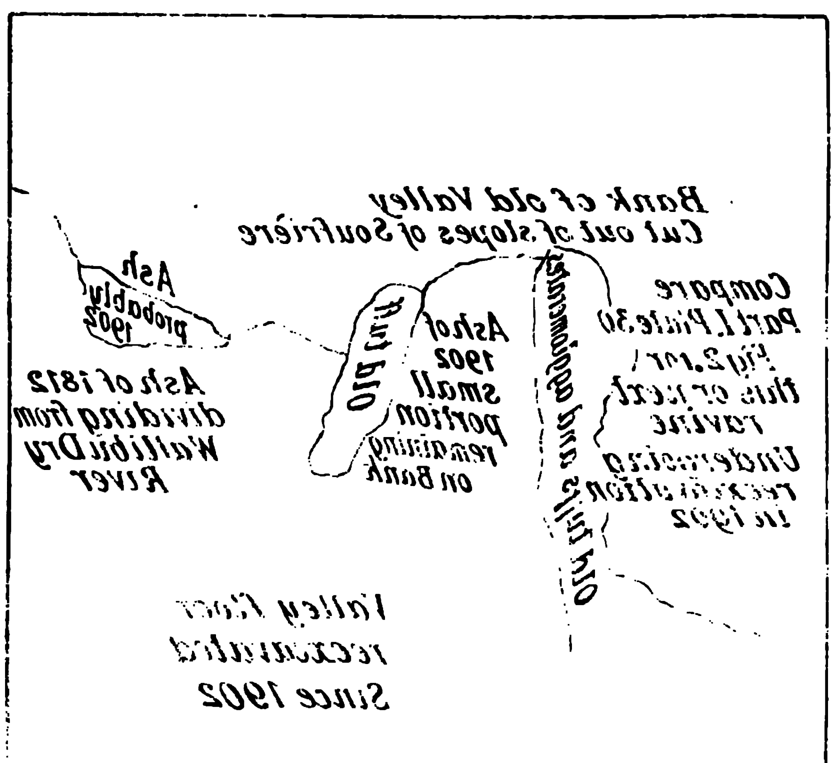
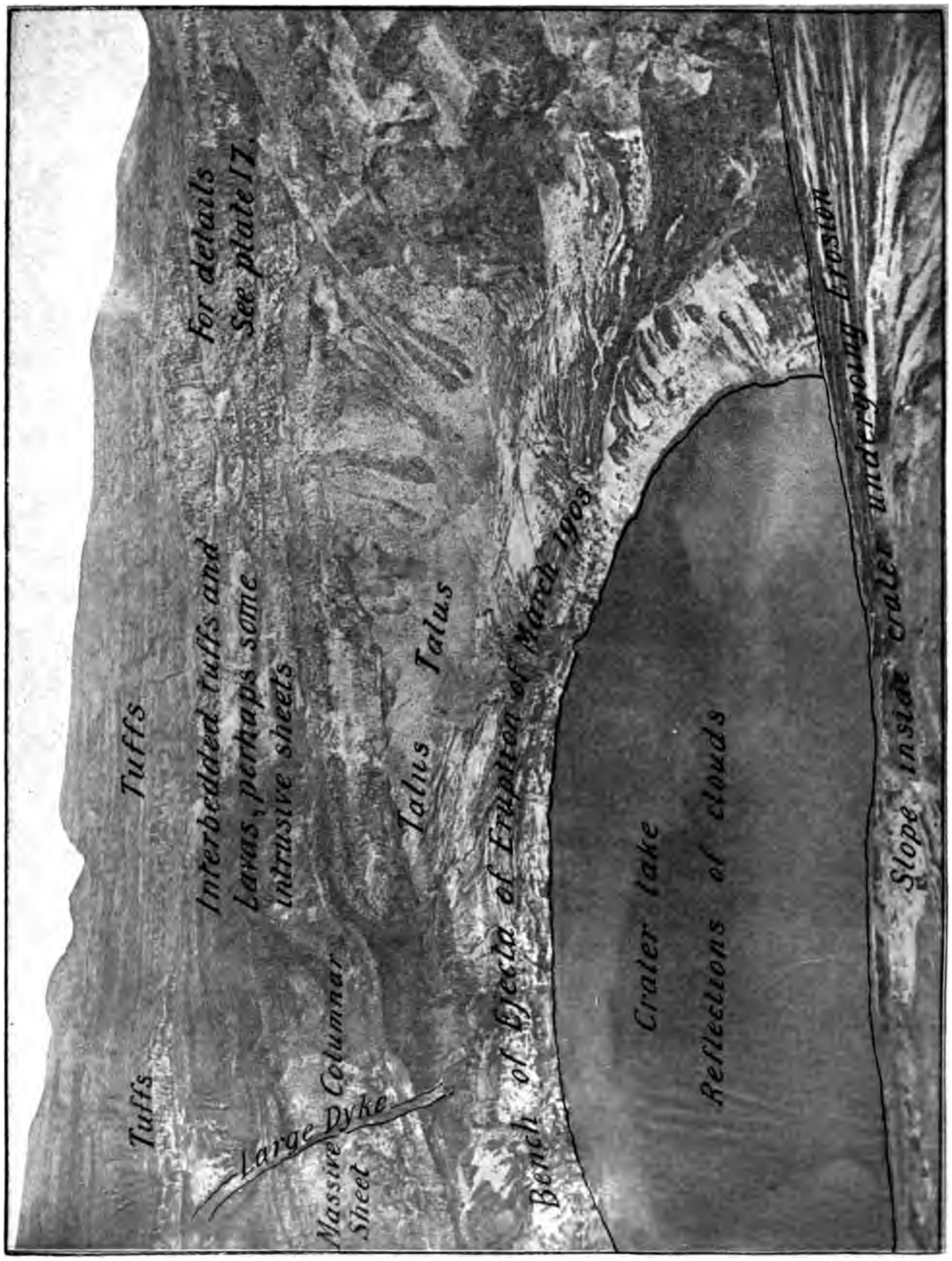
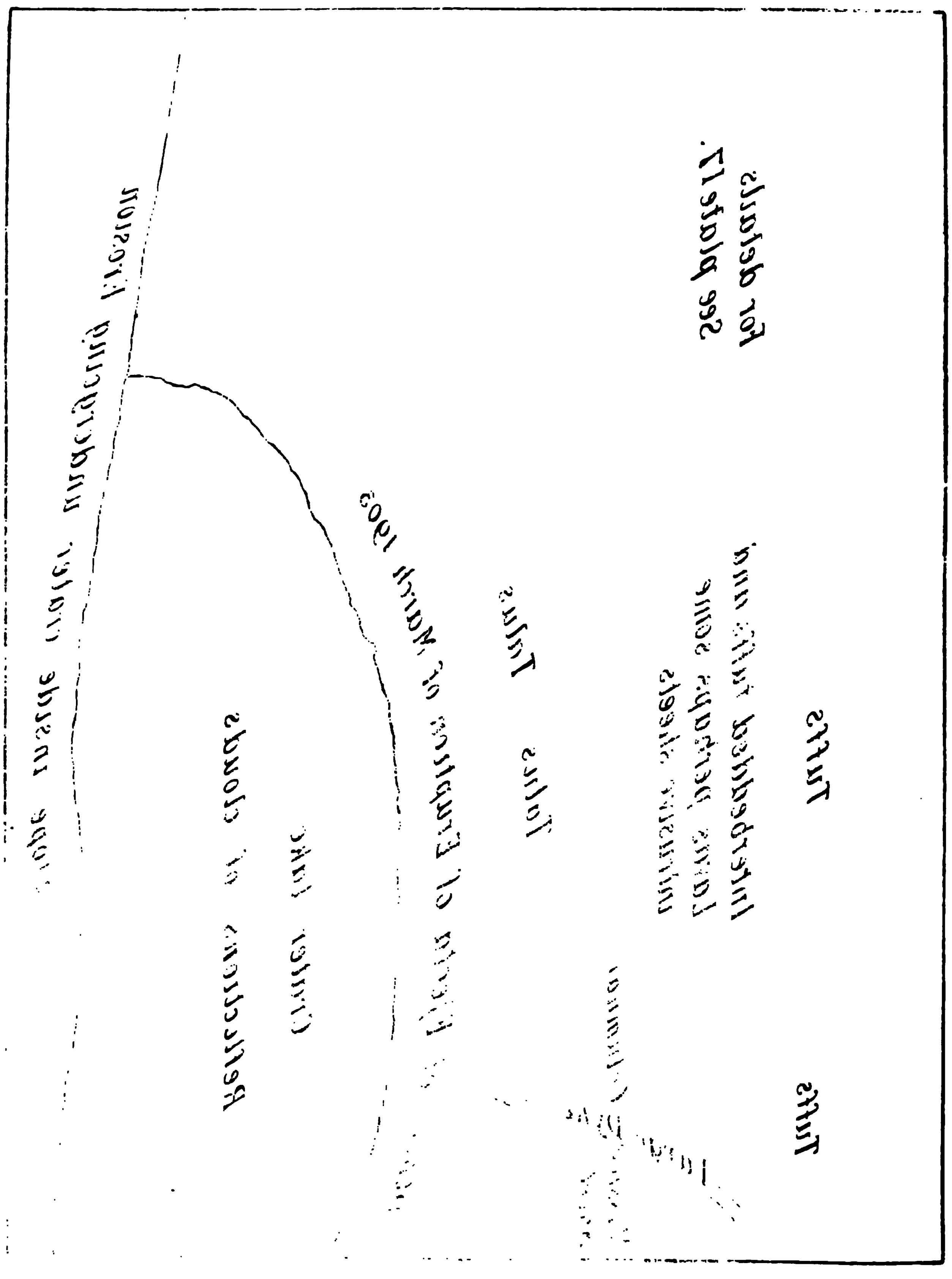

Bank of old Valley
Cut out of slopes of Soufrière
Ash
probably
1902
Ash of 1812
dividing from
Wallibu Dry
River
Old Tuff
Ash of
1902
small
portion
remaining
on Bank
Old tuffs and agglomerates
Compare
Part I Plate 30
Since 1902

Fig. 1. *Terraces on South bank of Lower Wallibu.*

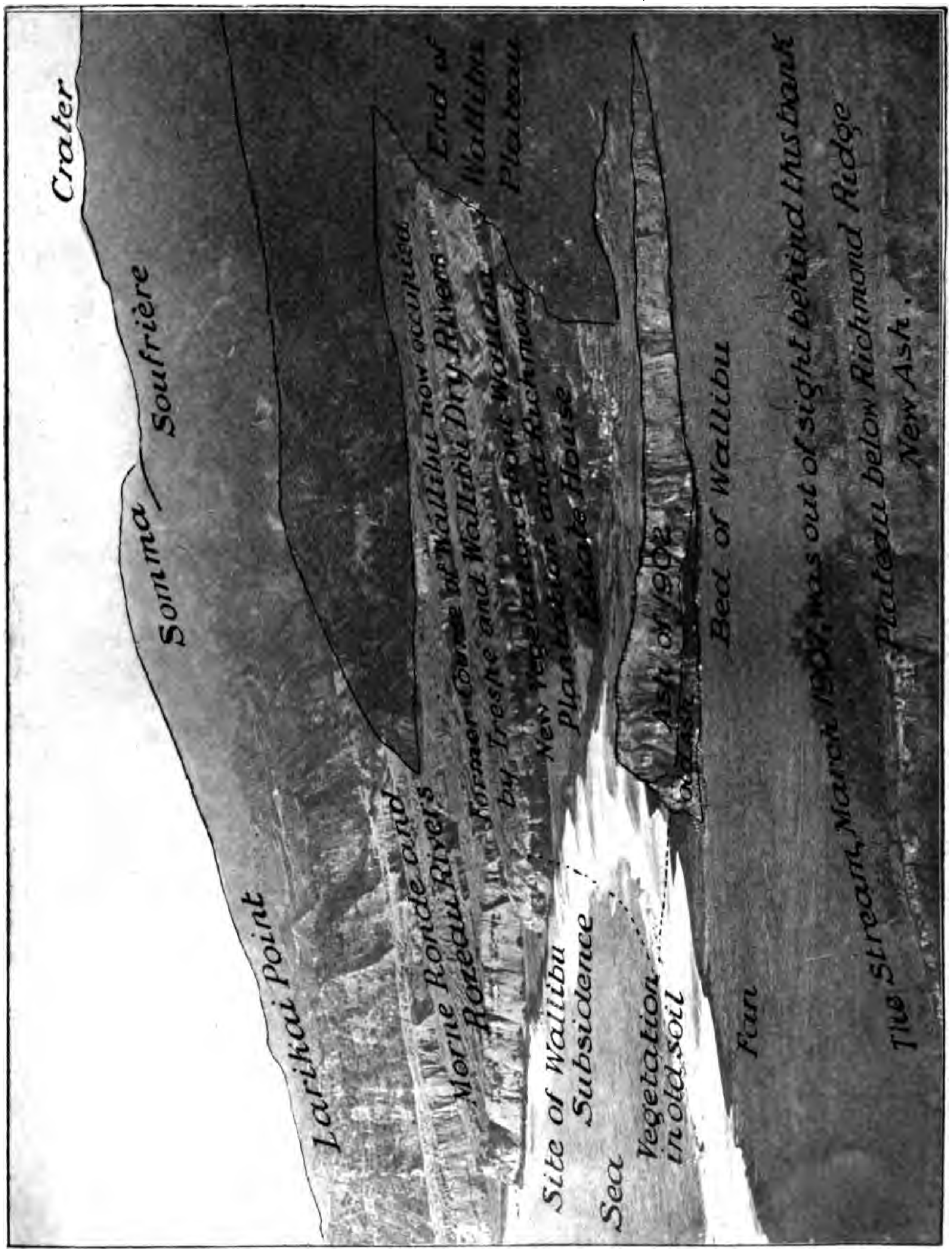
Fig. 2. *Trespé Ravine.*



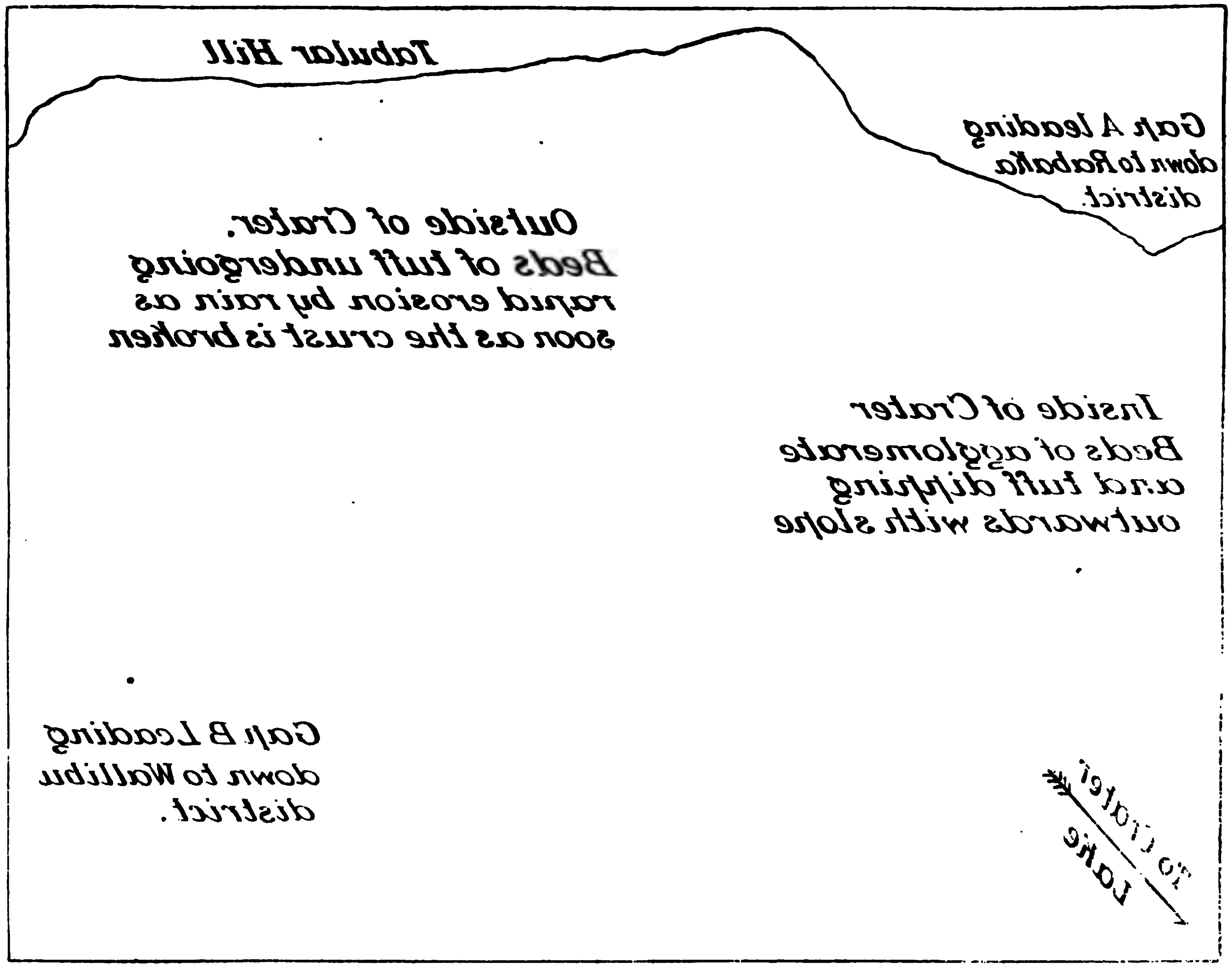
The Crater of the Soufrière, from the South-west lip.

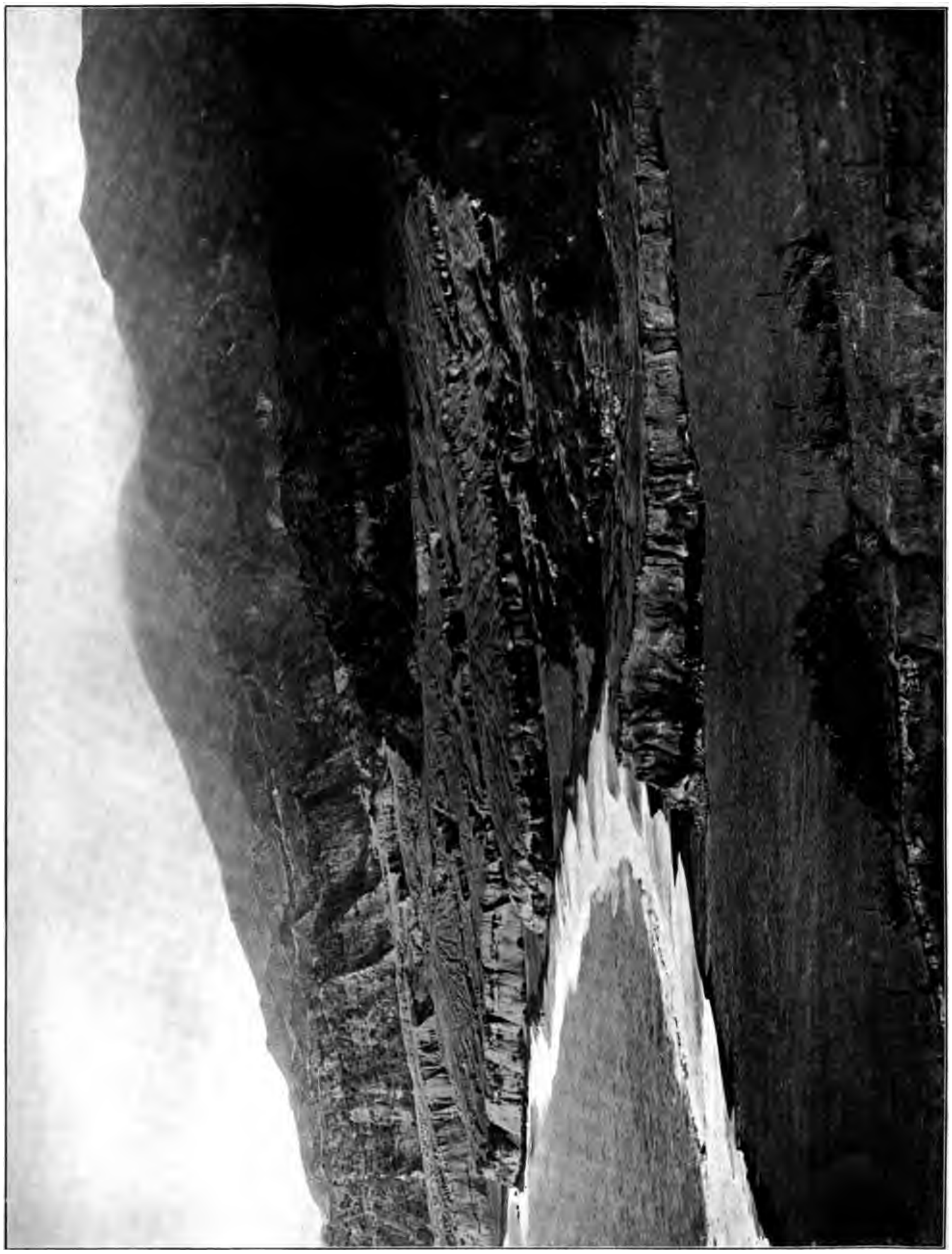

For details
See plate17.
Tuffs
Tuffs
Interbedded tuffs and
Talus
Talus
Crater lake
Reflections of clouds
March 1905
undergoing Erosion

The Crater of the Soufrière, from the South-west lip.

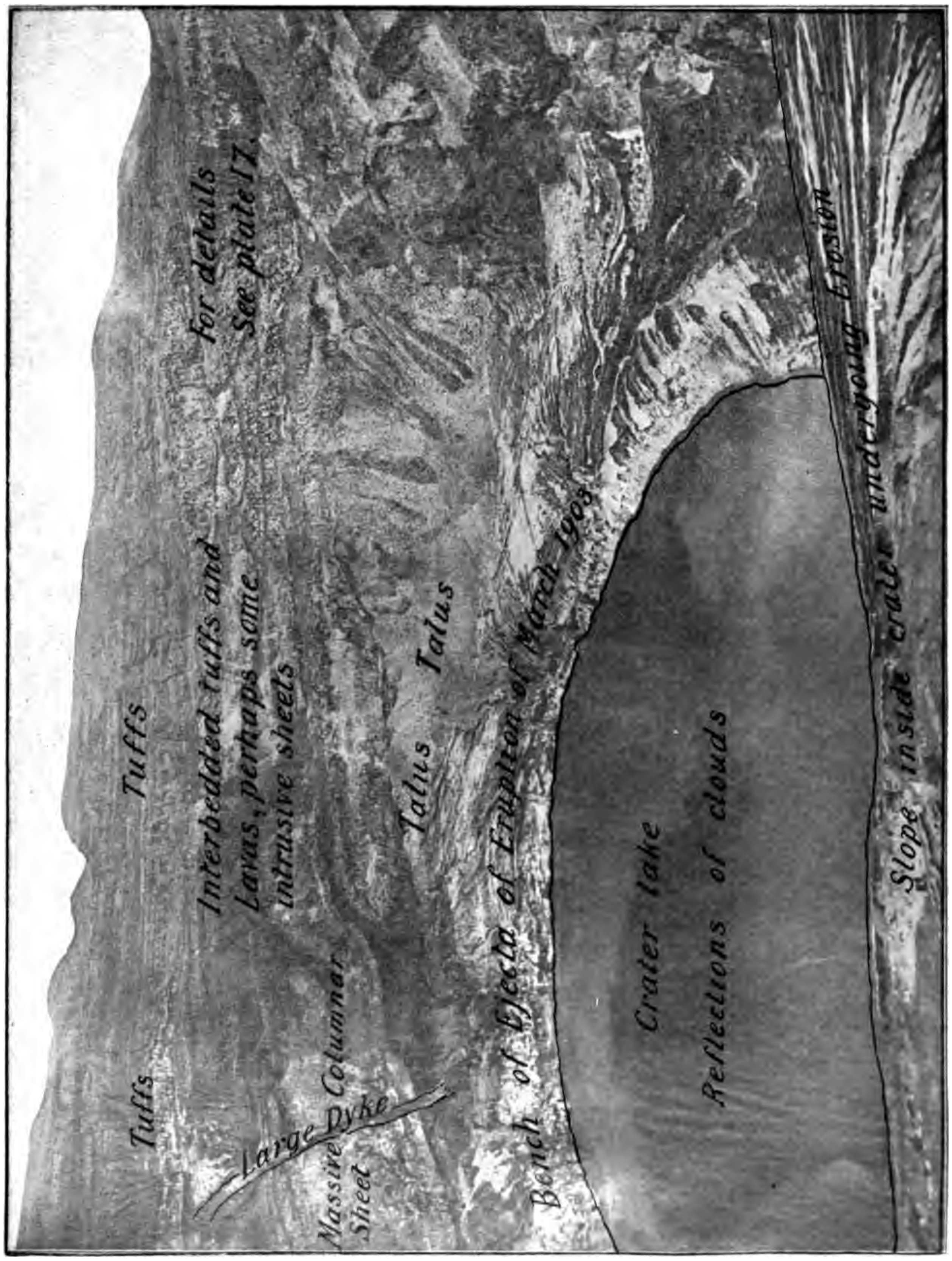


Mouth of Wallibu, from Plateau below Richmond Ridge.

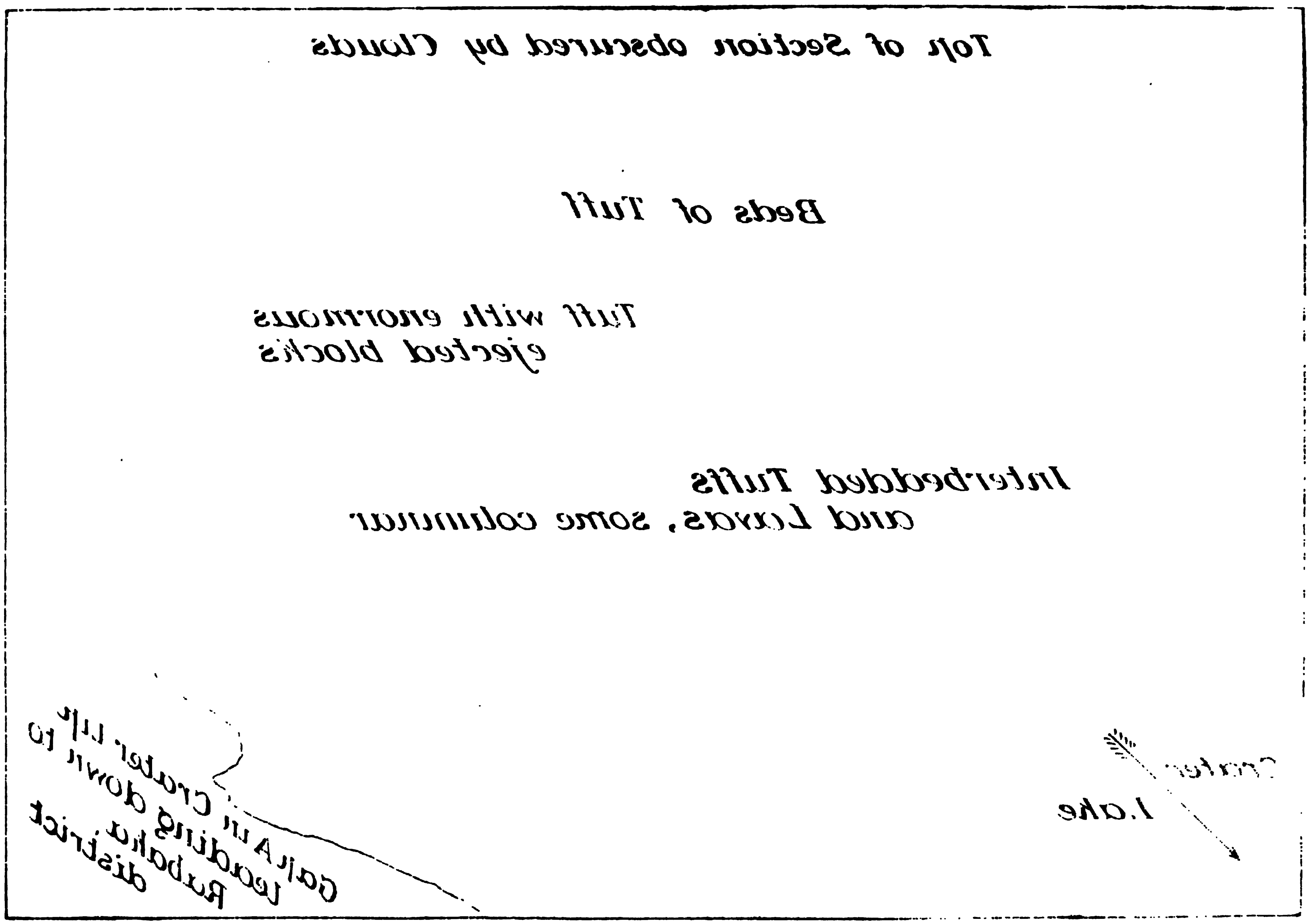

Tabular Hill
Gap A leading down to Rabaka district.
Outside of Crater. Beds of tuff undergoing rapid erosion by rain as soon as the crust is broken
Inside of Crater Beds of agglomerate and tuff dipping outwards with slope
Gap B Leading down to Wallibu district.
To Crater Lake



Mouth of Wallibu, from Plateau below Richmond Ridge.

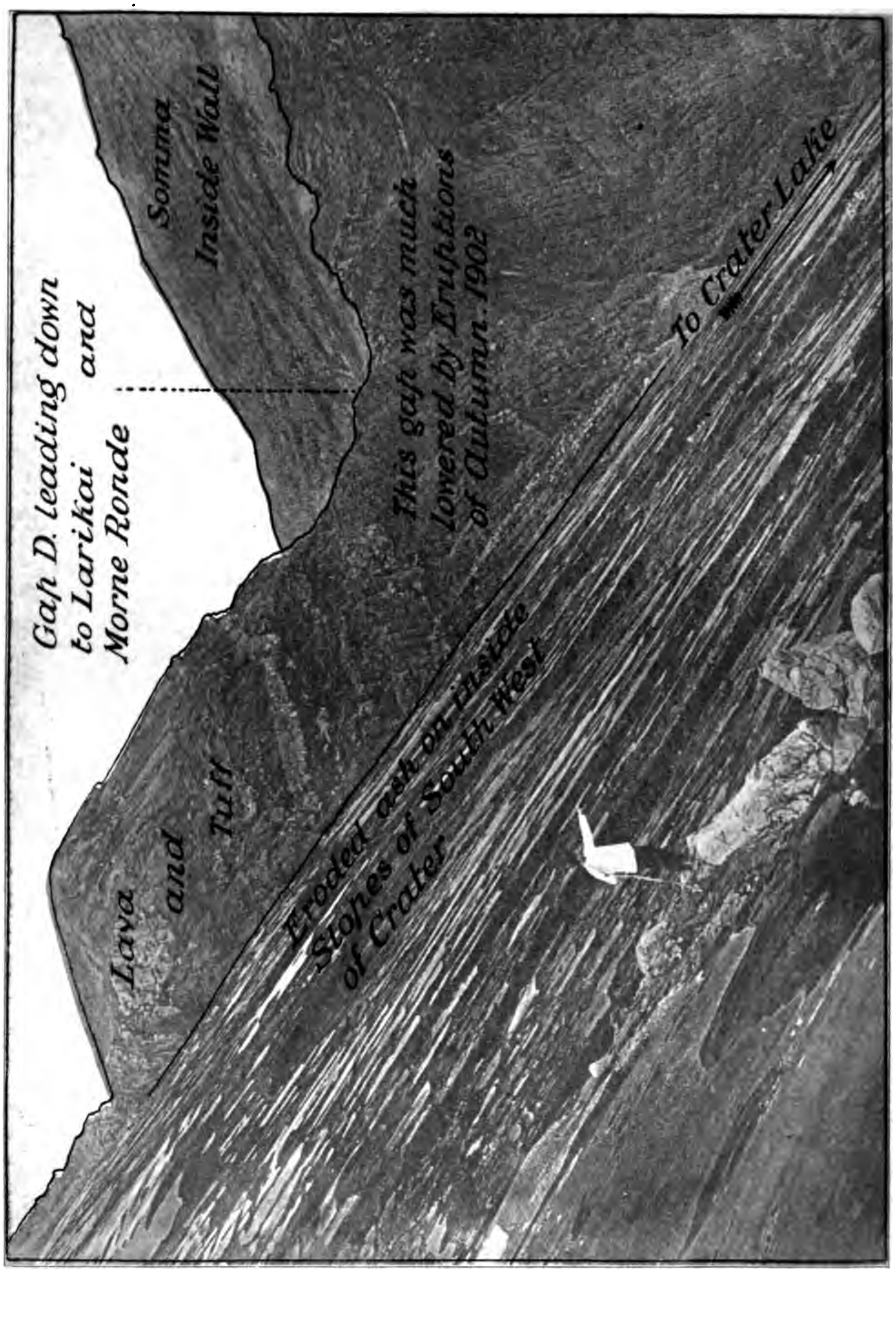


The Crater of the Soufrière, from the South-west lip.

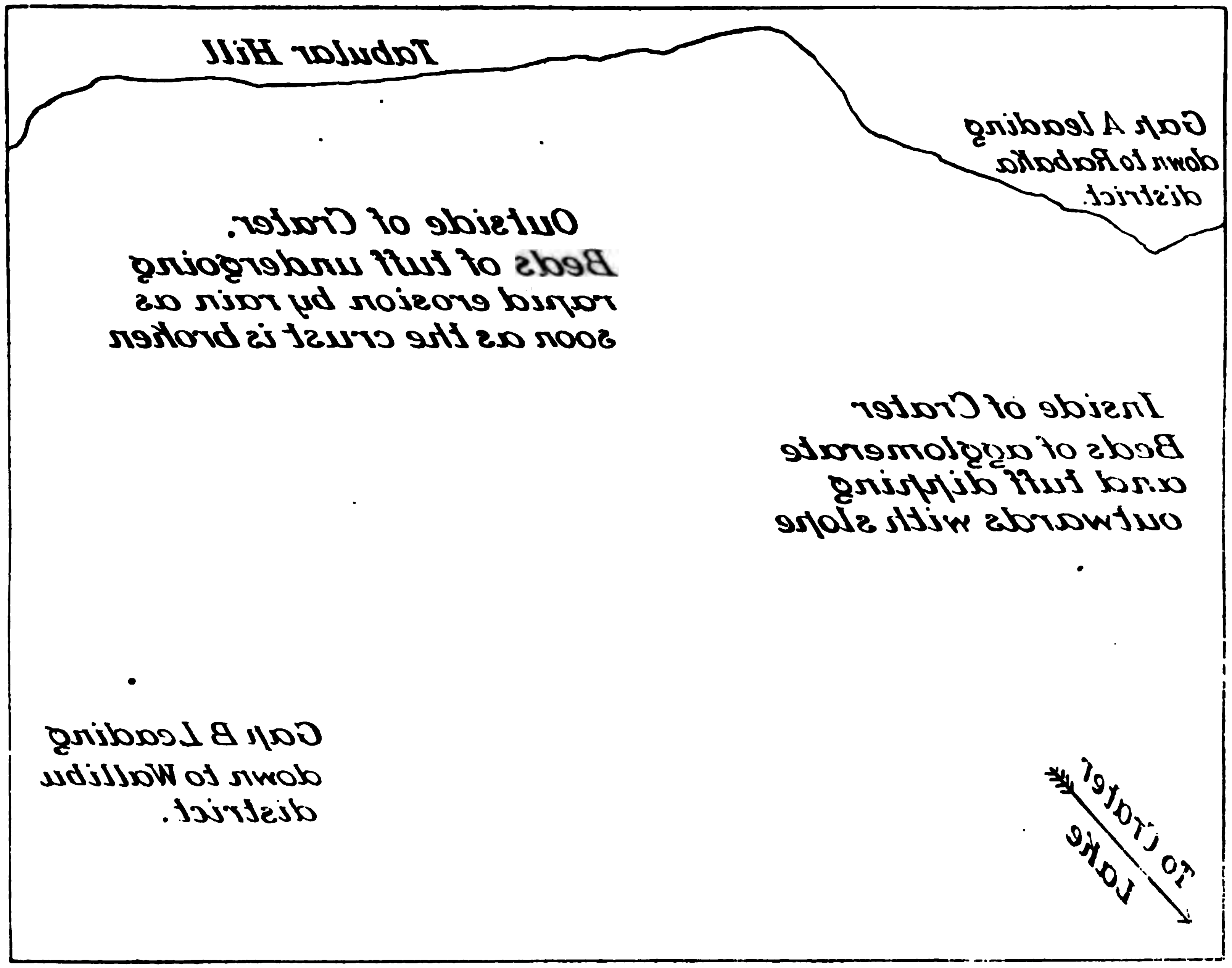


Top of Section obscured by Clouds
Beds of Tuff
Tuff with enormous ejected blocks
Interbedded Tuffs and Lavas, some columnar
Crater
Lake
Gap in Crater lip leading down to Rubaka district

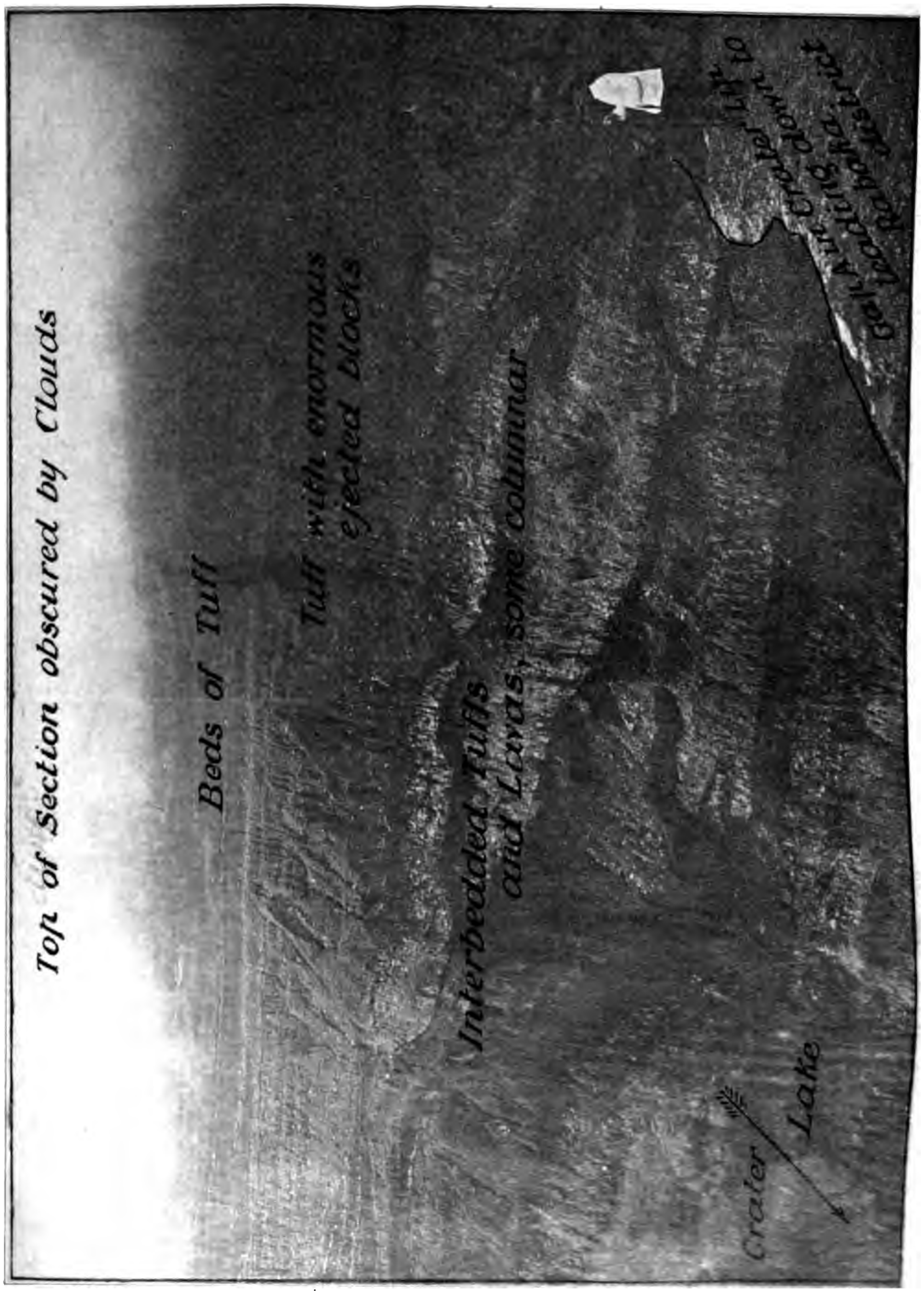
The Crater of the Soufrière, from the South-west lip.



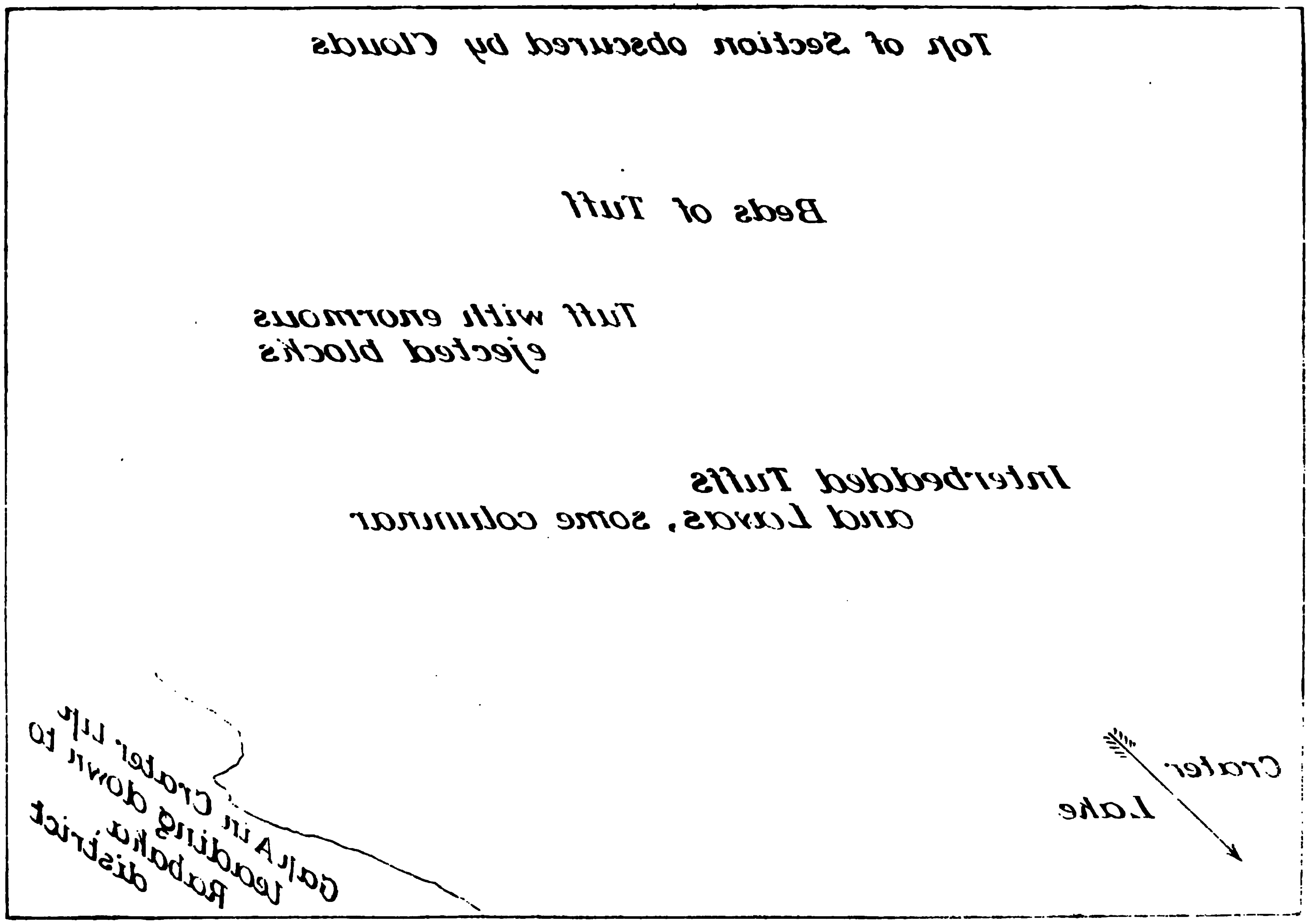
West lip of Crater.


Tabular Hill
Gap A leading down to Rabaka district.
Outside of Crater. Beds of tuff undergoing rapid erosion by rain as soon as the crust is broken
Inside of Crater Beds of agglomerate and tuff dipping outwards with slope
Gap B Leading down to Wallibu district.
To Crater Lake

Crater of the Soufrière; south lip, from West.

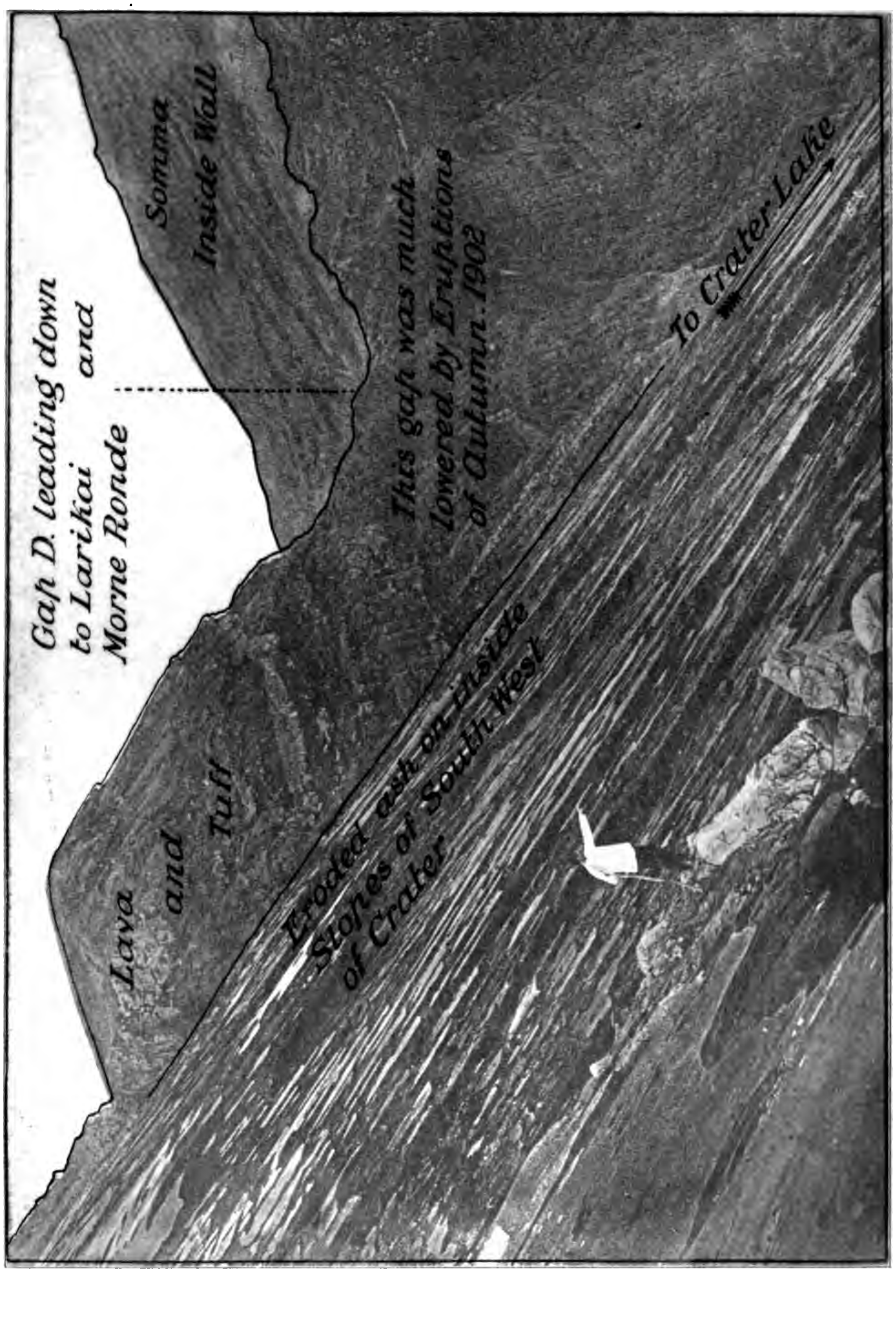


North wall of Crater, Eastern end.

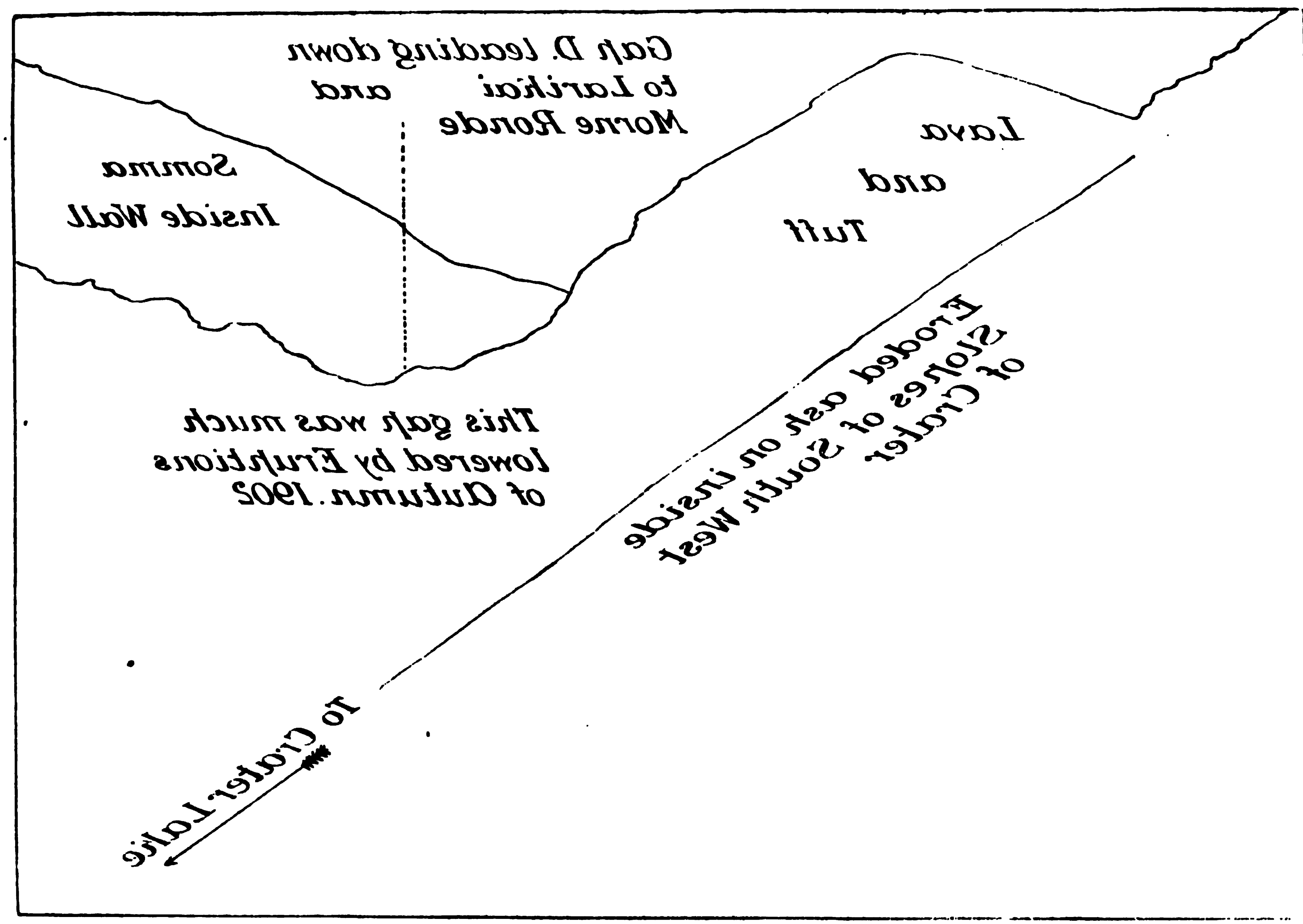


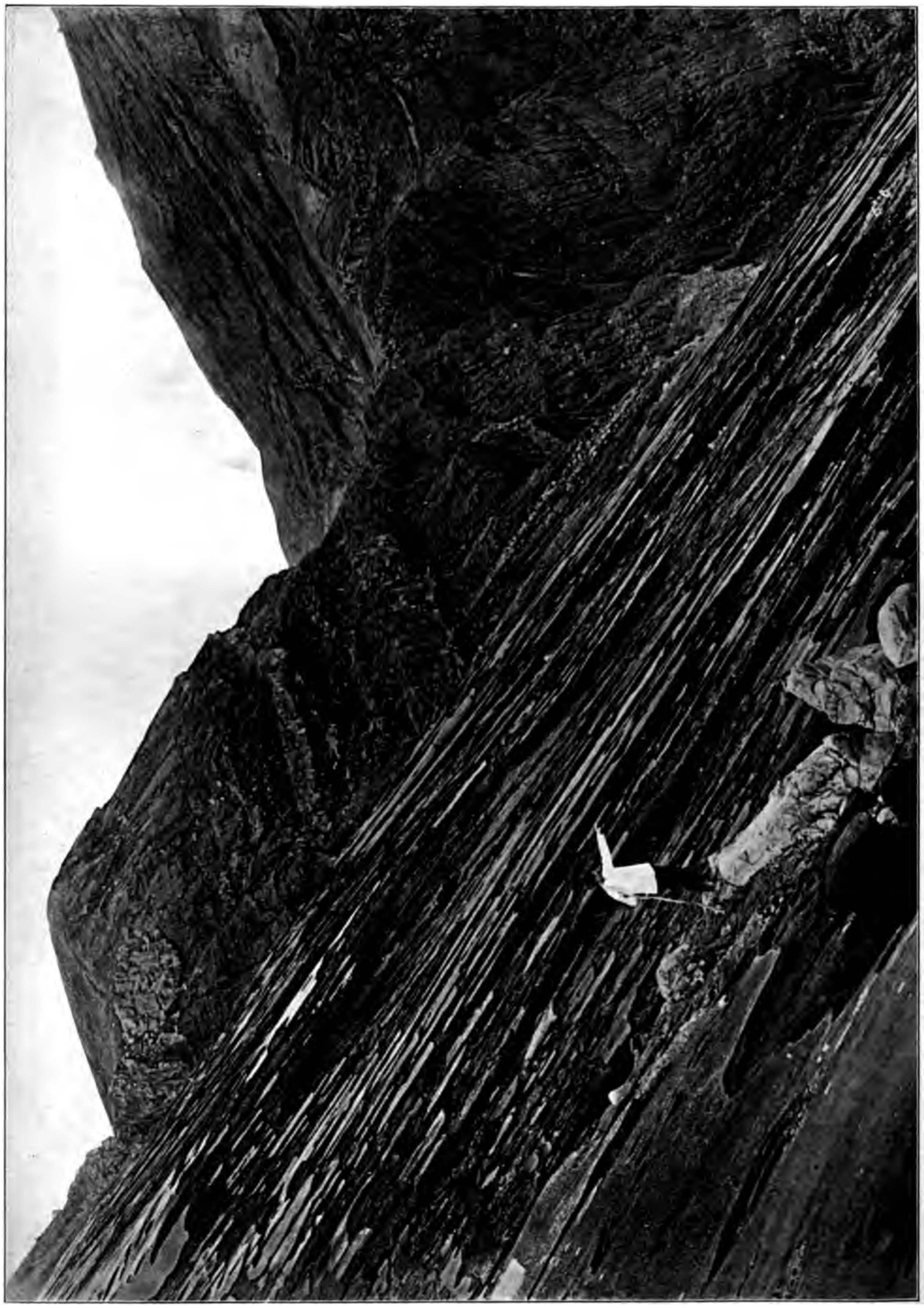
Top of Section obscured by Clouds
Beds of Tuff
Tuff with enormous ejected blocks
Interbedded Tuffs and Lavas, some columnar
Crater Lake

North wall of Crater, Eastern end.

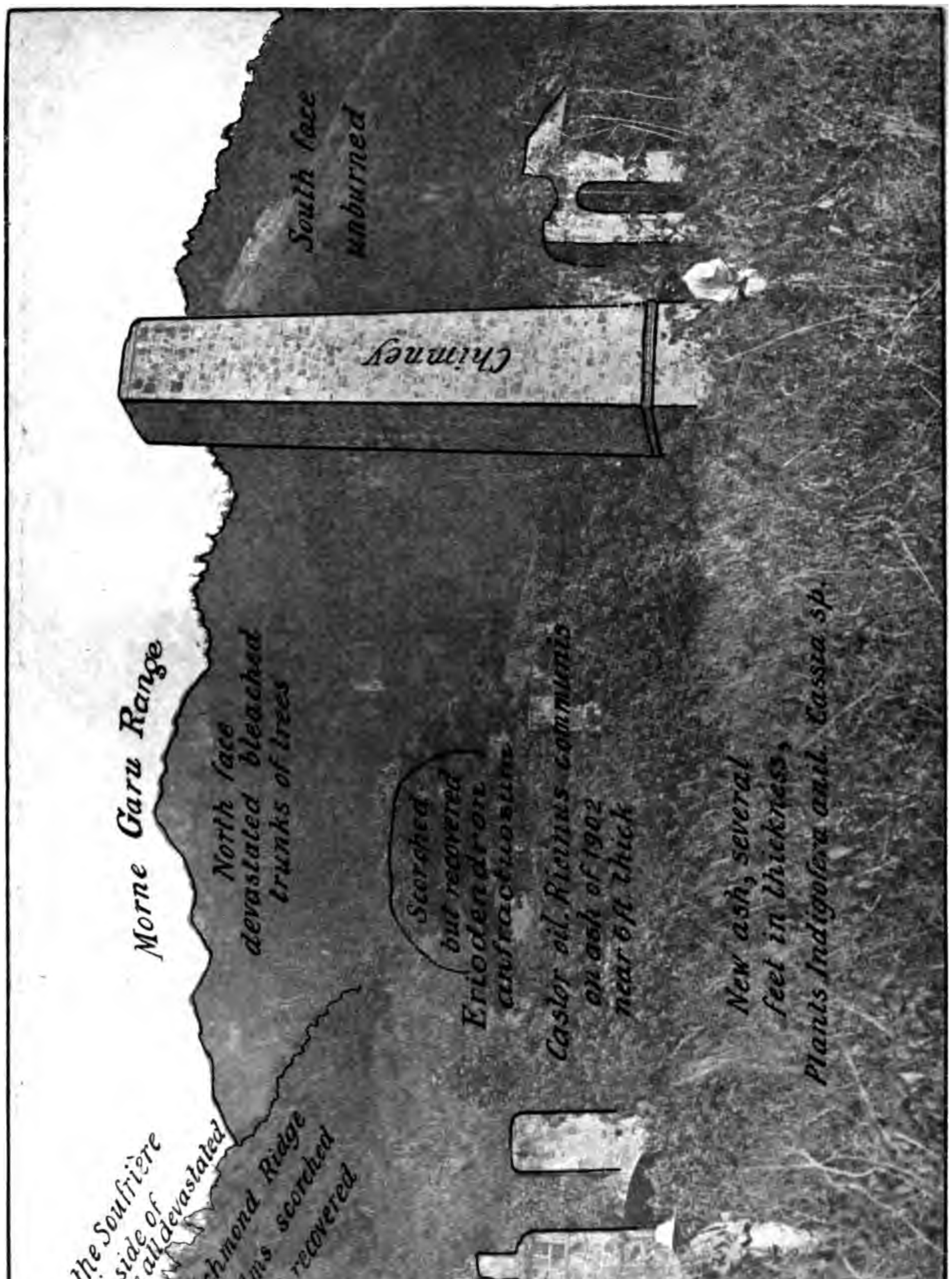


West lip of Crater

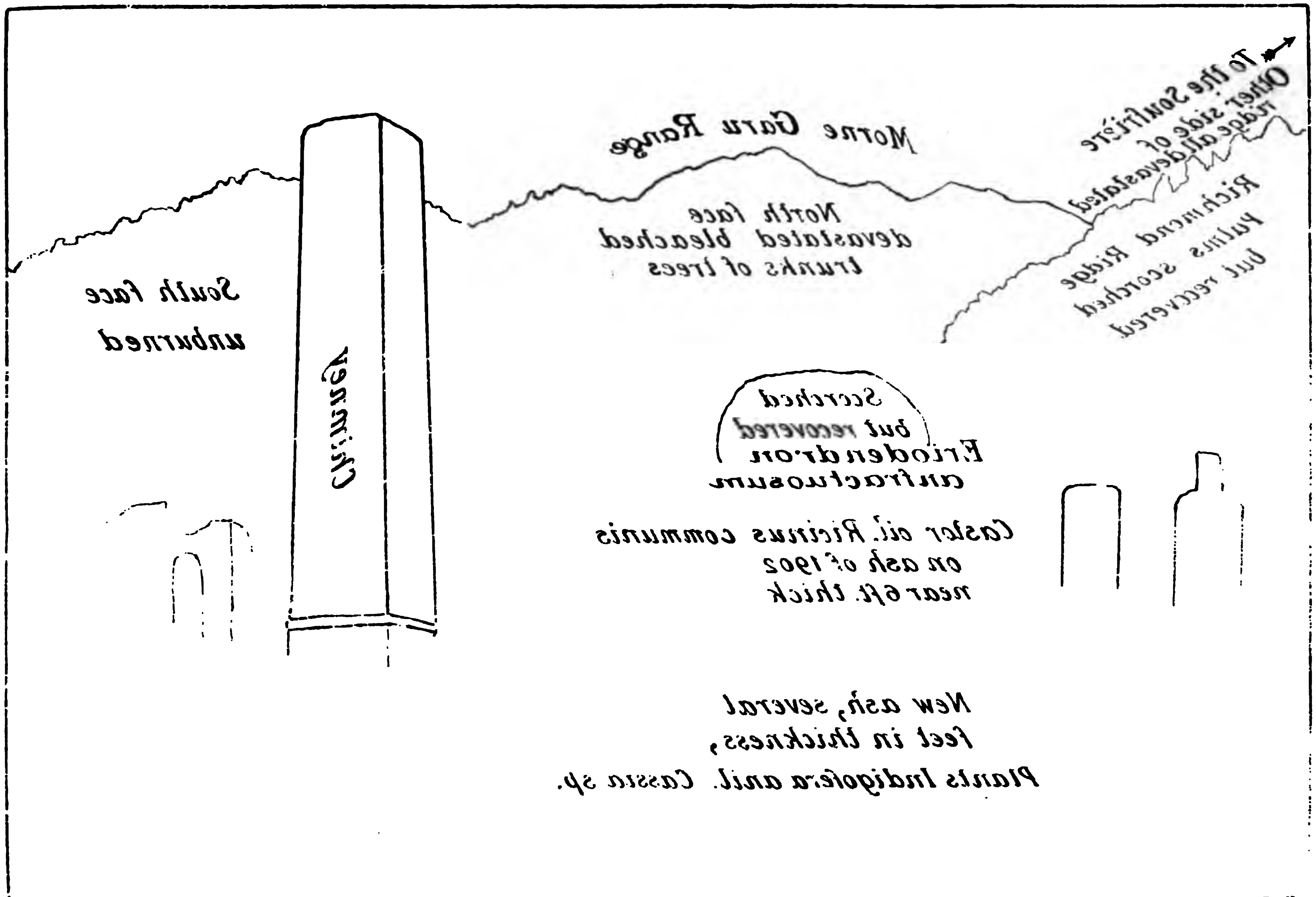

Gap D. leading down
to Larikai
and
Morne Ronde
Somma
Inside Wall
Lava
and
Tuff
This gap was much
lowered by Eruptions
of Autumn. 1902
Eroded ash on inside
Slopes of South West
of Crater
To Crater Lake



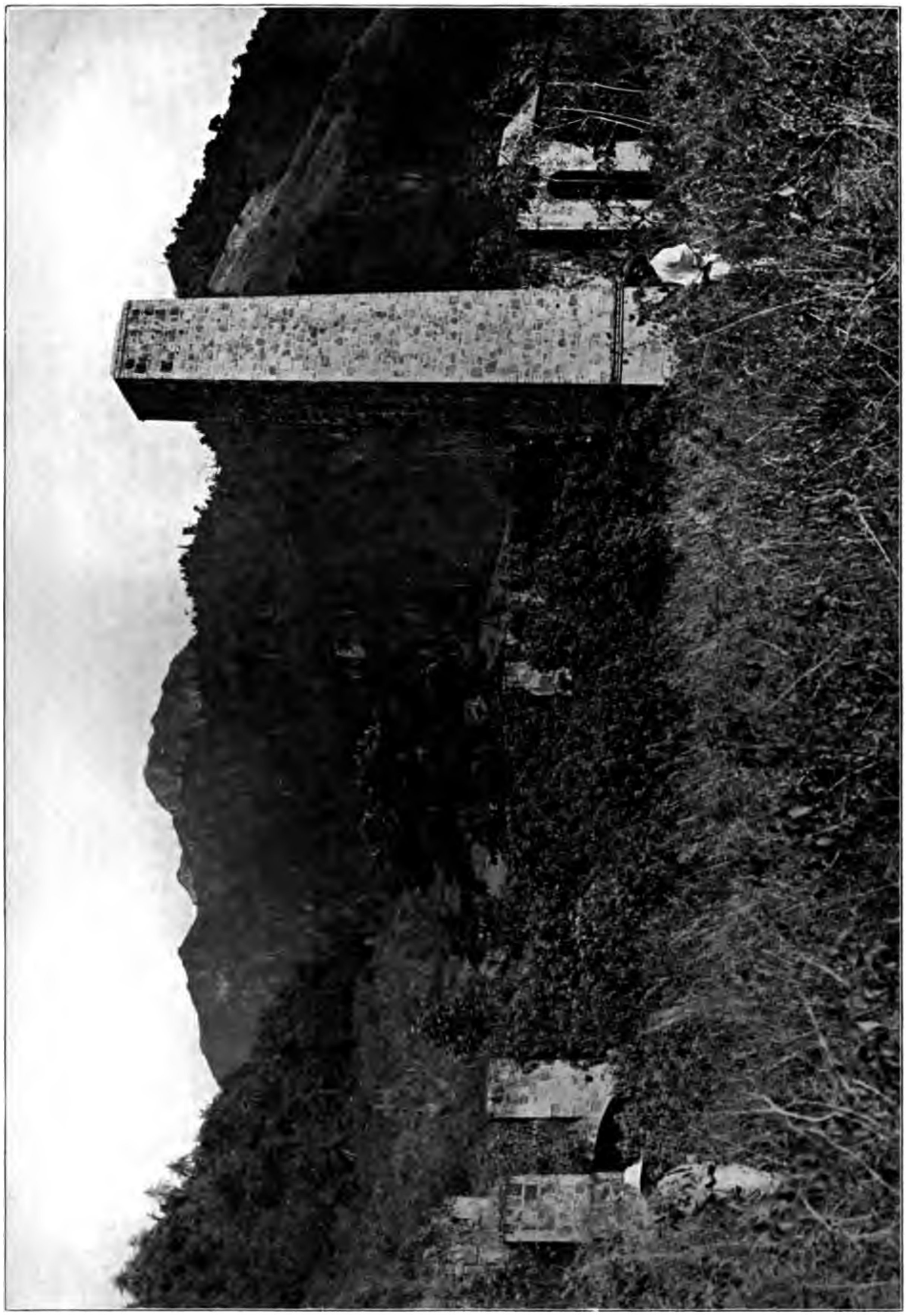
West lip of Crater.



Richmond Plantation Works, 1907, from the West.



Morne Garu Range
To the Soufrière
Other side of ridge all devastated
North face devastated bleached trunks of trees
Richmond Ridge
Palms scorched but recovered
South face unburned
Chimney
Scorched but recovered
Eriodendron anfractuosum
Castor oil. Ricinus communis on ash of 1902 near 6ft. thick
New ash, several feet in thickness,
Plants Indigofera anil. Cassia sp.



Richmond Plantation Works, 1907, *from the West.*

Fig. 1. *Near Richmond Works.* 1907. (Pluchea Odorata.)

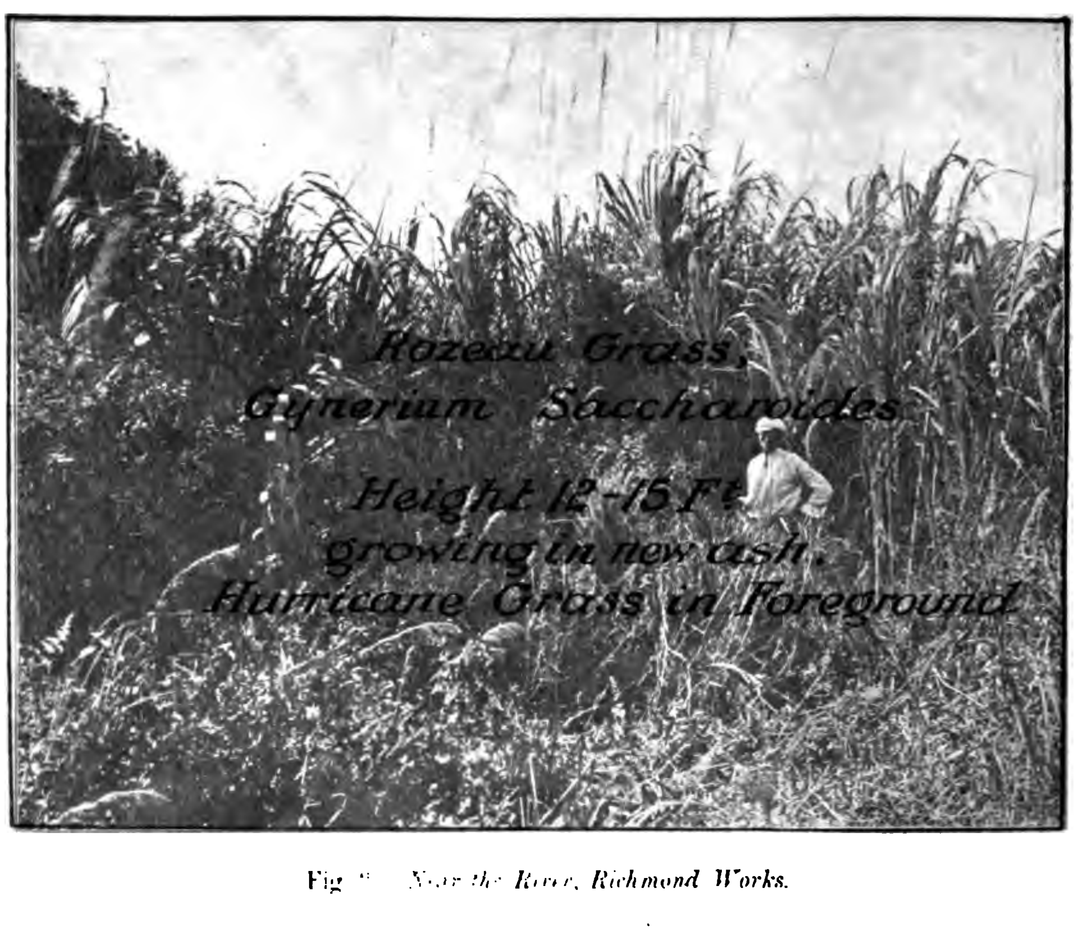


Fig. 2. *Near the River, Richmond Works.*

"Cattle Tongue",
Pluchea Odorata,
Very abundant.

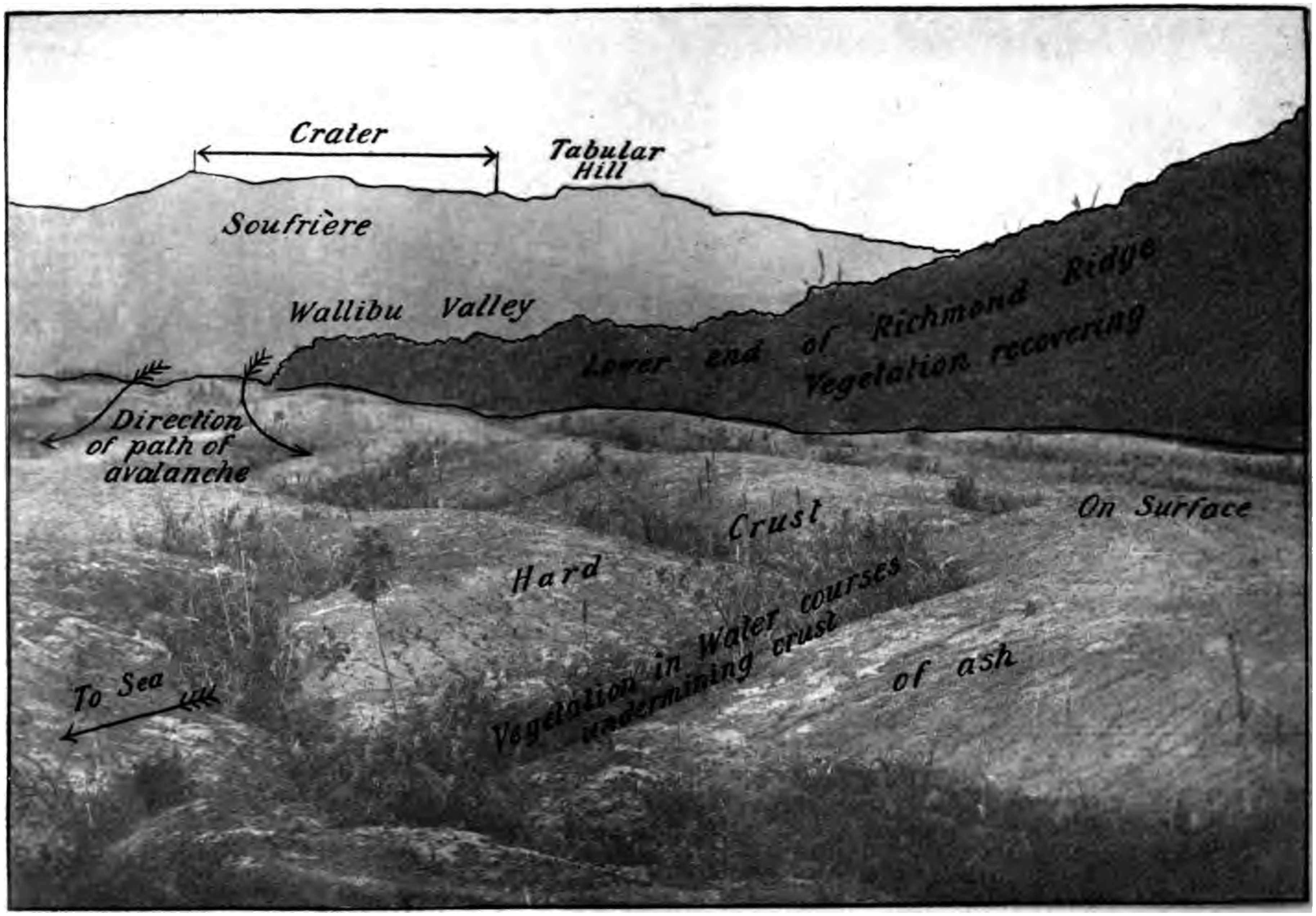
New ash
2 to 6 ft thick

Rozeau Grass,
Gynerium Saccharoides

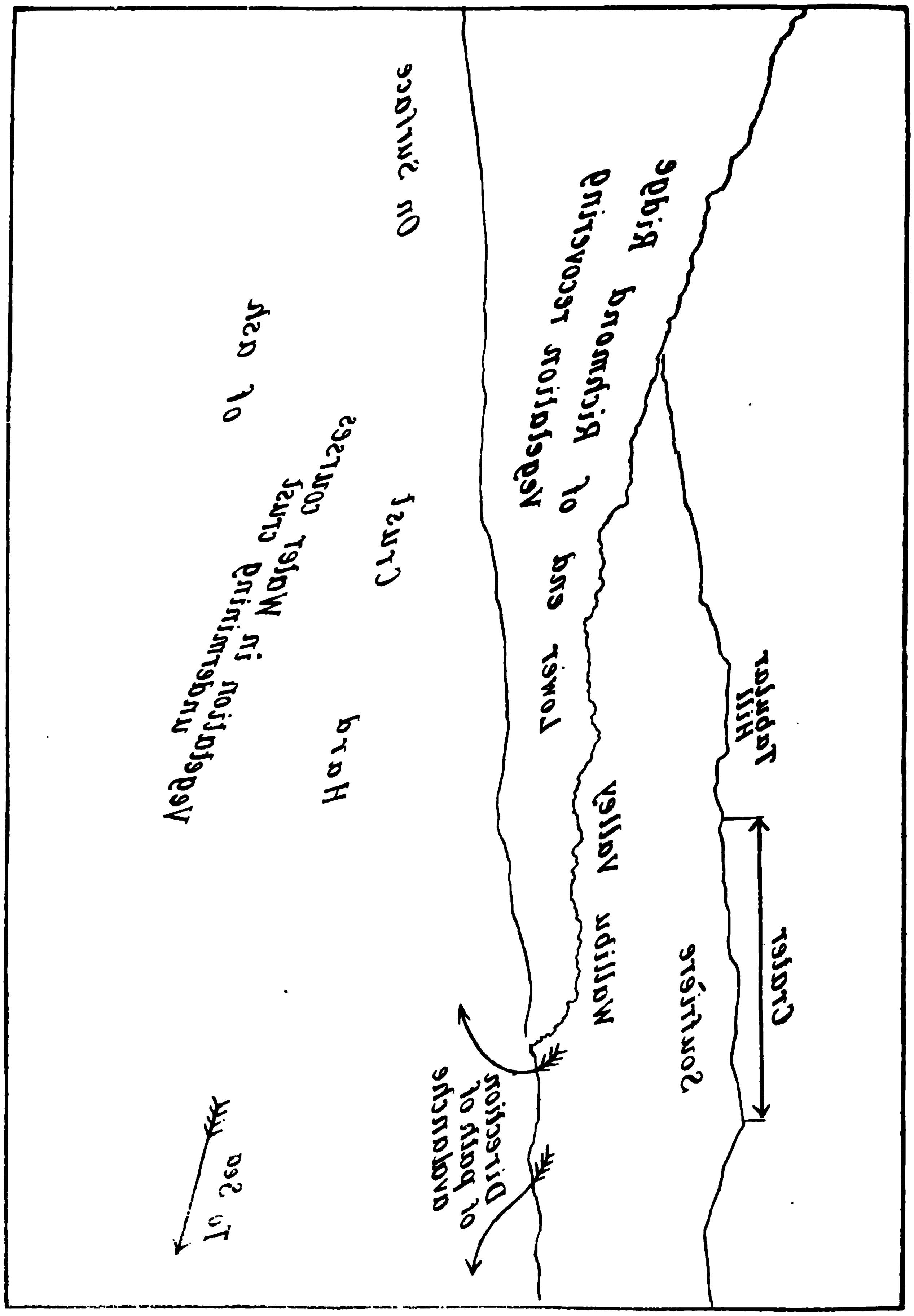
Height 12-15 Ft
growing in new ash.
Hurricane Grass in [illegible]

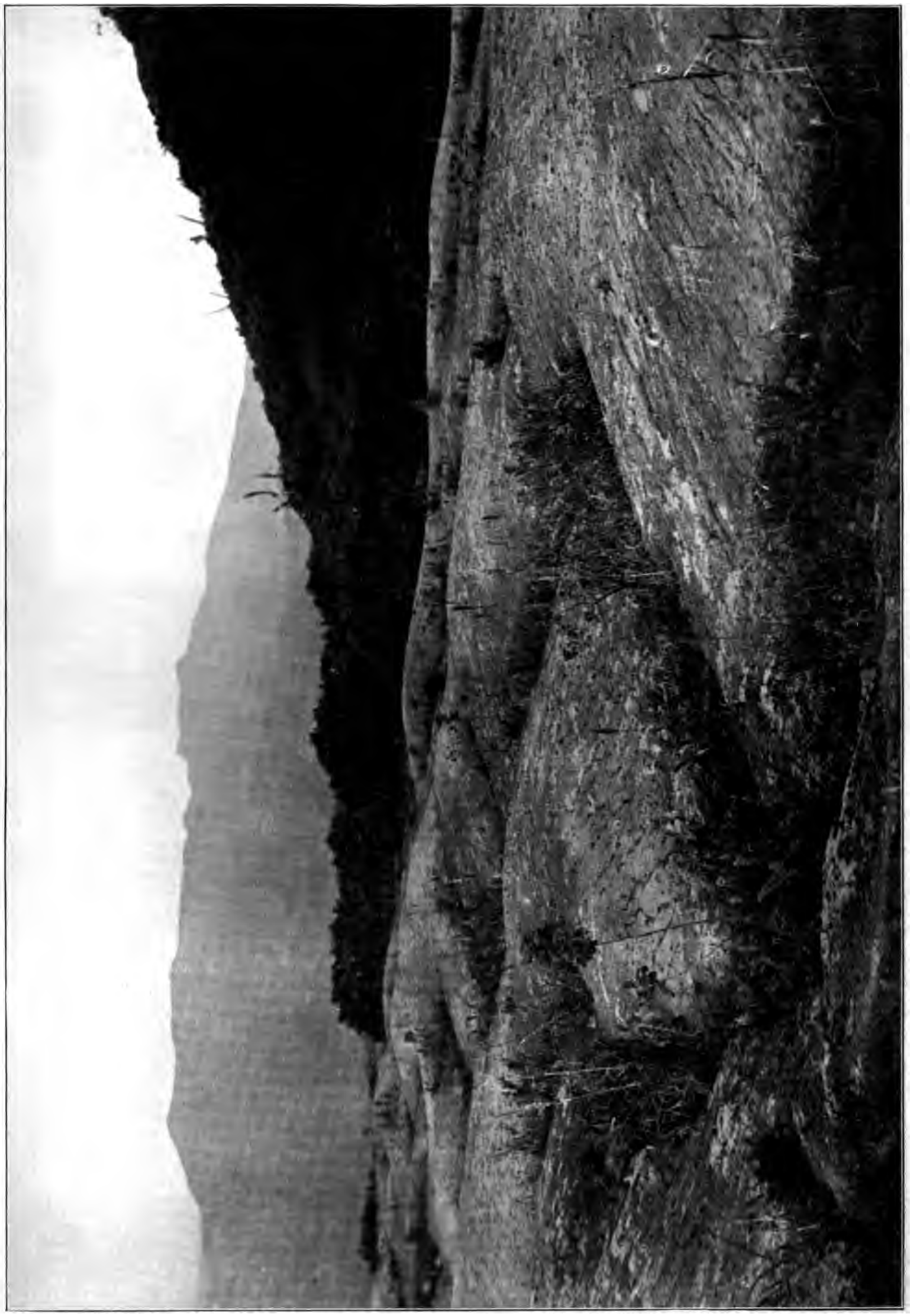
Fig. 1. *Near Richmond Works* 1907. (Pluchea Odorata.)

Fig. 2. *Near the River, Richmond Works*



The Avalanche, below end of Richmond Ridge


Crater
Tabular Hill
Soufrière
Wallibu Valley
Lower end of Richmond Ridge
Vegetation recovering
Direction of path of avalanche
On surface
Hard Crust
Vegetation in Water courses undermining crust of ash
To Sea



The Avalanche, below end of Richmond Ridge.

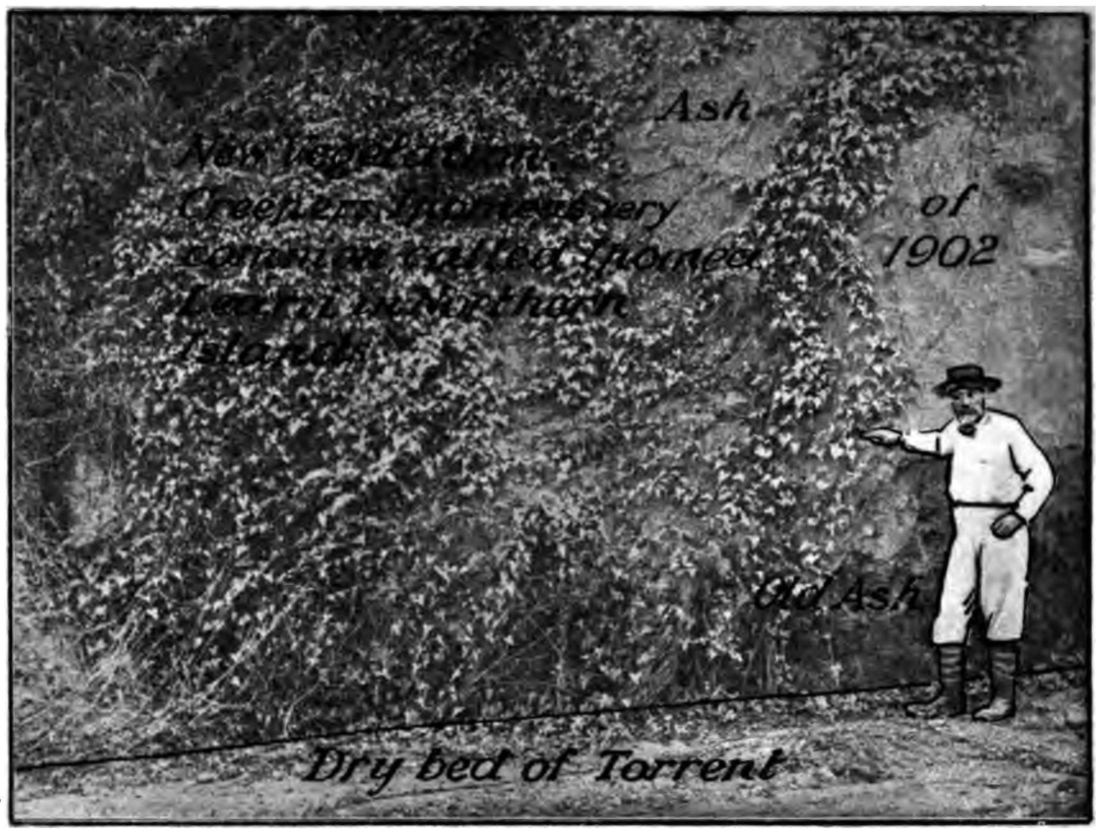


Fig. 1. *North Wall of Trespe Valley.*

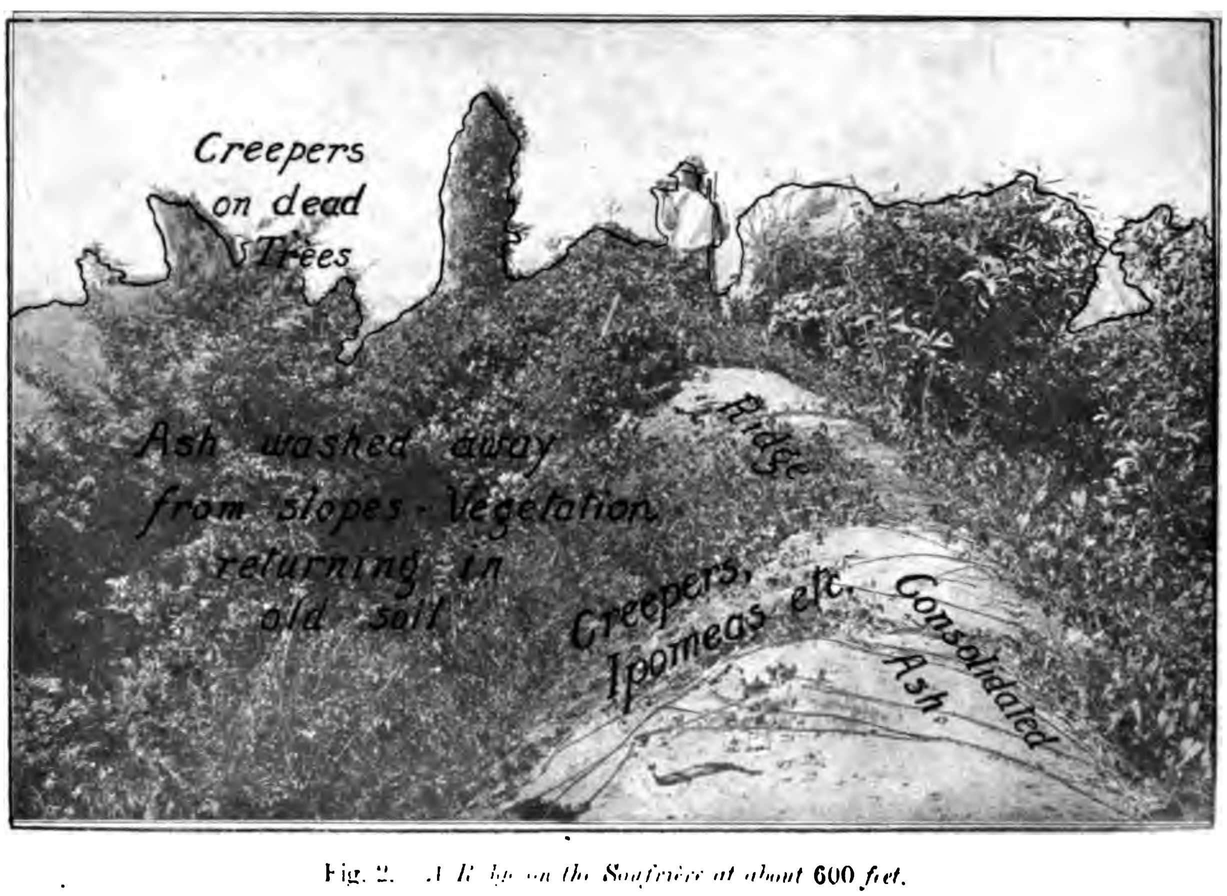
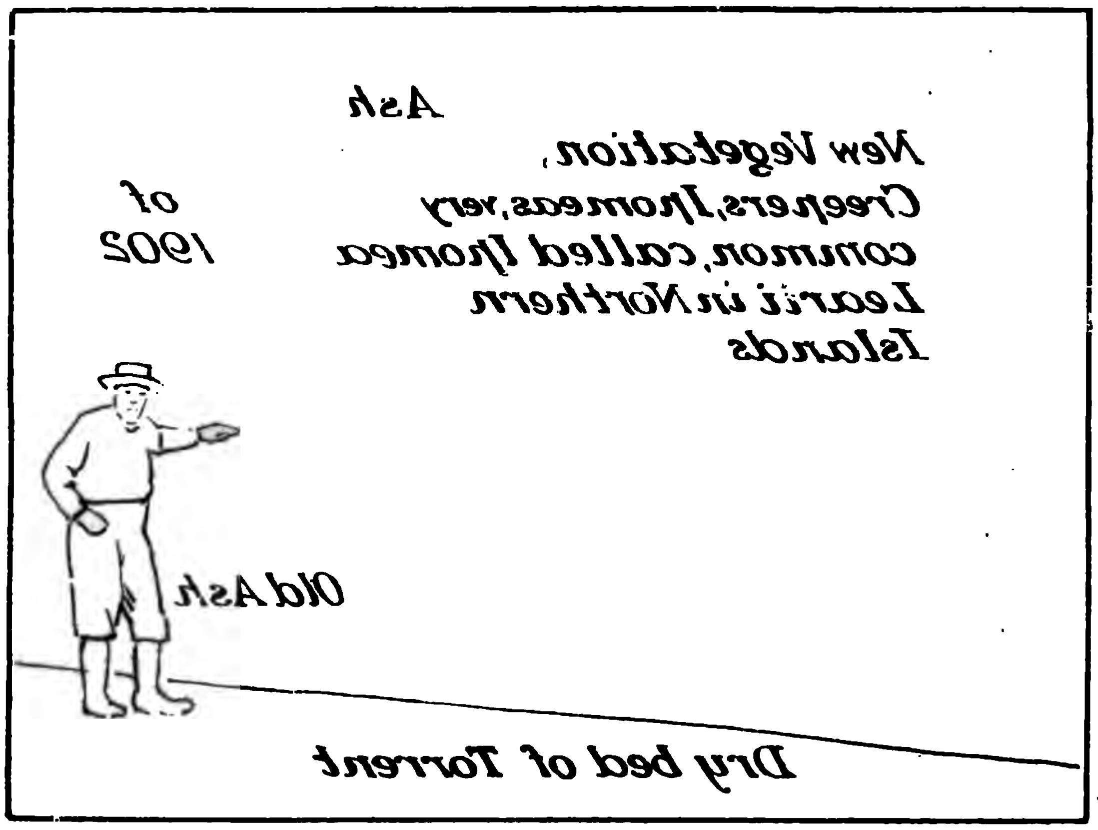


Fig. 2. *A Ridge on the Soufrière at about* 600 *feet.*


Ash
New Vegetation,
Creepers, Ipomeas, very
common, called Ipomea
Learii in Northern
Islands
of
1902
Old Ash
Dry bed of Torrent

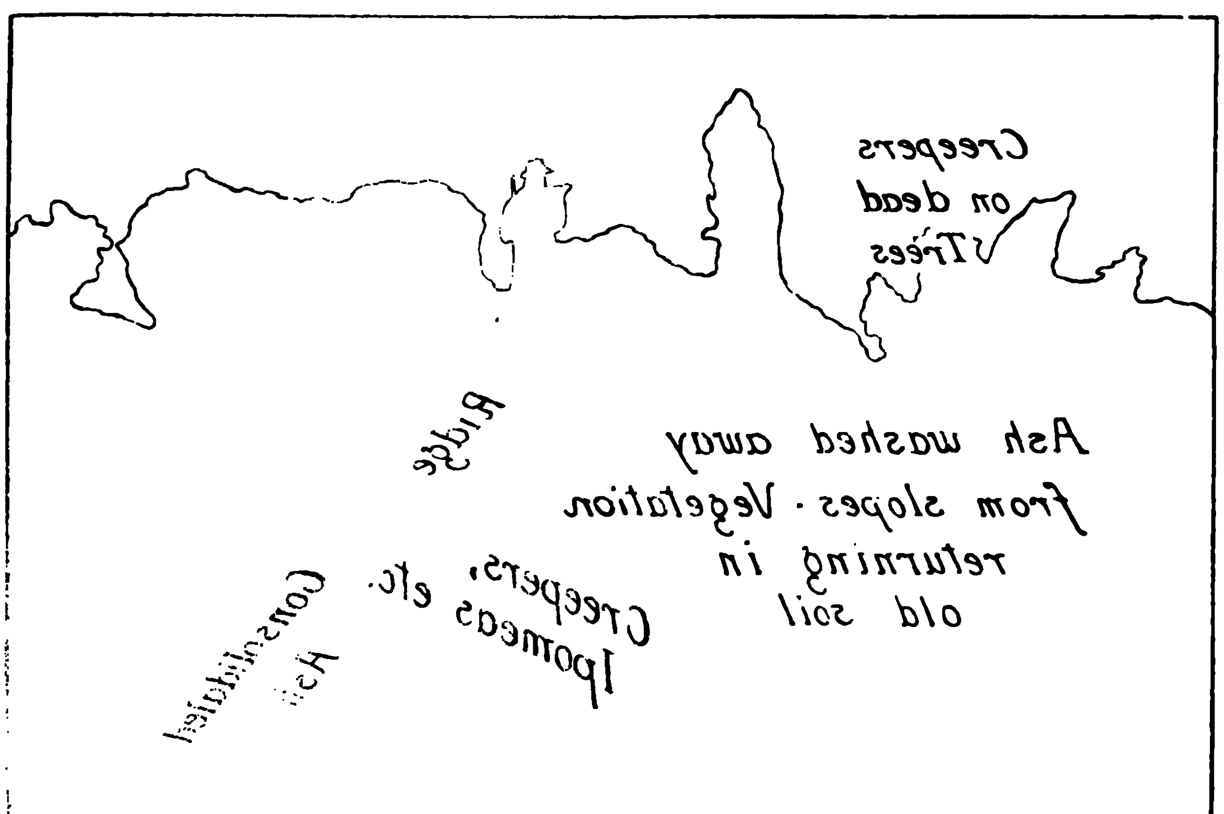
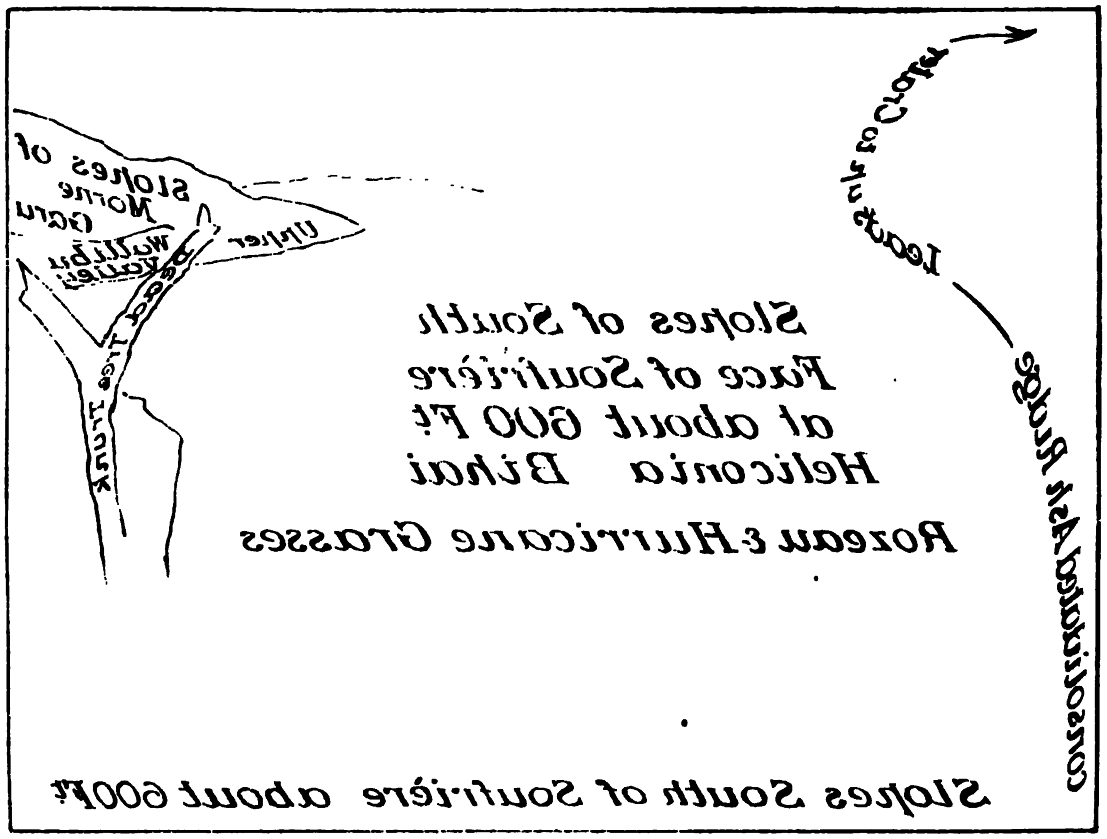

Creepers
on dead
Trees
Ridge
Ash washed away
from slopes - Vegetation
returning in
old soil
Creepers, etc.
Ipomeas
Consolidated
Ash

Fig. 1. *North Wall of Trespe Valley.*

Fig. 2. *A Ridge on the Soufrière at about* 600 *feet.*

Fig. 1. *South Slopes of Soufrière at about* 600 *feet.*

[illegible]


Slopes of Morne Garu
Upper Wallibu Valley
Dead Tree Trunk
leads up to Crater
Consolidated Ash Ridge
Slopes of South Face of Soufrière at about 600 Ft
Heliconia Bihai
Rozeau & Hurricane Grasses
Slopes South of Soufrière about 600 Ft

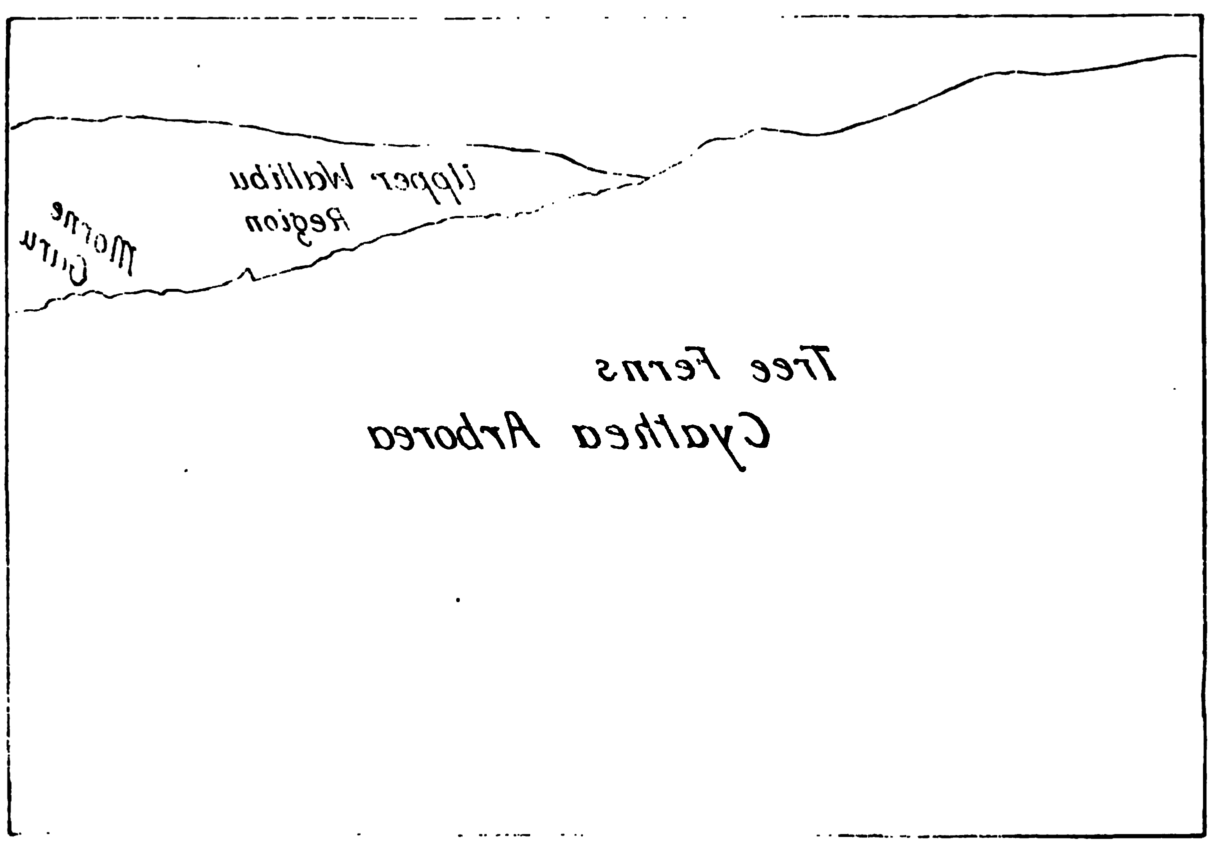
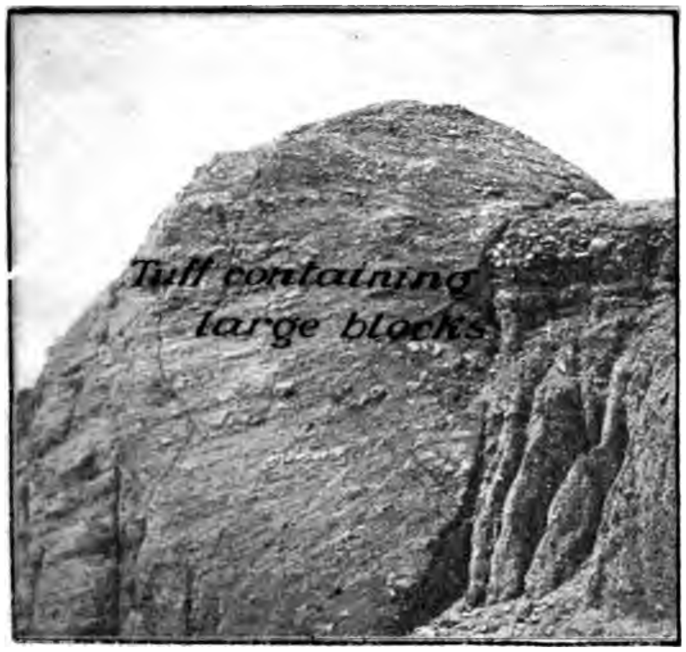

Morne Garu
Upper Wallibu Region
Tree Ferns
Cyathea Arborea

Fig. 1. *South Slopes of Soufrière at about* 600 *feet.*

Fig. 2. *Slopes of Soufrière at about* 800 *feet.*

Fig. 1. *The Crater of Montagne Pelée, March* 13, 1907.

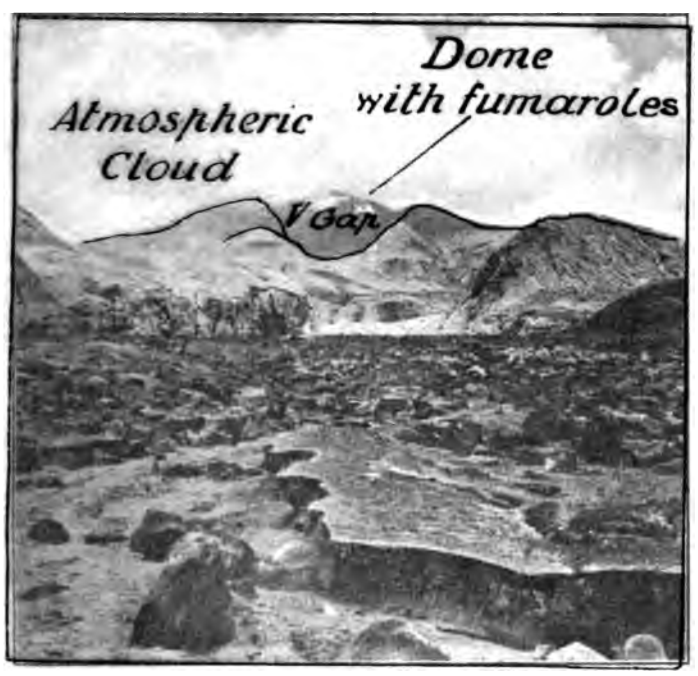
F[illegible] 2. [illegible] Pelée, *North side, at about* 1500 *feet.*


Tuff containing
large blocks


Tuff containing
large blocks

[illegible]

Fig. 2. [illegible] of Fig. 1.


Dome
with fumaroles
Atmospheric
Cloud
V Gap


Blocks transported by
torrential rain

Tuff containing
large blocks

Tuff containing
large blocks

Blocks transported by
torrential rain

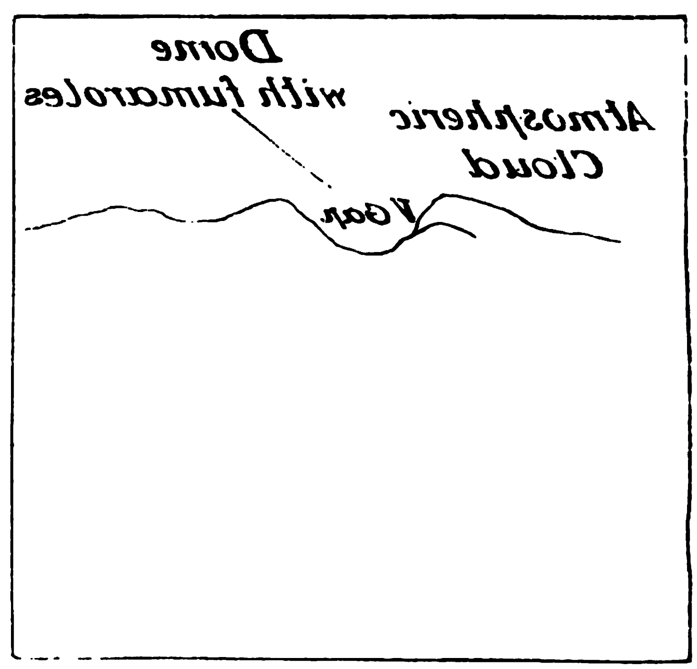


Fig. 1. *Tuff-agglomerate, scored by avalanches. General view.*

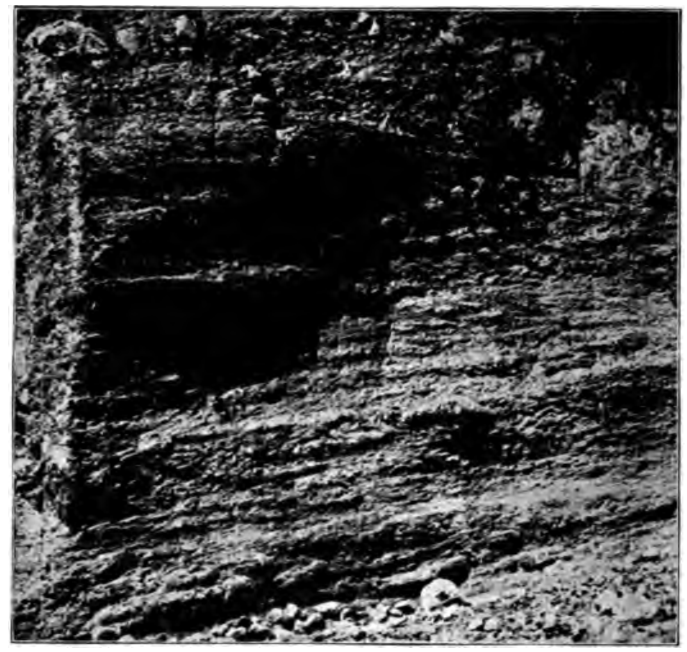


Fig. 2. *Details beyond left corner of Fig.* 1.

Fig. 3. *Valley of Rivière Blanche, from near shore.*

Fig. 4. *The new Delta at Basse Pointe.*

VIII. *Petrographical Notes on the Products of the Eruptions of May,* 1902, *at the Soufrière in St. Vincent.*

By JOHN S. FLETT, *M.A., D.Sc.*

Communicated by H. B. WOODWARD, *F.R.S.*

Received January 20,—Read January 23, 1908.

[PLATES 26–27.]

CONTENTS.

THE rocks collected during our visit to the West Indies, in 1902, included specimens of the ashes, ejected blocks, &c., cast out by the eruptions of May, and of such lavas, belonging to previous eruptions of the Soufrière and the extinct volcanoes of the south part of the island, as were in good preservation and easily accessible from our line of route. We are also indebted to Mr. MACDONALD, Mr. DARRELL, and other inhabitants of St. Vincent, and to Sir DANIEL MORRIS and the officers of the Imperial Agricultural Department for the West Indies acting under him (more particularly to Mr. HENRY POWELL, Curator of the Botanic Station, St. Vincent), for specimens sent us after our departure for England. Professor LACROIX has very kindly furnished us with specimens of the older rocks of St. Vincent, which he collected during his visit, and of an ejected block containing cordierite, which he found on the edge of the crater in January, 1903.

The Ejecta of the Eruptions of May, 1902.

Among the materials ejected during May, 1902, there were not only ashes and sand, with volcanic bombs which were derived from the active magma within the crater, but also large quantities of the older rocks of the mountain which had been torn from the walls of the crater and were mingled with the new ashes. The difficulties of collecting from the deposits of hot sand laid down by the avalanche were considerable, as the principal stream sections of the new materials were too hot and too unstable to be approached. Fragments lying on the surface of the avalanche evidently belonged to the most recent stages of the volcanic activity. The deeper parts of the new deposit were usually inaccessible, but where the secondary steam explosions had built small cones on the rivulets it was easy to collect blocks that had been projected from the interior of the beds of hot ash. These form the major part of the ejected blocks of 1902 contained in our collections.

The ashes and sand gathered in Barbados, Kingstown, Chateaubelair, and other localities during May, 1902, and at subsequent times can, of course, be assigned at once to their respective eruptions, and, with the large semi-vitreous bombs scattered over the surface of cultivated grounds on both the windward and leeward sides of the island, may be taken as satisfactory evidence of the nature of the new magma within the crater. It seems clear, however, that some of the previous eruptions produced bombs not essentially differing from those of 1902, and these can only be distinguished by the traces of decomposition they sometimes show, or by the positions in which they are found.

Volcanic Sand and Dust.

As stated in the first part of this report, fine sand and dust formed the greater part of the hot avalanche, and were the only materials transported to a considerable distance. The Barbados dust has been described by several writers,* and is now well known to most of those who are interested in volcanoes. We have also examined specimens from Kingstown, Calliaqua, and other localities in the south part of St. Vincent, and from Wallibu, Georgetown, and the southern flanks of the Soufrière. These have a great similarity in general character, though they may not be of

* Flett, John S., "Note on a Preliminary Examination of the Dust that fell in Barbados after the Eruption in St. Vincent" 'Quart. Jour. Geol. Soc.,' vol. 58, p. 368 (1902). Falconer, John D., "Volcanic Dust from the West Indies," 'Nature,' vol. 66, p. 132 (1902). Porter, T. C., "Volcanic Dust from the West Indies," 'Nature,' vol. 66, p. 131 (1902). Klein, C., "Ueber die am 7. Mai 1902 vom Vulkan Soufrière auf St. Vincent ausgeworfene vulkanische Asche," 'Sitzb. Berlin. Akad.,' 1902, p. 992. Diller, J. S., "Volcanic Rocks of Martinique and St. Vincent," 'National Geographic Magazine,' vol. XIII., p. 285 (1902). Smith, Longfield, "Volcanic Eruptions in the West Indies," 'West Indian Bulletin,' vol. III., p. 271 (1902).

absolutely identical origin. Those that were carried to some distance were emitted from the crater during the height of the paroxysm of the afternoon of May 7th. Those gathered near the Soufrière may have been mixed with materials emitted at a subsequent time, either during the first or second eruption (May 7th and 18th, 1902). Sand from the Soufrière contains, as might be expected, a larger number of fine lapilli; the Barbados dust consists mainly of single crystals, or fragments of crystals, with small grains of more or less vitreous character. But the same ingredients occur in all the dusts in very much the same proportions. There are slight differences in the relative abundance of the component minerals which can be traced very clearly in the chemical analyses of samples from different localities (see p. 311), but these differences are not great.

Sir Daniel Morris has sent us samples of the Barbados dust-fall of May 7th and 8th, 1902, collected at different hours. These show that the material which fell during the later hours was finer grained and rather more pale coloured than that which fell earlier. It is to be expected that as the dust cloud was at a great height the coarser and heavier minerals would first subside. Fragments of broken felspar crystals and of glass are distinctly more common in the later part of the dust-fall and account for its paler colour.

The most striking feature of these dusts is the large proportion of crystalline minerals they contain, and this led us to bring forward the hypothesis that the magma, "or at least the upper part of it which gave rise to the great black cloud, was to a large extent crystallised, contained comparatively little fluid matter, and was accordingly near the temperature of consolidation, or may even in part have solidified already" (Report, Part I., p. 523). This hypothesis received the most unexpected confirmation at a slightly later period when it was announced that the magma in Pelée was being extruded as a solid vertical column or obelisk which attained at one time a height of 900 feet.

Of the minerals of these dusts the most abundant is plagioclase felspar. Its crystals are often broken, but the smaller may be perfect, especially when they have an adherent pellicle of glass. Optical and specific gravity tests, especially the extinctions of cleavage flakes, show that they range from labradorite to basic bytownite (An 50 per cent. to An 84 per cent.). They are full of glass enclosures, often of regular shape, with fixed bubbles. Zonal structure is very common in them; in fact, they present similar characters to those of the phenocrysts in the bombs, to be described later. The commonest faces are 001, 010, 110, $1\bar{1}0$, $10\bar{1}$, $20\bar{1}$. The augite is pale brownish-green, very slightly pleochroic in thick grains. Good crystals are rare and show 100, 010, 110, 111. The extinction angle $Z:c$ is about 45 degrees. Hypersthene is always present in considerable amount and often its crystals are very perfect. Their faces are 100, 010, 110, and probably 111. Frequently the crystals are broken across, along planes of fracture perpendicular to the prism axis; they then show squarish octagonal outlines with the pinacoids larger than the prism faces.

The pleochroism is strong and is of the usual character. The optic axial angle (negative) is large (2E over 120 degrees, 2V over 60 degrees). Glass enclosures and grains of magnetite are common in the pyroxenes. Olivine occurs in small grains; perfect crystals are not found, but only splinters which often show a conchoidal fracture. It is colourless or pale brown (perhaps from oxidation in presence of hydrochloric acid gas and air), and its presence is easily confirmed by treating the powder with strong cold acid when it is covered with a film of gelatinous silica, even before the basic felspars are attacked. Hornblende, as reported by FALCONER and KLEIN,* is found occasionally. So far as we have seen it is always brownish-green and occurs only in irregular fragments. Most of the iron oxide is titaniferous magnetite in small rounded grains; pyrites, apatite, and possibly zircon are also present.

Non-crystalline or glassy material occurs in all the dusts, though less abundant than the crystals. It is partly in minute fragments, partly in thin films surrounding the crystals, and partly in the form of small, rounded vesicular lapilli. The steam cavities which abound in it are empty. Between crossed nicols some of these lapilli contain small crystals evidently belonging to the second generation, showing that crystallisation was preceding in this portion of the rock as it ascended in the crater. Much of the glass, however, is perfectly vitreous, and this portion was probably liquid at the moment of projection. Occasionally the glass has been drawn out into threads while still in a viscous state. The lapilli, however, are not highly pumiceous and the splinters do not have those arc-shaped, concave outlines which are found in shattered pumiceous glasses (*e.g.*, those emitted by Krakatoa in 1883).†

In the first part of this report we have stated our belief that the magma of the Soufrière, though in large part crystallised, was not entirely solid at the moment when it was shattered into dust and the great black cloud emerged from the crater. Professor LACROIX ‡ has found that the later *nuées ardentes* or Peléean clouds of Montagne Pelée were produced by the disruption of a solidified magma. But the facts of the eruption of May 7th in St. Vincent, as given by us in the first part of this report, are sufficient to prove that the magma was a semiliquid mass as it ascended in the crater. The crater lake was at its usual level at 11 a.m. on Tuesday (May 7th); at midday on Wednesday the lake was discharged by overflowing the southern lip of the crater. Thus in 24 hours it had risen about 1000 feet, or 40 feet per hour. Yet, according to the evidence of all who knew it before and have seen it since, the interior of the crater was not greatly modified and many of its old features were recognisable after the eruption. Only a plastic, semiliquid mass could have risen so rapidly and could have been ejected with so little disturbance and so little permanent alteration of the topography of the interior of the crater. The great rock column

* *Loc. cit.*

† SYMONS, G. J., 'The Eruption of Krakatoa and subsequent Phenomena,' Plate 4 (1888).

‡ 'Montagne Pelée,' pp. 206, 208, 383.

which rose from the crater of Pelée in the latter part of 1902 proves that the magma, once solid, is not highly explosive.

The Bombs.

The slaggy black bombs, which were abundant especially on the surface of the new ash deposits in the valleys of the Wallibu and the Rabaka Dry River, all consist of hyalopilitic hypersthene andesite usually containing accessory olivine and sometimes hornblende. They are highly vesicular throughout (Plate 26, fig. 4). A description of their general appearance has been given in the first part of this report. The felspars are the most conspicuous minerals in the hand specimens, some of the larger phenocrysts being more than a third of an inch in length. The pyroxene and olivine formed smaller crystals easily visible without the aid of a lens. The olivine is yellow-green in colour; the matrix is dark grey to black.

The abundant porphyritic felspars are always much zoned, the centres consisting of irregular highly corroded remnants of very basic plagioclase. Around these are successive deposits of felspar varying in composition, more basic and more acid bands often alternating repeatedly. The margins are more acid and more uniform in composition, and are often bounded by good crystalline faces similar to those found in the felspars of the dusts. Albite and Carlsbad twinning are almost universally present, and pericline twinning very frequently. Baveno twins occur, but are rare. Glass cavities with bubbles abound in the felspars, and often have a zonal distribution.

Owing to their perfect freshness these felspars are easily determined by modern optical methods; their specific gravities are not to be relied on because of the complex zoning and the glass enclosures, but fragments from the interior of a large phenocryst sank in a liquid at 2·745 (temperature, 2° C.), indicating 85 per cent. of anorthite in the felspar. The method of determination adopted wherever possible was the measurement of conjugate angles of extinction in Carlsbad-albite twins cut perpendicular to the zone of symmetry of albite twinning. The stereograms of ROSENBUSCH* were used, which differ somewhat in the basic end of the plagioclase series from those of MICHEL LÉVY. Consequently the proportions of anorthite in the felspar are slightly lower than those given by Professor LACROIX, who employed MICHEL LÉVY'S diagrams, but the results accord closely if we allow for this. The values given by Professor BECKE in his recent papers on the optical orientation of the plagioclases were also used wherever possible. Determinations by the position of equal illumination in zoned sections, perpendicular to the plane of symmetry of albite twins, proved useful as confirmatory evidence, though not so valuable as conjugate extinctions. Sections perpendicular to the bisectrices were not frequently made use of, as often

* ROSENBUSCH, H., "Mikroskopische Physiographie," Band I., Heft 2 (1905). MICHEL LÉVY, A., "Étude sur la Détermination des Feldspaths" (1894, 1896, 1904). BECKE, F., "Die optischen Eigenschaften der Plagioklase," 'Tschermak's Min.-Pet. Mittheil.,' vol. xxv., p. 1 (1906).

much time is required to find satisfactory ones. The optical sign in convergent light is easily observed and often valuable. The microlites of the groundmass were determined by their refractive index as measured against oils and Canada balsam, their maximum extinctions in sections from the zone 001,010 (longitudinal sections), and their extinctions in sections perpendicular to this zone.

The most basic cores of the porphyritic felspars contain about 85 per cent. of anorthite; a great part of the crystal yields extinctions almost identical with those given by ROSENBUSCH for bytownite (with 75 per cent. of anorthite). The outer margin is more acid than this, having usually about 50 per cent. anorthite, while the external borders may have as low as 40 per cent. A single crystal may thus have zones which vary from the composition of bytownite-anorthite to that of andesine. The groundmass felspars are usually long and narrow, often branched or hollow at their ends, and with few glass enclosures. They belong to andesine, having usually 40 to 35 per cent. of anorthite.

The augite is pale green or greenish brown, and is free from zonal and hour-glass structures. Many of the crystals are idiomorphic, but others have irregular outlines, as if corroded. Repeated twinning on the orthopinacoid may occur. Transverse sections often show good outlines with the pinacoid faces as large or larger than the prisms. The extinction angle $Z : c$ is 45 or 46 degrees, and the axial angle 2E is 110 degrees. The hypersthene is usually idiomorphic, its prisms being four or five times as long as broad. It has eight-sided cross-sections, with the prism faces small, while the pinacoids are large. It is optically negative with axial angle 2V over 60 degrees and the usual pleochroism of this mineral in andesitic rocks:—$Z = c$ green, $Y = b$ reddish brown, $X = a$ paler reddish brown. Parallel growths of augite and hypersthene occur, the augite being external. Both these minerals frequently contain enclosures of glass and magnetite.

Olivine is not always present, but it occurs in more than one-half of the microscopic sections of these bombs. It is never very abundant, and may be regarded as an accessory mineral. In most cases its grains are rounded, though occasionally they present crystalline outlines. Evidently the mineral has suffered corrosion in the period which preceded the eruption, and this accounts for its rounded shapes and the frequency with which it is surrounded by borders of granular hypersthene. The formation of hypersthene in andesites of this sort by corrosion of olivine has been described by many writers, *e.g.*, in the rocks of Martinique. Many of the crystals, however, have no such border, probably because the movements of the still liquid matrix, during the rise of the magma, swept away the hypersthene grains from around the olivine. The two minerals are never in regular parallel growth, and the hypersthene grains have no constant orientation with reference to one another. Agglomerations of hypersthene also occur which probably occupy the place of a former olivine crystal (Plate 26, figs. 1 and 2). It may be mentioned that another feature of these rocks, which is very constant, is the presence of glomero-porphyritic groups of augite, hypersthene, plagioclase and magnetite, very often consisting of granular or imperfect crystals closely packed together.

Dark greenish-brown hornblende is not often seen in sections of these bombs. It is always irregular in shape and corroded; the other ingredients are iron oxides (titaniferous magnetite), pyrites and apatite.

The groundmass is of the hyalopilitic type, consisting of felspar and augite microlites, with magnetite embedded in a dark brown glass. The felspars are mainly andesine, as stated above. The pyroxene is often in long narrow prisms. Hypersthene has been recorded in the groundmass of many of the Martinique rocks, but in St. Vincent, where the microlites are large enough to react clearly on polarised light, they have mostly an oblique extinction, and cross-sections may show twinning on a pinacoidal face; hence they belong to augite. The iron oxides form small octahedra. The glassy base varies somewhat in abundance, and is occasionally nearly free from crystals of the second generation. These rocks are always vesicular, and their steam cavities are empty.

A number of excellent analyses of the dust and bombs of the eruption of the Soufrière in May, 1902, have appeared. Of these we select the following as the most complete. The great similarity is at once apparent. The first analysis probably represents most closely the composition of the magma in the later stages of the eruption. The second analysis contains an abnormally high percentage of water, which leads us to suspect that the specimen was not a recent bomb, but an old and somewhat weathered one. No other analysis of the recent products of the Soufrière or Pelée shows so much combined water, except one which Professor LACROIX* suspects for precisely the same reason. Analysis IV. of the dust that fell at Chelston, Barbados, has been criticised by Dr. HILLEBRAND,† who doubts whether nickel and cobalt are present in these rocks. Repeated tests, however, both in the laboratory of the Geological Survey of Great Britain and by other analysts to whom samples were sent, confirm the substantial accuracy of the analysis in this respect, though the amount of cobalt and nickel may be very slightly over-estimated. The curious feature of this analysis is that it proves the Barbados dust to contain less silica and alkalies and more magnesia, lime and iron oxide than the average magma of the eruption. In other words, the glass and acid felspars were not deposited in Barbados in normal amount, but were swept past it by the anti-trade wind. Analyses V. and VI. of ash collected 150 miles further away show, as might be expected, exactly the converse. This brings out clearly the sifting action of air currents on clouds of volcanic dust.

Professor LACROIX‡ has computed that PISANI'S analysis shows that the rock, it completely crystallised, would have yielded:—

* 'La Montagne Pelée,' p. 527.

† 'National Geog. Mag.,' XIII., p. 299, 1902.

‡ 'La Montagne Pelée,' p. 599.

Quartz		9·00
Felspars:—Orthoclase		5·00
	Albite	30·39
	Anorthite	32·15
Pyroxenes		17·98
Magnetite		4·41
Ilmenite		1·52
Apatite		0·34
H_2O		0·34

	I.	II.	III.	IV.	V.	VI.
SiO_2	56·71	55·08	55·64	52·81	57·62	57·75
TiO_2	0·77	0·80	0·98	0·95	0·87	0·70
Al_2O_3	18·80	18·00	18·21	18·79	19·76	17·70
Fe_2O_3	3·12	2·46	3·63	3·28	3·43	2·84
FeO	5·35	4·57	4·83	4·58	3·90	2·73
MnO	—	0·21	0·19	0·28	0·08	—
CoNiO	—	—	—	0·07	—	—
MgO	3·62	3·34	3·48	5·19	1·82	3·51
CaO	8·06	7·74	8·10	9·58	6·25	8·11
BaO	—	—	0·03	—	—	—
Na_2O	3·65	3·45	3·55	3·23	3·79	5·03
K_2O	0·77	0·65	0·58	0·60	0·71	0·94
H_2O	0·11	2·05	0·74	0·37	0·90	1·00
H_2O	—	—	—	—	—	—
P_2O_5	0·08	0·17	0·11	0·15	0·17	tr.
S	—	—	0·04	—	0·11	—
SO_3	—	0·24	—	0·33	—	—
Fe_7S_8	—	0·91	—	—	—	—
Cl	—	—	—	0·14	—	—
	100·95	99·67	100·15	100·35	100·08	100·31

I. Vitreous bomb from the Soufrière (anal. PISANI, cited from LACROIX, 'Montagne Pelée,' p. 598).

II. Lapilli collected at Langley Park, St. Vincent (anal. SCHMELCK, 'Chem. Zeit.,' XXVII., 1903, p. 34).

III. Pumice from St. Vincent collected by Lieutenant PENNY (anal. STEIGER, 'National Geog. Mag.,' XIII., p. 291, 1902).

IV. Dust that fell in Barbados May 8th, 1902 (anal. POLLARD, 'Quart. Jour. Geol. Soc.,' LVIII., p. 368, 1902).

V. Dust that fell on the ship "Coya," 250 miles W.S.W. of St. Vincent (anal. STEIGER, 'National Geog. Mag.,' XIII., p. 291, 1902). (Contains also 0·29 SO_3, 0·20 CaO, 0·08 Na_2O, soluble.)

VI. Lapilli collected at Langley Park, St. Vincent (anal. SCHMELCK, 'Chem. Zeit.,' XXVII., 1903, p. 34).

Old Bombs.

Among the materials washed down by the rivers on both sides of the island were many lapilli and small vesicular bombs, which closely resembled those of the recent eruption, but had a weathered appearance. On section these proved to be hyalopilitic hypersthene andesites very similar to those above described. Probably they were washed out of the ash beds deposited by the eruptions of 1812 and 1718, or even at an earlier date.

Blocks of Older Andesites.

These were easily distinguished from the new bombs by their angular outlines (due to fracture), their less vesicular character, and the traces of weathering or fumarole action they often exhibit. Many of them were 2 feet in diameter, while some were 5 feet long and 4 feet thick. Of these rocks the greater part were hyalopilitic hypersthene andesites with accessory olivine, and differ little from the new bombs of 1902, except in their more solid texture and the general absence of steam cavities. Their groundmass is more crystalline, as a rule, than that of the bombs, owing to their having cooled more slowly, but there is considerable variation in this respect, as some contain much brown glass, while others show very little of it. Many of them are very fresh, and must have been derived from the solidified magma of previous eruptions which occupied the passages leading to the base of the crater, or formed its floor. When the vitreous base is abundant, these rocks have a dark lustrous appearance; when the groundmass is more crystalline they are more grey in colour. All carry phenocrysts of plagioclase, augite, and hypersthene; olivine appears in most of them, and is often surrounded by hypersthene; hornblende is rare. The olivine may contain small dark brown octahedra of chromite or picotite. The hypersthene, when the groundmass is well crystallised, may have narrow borders of augite due to corrosion during the last stages of solidification.

A few of these rocks contain as much olivine as hypersthene, and may be classified as hypersthene basalts (Plate 27, fig. 5). The great resemblance which these old andesites and old bombs present to the new products of the magma of 1902 proves that there has been little change in the nature of the materials emitted by the Soufrière for a very considerable period.

An interesting structural variation presented by some of these andesites is flow-brecciation. In a few of them, although the rocks appear perfectly massive in the hand specimens, the porphyritic crystals are broken to fragments (Plate 26, fig. 8). This is especially noticeable in the zoned felspars, as the banding does not then continue round the whole crystal, but stops abruptly at the broken edges. These rocks have a rather crystalline matrix, never a glassy one, and are not vesicular. They show no flow banding, but in the groundmass there are patches of different structure which look almost like enclosed fragments. It is clear that the brecciation took place before the rock was entirely solid, as later deposits have gathered on the broken faces of some of the larger felspars, forming thin continuous marginal zones. At the same time there can be no doubt that the matrix was already partly solid, as the brecciation affects it also. On Montagne Pelée* brecciated rocks are common, and

* 'La Montagne Pelée,' pp. 513, 514 (1904).

have arisen in several different ways. On the Soufrière they are rare, and as they occur only in scattered blocks among the ashes, there is nothing to indicate in what manner they have originated.

The alterations which the ejected blocks of former lavas have experienced are due to weathering, to fumarole action and propylitisation, and to contact action.

The weathered blocks show changes of a familiar type. Their olivine is replaced by serpentine and carbonates; their hypersthene by bastite; the felspars become cloudy with kaolin and carbonates. In the groundmass the glass is devitrified and stained with limonite and chlorite.

In some cases the groundmass has been replaced extensively by silica. This may be brownish chalcedony showing spherulitic structure, almost the same in appearance as a spherulitic glass, but harder than steel when tested with a knife. The fibres of the spherulites have positive elongation. More common is quartz in small irregular patches replacing the glassy base and enclosing microlites of felspar. This gives these rocks a secondary micropoikilitic structure.

In small cavities in many of these ejected blocks, scales of tridymite are found, and Professor LACROIX has observed cristobalite also in some of them.* It has been pointed out by WEINSCHENK† that tridymite is a fumarole deposit, and indicates that the rocks have been subjected for some time, in the solid condition, to the action of steam at a high temperature. In St. Vincent, as in Martinique, it does not occur in the new bombs of the first eruptions of 1902. Professor LACROIX‡ has made some very interesting observations on its development in the ejecta of Pelée. It began to appear in the vesicular andesites during the winter 1902–03, that is to say, six or eight months after the eruptions had begun. In the materials cast out in 1904, after the dome had stood for some time, tridymite was abundant. It appeared in the enclosed blocks before it was found in the new lava itself.

Rocks of propylite type are also found among the ejected blocks. They are grey or greenish grey masses in which the felspars are often decomposed along certain zones or at their centres, but elsewhere fresh. In these rocks pyrite is common and indicates the operation of sulphurous gases from fumaroles. Chlorite and epidote replace the augite, the hypersthene often yields a pale coloured fibrous mineral with strong double refraction, perhaps iddingsite or a secondary mica. Quartz occurs in some of these rocks; carbonates are scarce. The igneous structures may be perfectly retained, even when the original minerals have entirely disappeared; the whole mass between crossed nicols is nearly isotropic, and apparently consists mainly of kaolin and limonite, but the outlines of all the porphyritic crystals are clearly visible in ordinary light.

The ultimate stages of fumarole decomposition are not well illustrated in

* 'La Montagne Pelée,' p. 593, 1904.

† 'Die gesteinsbildenden Mineralien,' Edit. I., p. 76, 1901.

‡ *Ibid.*, p. 519.

St. Vincent, as since 1812 the Soufrière crater was occupied by a lake of water and the escape of steam did not take place on a large scale. In Dominica and St. Lucia there are many "Soufrières" discharging sulphurous gases. The crater of Pelée contained a "Soufrière" of this kind, and Professor LACROIX has given a full account of the products of fumarole action in Martinique.

It is rather a remarkable fact that of all the specimens which we collected of older andesitic rocks ejected during the 1902 eruptions only one shows contact alteration. The fresher specimens could not be expected to suffer much change by being again raised to the temperature at which they consolidated. With the weathered rocks it is different, for their secondary minerals would certainly be modified had they been enveloped in the new incandescent lava. Hence we may infer that the ejected blocks above described were mainly the materials which plugged the orifice of the volcano and were cleared out by the rise of the magma.

The specimen which does show contact alteration is a fine grained, dark coloured and banded rock. It consists essentially of dark brown biotite in small scales, rounded or nearly idiomorphic when enclosed in the felspars; hypersthene in minute pleochroic grains; a little augite of similar habit, iron oxides and granular, usually untwinned felspar. The latter is andesine and labradorite; the whole rock has typical hornfels or "pflaster" structure and is indistinctly spotted. Its composition shows that it is igneous, and there can be little doubt that it was originally a fine banded andesitic tuff. In one part the specimen shows larger phenocrysts of bytownite-labradorite felspar, with aggregates of hypersthene and augite (chondritic groups) replacing porphyritic pyroxene. These lie in a fine matrix rich in biotite like that above described. This portion of the specimen seems to be a fragment of andesite in the tuff. The rock is crossed by little veins filled with recrystallised hypersthene. It presents many points of resemblance to the contact-altered andesites of the Cheviots and of Lorne.

Quartz Andesites.

In the ash beds of the 1902 eruptions there are a limited number of andesitic rocks which present some remarkable characters which seem to indicate that they have undergone alteration of an unusual type. These rocks are milky white or pale grey, often with dark patches which represent the ferro-magnesian minerals. Many of them are brecciform; in fact, they look like whitened or bleached tuffs. It is difficult to prepare microscopic sections of them, as they fall to pieces when being mounted.

Under the microscope they prove to be full of quartz which occurs only in the matrix and not as phenocrysts (Plate 26, fig. 5). The original basic felspars of the andesites remain, though small grains of quartz may form along their margins. These felspars often show intense zoning and have much the same characters as those of the andesites and hypersthene basalts. The primary olivine, augite, hypersthene, and hornblende have more or less completely vanished. In their place we have aggregates of dark brown biotite, pale green augite, and hypersthene in small grains which may have parallel orientation, so that they build up skeleton crystals the interstices of which are filled with quartz and felspar. These aggregates do not form good pseudomorphs, and the minerals they represent cannot be identified by their outlines. They are strikingly different, however, from the idiomorphic plagioclase crystals. The process of alteration can be seen in certain large crystals of brown hornblende which are rather common in these slides. The amphibole is reduced to a series of irregular patches (Plate 26, fig. 3), which can be recognised as having belonged to one crystal from their parallel orientation and simultaneous extinctions. The interspaces are filled up by granules of hypersthene and scales of dark brown biotite. These are the only rocks from St. Vincent with the exception of the norites and andesite-hornfelses in which biotite has been observed. In these secondary aggregates pale green augite occurs also, so similar to the hypersthene in colour and mode of growth that it can hardly be distinguished except by its optically positive character and its lack of pleochroism. The hypersthene has a large apparent axial angle, though it is pale green, and is always optically negative. Very little iron oxide occurs in these aggregates.

The groundmass consists of quartz, felspars, hypersthene, tridymite and an isotropic material. The quartz may be in irregular grains; very often, however, it is in perfectly formed double pyramids which, when the matrix is dissolved away, are beautifully sharp. It contains few enclosures, mostly tridymite. The felspars are of many kinds; some are highly zonal and consist mainly of labradorite at their centres with margins of andesine; there are also irregular plates of untwinned alkali felspar which are covered with scales of tridymite. Hypersthene appears in the groundmass as grains and as perfect minute prisms of the usual shape. Iron oxides are practically absent. An isotropic material surrounds and separates all the crystalline minerals of the groundmass in very thin colourless or yellow films. It is dissolved by boiling with caustic potash for some time, and this suggests that it may be a form of colloid silica, but its refractive index is 1·484, but varies slightly, and no kind of opal is known which has so strong refringence. It has also very nearly the same index of refraction as the more acid varieties of andesitic glass which were examined by Professor LACROIX* in Martinique.

It is clear that these rocks have undergone alteration. Their pale colour shows that they contain but little iron; the great abundance of quartz in many of them leads us to suspect that there has been an introduction of silica. The transformation of the hornblende might be ascribed to fusion, or to contact alteration. That the changes have taken place at a high temperature is clear from the occurrence of veins of pyroxene traversing the groundmass, and filling cracks in porphyritic felspar. This shows that after the rock had consolidated there was a formation of augite. They

* *Op. cit.* p. 511.

have at the same time very little in common with the rocks which have been weathered under atmospheric conditions, or with the propylites. It seems probable that steam, acting at high temperatures and pressures, was the modifying agency. Perhaps these rocks lined fissures beneath the crater through which gases ascended after the eruptions of 1812 and 1718.

In St. Vincent quartz-bearing andesites are rare; in Martinique, where the magma was more acid and the volcanic activity more continuous, they are common. Professor LACROIX has some very interesting notes on these rocks. They did not appear at the first eruptions; but in 1904 the materials produced by the rupture of the dome were full of quartz. He concludes that it arose in those rocks which were situated beneath the surface of the dome, and were affected for a long period by steam emitted from the magma.*

Cordierite Andesites.

Six months after we left St. Vincent Professor LACROIX found two specimens of cordierite-bearing rocks on the Soufrière, one an andesite, the other a variety of quartzite. In our collection there are no cordierite-bearing rocks; probably they were not emitted by the first eruptions; if they were, they must have been very scarce. At Martinique, quartz andesites and cordierite andesites were not obtained till the volcano had been in activity for some months. Some of these rocks seem to bear a close relationship to the quartz andesites above described, but for particulars regarding them we may refer to Professor LACROIX's monograph on Montagne Pelée (p. 597).

Anorthite-Olivine Blocks.

Many crystalline masses, consisting mainly of anorthite and olivine, with augite, hypersthene, and hornblende, occurred among the new ash deposits. They were mostly in a perfectly fresh condition; some, however, must belong to previous eruptions, as their minerals show decomposition. In St. Vincent, several people showed us similar blocks which had been picked up on the Soufrière before 1902; we also saw these blocks in the older tuffs and lavas of the mountain. They occur also in Martinique, St. Kitts, and other islands of the Antilles.

They present a great diversity of appearance in the hand specimens. All are rich in felspar, which is usually milky white rather than glassy and transparent. Olivine in rounded, greenish yellow, or brownish grains, is the next mineral in abundance, and then augite in black crystals which are pale green in thin sections. Dark elongated prisms of hornblende are common in some of these rocks. Of the ferro-magnesian minerals hypersthene is the least frequent.

They have usually the appearance of granular crystalline rocks, the grains ranging in size from half-an-inch downwards. Some contain larger crystals, which give them

* *Op. cit.*, p. 521.

a porphyritic appearance; others have finer grained bands, which may possibly be veins. We obtained also some blocks rich in long bladed crystals of hornblende (over an inch in length). These are arranged parallel to one another, giving the rock a coarsely gneissose character; or it might be compared to a comby vein with prismatic crystals perpendicular to the boundary walls. There is little olivine in these specimens. Others have a drusy structure with small cavities lined by the terminations of idiomorphic crystals. None of the masses was of large size; specimens over a foot in diameter were scarce. On the other hand, many of the fragments which lay near one another on the ashes were very much alike, as if they were parts of a large block which had been shattered on striking the ground. The great variety in the appearance of these blocks indicates that if they come from a single rock mass situated beneath the volcano, that mass must be very heterogeneous. These blocks were all exceedingly friable, and fell to powder when struck with the hammer, so that thin chips could not be detached from them, a property which will be explained when their microscopic characters are described.

In thin sections none of the minerals have definite crystalline form. The olivine is rounded and often much cracked. The augite is pale green and not dichroic. Its extinction angle $Z : c$ is 45 degrees; the optic axial angle 112 degrees. Twinning on 100, simple or repeated, is common. The hypersthene has the usual pleochroism, not very intense: its axial angle 2V is over 60 degrees. The felspar, which is the most abundant constituent, very seldom is zoned. Pericline and albite twinning are both frequent; Carlsbad twins are few. Conjugate extinctions in sections of Carlsbad-albite twins indicate a high percentage of anorthite (85 to 90 per cent.). In convergent light the sections are negative. The specific gravity of the powdered felspar is on an average 2·75. The refractive index and double refraction are both very high. The hornblende is brownish green, fairly deep in colour, and is often in parallel growth with the augite, the two minerals having their prism axes and zones of symmetry parallel. Sometimes the amphibole surrounds the pyroxene; at other times they are intergrown. The pleochroism of the amphibole is X yellow, Y yellow green, Z darker brownish green. $Z : c$ about 13 degrees in sections showing vertical emergence of the optic normal. $Y = b$.

All the minerals contain small glass cavities with a fixed bubble; they may also show large enclosures of brown glass. Some of the cavities seem to be empty. Fluid enclosures with mobile bubbles, though they might be expected to occur, were not seen. None of the minerals, though the rocks have plutonic structure, have the dark platy enclosures which produce schiller. As a rule there is no definite zonal or crystallographic arrangement of the glass cavities.

In structure these rocks resemble gabbros and troctolites (Plate 27, figs. 1 and 2). The felspar has partly crystallised after the augite, and may be enclosed in it, but is never enveloped by olivine, which has probably been the earliest of the silicates.

The rocks consist generally of nearly equidimensional grains, fitting together in a perfect mosaic. If regarded as true plutonic rocks they may be classified as gabbros, troctolites, anorthosites, &c. (or seeing that their felspar is anorthite, as allivalites, harrisites, &c.). They have evidently formed under plutonic conditions. Hornblende and olivine are frequent in them, but these minerals are unstable at the levels to which the magma ascends before effusion, and are gradually dissolved. Professor LACROIX has described and figured* fused crystals of hornblende in nodules of this sort from St. Vincent, but we have not met with any in our specimens, where these minerals are always perfectly clear and sound. The felspars of these rocks resemble those of the early central portions of the phenocrysts of the lavas, though somewhat more rich in lime and containing more enclosures. The absence of outer zones of bytownite and labradorite shows that these felspars ceased growing at great depths. All the minerals, however, are like those met with, under certain conditions, in the lavas; hence there can be no doubt that these crystalline rocks are from the same magma, but they have formed at great depths and are more basic in character than the rocks erupted at the surface.

A very interesting structural feature of these rocks is that their minerals are not in perfect contact with one another, but are separated by the thinnest possible films of brown glass (Plate 27, fig. 1). The vitreous material even passes into the cracks and cleavages of the felspars. It seems to enter the original cavities and enlarge them by corroding the surrounding mineral. This glass contains usually only small dusty grains of black magnetite. Near the edges of the specimens the finest veins unite to form thicker ones, which sometimes contain microlites of andesine and labradorite; the glass is consequently similar to that of the hyalopilitic andesite matrix. This makes it probable that the glass veins are an injection of that portion of the magma which was liquid at the time of the eruption; it explains also the absence of zones surrounding the anorthite and intermediate in composition between it and the andesine of the glass. The very friable character of the nodules arises from the presence of these films of brittle glass separating the crystals.

The subjoined analyses show the composition of two crystalline blocks collected in St. Vincent by Professor LACROIX. The second indicates the great abundance of anorthite in some of them; compared with the first, it proves a considerable range in composition in these blocks, though both of them are highly basic. The other three analyses are of anorthite, hypersthene, and hornblende, in a similar block from St. Kitts. Dr. FELS's paper contains also particulars of the crystallographic and optical properties of these minerals. Analysis III. is interesting as proving that the felspar is not absolutely pure anorthite, but corresponds to Ab $12\frac{1}{2}$, An $87\frac{1}{2}$. The felspar of Professor LACROIX's rock must be rather more basic than this. The St. Kitts hypersthene contains 18 per cent. of iron oxides; a sample of hypersthene separated from the rocks of Martinique contained 27·7 per cent.† of iron oxides; if we

* *Op. cit.*, Plate 26, fig. 6, and p. 542.

† LACROIX, A., *op. cit.*, p. 506.

judge by the optic axial angle, which in this group of minerals varies with the percentage of iron present, the St. Vincent hypersthene is not quite so ferriferous as that of Martinique.

	I.	II.	III.	IV.	V.
SiO_2	47·15	45·0	44·17	50·54	43·26
TiO_2	0·90	0·3	—	—	0·29
Al_2O_3	22·30	32·5	35·06	3·94	13·15
Fe_2O_3	2·22	0·2	—	0·90	2·27
FeO	6·93	3·0	0·58	17·08	10·50
MgO	5·15	0·7	0·57	25·71	15·06
CaO	12·30	17·1	18·84	1·82	12·11
Na_2O	1·81	0·8	1·21	0·79	3·49
K_2O	0·35	0·2	0·43	0·55	0·57
P_2O_5	0·19	—	—	—	—
H_2O	1·00	—	0·59	—	0·21
	100·20	100·8	101·45	101·33	100·91

I. Dioritic enclosure (anorthite-hornblende rock) Chateaubelair (anal. PISANI, cited from LACROIX, 'La Montagne Pelée,' p. 598).

II. Troctolitic enclosure (anorthite-olivine rock), St. Vincent (anal. ARSANDAUX, *ibid.*, p. 598).

III. Anorthite from an anorthite-olivine block from St. Kitts (anal. FELS, 'Zeits. Kryst.,' XXXVII., p. 459, 1903).

IV. Hypersthene from an anorthite-olivine block from St. Kitts (*ibid.*).

V. Hornblende from an anorthite-olivine block from St. Kitts (*ibid.*).

Norites, Quartz-Norites (Andes-Norites).

These are less common than the anorthite-olivine blocks, but are of interest because they represent a type known also in Martinique and some of the other islands and of wide distribution among the volcanoes of the Andean or Pacific facies.* They consist of plagioclase, augite, and hypersthene, and are rather fine grained and holocrystalline, or contain a little glass. Larger phenocrysts of plagioclase may occur, but are scarce. Their felspars, in contrast to those of the anorthite-olivine blocks, are invariably much zoned and are often idiomorphic. They show Carlsbad, albite and pericline twinning in great perfection. The centres of different crystals proved to contain 80, 75, and 60 per cent. of anorthite; bytownite is evidently the prevailing type. These centres are corroded and surrounded by more acid zones succeeding one another in great numbers; more and less acid bands may alternate repeatedly. The margins are often andesine with 35 per cent. anorthite, but oligoclase (20 per cent.

* ROSENBUSCH, H., 'Mikroskopische Physiographie,' B. II., p. 292 (1907); HÖGBOM, A. G., "Zur Petrographie der Kleinen Antillen," 'Bull. Geol. Inst. Upsala,' vol. vi., p. 214 (1905).

anorthite) forms the outer borders of some crystals. Glass cavities are frequent (Plate 27, fig. 3). In all their features these felspars resemble the phenocrysts of the andesites.

Augite and hypersthene are about equally common, the former sometimes euhedral, but often anhedral; the latter always occurs in long prisms similar in shape to those of the lavas. The augite has a green colour and simple or repeated twinning on 100. The hypersthene is pleochroic in the usual tints; one section gave an optic axial angle $2E = 132$ degrees (which corresponds to $2V = 65$ degrees). Parallel growths between the pyroxenes occur as in the andesites; they also contain glass enclosures. A few scales of dark brown biotite are sometimes present. Olivine occurs in several of these norites, but is scarce and is always surrounded by corrosion borders of hypersthene (Plate 26, fig. 1). The other ingredients are magnetite and apatite.

In all these rocks there are traces of a matrix between the larger crystals, though this is not abundant. In some it is felspathic and consists of small imperfect crystals of andesine. In others it is a brown glass, very scanty in amount. This glass resembles that of the enclosures and does not seem to be a later injection, as in the anorthite-olivine nodules. Most of these rocks, however, contain a small amount of micropegmatite (Plate 26, fig. 7), which serves as a groundmass and forms aureoles around the felspars. The latter then have borders of oligoclase; the felspar of the micropegmatite is untwinned alkali felspar with lower refractive indices than those of the quartz.

These rocks approach closely in composition and in the peculiarities of their minerals to the effusive andesites and differ greatly from the anorthite-olivine nodules. The scarcity of olivine, the zonal structure of the felspars, and the presence of glassy base in some of them proves that they crystallised at intermediate depths and pressures. They represent the rocks which would have been produced had the andesitic magma solidified without forcing its way to the surface.

Sedimentary Rocks.

Calc-silicate Hornfelses.—The sedimentary rocks ejected by the eruptions of May, 1902, all occurred in small fragments among the ash and were much contact-altered. The commonest were fine grained, pale green or greyish-green calc-silicate rocks. In all probability they represent sedimentary beds which lie beneath the volcano. The hand specimens are often banded, apparently owing to original bedding; often they are crossed by irregular veins, and they may show spots due to local aggregation of wollastonite, augite, or other minerals. Similar blocks had been thrown out by previous eruptions, and as they are fine grained and tough were used by the Caribs in the manufacture of stone implements.

These rocks contain little carbonates and most have originally been impure siliceous and argillaceous limestones. Some consist mainly of wollastonite, with granular augite and sphene; in others lime-felspar is common, while a few contain small rounded grains of quartz. The absence of hornblende, garnet, vesuvianite, and epidote is rather striking.

The wollastonite, which is the most important mineral, forms plates, fibres, and irregular blades. Sometimes it shows traces of idiomorphism, being elongated parallel to the *b* axis. Very often its fibres are sub-radiate, or have a tendency to spherulitic or stellate groupings. The augite is dark green, sometimes brownish green, and forms only small grains which rarely exhibit crystalline faces. The felspar, also, is anhedral as a rule. It shows albite twinning, more rarely Carlsbad and pericline twinning, and belongs to the basic end of the plagioclase series, being near anorthite in composition. Quartz is rare and occurs only as rounded grains. Granular sphene is always present, but never well crystallised.

The green veins which traverse these rocks are mainly augite; the white patches consist of wollastonite and felspar, but the rocks show little uniformity in structure or in the shape and size of their component minerals.

Where anorthite is abundant it has a tendency to idiomorphism, and its crystals are frequently bounded in part by good crystalline faces (Plate 27, fig. 4). The matrix is then wollastonite, augite, and smaller grains of felspar. The large felspars enclose wollastonite, augite, and the other minerals of the rock. The porphyritic crystals give rise to a structure somewhat resembling those of igneous rocks. Professor LACROIX has noted the same phenomenon in the calc-silicate hornfelses of St. Vincent.

Quartzites, Baked Sandstones.—We obtained also a few fine-grained contact-altered rocks consisting mainly of quartz. They may have been sandstones or siliceous portions of the underlying sedimentary beds, or perhaps secondary deposits of quartz among the igneous rocks.

Albite Rock.—The most peculiar of these rocks is a small pale-coloured fragment which proved in microscopic section to consist of albite and pleochroic green augite (ægirine augite). In the calc-silicate hornfelses the pyroxene sometimes has a weak pleochroism; in the granular augite of this rock it is quite strong and ranges from yellow to dark green. The albite forms long prisms, not perfectly idiomorphic, but with irregular or indented edges. A little quartz occurs among the felspars. There are no phenocrysts. The origin of this rock is obscure; it is unique in our collections, and no similar ejecta have been found in Martinique. As its pyroxene resembles that of some of the calc-silicate hornfelses, we have placed it with them.

THE OLDER IGNEOUS ROCKS OF ST. VINCENT.

Our collections do not include a large number of specimens of the older igneous rocks of St. Vincent, but they have been supplemented by a series which Professor LACROIX sent us, and these enable us to show what are the main petrographical features of the island. Professor BERGEAT has grouped the rocks which were collected by Professor SAPPER* as felspar basalts, hypersthene-bearing basalts, basalts, olivine augite andesites, hypersthene andesite, hypersthene augite andesite, and hornblende pyroxene andesite. Professor LACROIX† has classified his specimens as andesites, andesilabradorites and labradorites with augite and hypersthene, and basalts. Recognising that they all belong to one series and are linked together by intermediate types, we shall describe them as hypersthene andesites (with accessory olivine and hornblende), hypersthene basalts (with both olivine and hypersthene) and olivine basalts; this terminology is more in accordance with the nomenclature current in Great Britain.

The *hypersthene andesites*, except that they are more or less decomposed, bear a strong resemblance to those ejected by the Soufrière during 1902. They are all porphyritic, the minerals of the first generation being plagioclase, augite, and hypersthene, while the groundmass consists of augite, plagioclase, and iron oxides. Magnetite and apatite are constantly present; hornblende occurs in a few specimens, as in the recent bombs of the Soufrière. Olivine is more common, and is often surrounded by a resorption border of hypersthene. Small nodules or glomero-porphyritic groups of hypersthene are common in these rocks, and represent the final stages of resorption of olivine (Plate 26, fig. 2). They often contain branching growths of magnetite at their centres, showing that part of the iron oxides was rejected in the transmutation from olivine to hypersthene. The hypersthene is usually idiomorphic, but when the matrix is comparatively well crystallised, a zone of augite surrounds it, and has probably formed by corrosion of the hypersthene during the last stages of crystallisation of the groundmass. The porphyritic felspars are much zoned, consisting of bytownite (80 per cent. anorthite) at their centres, while their margins are acid labradorite and andesine. The groundmass felspars are andesine (about 40 per cent. An), and occur as small elongated laths; the augite of the second generation is granular and usually anhedral. Most of these rocks contain little glassy base, and are far less rich in this substance than the recent bombs of the Soufrière, but had the latter cooled slowly as in a lava flow, they would have very much the same structure as many of the older andesites.

As indicated by the ejected blocks of the 1902 eruption, there is much hypersthene andesite in the Soufrière, though hypersthene basalts occur there also, and Professor BERGEAT‡ mentions two olivine basalts from the Black Ridge on the mountain. Hypersthene andesites are exposed at Morne Ronde, Larikai, and Baleine, and occur also at Cumberland, north of Chateaubelair.

The *hypersthene basalts* are richer in olivine than the hypersthene andesites, but contain less hypersthene (Plate 27, fig. 5). They may be defined as consisting of plagioclase, augite, olivine and hypersthene, with the last two minerals in nearly

* KARL SAPPER, 'In den Vulkangebieten Mittelamerikas und Westindiens,' p. 194 (1905).

† *Op. cit.*, p. 592.

‡ In KARL SAPPER, 'In den Vulkangebieten Mittelamerikas und Westindiens,' p. 194 (1905).

equal proportions. The olivine shows resorption with formation of hypersthene; the latter is often partly replaced by augite. The porphyritic structure of the andesites is repeated in this group. The large felspars are highly zonal, and have centres of bytownite (75 to 85 per cent. anorthite), while the margins are labradorite (about 50 per cent. anorthite). There is rarely much glass in the matrix of these rocks, and in this respect they show affinities to the basalts. Hypersthene basalts occur in small numbers among the ejected blocks of the Soufrière, and are found also at Chateaubelair, Cumberland, Buccament, and other portions of the island. According to Professor BERGEAT the Somma of the Soufrière contains rocks of this type.

The *olivine basalts* consist of plagioclase, augite, and olivine. Hypersthene is rare or absent and hornblende is not known to occur in them. Coarsely porphyritic and finely porphyritic types occur. Some carry large phenocrysts of felspar; others contain only porphyritic augite and olivine. Many of the latter group are very rich in olivine (Plate 27, fig. 6), which acquires a rusty brown colour as it weathers and ultimately passes into serpentine. The large felspar phenocrysts are much zoned, though not so markedly as those of the andesites. Their centres are similar to those of the felspars in the hypersthene basalts; the borders are labradorite and in the groundmass the small elongated microliths have labradorite centres with outer zones of andesine. Olivine may occur as small crystals of the second generation in the groundmass. The augite is less green and more brown in colour than in the andesites. Traces of a vitreous base are to be seen in some basalts near Cumberland, but this is not common. Tridymite may occur in cracks and cavities in the groundmass.

Basalts have been described from Chateaubelair Point by Professor LACROIX. He compares them with the rock of Ramiers Island in Martinique. Professor BERGEAT identified specimens from Buccament and the Soufrière. They occur also at Barroualee, Cumberland, Calliaqua, and Kingstown. Many of the largest lava flows appear to belong to this group.

Two analyses (cited from Professor LACROIX) are given below, one of a hypersthene basalt, the other of an olivine basalt from St. Vincent. They show very well the decrease in silica and the alkalies, accompanied by an increase in lime and still greater increase in magnesia, which are to be expected from the mineralogical constitution of these rocks. Compared with the analyses of recent bombs, already given, they prove that the hyalopilitic hypersthene andesites recently erupted are the most acid lavas known to occur in the island.

The petrography of St. Vincent, so far as is known, is less varied than that of Martinique, Grenada, and Dominica. Hornblende andesites, dacites, trachytes, and rhyolites apparently do not occur, and there is no evidence that plutonic rocks are anywhere exposed at the surface. The absence of the more acid types which are found in Martinique and Dominica is the most striking feature of the petrography.

	I.	II.
SiO_2	53·51	48·71
TiO_2	1·06	1·08
Al_2O_3	18·90	18·40
Fe_2O_3	3·37	3·70
FeO	5·70	5·33
MgO	4·38	10·30
CaO	9·15	10·11
Na_2O	3·13	2·34
K_2O	0·51	0·43
P_2O_5	tr.	0·06
H_2O	0·12	0·25
	99·79	100·71

I. Hypersthene basalt (*labradorite à hypersthène*) from the Somma of the Soufrière (anal. PISANI).*
II. Olivine basalt from Chateaubelair Point (anal. PISANI).*

All the rocks are basic types of andesite and basalts. Hypersthene and olivine are the characteristic minerals with highly zonal crystals of plagioclase.

During the recent eruptions in Martinique and St. Vincent, in spite of all variations the more basic character of the ejecta in the southern island has been maintained throughout. Perhaps for this reason the outbursts have been fewer and less spasmodic; other consequences are the comparative scarcity of pumice, the absence of bread-crust bombs which were partly solid when they struck the ground, and the non-appearance of quartz in the new St. Vincent andesites. After the emergence of the dome in the crater of Pelée, many of the ejected blocks had a quartzose groundmass.

The greater viscosity of the magma in Martinique led to the extrusion of the lava as a high pillar which rose from the crater. No counterpart of this is known on the Soufrière, where the floor of the crater is now almost exactly at the same level as before the 1902 eruptions. The more basic character of the rocks of the Soufrière probably accounts also for the greater abundance of anorthite-olivine blocks.

In spite of these differences there is a great similarity between the products of the eruptions in Martinique and St. Vincent. Representatives of every type of rock described here† have been obtained by the French geologists from the active or extinct volcanoes of Martinique.

The material of the eruption of 1902 is the most acid which has been found in St. Vincent, where also hypersthene andesites are most common in the Soufrière at the north end of the island. For a prolonged period this volcano has erupted only andesitic materials. In its earlier stages, when flows of lava were more common,

* LACROIX, A., 'La Montagne Pelée,' p. 598.

† With the exception of the albite rock described on p. 322

hypersthene basalts were emitted. The latest eruptions have been entirely of the spasmodic type, the effusive having given place to the explosive phase. This may not be without significance, especially seeing that most of the great explosive outbursts of recent years, Krakatoa, Bandaisan, Tarawera, Santa Maria, &c., have been produced by andesitic magmas. This may be explained by supposing that a magma of this nature retains its steam in solution till it is on the point of solidification, and then releases it suddenly with great violence.

The Dusts that fell in Barbados in 1812, October 1902, and March, 1903.

By the kindness of Sir Daniel Morris and of the Rev. N. B. Watson, vicar of St. Martin's, Barbados, we have received specimens of all the dust-falls of volcanic ash from St. Vincent, which are known to have taken place at Barbados. Their dates are May 1, 1812, May 7, 1902, October 16, 1902, and March 22, 1903. All consist of the same minerals and have very much the same appearance. They differ slightly in colour and in coarseness. The dust of 1812 is distinctly paler brown than that of May 7, 1902, and that of March 22, 1903, is rather darker. The dust of October 16, 1902, is very fine and of a grey colour, resembling in this respect the finer dusts from Montagne Pelée in Martinique. It is the lightest coloured of all the Soufrière dusts which have fallen in Barbados.

Samples of these dusts were passed through sieves having 30, 60, and 90 meshes to the inch. This gives a rough test of the size of the component grains. The meshes of these sieves were measured under the microscope and proved to have the average diameters stated in the last column of the table.

Meshes to 1 inch.	1812.	May 7, 1902.	October 16, 1902.	March 22, 1903.	
	per cent.	per cent.	per cent.	per cent.	mm.
30 retains . . .	0·17	0	—	0·0	>0·73
60 ,, . . .	11·76	5	—	0·1	>0·31
90 ,, . . .	7·97	26	1·8	0·2	>0·19
90 passes . . .	80·10	69	98·2	99·7	—

These show that the 1812 dust contained most coarse particles. Many of these were small vesicular pieces of pumice, very light, and hence likely to be transported to a great distance. The dust of May, 1902, is coarser than any other Barbados dust of the recent eruptions, probably because it had been projected into the air with greater violence and to a greater height; hence, when the cloud passed eastwards over Barbados, it still retained a larger proportion of the coarser particles.

The minerals of these dusts are the same as those of the May eruptions of 1902. All contain plagioclase felspars, augite, hypersthene, and olivine. Hornblende was seen only in the dust of May, 1902. Glassy material, more or less devitrified by crystallisation, magnetite and apatite also are present in all the samples. There are, however, points by which these dusts can be distinguished from one another. The 1812 dust is by far the richest in brown glass,* often very free from microlites; it occurs largely as minute rounded spongy lapilli. The dust of October, 1902, which is very fine and pale coloured, is also rich in glass, which occurs as minute broken splinters. In this dust also broken felspars are very common, which circumstance

ANALYSES of Volcanic Dusts from St. Vincent, which fell in Barbados.

	I.	II.	III.
SiO_2	52·81	50·722	51·523
TiO_2	0·95	1·150	1·000
Al_2O_3	18·79	12·550	21·648
Fe_2O_3	3·28	9·484	6·372
FeO	4·58	4·676	
MnO	0·28	0·450	—
$(CoNi)O$	0·07	—	—
CaO	9·58	10·100	10·000
MgO	5·19	5·911	4·716
K_2O	0·60	0·531	0·675
Na_2O	3·23	3·451	3·551
P_2O_5	0·15	0·192	0·141
SO_3	0·33	0·108	0·124
Cl	0·14	—	—
$H_2O - 105°$ C.	0·20	0·130	0·190
$H_2O + 105°$ C.	0·17	0·545	0·060
	100·35	100·000	100·000

I. Dust that fell on Barbados, May 7 and 8, 1902 (anal. Dr. W. POLLARD, 'Quart. Journ. Geol. Soc.,' LVIII., p. 369, 1902).

II. Dust that fell on Barbados, March 22, 1903 (anal. Professor D'ALBUQUERQUE, 'West Indian Bulletin,' vol. IV., p. 98, 1903).

III. Dust that fell on Barbados, May 7 and 8, 1902 (anal. Professor D'ALBUQUERQUE, 'West Indian Bulletin,' vol. III., p. 283, 1902).

probably accounts for the greyish colour of the samples. Olivine is comparatively infrequent. The dust of March, 1903,† is also fine grained, but is very dark in colour, being deep brown. This dust contains more olivine than any other of the specimens examined, and its crystals are often coated with very dark films of glass. Professor LONGFIELD SMITH‡§ has noted that this dust is richer in ferromagnesian

* PRIOR, T. G., 'Quart. Journ. Geol. Soc.,' LVIII., p. 370 (1902).

† BONNEY, T. G., "Notes on March Dust from the Soufrière," 'Nature,' vol. 67, p. 584 (1903).

‡ SMITH, LONGFIELD, "Volcanic Eruptions in the West Indies," 'West Indian Bulletin,' vol. III., p. 271, 1902).

§ Anon., "Notes on fall of Volcanic Dust at Barbados, March 22, 1903," 'West Indian Bulletin,' vol. IV., p. 91 (1903).

minerals than any of the others, and that augite is the predominant pyroxene. If we compare the analyses given below, it is clear that the 1903 dust is more like a hypersthene basalt in composition. The May dust of 1902 resembles a hypersthene andesite. Yet as the 1903 eruption was a small one compared with that of May, 1902, it might have been expected that a larger proportion of the heavy particles would have subsided before the cloud reached Barbados. From this it seems clear that there was a slight change in the composition of the magma erupted by the Soufrière during the 12 months for which it had been in activity, and that the last emissions were more basic than the earlier. As Professor D'ALBUQUERQUE's analysis is not stated in exactly the same way as Dr. POLLARD's, we give also the results of his examination of the dust of May 7 and 8, 1902, for comparison; it shows the more acid character of the latter clearly.

APPENDIX.

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DESCRIPTION OF PLATES.

PLATE 26.

Fig. 1. *Norite*, Wallibu, St. Vincent (polarised light, magnified 55 diameters).

Shows a crystal of olivine surrounded by a corrosion border of hypersthene.

Fig. 2. *Hypersthene basalt*, Calliaqua, St. Vincent (magnified 24 diameters).

A hypersthene cluster full of spongy magnetite, the product of the resorption of olivine.

Fig. 3. *Quartz andesite*, Soufrière, St. Vincent (magnified 47 diameters).

Part of a large crystal of hornblende which is being replaced by hypersthene, biotite and felspar. The scaly biotite is very dark; the hypersthene and felspar are pale coloured. The hornblende (dark) occurs only as islands surrounded by the other minerals.

Fig. 4. *Bomb* (*hypersthene andesite*) of the May eruptions, 1902, Wallibu, St. Vincent (magnified 36 diameters).

The photograph shows phenocrysts of augite, hypersthene, and plagioclase felspar in a vesicular, semi-vitreous groundmass.

Fig. 5. *Quartz andesite*, Soufrière, St. Vincent (magnified 47 diameters; polarised light).

Highly zoned phenocrysts of plagioclase felspar lie in a matrix full of small brightly polarising grains of quartz.

Fig. 6. *Hypersthene andesite*, Soufrière, St. Vincent (magnified 24 diameters; polarised light).

Below the centre of the photograph there is an idiomorphic cross-section of hypersthene so placed that it is extinguished; around it there is a narrow border composed of granular augite.

Fig. 7. *Quartz norite,* Soufrière, St. Vincent (magnified 55 diameters; polarised light).

The minerals represented are pyroxene and plagioclase felspar. The spaces between them are occupied by micropegmatite.

Fig. 8. *Hypersthene andesite,* Soufrière, St. Vincent (magnified 48 diameters; polarised light).

All the phenocrysts are broken and have very irregular forms. This is an instance of brecciform structure in the andesites.

PLATE 27.

Fig. 1. *Anorthite-olivine block,* Rabaka Dry River, St. Vincent (magnified 26 diameters).

The crystals shown in the photograph are mainly anorthite, with a few grains of olivine. None are euhedral; thin films of dark glass separate the minerals and pass along their fissures and cleavages. The anorthite shows many enclosures, irregularly arranged.

Fig. 2. *Anorthite-olivine block* (magnified 26 diameters).

The photograph, taken with crossed nicols, shows the polysynthetic twinning of the anorthite, interrupted along lines of fracture, the optically simple olivine and the dark threads of glass between the crystals.

Fig. 3. *Norite (andes-norite),* Wallibu, St. Vincent (magnified 23 diameters).

This rock consists of nearly idiomorphic felspars, with many glass enclosures, augite, hypersthene, and iron oxide. Between the crystals there is a small amount of glassy base.

Fig. 4. *Calc-silicate hornfels,* Dry River, Lot 14, St. Vincent (magnified 33 diameters).

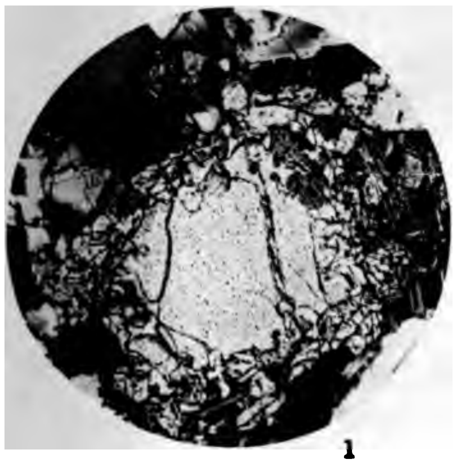
The fine grained matrix consists of granular augite, wollastonite, sphene, and felspar. The large anorthites show traces of idiomorphism, giving the rock a porphyroblastic structure; they contain many enclosures of wollastonite, augite, &c.

Fig. 5. *Hypersthene basalt,* River Bed, Lot 14, St. Vincent (magnified 14 diameters).

The olivine of this rock is weathered to serpentine and is represented in the photograph by dark patches. Hypersthene (idiomorphic) is seen below the centre to the left. The other porphyritic crystals are augite and plagioclase felspar.

Fig. 6. *Olivine basalt,* Richmond Point, St. Vincent (magnified 14 diameters).

This rock contains many small phenocrysts of olivine (partly decomposed), felspar, and augite in a finely crystalline groundmass.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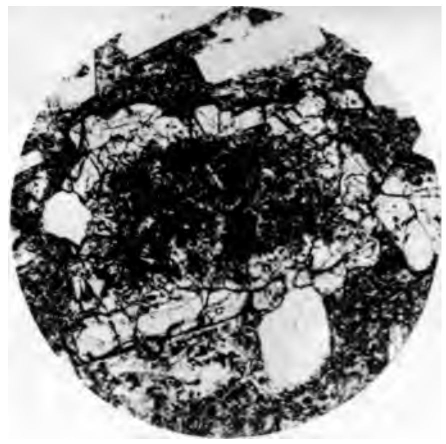
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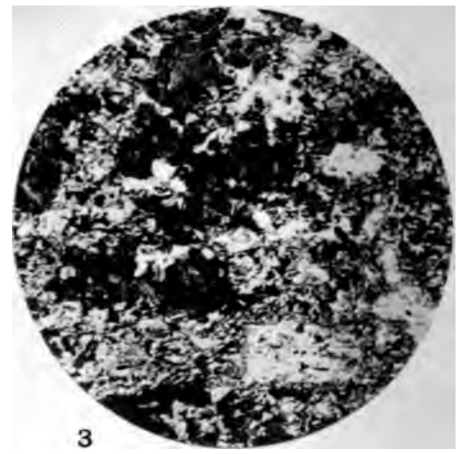
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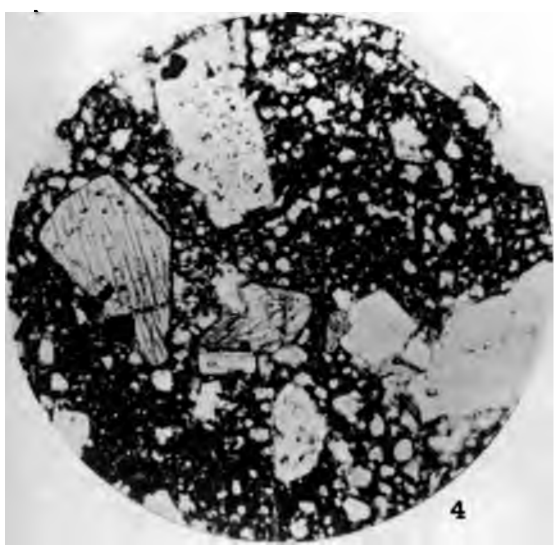
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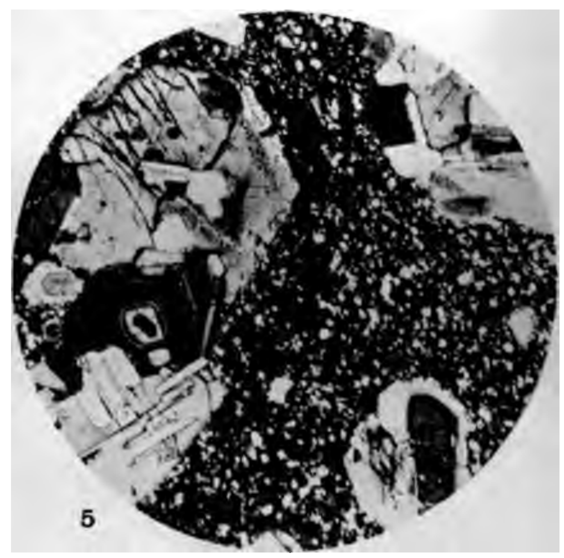
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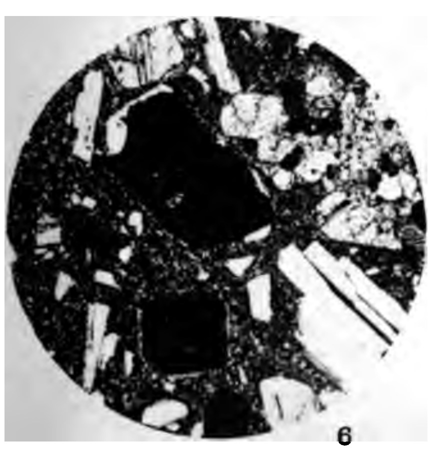
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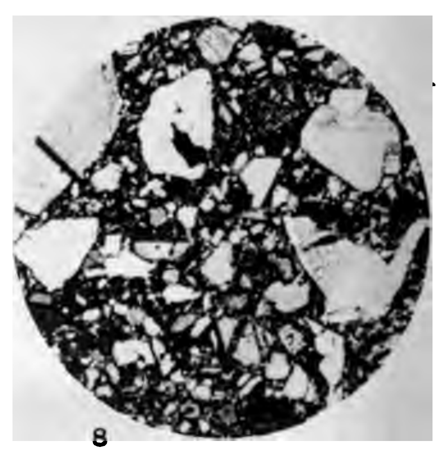
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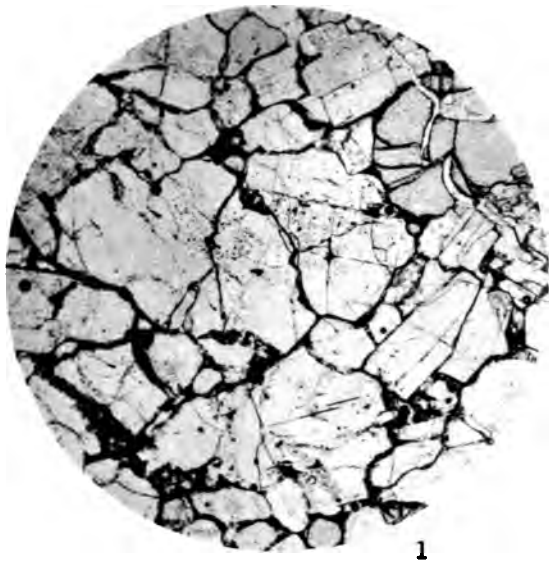

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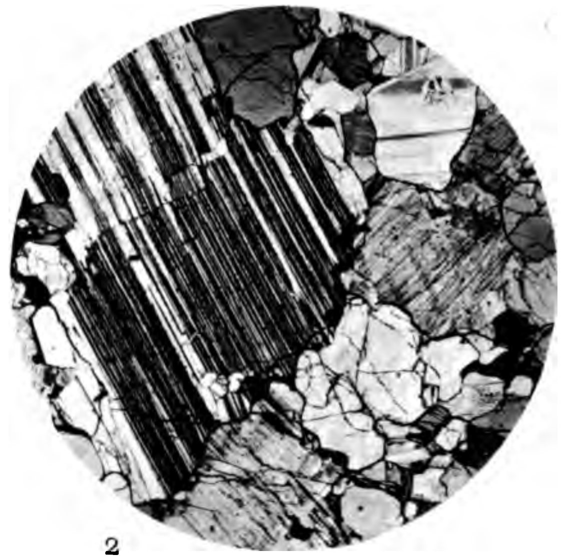

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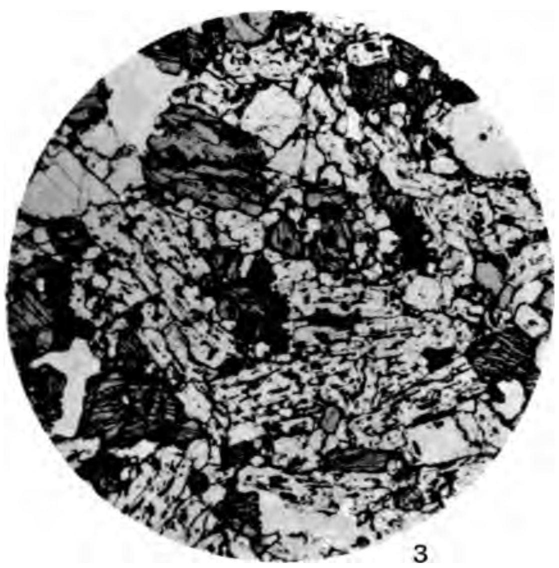

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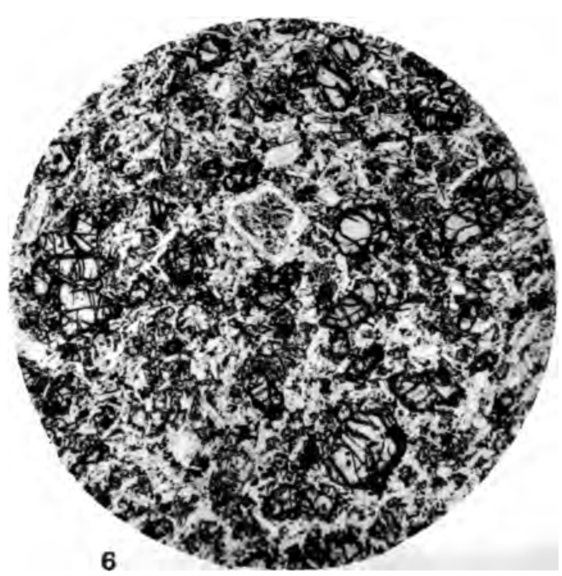

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