Article XXVI. — MARTINIQUE AND ST. VINCENT; A PRELIMINARY REPORT UPON THE ERUPTIONS OF 1902.

By EDMUND OTIS HOVEY.

PLATES XXXIII–LI.[1]

INTRODUCTION.

On May 9, 1902, the civilized world was startled by the news that a great eruption of Mt. Pelée on the island of Martinique had taken place the preceding day. On May 10 this news was confirmed with the addition of details regarding the annihilation of St. Pierre, the largest and most beautiful city in the Lesser Antilles, and the dispatches also contained the information that on Wednesday, May 7, the volcano known as La Soufrière on St. Vincent had suffered a great eruption attended by much loss of human life and property. Scientific interest in the West Indian volcanoes was of course at once aroused, and geographers and geologists desired to study the phenomena connected with such eruptions. Mr. Morris K. Jesup, president of the American Museum of Natural History, perceived the value of the opportunity, laid the matter before the trustees of the institution immediately, and it was decided to send the author to the islands as the representative of the Museum. Passage was secured for me upon the United States cruiser 'Dixie,' sailing from New York May 14 with supplies for the impoverished inhabitants of the devastated islands, and I arrived at Martinique May 21. The following pages constitute a preliminary report upon the observations made during the period of almost seven weeks, from May 21 to July 6, 1902, inclusive, which I spent upon the islands. About three weeks of this time was devoted to the study of the Soufrière and about four weeks to Mt. Pelée.

From May 21 to 28 I kept my headquarters on board the

[1] Except as noted, the illustrations accompanying this article have been made from photographs taken for the Museum by the author.

'Dixie' and made excursions to St. Pierre and along both sides of St. Vincent in company with the other geologists, viz.: Prof. I. C. Russell, Dr. T. A. Jaggar, Jr., and Messrs. R. T. Hill and G. C. Curtis, who were fellow passengers on the 'Dixie.' At Martinique we were transported by the U. S. tug 'Potomac,' while at St. Vincent we were taken about by the Royal Mail steamer 'Wear,' which had been chartered by the Colonial Government for the purpose of distributing relief supplies. Here I wish to record my appreciation of the hospitality accorded me by Captain R. M. Berry, U. S. N., and other officers of the 'Dixie.' Furthermore, my work on St. Vincent was greatly facilitated by the intelligent activity of Mr. F. W. Griffith, government clerk, Kingstown, acting under general instructions from Sir Robert Llewellyn, C.M.G., Governor of the colony, and by the assistance of T. MacGregor MacDonald, Esq., a planter. Some of Mr. MacDonald's estates, especially the Windsor Forest estate northwest of the volcano, were destroyed by the eruption of the Soufrière, and his notes made during the progress of the great eruption of May 7 record the observations of a calm eye-witness and are of especial value to a student of the event.[1] James E. Richards, Esq., merchant, of Kingstown, gave very practical proof of his hospitality by placing at the disposal of my colleagues and myself his cottage at Petit Bordel, on the leeward (west) side of the island near Chateaubelair, from which there was an unobstructed view of the volcano. It would be impracticable to mention by name all who assisted me in one way or another, for the people were very hospitable. As to Martinique, my letter of introduction to the governor, M. G. L'Heurre, from M. Bruwaert, French consul general in New York, led that official to write a letter to the civil authorities of the colony, which proved to be all that could have been desired for obtaining any help or information which it was in the power of

[1] Mr. MacDonald's notes were published in full in the Kingstown 'Sentry' of May 16, 1902. They have been published also in the 'Century Magazine' for August, 1902, Vol. LXIV., pp. 638–642. The compiler of the latter account in his preliminary notes has confounded the Richmond Vale estate with the Richmond estate. Mr. MacDonald, fortunately, does not own the Richmond estate, which lies between Richmond and Wallibou Rivers and was destroyed by the eruption. The Richmond Vale estate belongs to the MacDonald brothers and was not seriously injured. The house is half a mile northeast of Chateaubelair.

the officials to furnish. The mayors of Fort de France, Carbet, Ste. Marie, and Basse Pointe, and the mayors' deputies at Morne Rouge and Grand Rivière, were of particular assistance; also the attentions of M. Marsau of the mayor's office, Fort de France, and the librarian of the Schoelcher library should be mentioned.

During the night of May 28 the 'Dixie' sailed from St. Vincent, leaving me, in company with Dr. T. A. Jaggar, Jr., of Harvard University, and George Carroll Curtis, of the United States Geological Survey, to prosecute studies on St. Vincent before taking up in detail the investigation of the volcanic phenomena of Martinique. On June 5 Dr. Jaggar left the party and did not again join us in field work, and from that date onward Mr. Curtis and I worked conjointly in obtaining field data. In this Preliminary Report the phenomena observed on St. Vincent receive treatment first, partly because they were studied first, but more because they furnished a satisfactory explanation of some of the phenomena observed on Martinique which, otherwise, would have been difficult to understand. Extended arguments and the elaboration of many interesting details, together with the results of microscopical and chemical studies yet to be made on the ejecta of the eruptions of both volcanoes, are left for my final Report. The maps accompanying this Report, Plates XXXIV and XXXV, have been prepared from the British Admiralty charts and have been reduced to the same scale, for convenience of comparison. In each map the area of most serious present devastation (May and June, 1902) is indicated by cross-lining. The principal routes traversed by the author are shown by the red lines upon the maps.

The Soufrière.

The first ascent of the Soufrière, since the eruption of May 7, 1902, was made on Saturday, May 31, by Messrs. Jaggar, Curtis, MacDonald, and myself with six porters. We went up from the site of Wallibou village, on the leeward (west) side, following the remains of the old trail to the rim of the crater at 2790 feet above the sea, an elevation obtained by taking

the mean of the readings of three aneroid barometers.[1] We found the crater probably unchanged in diameter, as nearly as Mr. MacDonald could tell, and therefore to be about nine-tenths of a mile in diameter from east to west and eight-tenths of a mile from north to south, judging from measurements made on the map. The beautiful crater lake, for which the Soufrière was famous before the eruption, had disappeared of course, but there was a small lake of boiling water in the bottom of the pit, from the southeastern quarter of which steam was ascending in a strong column (see Pl. XXXVII). This column at intervals was carrying up quantities of black sand with it to moderate heights above the bottom of the crater. We estimated the surface of the boiling lake to be about 1600 feet below the point on which we were standing, and 2400 feet below the highest point of the rim. The lake seemed to be shallow, judging from some nearly flat ground in the bottom of the crater northeast of the water. Our estimate would indicate that the surface of the water was 1200 feet above the sea. The surface of the old crater lake was 1930 feet (chart) above tide. Its depth in the centre was 87½ fathoms, according to the statements of P. F. Huggins, engineer, of Kingstown, St. Vincent, who told me that he sounded it in 1896. His line was too short to reach bottom in the northwestern part of the lake.

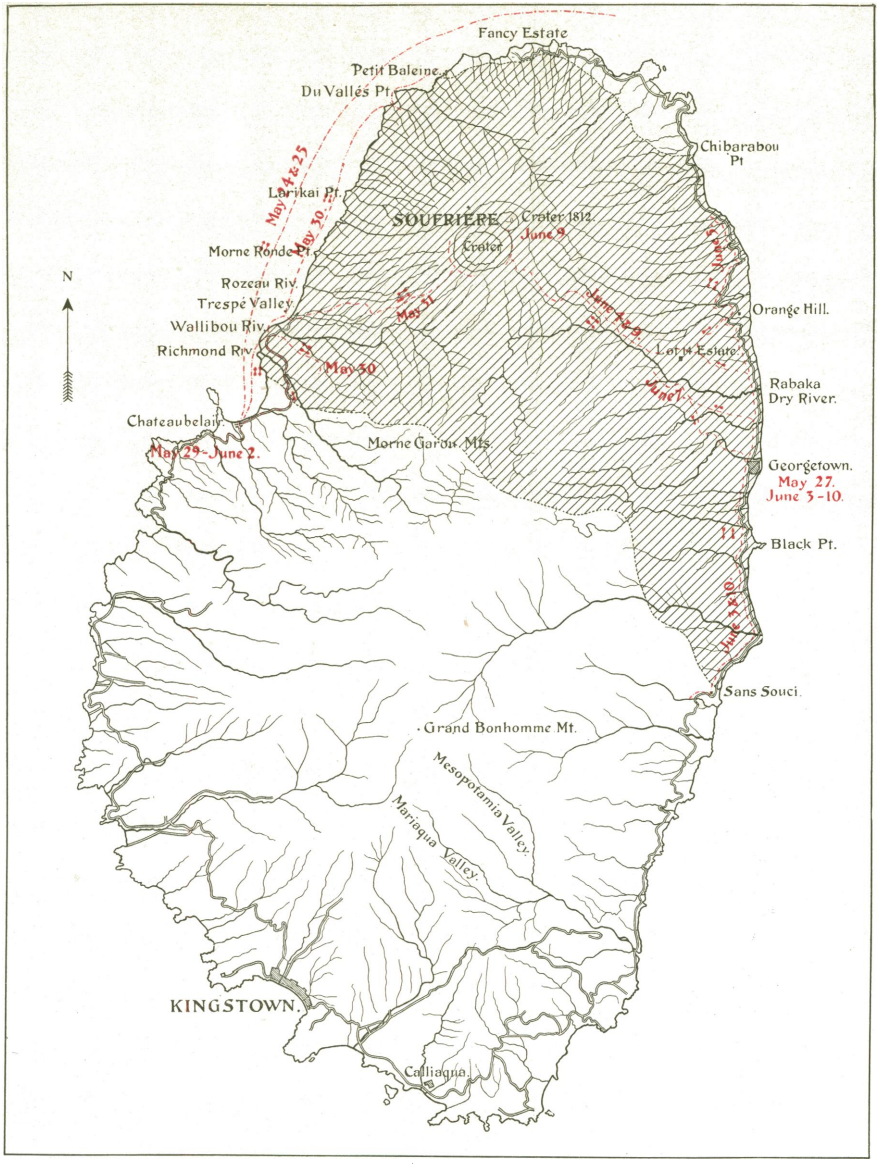
Almost directly opposite the point where we first reached the rim was the wall and saddle between the 'Old' crater and the crater of 1812, apparently unbroken by the eruption. From the lower third of this series of nearly vertical rock-faces and agglomerate beds there issued a strong stream of water which cascaded down the precipices and flowed across a rather narrow strip of nearly level ground in the bottom of the crater and emptied into the boiling lake. It seemed as if this stream must be the discharge of the waters now collecting in the crater of 1812, where there was a little lake before the eruption of the present year. The western side of the crater rim showed a gash leading into the Larakai valley, but the bottom

[1] All the altitudes recorded in this article were obtained by means of aneroid barometers, except as otherwise stated in the text.

NOTE TO PLATE XXXIV.

The area of devastation indicated on this map represents as nearly as practicable the condition of affairs produced by the eruptions of La Soufrière in May, 1902. The outburst of September 3 is reported to have extended considerably the area of present ruin, especially on the western side of the island. The cable dispatches report that the estates of Richmond Vale, Sharps, Petit Bordel, Cull's (= Swat's?) Hill, Trumaka, and Cumberland have been destroyed, while a private letter informs the author that much volcanic sand fell as far as Peter's Hope, five miles south of Chateaubelair. On the leeward side of the island, therefore, the boundary line of the devastated area probably should be placed about three miles south of its location on this map. Sufficient data are not at hand yet for entire revision of the map.

September 15, 1902.



MAP OF THE ISLAND OF ST. VINCENT.

The cross-lined area shows approximately the area devastated by the eruption. The lines in red show the principal routes traversed by the author.

of the gash was more than a thousand feet above the bottom of the crater. Mr. MacDonald said that the gash was there before the eruption took place, but that it seemed to him to have increased in size since the outbursts began. The gash is very much smaller than that in the southwest side of Mt. Pelée, and it does not seem to have had any appreciable, or, better, any determinable, effect in concentrating the force of Soufrière's volcanic hurricanes. Tremendous avalanches of rocks and earth descended the inner precipitous slopes of the crater at intervals during our stay on the rim. They made a great deal of noise, and probably occasioned some of the 'groaning' of the volcano reported by the islanders.

On June 4 Messrs. Jaggar, Curtis, and I made an attempt at the ascent from the windward side. We reached the altitude of 3200 feet, but turned back without getting to the crater itself, on account of dense storm clouds. On June 9 Mr. Curtis and I made our third ascent, alone, except for one guide, and reached the rim of the crater on the southeastern side two or three hundred yards beyond the spot at which we had turned back on the preceding occasion. For fifteen or twenty yards back from the edge of the rim there were crevices in the ground many yards long and up to three inches wide, which formed lenses with the edge itself and indicated the imminence of landslides into the crater. We pushed along the rim northward, until, at an altitude of 3550 feet above the sea, we stood between the large crater and the crater of 1812. The summit of the Soufrière east of the large crater and south of the small one is formed by a rather small plateau which slopes gently toward the southeast, closely analogous in position to the small plateau on the eastern summit of Mt. Pelée which was the site of the Lac des Palmistes. This plateau was covered with a bed of dust, lapilli (= volcanic sand and gravel), and boulders which was ten to fifteen feet thick in places, and the trenches cut by recent rains made travelling very laborious, except near the edge of the crater.

In spite of clouds and rain, this visit, through occasional glimpses of the interior, enabled me to determine that the crater of 1812, which for nearly a century has gone by the

name of the 'New' crater, took no active part in the eruptions of May of the present year, a conclusion based on the following considerations: the saddle between the two craters appeared to be intact, confirming the observation made from the other side of the large crater; a knife-edge ridge which ran at a steep incline from the saddle to the bottom of the small crater and formed the pathway for descent into it before the eruption was still there, and had on its slopes bare trunks of trees standing; in the bottom of the crater along the base of this ridge we could see talus slopes of dry (?) dust and lapilli which had slid and rolled down its sides; although the roaring of the steam and boiling water nearly half a mile below us in the large crater was obtrusively discernible, no sound whatever came from within the crater of 1812; the rim of the small crater showed less and less dust as one receded from the edge of the great crater. Samuel Brown, a ranger, or caretaker, on the Lot 14 estate on the southeast slopes of the Soufrière, who was our guide when we reached the small crater, told us that he watched the eruption of May 7 until the great outburst at two o'clock and that no cloud of steam or 'smoke' rose from the small crater. Furthermore, at the time of my leaving the island, June 10, no column of steam had risen above that crater since May 7. Brown was at the sugar factory of the estate, three and one-half miles in a straight line east-southeast from the crater, a most favorable spot from which to observe what was going on at the summit of the mountain. He saved his life by running into the rum cellar of the factory and closing the door and the window shutters just before the volcanic blast swept over the building. On inquiry in Georgetown I found persons who had watched the eruption from the town and had noted the fact that no column of steam rose from the small crater.

The Soufrière, and, in fact, the whole of the island of St. Vincent, is made up of ancient lava flows alternating with volcanic fragmental deposits or tuffs.[1] These tuffs consist of boulders of all sizes imbedded in a matrix of coarse and fine gravel and sand, the whole being compacted into a rather soft

[1] The alternation of lava beds and tuffs is illustrated in Figure 2 of Plate XXXVII.

rock, which is known as 'tuff agglomerate' or merely 'agglomerate.' These ancient agglomerates show that there have been many eruptions of the volcanoes of St. Vincent of the same character as that of 1902. They contain bombs as well as blocks. The beds of solid rock on the island show that many of the ancient eruptions were accompanied by extensive flows of molten lava. The porous agglomerates have suffered much from the decomposing action of percolating waters, and the lava beds show extensive alteration due to the same agency. Beautiful spheroidal weathering is common in the basalts of the southeastern part of the island and in the elevated beach conglomerates of the windward coast.

Although there are many ancient lava beds in the composition of the mountain, no *stream* of melted lava has issued from the Soufrière during the present eruption. The 'bread-crust' bombs, however, which occur plentifully on the mountain sides, especially on the windward slopes, show that during the present eruption molten lava has been present in the throat of the volcano, and that many lumps of melted or half-melted rock were thrown into the air. Besides the bombs, the volcano ejected blocks of ancient andesitic lava of several kinds and of varying degrees of coarseness of grain, and of all sizes up to masses six or eight feet across, and vast quantities of coarse and fine lapilli and dust. Most, if not all, of the blocks were thrown out at high temperatures, as is shown by their cracked condition, though they were not actually fused. Although a few bombs, some of which were twelve to fifteen inches across, were found on the leeward side as far away from the crater as the site of Richmond village, three and one-half miles from the crater, by far the largest number of both bombs and blocks, as well as the largest specimens, were found on the windward side, bombs fifteen to eighteen inches in diameter being common in the bed of the Rabaka Dry River. The proportion of old lavas in the ejecta of the Soufrière seems greater than in those of Pelée, and there is greater variety, apparently, in their composition.

The area of devastation on St. Vincent is very large in proportion to the total area of the island. After plotting it out

carefully on the British Admiralty chart and measuring the area with a planimeter, I find it to be forty-six square miles, practically one-third the entire area of the island. From much of this devastated area, however, the ashes are being washed off so rapidly by the rain that vegetation is already asserting itself and within another year crops will be growing there again.

Extensive landslides have taken place on the western side (see Pll. XXXIII and XXXVIII), removing a strip of coast, in places one hundred yards wide, continuously from the mouth of the Wallibou River to Morne Ronde village, a mile and a half to the north, and at intervals for two miles farther north. These landslides have left precipitous walls along the shoreline, and deep water is found where villages stood and prosperous plantations existed before the eruption. We had no sounding line, but our boatmen could not touch bottom with a twelve-foot oar three feet from shore on the site of Morne Ronde village. The sections left by the slides show that the land which has disappeared consisted of delta and coast-plain deposits, material which would be dislodged easily from the more substantial lava flows and agglomerate beds by the vibrations due to the eruptions. The eastern, or windward, side of the island is not nearly as steep as the leeward, and landslides have not occurred there as features of this eruption. On the contrary, the windward shoreline from Black Point, a mile south of Georgetown, northward almost to Chibarabou Point, more than six miles distant, has been pushed out by the vast quantities of fresh lapilli which have been brought down from the slopes of the volcano by the rivers and the heavy rains, during and since the eruptions, and distributed by the ocean currents.

A large amount of material, too, was brought down by the Rabaka Dry River an hour in advance of the great outburst of May 7, which seems to have been due to the bodily discharge of a portion, at least, of the old crater lake into the headwaters of that stream. Survivors who attempted to cross the Rabaka Dry River toward noon of that day report that they were prevented by a torrent of 'boiling hot' water and mud rush-

ing down the valley and that a wall of water and mud fifty or more feet high (they compared it with the height of a factory chimney) came out of the upper reaches of the river and swept out to sea. There was no heavy rain that day before the eruption took place, but the lake still was in the crater early in the day, according to the tale of a fish-woman who had ascended the mountain from Georgetown that morning on her way home to Chateaubelair. The trail led along the rim of the crater for half a mile. The woman reached the rim at nine o'clock and found that fissures had appeared in the ground and that the lake was at a higher level than usual and boiling. She rushed back to Georgetown to warn the people, but her tale was discredited. Mr. MacDonald's notes contain the entries: "12.55 P.M. Enormous discharge to windward side, color darker. 1 P.M. Tremendous roaring, stones thrown out to windward thousands of feet."[1] While this does not *prove* the bodily outthrow of the lake, it shows that there was a great outburst from the crater just in advance of the flood in the Dry River valley.

It is evident that there was a blast or a series of blasts of hurricane violence from the crater of the Soufrière as well as from that of Mt. Pelée, as a feature of the eruptions of 1902. The effects were not so appalling, however, on St. Vincent as on Martinique, because no large city was destroyed there. The overturned trees constitute the principal evidence on the island of St. Vincent. They all point away from the crater, except for slight modifications due to local topography (see Pl. XXXIX, Fig. 2). The blasts extended radially in all directions from the crater, suggesting the explanation that great volumes of steam, rising from the throat of the volcano, could not find room for expansion upward, on account of the column of steam and ashes which had preceded them, and the ashes falling therefrom, and that they expanded with explosive violence horizontally and downward, following the configuration of the mountain. This accords with the testimony of Mr. MacDonald and other eye-witnesses of the eruptions, who say that they saw the clouds of 'smoke' (dust-laden steam)

[1] Century Magazine, Vol. LXIV, p. 639. August, 1902.

rushing down the sides of the mountain with terrific speed. This dust-laden steam was able to do much work of erosion, as is shown by the horizontally scoured sides of some of the exposed cliffs and by the trunks and roots of overturned trees. The roots particularly have been charred by the heat and carved into fantastic, pointed shapes, as if they had been subjected to the action of a powerful sand-blast. As already stated, the disposition of the roots and trunks clearly indicates the crater as the source of the blast. Erosion has not materially affected the original surface of the ground as yet, because almost everywhere one can find the living roots and charred blades of grass and other vegetation beneath the covering of dust and lapilli, the first of which acted as a protection against the heat of the rest. The erosive action now, however, is that the heavy rains take up vast quantities of the loose lapilli for use as a powerful scouring agent in attacking the denuded hillsides, and thus old valleys are being deepened and widened.

The particular feature of the eruption of the Soufrière was the enormous amount of dust which was thrown into the air and distributed over a vast, somewhat elliptical area, the extent of which cannot yet be calculated for lack of data. The British steamship 'Coya' had an eighth of an inch of volcanic dust from this volcano fall on her deck when she was two hundred seventy-five miles east-southeast of St. Vincent. The steamer encountered the dust at 10.30 P.M., May 7, eight and one-half hours after the eruption of the Soufrière began, indicating transport against the prevailing wind at more than thirty-two knots per hour. Reports of vessels from the west (leeward) of the island have not come to my notice, but the statements of the islanders would indicate that the greater proportion of the cloud of dust went to the east and southeast. The dust was spread like a gray mantle over the island, generally diminishing in thickness from the crater outwards, but collected in vast deposits in certain valleys on the sides of the mountain, where the conditions seem to have been particularly favorable. The chief of these beds were formed in the Wallibou, Trespé and Rozeau valleys on the leeward (west) side, and in the valleys of the Ra-

baka Dry River and its tributaries on the windward (east) slope, with by far the greatest thickness along the Wallibou and Rabaka Dry Rivers. In the valley of the Wallibou the deposits were not less than sixty feet deep in places, while in the Rabaka Dry River the fresh material filled a gorge which is said to have been two hundred feet deep before the eruptions began (see Pl. XXXIX, Fig. 1). From a distance this deposit looks as if it were a glacier coming out of the mountains.

Such great accumulations of hot lapilli and dust retain their heat for a long time and they have given rise to secondary, or superficial, eruption phenomena of striking character and considerable interest. The river water and the water from the tropical showers percolating through the beds have come into contact with the still highly heated interior, causing violent outbursts of dust-laden steam. We saw one of these outbursts from the Wallibou valley send up a column of such vapor fully a mile in height. The action lasted for nearly an hour. The secondary eruptions illustrated by the figures on Plate XL took place on a clear, dry morning and must have been caused by the percolating river waters. On May 30 we witnessed the throwing of a dam across the stream and the formation of a temporary lake by a heavy secondary outburst of dust-laden steam from the lapilli-bed in the Wallibou valley. This eruption is illustrated in figure 2 of plate XL. After the eruption ceased, the little lake soon rose to the top of the dam and quickly cut its way down to the old level, sending a 'mud-flow' down the gorge to the sea. Such a lake in the valley of the Rabaka Dry River cut its new outlet through a narrow ridge of the old agglomerate constituting the wall of the cañon, forming as it did so a beautiful series of channel-bowls, pot-holes and scratched corkscrew channels.

When we first reached St. Vincent, the dust, especially that covering the Richmond estate, showed in marked manner the wind-drift surface so familiar in the case of freshly fallen snow, and in many places these drifts were from three to four feet deep (see Pl. XLI). There were several heavy rains between May 24 and 29, so that the appearance of the surface was very different on May 30 from what it was when I first saw it. Its

drifted character was not nearly as evident and the beautiful dendritic drainage, which was already in evidence on May 24, had been greatly extended and intensified (see Pl. XLII). Geological operations, which under ordinary conditions are so slowly performed as to be imperceptible, were being carried forward rapidly under our very eyes. One item of interest was the action of the Wallibou River itself as it cut into and undermined the beds of dust and lapilli along its banks. Its waters became so overloaded with sediment that they could only flow in pulsations, showing that intervals of time were needed by the stream to gather strength to force its way along with its burden. On May 24 these waves or pulsations were from fifteen to forty seconds apart. Such mud streams carry large boulders down their beds and have great erosive power.

When the great cloud of ejecta rose from the Soufrière at 2 P.M., May 7, the portion which was traveling eastward seemed suddenly to split, according to the accounts of eye-witnesses, when it was some distance beyond the island, and to send a part back to the land. This is in accord with the fact that unprotected windows in the eastern side (that farthest from the crater) of houses in the devastated district along the windward coast were all stripped of their glass, while immense quantities of dust were carried to the island of Barbados, 90 miles due east, and beyond.

An official estimate of the loss of life on St. Vincent by the eruption places the number of killed at 1350. The actual number of bodies buried was 1298, including those of the wounded who died in the hospitals. Almost all of the people who passed through the fury of the eruption and escaped uninjured had taken refuge in cellars the only openings into which were on the side farthest from the crater and were, moreover, tightly closed with wooden doors or shutters. The most striking example of such protection was at Orange Hill, on the windward coast, two and one-half miles north of Georgetown, where one hundred thirty-two persons were saved unharmed in an empty rum cellar. This cellar, which is only partly underground, is part of a sugar factory

situated on a rather flat divide between two ravines which may have tended to separate the volcanic storm somewhat, though the roof of the building over the cellar was demolished by the ejecta. The only openings into the cellar were a door and two windows on the side opposite the crater, and these were provided with heavy wooden shutters which were kept closed during the fury of the eruption. The experiences of the people in these cellars suggest the great desirability of constructing similar places of refuge for use in time of hurricane as well as of volcanic eruption.

The deaths on St. Vincent seem to have been due, principally, to the following causes: (1) asphyxiation by hot, dust-laden steam and air, (2) burns due to hot stones, lapilli and dust, (3) blows by falling stones, (4) nervous shock, (5) burning by steam alone, and (6) strokes of lightning. The last mentioned cause is perhaps somewhat doubtful, for though it is very generally named by the survivors, there has been no substantiation mentioned beyond the fact that there was a great deal of extremely vivid lightning during the eruption. The action of steam may account for burns received underneath the clothing where the clothing was not even charred. Sulphur dioxide, SO_2, and hydrogen sulphide, H_2S, were observed in troublesome quantities in the steam coming from the crater, and it is more than probable that these gases, especially the former, added very materially to the deadly character of the dust-laden steam. Strange as it may seem, not an autopsy was made on any of the hundreds of victims of the catastrophe, so that it never can be known definitely what part was played by these or other poisonous gases in the destruction of human life.

Mt. Pelée.

The destruction of human life overshadows every other consideration, in popular estimation, at least, when one speaks of the eruption of Mt. Pelée which took place May 8, 1902. The sweeping of between twenty-five and thirty thousand human beings out of existence almost in a moment presents a holocaust with but few parallels in the history of the world.

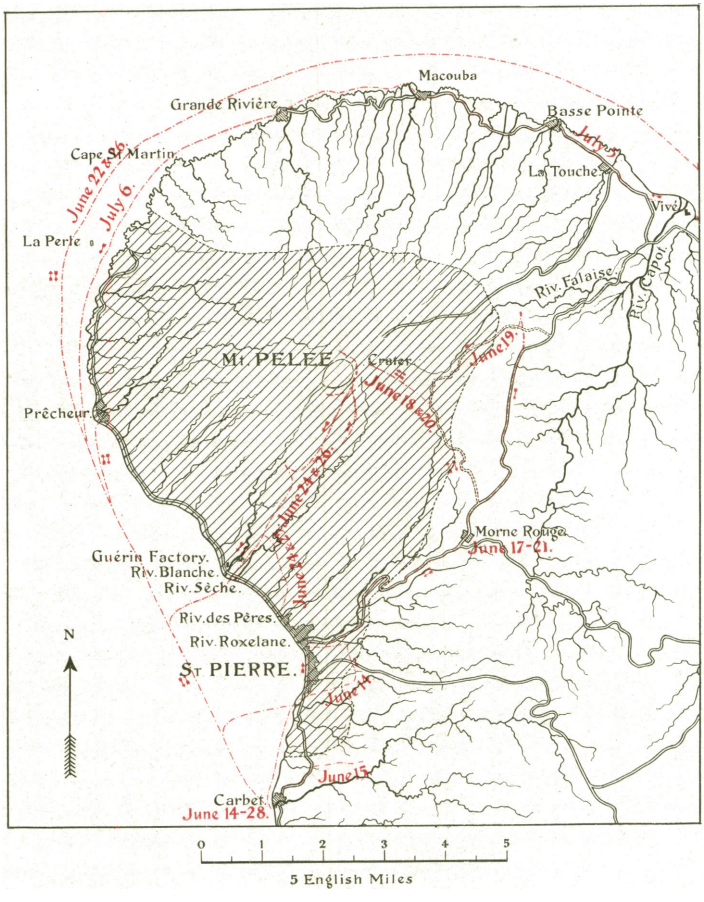
The eruptions of Krakatoa, Tomboro and Bandai San and the Lisbon earthquake of 1755 come to mind as natural catastrophes of even greater destructiveness to life, but nothing has occurred within a century which has so stirred the civilized world as has the annihilation of the beautiful city of St. Pierre, the "pearl of the Lesser Antilles." The present eruptions of Pelée and the Soufrière will not, however, take first rank among those which have torn these and other Caribbean volcanoes, but they are extensive enough and are of such a character as to merit the study they have been and are receiving. Perhaps these eruptions, too, will add something to the world's knowledge of the science of vulcanology.

The area of devastation caused by this eruption of Pelée is less than that due to that of La Soufrière (compare maps, Pll. XXXIV and XXXV). Plotting the area on the Admiralty chart as well as possible, after inspecting all sides of the volcano, and measuring it with a planimeter, I find that thirty-two square miles of Martinique were laid waste by dust, lapilli, stones and 'mud.' The area is not as symmetrically disposed about the crater as is the case on St. Vincent, probably because the crater of Pelée is so much lower on the southwest than on the other sides and the great gash opening into the gorge of the Rivière Blanche, together with the configuration of the neighboring 'mornes,' or ridges, has given direction to all the violent explosions which have occurred. Although the whole island has received débris from some of the outbursts and dust has been scattered over a wide area, the district over which the vegetation was killed, at least temporarily, is included within a line beginning at the sea coast, about midway between St. Pierre and Carbet, though the palm trees along the coast at the base of the bluffs were scorched as far as Carbet Point itself. Passing inland about a mile the line curves sharply to the north and east of north to the Roxelane River, then goes northeastward along this river and one of its tributaries, paralleling the main street of Morne Rouge within a quarter of a mile, swings then to the east of La Calebasse and rises somewhat on the northeastern flanks of Pelée, apparently passing along the south side of Pain de Sucre and

NOTE TO PLATE XXXV.

This map shows the area of most serious devastation resulting from the eruptions of Mt. Pelée which occurred between May 5 and July 6, 1902. The telegraphic reports received regarding the eruptions of August 28 and 30 and September 3 indicate that the area of devastation has been greatly extended to the north, east, and south. The beautiful village of Morne Rouge has been razed, four or five houses and the massive cathedral alone being left standing. Carbet lies under a foot of ashes. The towns along the northern coast do not seem to have been entirely destroyed. Judging from the reports mentioned, the map here presented, with the exception of a few square miles in the southeast corner, gives very nearly the district which should be included within the present area of devastation.

September 15, 1902.



MAP OF THE NORTHWESTERN PART OF THE ISLAND OF MARTINIQUE.

The cross-lined area shows approximately the area devastated by the eruption. The lines in red show the principal routes traversed by the author.

then northwestward, leaving the island midway between La Perle Rock and Cap St. Martin. Much of this area is already springing into verdure again; the grass was already very noticeable on the hill slopes encircling St. Pierre by July 1, and green vegetation was to be seen even nearer the source of destruction. When we first arrived at Martinique (May 21) the line between the scorched and unscorched areas was strikingly sharp, and was still very noticeable six or seven weeks later. In many places the line of demarkation passed through single trees, leaving one side scorched and brown, while the other side remained as green as if no eruption had occurred.

The material ejected by Pelée during this series of eruptions consists of dust in vast quantities,[1] fine and coarse lapilli, bread-crust bombs (see Pl. LI) of all sizes from one inch to three feet and more across, and blocks of small and great size, the cracked condition of which shows that they have been highly heated. The freshly fallen ashes had a curious resemblance in appearance to snow, which gave a peculiar Alpine aspect to the mountain, and is noticeable in some of the photographs. No *stream* of molten lava has issued yet from the volcano as a feature of this eruption, though such flows were common in the early history of Pelée, as they were in that of St. Vincent's Soufrière. The bread-crust bombs prove, however, that much lava has been thrown out in the condition of melted or half-melted masses. These bombs usually are more or less pumiceous in texture, and they show the 'bread-crust' surface much more distinctly than do the more basic bombs of the Soufrière. The largest of the bombs observed was one fifteen feet long on the southeast slope of Morne Lacroix at an elevation of 3950 feet above the sea. The largest ejected block that we saw was one on the surface of the mud-flow between the rivers Blanche and Sèche and not more than two hundred yards from the sea coast. Its dimensions are about 22 feet high, 30 feet long and 24 feet broad, and it is of the light gray andesitic lava forming one of the ancient lava beds near the summit of the mountain (see

[1] One hundred twenty tons of dust and lapilli were removed from the decks of the 'Roddam' after her arrival in the harbor of Castries, St. Lucia, according to the personal statement of one of the agents of the line to which the steamer belonged.

Pl. XLVIII, Fig. 2). An outcropping bed of rock very similar in appearance to this occurs at an elevation of about 3350 feet in the rim of the present crater, at the side of the great gash in its southwest side. When I inspected this block on June 25, I found it too hot on the surface to bear the hand upon it long at a time, the great mass was cracked in several directions, and steam and sulphurous gases were emanating from the cracks. It seems certain that this enormous block was thrown out of the crater in a highly heated condition during the present eruption, but it may have reached the place where it now is partly through the agency of the great mud-flow on which it rests.[1] Many other great boulders, some of which are of nearly half the dimensions of the one just described, lie near by on this mud plain.

The area of distribution of the ejecta cannot be designated accurately yet for lack of data. The U. S. collier 'Leonidas' received a quarter of an inch of dust on her deck from the great outburst of June 6 when she was 102 miles west of Martinique. It took the ship from 3 P.M. until nearly 6 o'clock to traverse the cloud of dust. This eruption began at 10.15 A.M. and was one of the heaviest of the whole series. I was in Georgetown, St. Vincent, at the time and felt the shock distinctly. From 3 o'clock onward that afternoon until after sunset heavy clouds of dust from the Pelée eruption passed over St. Vincent, much of it falling upon the island. The top of the cloud of dust as it passed over the mountains seemed to me to be about 6000 feet above the sea, so that the last deposits must have been made far south of St. Vincent. The shocks or detonations from some if not all of the great outbursts were felt in St. Kitts and Trinidad, though not in some of the intervening islands.

Two illustrations of the force with which the bombs and blocks strike may be permitted here. On the sea coast near the Fort Villaret church in the portion of St. Pierre north of the Roxelane River there was a large distillery in which there

[1] On seeing my photograph of this great block, Prof. Heilprin told me that he thought that it was not on the plateau at the time of his visit, because he did not see it. Unless it was buried then and has been brought to light since by erosion, the block probably was thrown out of the volcano in the great eruption of June 6.

were four big storage tanks constructed of quarter-inch boiler iron plates riveted together. These tanks (see Pl. XLVII) look as if they had been through a bombardment by artillery, being full of holes which vary in size from mere cracks at the bottom of indentations to great rents 24, 30 and even 36 inches across, while a strip several feet long was torn off from each of two. Most of the holes are irregular in shape, but some are nearly circular, and the cracks are single or intersecting. The direction of impact was essentially the same in all instances, namely, from the crater, and at least two holes, the sides of which were not completely torn open, had stones wedged in them when we examined the place. The other illustration is found on the southeastern flanks of Mt. Pelée, along the trail leading from Morne Rouge to the summit, where numerous elliptical or spoon-shaped depressions occur in the rather loose soil of the mountain side, especially between the elevations of 2400 and 3000 feet above tide. These holes are of all sizes from 2 feet in diameter upward, the largest one which we saw being 40 feet long, twenty-5 feet wide and 5 feet deep, but the depth had evidently been reduced by the sand which had been washed into it by recent rains. The longer axis of this depression was N. 50° W., pointing directly at the crater, and the longer axes of all the other holes observed were pointing toward the same center. The deepest part was on the up-hill side. On the down-hill side of each depression we found the cause of the phenomenon, and it was a bomb or ejected block from the volcano, which had struck the ground with a splash, throwing the earth in all directions and usually bounding or rolling out of the hole which it had made. Sometimes the blocks which did the work were found intact, but sometimes they had burst asunder after striking. All showed that they had come out of the volcano in a highly heated condition. Such splashes as these can be made experimentally on a small scale in any bed of stiff mud by means of well-directed stones.

Many stones must have fallen in St. Pierre, but they are so mingled with the rubble stones from the walls of the ruined buildings that usually they are not easily distinguishable

therefrom (see Pl. XLV). Great quantities of small, rounded fragments of yellow pumice are to be found now amid the ruins, the fine gray dust having been washed away to a considerable extent by the copious rains which have fallen since the great eruptions. Most of the pebbles of pumice were less than three inches in diameter. They are evidently from the old tuff agglomerate and must have been torn from the beds through which the volcanic vents pass and from the interior of the old cone. Stones fell all over the island in some of the eruptions. It is reported that during that of May 20 one weighing two and a quarter kilos (about five pounds)[1] fell through the hatch of the Norwegian bark 'Helga,' which was at anchor in the harbor of Fort de France. The stone is said to have been so hot that it set fire to the soft coal into which it fell.

Four ascents of Mt. Pelée, in the course of which the crater rim was traversed from the great chasm on the southwest along the southern and eastern edge more than two-thirds of the way around the circle, and the remainder also of the rim was clearly seen, enabled us to form a reasonably definite idea of the center of activity and what was going on therein. Twice we followed the trail from Morne Rouge to the summit, which led us for a considerable distance along the right (southern) brink of the cañon of the Falaise River, and on the day intervening between these ascents we examined the gorge of the Falaise carefully from the point where the Morne Rouge trail to the summit strikes it nearly to its junction with the Capot River, a mile or more beyond the area of devastation. The upper reaches of the gorge certainly present the scene of desolation so graphically described by George Kennan,[2] but the 'Falaise crater' mentioned by him and by Professor Heilprin[3] and indicated on Hill's map[4] can hardly be a true crater. We saw the same accumulations of volcanic ash in the gorge at an elevation of 1800 to 2000 feet above the sea (aneroid reading)

[1] It seems probable that the weight was one kilo (= two and one-fifth pounds) and that it was incorrectly reported through confounding metric and English units of weight.

[2] The Outlook, Vol. LXXI, pp. 773, 774. 26 July, 1902.

[3] McClure's Magazine, Vol. XIX, p. 363. August, 1902.

[4] See page 359.

that Heilprin and Kennan mention as forming a crater from which mud-flows were hurled down the gorge to the sea, and we saw steam issuing from them, but to us who had studied the phenomena on St. Vincent it seemed perfectly evident that the outbursts in the gorge of the Falaise were comparatively feeble examples of secondary or superficial eruptions of the same character as those which took place on such a grand scale from the ash-beds of the Wallibou and Rabaka Dry Rivers. Percolating rain or river water caused the hot ash-bed to explode, throwing a loosely aggregated dam across the stream and causing the water to pond back until it obtained sufficient force to break through the obstacle. Then the waters, loaded with volcanic débris from the hillsides and the ash-bed dam, rushed down the gorge, gathering additional material from the walls of old tuff and picking up great boulders in their course, and the load of mud and stones was deposited along the flat land near the mouth of the stream or carried to the sea coast to build out the deltas and the shore-lines. This was the history of events in the Falaise and probably at Basse Pointe, Macouba, Grande Rivière and other places; and it was the history of some, but not all, of the mud-flows in the Prêcheur, the Mare, the Blanche, the Sèche, and the Des Pères rivers. Since the eruptions began there have been great floods in the Roxelane River, but it seems doubtful whether or not this stream has carried any true mud-flows down its gorge.

The actual crater is apparently somewhat oval in shape, with its longer axis stretching northeast and southwest. The highest point of the rim is on the northeast side and is what is left of the peak known as 'Morne Lacroix.'[1] By taking the average between the readings of our two barometers, we

[1] The following quotation from 'Les Colonies' of May 5, as translated in the Century Magazine for August, 1902 (Vol. LXIV., p. 623), seems to show that the name 'Morne Lacroix' applies to the highest peak on the western edge of the crater, and that the highest peak of the eastern rim, the one which Curtis and I determined to be 4200 feet high, is what remains of the Ti-Bolhommes, but I follow the descriptions of Lafcadio Hearn and other travellers in locating Morne Lacroix east of the great crater containing the Étang Sec.

"The guide, M. Julien Romain, who is one of the Morne Pavillot property-holders, went up the mountain ten days ago, after the awakening of the volcano. We reproduce the substance of his interesting account, which was very gracefully related.

"The mountain has for its highest summit Morne Lacroix, and describes a vast circle, the bottom of which measures close upon six hectares [nearly fifteen acres] in surface.

"This circle, which we are now defining according to lines upon the guide's indica-

determined its altitude to be 4200 feet above the sea.[1] It consists of ancient andesitic lava. Almost directly opposite this is the lowest point of the crater, where the great gash formed by the gorge of the Rivière Blanche occurs (see Pl. XLIII, Fig. 2). The lava bed forming what may be considered the rim of the crater on the southeast side of the gash is 3350 feet above tide, while the real bottom of the gorge where it issues from the crater is five or six hundred feet less in altitude. From this lava bed the rim rises rapidly (30° to 35°) to about 3750 feet above tide (see Pl. XLIV, Fig. 1) and then more gradually along the southern edge until 3950 feet is reached on the eastern edge. The northwest side of the southwestern gash is formed by a pinnacle of ancient lava which appears to be about 4000 feet above the sea, but may be higher. From this point the rim drops somewhat toward the north, but gradually rises again toward the east until the point of rock on the northeast, already mentioned, is reached again. This great crater is about half a mile across, an estimate that is based upon the proportion which it bears to the height of the mountain, looked at from the sea, and from the fact that it took us twenty minutes to walk along the southern third of the rim from our first cairn to the Rivière Blanche gorge without stopping. The walking was not bad, considering the location of the route, and I should estimate the distance traveled in this time at not less than half a mile.

The breadth of the rim varies from a mere knife-edge on the south, north and northeast sides to a sloping plateau fifty to one hundred yards wide on the eastern side. This plateau

tions, is limited on the south by Piton Marcel, on the east by the three peaks of Ti-Bolhommes, on the northeast by Morne Pavillon, and on the west by Morne Lacroix.

"The funnel measures, he says, more than thirteen hectares at the opening.

"Étang Sec lies almost in the center of this immense basin.

"Étang Plein [= Lac des Palmistes] is on the other side of the Morne [Lacroix?]

"The crater is on the southern slope of Morne Lacroix, and therefore on this [=St. Pierre] side of Étang Sec.

"This crater, which resembles a great sugar-pan, has nearly the form of a rectangle, thirty meters long and, at the minimum, twenty meters wide.

"In this pan, or rather this oblong caldron, was boiling a singular black mixture resembling bitumen. It rose in little puffs, emitted from time to time jets of white steam and boiling water, then fell back like creole *matété*, or molasses, only to rise again. Étang Sec was acting as a reservoir for the boiling waters escaping from the crater.

"The sources of Rivière Blanche are below, and on the slopes of Ti-Bolhommes."

[1] The French engineers located at Martinique are reported to have determined (by triangulation ?) that Morne Lacroix had lost 150 feet during the eruption, making its present altitude 4273 feet above tide.

is where Heilprin [1] locates the empty basin of the Lac des Palmistes, which was considered to be the old crater lake of Mt. Pelée. Studying this plateau carefully, we saw that it sloped gently southward and eastward from one side of a low divide running northeastward from the highest point of the crater rim across to a high ridge which paralleled the northern and northeastern sides of the crater. On the northwest side of this divide, the altitude of which was 3950 feet above tide, the plateau becomes a shallow valley and rapidly changes into a gorge discharging into the cañon of the Prêcheur River. Heilprin's description and his unpublished photographs show the existence on this plateau of a small lake-basin, and agree with the assertions of his guides as to its position and as to its depth of not more than five or six feet. He and his companion, E. E. Leadbeater, a New York photographer, state, furthermore, that this plateau and this portion of the crater rim were entirely or practically free from ash and dust deposit. When Mr. Curtis and I visited the spot, the great eruption of June 6 had taken place, and the surface was coated with a thick layer (more than four feet deep in places) of dust and ashes. This material had drifted into depressions to such an extent that we saw no indication of the existence of a lake basin in this plateau. We had a perfectly clear and cloudless period when on the spot, and saw the topography with distinctness. I cannot think that the plateau, including the lake basin, ever has been a primary crater or center of eruption, though at the time of my visits the ground was hot, a scalding temperature being reached less than a foot from the surface, and steam was issuing from numerous crevices. This probably was the site of the Lac des Palmistes, but, that lake was not located in the great ancient crater of Mt. Pelée.[2]

Judging from the account of the guide Romain, from the 'Notes relating to the history of the eruption of 1902,' as

[1] *Op. cit.*, p. 360.

[2] The photograph of the Lac des Palmistes published by Dr. Emil Deckert on page 425 of the 'Zeitschrift der Gesellchaft für Erd-kunde zu Berlin' for 1902 shows that body of water as it appeared in the rainy season of 1898. Deckert describes the lake as being but 2 meters deep and as lying in the middle of a morass or swamp upon a bed of lava. He regards this as a crater lake, though he mentions the fact that there is not and probably never could have been any crater wall on the east and north [south] sides. The eastern end of the Somma ring of Pelée bounds the little plateau on the north, but there

translated in the 'Century Magazine'[1] from the issue of 'Les Colonies' for May 7, from the description by Lafcadio Hearn,[2] and from my own observations while on and near the mountain, the Étang Sec was the real crater lake of Mt. Pelée corresponding, though dry since the eruption of 1851, to the crater lakes of La Soufrière, on St. Vincent, Mt. Misery, on St. Kitts, and others. Its basin is said to have contained water until the eruption of 1851 drained it. The Étang Sec is stated to have been 700 meters (2300 feet) above the sea; its plain was estimated to be about 300 meters (986 feet) across, and the great circle surrounding it was judged to be about 800 meters (2628 feet) in diameter at top. This last estimate agrees closely with my estimate of the diameter of the present crater at top. The walls of the ancient crater must have risen almost precipitously from 1600 to 2100 feet above the Étang Sec, except on the southwest, where was located the great gorge through which flowed the waters of the Rivière Blanche, the sources of which were within the ancient crater.[3] Before the eruption which began last April, the crater of Pelée, except for the size of the great gash, must have been very much like the crater of St. Vincent's Soufrière and that of Mt. Misery, St. Kitts, as I saw it July 8 on my way home, and probably those of the other volcanic cones of the Lesser Antilles.

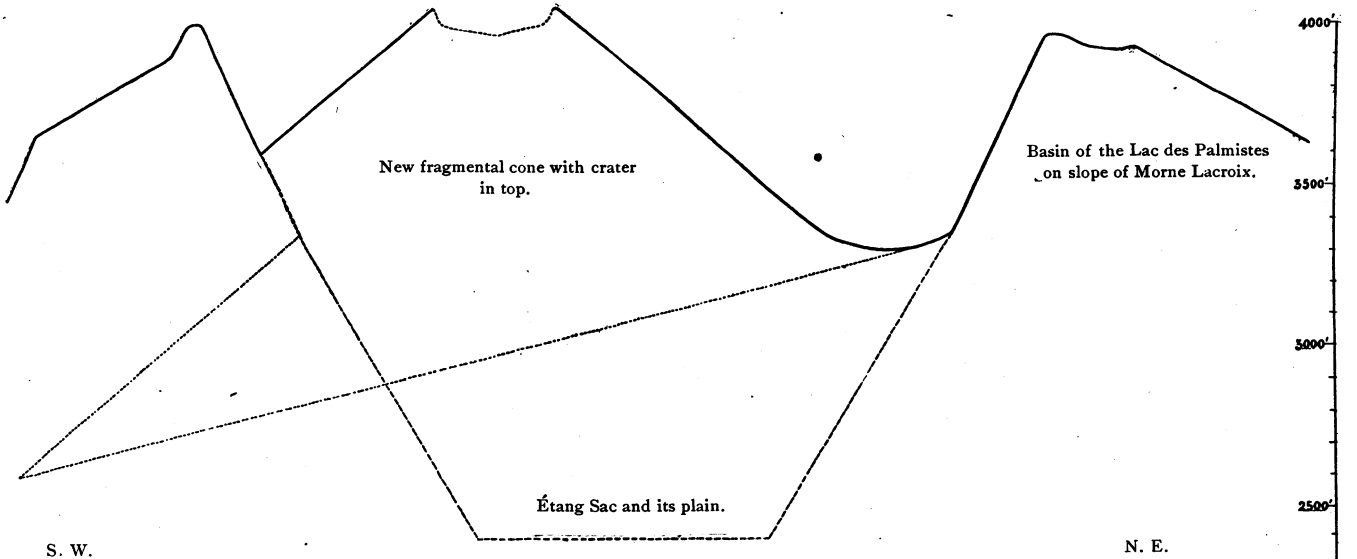
The whole interior of the crater was not seen by us entirely free from steam at any one time, but enough was observed for us to determine its character in its eastern, southern and western portions and to infer the shape of the remainder. The crater, like that of the Soufrière, is in the top of a broad,

is no cliff to the south, on the contrary the plateau slopes off to the south into the head ravines of the Falaise River. It seems as if Deckert must have gotten his north and south points interchanged in his description. The two small craters of 1851 mentioned by Deckert (*loc. cit.*, p. 426) are covered now, probably, by the inner cone, while the series of little craters in the gorge below those of 1851 must have become covered by the débris from the same cone, or have had the evidences of their existence destroyed by the tornadic blasts of the present eruption.

[1] Century Magazine, Vol. LXIV, p. 631. August, 1902.

[2] "Through a cloud-rift we can see another crater-lake twelve hundred feet below, said to be five times larger than the Étang we have just left [the Lac des Palmistes, near the summit]. It is also of more irregular outline. . . . It occupies a more ancient crater and is very rarely visited; the path leading to it is difficult and dangerous,—a natural ladder of roots and lianas over a series of precipices. 'Two Years in the French West Indies,' by Lafcadio Hearn. P. 288.

[3] See Romain, *loc. cit.*



SECTION ACROSS THE SUMMIT OF MT. PELÉE FROM S. W. TO N. E., JULY 6, 1902.

Horizontal and vertical scales the same. Heights hypothetical, except on northeast side. The shape of the crater in the inner cone is entirely inferential. The relation of the great southwestern gash to the fragmental cone is indicated by the dotted line. The broken lines complete the profile of the great ancient crater, as it existed before the eruption of May 8, 1902. The fragmental cone was the scene of greatest activity, but there seemed to be another considerable centre of eruption in the northeastern side of the crater at the base of Morne Lacroix.

truncated cone of ancient tuff agglomerate alternating with lava beds. Some diametral enlargement has taken place, perhaps, during this eruption, though not enough to change the sky-line of the top to any great degree, except in the southwest side. A careful study of the two photographs reproduced on Plate XLIII shows that the old gash there has been greatly widened, and perhaps deepened. The lower part of the outside of this old cone has an angle of slope of 20°, while the upper part is as steep as 30°, according to my determinations. Measurements of the inner slope gave values of 40° to 65° in the portion carved out of the old agglomerate, but the angles increased to 75°, 85°, and even showed great overhanging blocks on the eastern side where the old lava beds form the rim. In the western portion of the crater rises a cone of fragmental material, consisting of dust, ashes and large and small blocks and bombs. This cone is the scene of the greatest activity in the crater and it grew materially in size between the day when I first saw it, May 21, and July 6, when I got my last glimpse of it. It partly fills the old crater, and probably more than compensates for the material torn and undermined from the old walls and thrown out by the eruptive action of the volcano. A large proportion of the activity of the volcano, aside from that of the great outbursts, has gone into the building of this cone (see profile, Plate XXXVI).

The illustration, Plate XLIV, Figure 2, gives the sight I obtained of the inner cone from the eastern side of the crater. At that time its top must have been just about on a level with or, perhaps, somewhat higher than the camera, which was 3950 feet above tide, by aneroid reading. The photograph shows that there was a depressed crater in the top of the inner cone. My measurements of the angle of slope of the southern side of this cone determined it to be 38° to 40°, but there were precipitous portions. The material which rolls and slides down the southwest side of this cone continues directly into the gorge of the Rivière Blanche. The steep-sided valley formed by the inner cone and the inner slopes of the crater rim forms a continuation of the gorge of the Blanche and rises at a considerable angle from the southwestern gash to the base

of the rocky precipice on the eastern side of the crater, where it may be 800 feet in depth. The valley probably continues around the northern side of the inner cone rising in a spiral, for it appears at an elevation of at least 3600 feet on the western side, between the rim of the crater and the cone on the northwest side of the great gash. The new fragmental cone rises, apparently, on the site of the new crater mentioned by Romain, a conclusion which seems to be in agreement with the account of the eruption of May 8 by M. Fernand Clerc as given by Kennan,[1] which is as follows: "About eight o'clock, with a rending, roaring sound, a great cloud of black smoke appeared suddenly on the southwestern face of the volcano near its summit, and rushed swiftly down in the direction of St. Pierre, . . ." Before this outburst, M. Clerc had been observing the great column of vapor rising from the other principal center of eruption, which is located in the valley within the great crater at the base of the high point of rock on the eastern edge (the remains of Morne Lacroix). At intervals columns of steam rise energetically from other parts of the crater valley.

The history of the present series of eruptions may be epitomized somewhat as follows: the gradually returning activity of the volcano began to make itself very manifest in the latter part of April, since visitors to the crater found warm water in the basin of the Étang Sec on the 25th of that month, and the lake was deep. Columns of dust-laden steam rose from an opening within the old crater on the east side of the Étang Sec and from one on the west side of the same basin, and cones rose about these openings. Water in large quantity collected in the old lake basin, assisted, perhaps, by a dam formed across the gorge by the ejecta from the western crater. The water was heated by the action of volcanic forces. On May 5 the heated waters of the crater broke through this dam and rushed, as a deluge of mud and boulders of all sizes, down the gorge of the Rivière Blanche, and overwhelmed the Guérin sugar factory, which was situated at the mouth of the stream. On May 8 began the series of great explosions which have

[1] The Outlook, Vol. LXXI, p. 683. July 12, 1902.

sent steam laden with sulphurous gases, dust, ashes, and stones again and again over the southwest slope of the mountain with the violence of a tornado, several times reaching to St. Pierre and beyond. The author would explain the blasts in the same way as in the case of St. Vincent (see p. 341), but the great gash in the side of the crater of Pelée and the position of the neighboring ridges concentrated the force of the explosions in a certain direction and along a comparatively narrow zone — and the city of St. Pierre with its 26,000 inhabitants [1] and thousands of refugees lay in an amphitheatre, a regular *cul-de-sac*, directly in the path of the blasts. The new cone has risen above the western of the two openings just mentioned, and probably now entirely covers the site of the Étang Sec (see profile, Pl. XXXVI).

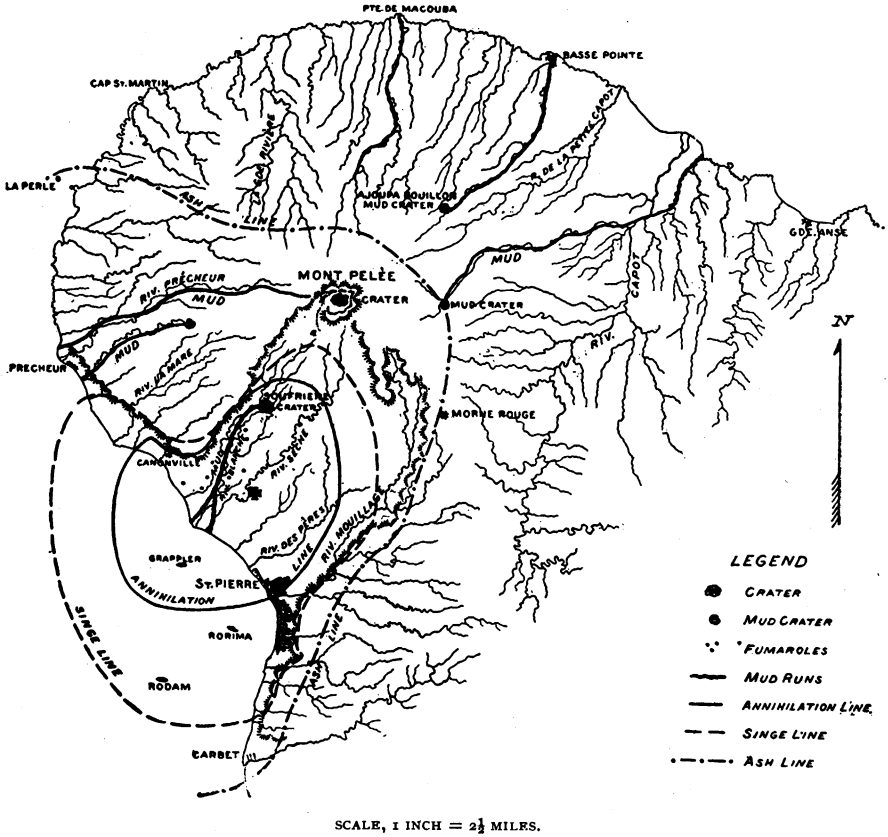
There seems to be no crater or center of eruption in the gorge of the Blanche below the great crater, or in the gorge of the Sèche,[2] but there has been much secondary action along the lower portion of their courses, and much steam, with or without large quantities of dust, has been thrown high into the air when water has reached the heated interior of the vast beds of volcanic ash deposited there during this eruption. Mud-flows and torrents have been very numerous down the

[1] Population in 1895, 25,382, according to the 'Century Atlas.'

[2] Prof. Angelo Heilprin has stated in his article in 'McClure's Magazine' for August 1902, and elsewhere, that eruptions have taken place from a crater located in the gorge of the Rivière Blanche some distance below the great crater. Mr. R. T. Hill has expressed the same idea in his extended article in the 'National Geographic Magazine' (Vol. XIII, pp. 251, 261) for July, 1902, and speaks of this as the center from which came the blast that destroyed St. Pierre. He has recorded the matter on a map which was published on p. 260 of the 'National Geographic Magazine' and which is reproduced here of the same size. Mr. Curtis was with Mr. Hill when the latter made the observations on which this map was based, and therefore knew the spot intended to be represented. He (Curtis) and I stood on the brink of the gorge of the Blanche overlooking it on June 24, examined it again with field glasses from the rim of the crater, where we obtained a view directly through the gorge lengthwise, and repeated the examination from the crater rim on June 26. We could see no crater or center of eruption in the gorge of the Blanche below the great crater, though there has been much secondary or superficial eruption of steam from the ash-beds along the gorge.

I cannot agree with the distribution of the 'zones of devastation' indicated on Hill's map or with the location of 'mud craters' as the origin of the mud-flows of the Sèche, the Blanche, the Falaise and other valleys. It is well to separate the devastation into zones of 'annihilation' and 'singeing,' in a general way, but the crater of the volcano should certainly be included within the former instead of being placed outside the latter, as is done on Hill's map. The real location of the singe line is nearly that of Hill's 'ash line' and is indicated approximately on my map (Plate XXXV), where it is called the limit of devastation. The 'ash line' should be placed at some undetermined distance far beyond the shores of the island of Martinique. The existence of real 'mud craters' on the slopes of Mt. Pelée seems very improbable, for the reasons given on pages 351 and 362 and elsewhere in this Report. The mud-torrents of the Grande Rivière, which were among the heaviest of those experienced on the north and northeast side of the island, are not indicated on Hill's map.

gorges of these streams and on the plateau between them. Some of these flows have come directly from the crater, especially in the case of the Blanche, others have originated on the exterior slopes of the old cone, while others have started in the heavy ash-beds in the gorges in the manner already described in connection with the Wallibou River, St. Vincent, and the Falaise River on the eastern side of Mt. Pelée.



SCALE, 1 INCH = 2½ MILES.

MAP OF NORTHWESTERN PART OF MARTINIQUE BY R. T. HILL.

Reproduced in the exact size from the 'National Geographic Magazine' (Vol. XIII).

On the Sèche-Blanche plateau at an elevation of about 1000 feet above tide and just below the beginning at this point of the steep cone there is an area of one or two acres which probably has been the scene of more secondary action than any other area on the flanks of the mountain, on account of its favorable location for the reception of immense quantities of hot ashes and stones from the eruptions of the volcano. The secondary outbursts from this spot seem to have led some observers to the conclusion that a real crater was located here. I traversed this place twice on June 24 and twice on June 26 and found the ground hot, with many strong fumaroles sending out highly heated air and vapor, but I should not regard it as a crater. Mud-flows have originated above, below and within this area which have rushed down the plateau, as well as along the old watercourses to the sea. I saw several places where such streams of fluid mud had originated through the breaking of the dikes of temporary ponds, which probably were made by secondary outbursts of steam, though the formation of such a pond is not essential to the starting of a mud-flow. The surface of one of the mud-flows on the plateau is shown in Figure 1 of Plate XLVIII. Subsequent rain has washed the fine mud from the stones.

These streams of mud and stones present some characteristics which distinguish them clearly from the surfaces of undisturbed ash-beds. The most striking of these is the existence of curved folds or wrinkles transverse to the direction of flow of the stream, the folds varying in size with the size of the flow. The little streams which break through crevasses in the edges of the main stream, for on a flat surface, the mud flows in partly elevated channels, show wrinkles parallel to the main channel, when they first leave the parent stream. The surface of an unmodified deposit of ash presents a drifted appearance like that of a field of snow or of dry sand on a sea beach, and the Richmond estate as illustrated in Plate XLI is a typical example. The plateau between the Des Pères and Roxelane Rivers, on which was located the Fort Quarter of St. Pierre, was covered with several feet of wind-drifted ash, and it was not a mud-flow or a series of mud-flows which

destroyed this portion of the city, as has been stated in several publications.

In addition to the showers of dry dust and ashes, there fell during the eruptions an immense amount of liquid mud which had been formed within the eruption cloud through the condensation of its moisture. This mud formed a tenacious coating over everything with which it came in contact. That drops of mud too formed in the air and fell as a feature of the eruption is proven by the condition of the walls of the houses in Prêcheur, on which I found flattened spheroids of dried mud which could have formed only in the manner indicated. These flecks of mud were two, four and even six inches across, where two or more had coalesced. They occurred mostly on the northern and eastern walls of the houses. The testimony of the people as to the occurrence of rain during the great eruptions is conflicting, but the existence of this coating and these drops of mud proves that much aërial condensation of steam accompanied the outbursts. Furthermore, the normal rainfall in the mountains is much greater than it is on the lowlands.

During the latter part of our stay on the crater rim on June 24 the rain fell in torrents and the deluge continued until we reached the hot area described on page 360 on our return journey, the heaviest portion of the storm lasting for an hour or an hour and a half. Here we found the fumaroles sending out more steam than they did on our upward journey. When we crossed the Sèche River, we found a foot and a half of yellow, muddy water in place of the two or three inches which we had noticed there in the morning. We had not climbed out of the lowest gorge of the river, before our attention was attracted by the heavy eruption that was taking place from the crater and that was sending enormous clouds of dust-laden steam down the gorge of the Blanche to a point below the so-called Soufrière crater. Thunder-like noises nearer at hand had already made themselves heard and in another minute a wall of hot water ten or fifteen feet high swept with railroad speed over the place where we had crossed the river, and rushed on to the sea. The roar of the torrent was like that of a train,

and the water dashing from side to side of the narrow gorge caused the ground on which we were standing to tremble like a ship when her propeller 'races.' The water was thick and as black as ink with its load of volcanic ash, and it transported with ease boulders five feet in diameter which it had excavated from its banks. In many if not most instances these boulders were the ejecta of the present eruption. To the left a stream of thick, yellowish mud was flowing down from the plateau of the Sèche-Blanche which we had left a quarter of an hour before and was cascading into the Sèche directly beneath us. Soon the black torrent cut into the ash-beds along its banks sufficiently to reach their still highly heated interiors and cause columns of steam to shoot hundreds of feet into the air. The steam columns carried great clouds of black and light brown volcanic sand scores of feet upward. The hot area of the plateau also was sending skyward great columns of steam, and the whole formed a scene seldom witnessed, difficult to describe and never to be forgotten. The next day we measured the gorge and found that the Sèche had deepened its channel at least ten feet in the loosely compacted recent ash during the hour which the flood lasted.

In this instance it seems evident that there was close connection between the heavy rain, the eruption and the black torrent. Two explanations present themselves for consideration: (*a*) the crater may have thrown a mass of accumulated rainwater and ashes bodily over into the head cañon of the Sèche; (*b*) the rain which fell into the crater may have been the exciting cause of the eruption, but the mud-torrent may have been due to the soaking of the heavy coat of ashes on the steep outer slope of the old cone at the head of the Sèche until the resulting fluid mass slid off from the comparatively hard surface beneath and poured down the gorge of the river. There was plenty of water-soaked mud and ashes on the upper part of the mountain to supply the avalanche and some of it was on the verge of fluidity at the time of our visit, hence the latter explanation seems the more reasonable. The little tributary of the Sèche which empties into it on the southeast side close to our point of observation did not show any corre-

sponding torrent, because it does not head on the side of the great cone.

The mud-flows which have descended the Prêcheur River cañon have had ample collecting ground in the 'Atrio del caballo,' to use a Vesuvian term, on the north and northeast sides of the great crater, where the fine dust settles in vast quantities ready, when sufficient water has been added to it, to descend through a narrow gorge into the valley of the Prêcheur. When I was walking along the crater rim above the 'Atrio' June 20, my footsteps started small mud-flows down the outer cone, so liquid was the mud at that time. The ordinary action of the volcano is to deposit dust of impalpable fineness on the inner face of the crater rim. When this deposit becomes thick, it is ready to be swept off by a copious rain and carried through the great southwestern gash out of the crater and down the gorge of the Rivière Blanche as a mud-torrent or flow. There does not seem to the writer to be any need of locating 'mud craters' at the heads of or along the line of the gorges which have been the courses which these torrents of liquid mud have followed to the sea.

Where the tuff agglomerate of the old (outer) cone had been freed from its coat of ashes, especially in its lower portion, *i. e.*, from 1000 to 2000 feet above tide, it showed a smooth, somewhat fluted surface, the soft boulders having been planed off even with the matrix. The whole showed striations parallel with the slope, so that the surface looked like the glaciated rock surfaces so common in the northern latitudes. The planing and the striations seem to have been due to the scouring action of the ash avalanches in this part of their course. They ceased where the steep slope of the cone changed to the gentle slope of the plateau and thus gave opportunity for the material of the avalanches to check its descent and pile up. The sides of the radial gorges on the flanks of Mt. Pelée show approximately horizontal striations. Near the stream beds such striations occur on both sides of the gorges, and are due to abrasion by the sand and stones carried by the torrents. High above the stream on the bluffs facing the crater there are similar striations, but these must have been made by

sand-blast action during the hurricanes of dust-laden steam resulting from the explosions during the great eruptions. These striations extend to the very tops of bluffs rising 500 feet and more above the stream beds at their bases. Some of the sand-blast striations are illustrated in Figure 2 of Plate XLIX.

Erosion seems not yet to have cut deeply into the old land-surface since or as a feature of the eruptions, because here and there all over the mountain side one can find undisturbed roots and charred grass still in place. The shore line from Ste. Marthe Point nearly to Cap St. Martin has been somewhat altered since the eruptions began, some of the river deltas having been built out by the new material brought down by stream and torrent, while others have been cut back by the waves. The most important example of the cutting back is near the mouths of the Sèche and the Blanche, where local land-slides have assisted the sea in forming nearly vertical bluffs from ten to thirty feet in height. These bluffs show sections of the old and the new material now composing the plain. The little ash island which was formed near the mouth of the Rivière la Mare between May 8 and 23, and which was visited on May 23 by Mr. Curtis and two companions, had been washed away by June 14. The stone pavement laid on the beach of St. Pierre was cut into in places, perhaps by the return waves from the ocean accompanying the great out-bursts.

The mud-flow which swept down the Grande Rivière reached the village of the same name at 4 A.M., May 8, four hours before the eruption occurred which destroyed St. Pierre. Three other great mud-flows have traversed this river: on May 11, June 6, and June 22, though no great eruption of Pelée took place on May 11 or June 22. The eruption of June 6 was one of the heaviest that occurred; this time the mud-torrent reached Grande Rivière village about an hour and a half before the eruption took place. The flood of May 8 was the most violent and was three meters (about 10 feet) deep where the valley of the river opens onto the sea coast, according to M. Delsol Désiré, the mayor's deputy of Grande Rivière.

He gave me the foregoing particulars in regard to these floods. The fine mud of these flows entered the buildings on the banks of the river as if it had been thick syrup. In one room that we examined the line of highest level was even with the top of an ordinary table, which would show that the mud was 30 inches deep in the room. At the time of our visit the deposit was nearly dry and it showed a shrinkage of but eight inches or 27 per cent. In another room the shrinkage was greater, showing that the mud there was thinner when it flowed in. Streams composed of such material as this would have great power in the transportation of boulders. The sizes of the boulders brought down by the mud torrents and deposited on the flood plain of the stream above the village and in its old channel may be inferred from Figure 2, Plate L. Some of those measured were eight feet across. The boulders seem to be from old deposits, since they have weathered surfaces. They show fresh abrasion along edges and at corners, due to their recent trip down the gorge. The mud is made up of gray material from the present eruption, together with a large proportion of yellow sand from the old beds through which the river runs. The vast amount of material brought down by the torrents has extended the delta plain fully five hundred feet into the sea and has pushed out the shoreline for several hundred yards on either side of the mouth of the river.

At Basse Pointe the history in regard to floods or torrents of mud has been similar. The principal disasters occurred on May 8 and 27, but the latter was the greater and most of the destruction was wrought on that occasion. Here too the deltal plain has encroached five hundred or six hundred feet on the sea and the ocean currents have spread the surplus material as a new beach for a long distance north and south of the mouth of the river, destroying the little artificial harbor of the town. Boulders ten feet across were brought down and left in the town by the floods, and deposits of sand, gravel, and boulders fifteen to eighteen feet deep rest upon the site of the old market place, which was at the mouth of the river. The thick mantle of mud which coated the great boulders when the first foreign visitors reached Basse Pointe after the floods, had

been washed off by the rains before we reached the place on July 5. The changes made in the shoreline may be learned in part from the photograph reproduced as Figure 1 of Plate L, the houses in the foreground being upon the old shoreline.

The ruins of the city of St. Pierre presented a very interesting field of study, but mostly in the line of speculations as to the cause or causes of the terrible destruction of human life. The walls of the houses (see Pl. XLV, Fig. 1) showed that one or more blasts of tornadic violence had swept over the city and that they came from the direction of the crater of Pelée, for the east and west walls — transverse to the direction of the crater from the city — were thrown down and demolished more generally than the north and south walls. Photographs taken between May 8 and 20 indicate that the first great eruption did less damage to buildings than was wrought by the second. The direction in which most of the trees were felled indicates the same thing, but the trees in the angle of Morne Mirail, which rises behind the middle of the city, were thrown over at all angles progressively, showing that a vortex was formed there. As is indicated by the gradually decreasing degree of destruction in passing from the northern to the southern part of the city (compare Pl. XLVI, Fig. 1, and Pl. XLVII with Pl. XLV), the blast diminished in force as it progressed and expanded, but when it reached Ste. Marthe Point it still had strength enough to throw the statue of Notre Dame de la Garde from its pedestal. The statue, which is of hollow iron ten or eleven feet high, now lies on the edge of the bluff with its foot about fifty feet S. 10° W. from its original position on the pedestal, and directly in line with the crater (see Pl. XLVI, fig. 2). The guns in the Ste. Marthe and Morne d'Orange batteries were thrown from their carriages in the same direction. More than once when I was on the rim of the crater or on the west flanks of the mountain I saw great clouds of dust-laden steam come out of the gash in the side of the crater with sufficient force to descend the gorge of the Rivière Blanche with great rapidity a full mile (*i. e.*, to Hill's 'Soufrière crater') before rising in columns. It was not difficult to imagine that, if this happened when the crater was sending a steam and dust

column only one or two thousand feet high, the action would be vastly greater and even like a hurricane in violence, when the crater was in full eruption and was sending its ash-laden steam column from five to seven miles, or more, into the air.[1] Captain Fraser of the steamer 'Madiana' told me that the hurricane of 1891 left Mt. Pelée as barren of vegetation as it is today. That blast of course carried no great load of volcanic ash like that which burdened this volcanic hurricane to assist it in the work of stripping the hillsides of their verdure.

It does not seem necessary to call in any forces new or strange to the history of vulcanism to account for the phenomena attending the eruption of Mt. Pelée, or the destruction of St. Pierre and its people. The 'flames' reported were perhaps the incandescent stones and bombs flying through the air; and these certainly would set fire to any combustible material upon which they fell. The officers of the French cable-repair ship 'Pouyer Quertier' were eye-witnesses of the eruption of May 8 and describe the cloud as being black when it issued from the crater, but say that it became luminous as it approached the coast.[2] Several times at night during our stay we saw the inner cone of the crater outlined and streaked with lines of 'fire' due to rolling and sliding red-hot rocks and lapilli, and this light was reflected from the steam clouds above the cone. The existence of notable quantities of burning or inflammable gases in the discharges from the volcano seems to me to be as yet undemonstrated.

On two occasions, June 24 and 26, I went into the crater for a short distance beside the southwestern gash and several times was surrounded with heavy clouds of steam from within the abyss. The steam, which was warm, but not hot, when it reached me, contained much sulphur dioxide, SO_2, and at times some hydrogen sulphide, H_2S, but I could not detect the odor of any other gas. The sulphur gases made the atmosphere

[1] Lieut. B. B. McCormick, U. S. N., in command of the 'Potomac,' was on his vessel in the harbor of Fort de France May 20 and made measurements of the angular distance to which the steam column rose during the great outburst that morning. The column subtended an angle of about 30° and the tug was 13.5 nautical miles in a straight line from the mountain. The height of that column therefore was approximately nine miles above the sea, no allowance being made for foreshortening.

[2] Heilprin, *loc. cit.*, p. 367.

difficult to breathe, but the most uncomfortable sensation was due to the irritation caused by the fine, angular dust getting into the respiratory passages and the eyes. Such a mixture, raised to a high temperature, and containing a large amount of dust and a considerable percentage of sulphur gases, would be almost instantaneously fatal to life. It was a cloud like this that rolled over and enveloped St. Pierre for several minutes about eight o'clock on the morning of May 8, and must have caused most of the deaths.

Some of the other causes of death were, (1) blows from falling stones which had been hurled out from the volcano, (2) crushing beneath falling walls and various objects (one man was found with his back broken by a sign which had fallen from over a store front), (3) burns due to hot stones and dust, (4) burns caused by steam alone and (5) by steam mingled with dust, (6) cremation in burning buildings, (7) nervous shock, (8) suffocation from lack of respirable air and, perhaps, (9) lightning. No autopsy was made on any of the thousands of victims of the disaster on Martinique, although men capable of performing such operations had the opportunity of making them within a very few hours after the eruption, hence there is no sure way of determining whether poisonous gases other than those mentioned played any part in the destruction of life. Immanuel Lédée, one of the survivors of the crew of the 'Roraima' told me that when the mucous membrane of his mouth, throat, and nose sloughed off on account of the burning, it was found to be full of the fine black (gray) dust. He was taken to the hospital at Fort de France after the eruption. Samson Cil-Barice,[1] the prisoner who is the sole survivor of the persons within St. Pierre at the time of the eruption, told me in Morne Rouge on June 18 that it was the hot dry 'sand' which sifted in through the window of his cell that caused his terrible burns.

The term 'stellar lightning' has been proposed by George Kennan for the particular form of electrical discharge characterizing the eruptions of Mt. Pelée. This expression, how-

[1] This name is spelled very differently in the various accounts of the disaster. The spelling here is that given me by my interpreter in the presence of the man himself.

ever, implies that the bolts shot out radially from a center in all directions at the same instant, whereas the shafts flew out successively in the different directions. Often they seemed to come from centers, but this appearance probably was due to the foreshortening of the line along which the successive flashes originated. The amount of electricity generated by the friction of the ascending column and the moving clouds of dust-laden steam against the surrounding atmosphere was very great, but much of the discharge seemed to be comparatively noiseless. At midnight of June 26 an eruption occurred which sent up a steam column to a height estimated at 12,000 feet above the top of the mountain. Much of this scintillating[1] lightning played about the column and the 'mushroom' cloud above, but no sound of thunder could be heard from our sloop, which was at anchor off Carbet, seven miles distant. The same form of electrical discharge was observed in connection with the great outbursts of La Soufrière on St. Vincent.

Appendix.

As the pages of this 'Preliminary Report' are passing through the press the newspapers report renewed violent activity in both St. Vincent and Martinique. These reports state that Mt. Pelée has been in constant eruption since August 15 with especially severe outbursts during the nights of August 25, 28 and 30 and September 3, and that La Soufrière broke out again September 1 and on September 3 suffered an eruption greater in force than those of May 7 and 18. No additional loss of life is reported from St. Vincent, but from Martinique comes the news that about 1500 victims must be added to the list of those destroyed by Mt. Pelée.

The dispatches indicate that the devastation on St. Vincent by this last eruption extended southwest considerably beyond the limits of the devastation of May 7 and 18, and that the area seriously affected then and indicated on the map

[1] 'Coruscating' is the excellent descriptive term applied by Dr. Jaggar.

accompanying this Report (Pl. XXXIV) has received a fresh coat of lapilli even greater than that received in May.

Under date of September 5, Wm. J. Durrant, druggist, of Kingstown, St. Vincent, writes me that great volumes of 'smoke' and steam began rising from La Soufrière at 1 P.M. of September 3, but that the violent outburst did not begin until 9:30 that night. Three hours later the eruption was at its height and the last explosion occurred at 5:40 A.M. The roaring of the volcano from midnight onward was continuous and was terrifying even at Kingstown, while the electric display about the great column of dust-laden steam surpassed those of May 7 and 18. The matter ejected by this last eruption is described by Mr. Durrant as being 'a heavy, black sand[1] of the coarseness of blasting powder, with plenty of pumice, but very few stones.' Very little light gray ash like that of the May eruptions fell this time. Richmond

[1] A sample of the material thrown out by the eruption of the Soufrière September 3 was received from Mr. Durrant September 25 and has been examined while these last pages are on the press. It consists of fine and coarse volcanic sand and gravel, apparently for the most part comminuted ancient lavas of the volcano. The fragments from 3 to 15 millimetres across show the coarsely crystalline structure of the old lavas and many of them show that they are parts of weathered masses. Olivine, pyrite (pyrrhotite?) and porphyric crystals of feldspar, hypersthene and hornblende are abundant in these fragments and the separated minerals make up a large proportion of the particles about 2 millimetres in diameter. A comparatively large fragment (20 mm. in diameter) shows phenocrysts of feldspar imbedded in dark brown and light brown scoriaceous glass which is apparently fresh. All the fragments and the particles of sand are coated with dust which seems to be as fine as any that fell during the May eruptions, so that the explanation of Mr. Durrant's statement regarding the relative absence of fine dust from the ejecta of September 3–4 may be that the wind carried most of such material northward and westward away from Kingstown, his point of observation. The cloud from this eruption of La Soufrière is reported to have produced darkness for about six hours on September 4 in Fort de France, Martinique.

The dust-coated sand is dark gray when dry, but is almost black when wet, justifying the description quoted from Mr. Durrant's letter. Comparison of this new material, however, with that collected by myself, May 23–June 10, indicates that there is no essential difference between the ejecta of the earlier and the later eruptions.

The following chemical analysis, which was not received in time for insertion in its proper place in this Report, is of dust from the May eruptions which I collected May 27 in a room in the Langley Park estate house, about one mile north of Georgetown, St. Vincent, in which 21 dead bodies were found after the eruption of May 7. The analysis was made by Dr. W. F. Hillebrand of the United States Geological Survey, to whom our acknowledgments are due, and is the unpublished analysis referred to in his article in the 'National Geographic Magazine' for July (Vol. XIII, p. 297) as emphasizing the greater amount of sulphur present in the ejecta of La Soufrière than in those of Mt. Pelée. The absence of chlorine is interesting as indicating fresh waters as the source of the steam of the eruptions.

SiO_2	55.08	
Al_2O_3	18.00	
Fe_2O_3	2.46	(Only approximate, because of effect of pyrrhotite, 0.91 %—see below.)
FeO	4.57	
MgO	3.34	
CaO	7.74	
Na_2O	3.45	
K_2O	0.65	
H_2O at 100° C.	0.66	
H_2O above 100° C.	1.39	
TiO_2	0.80	

Vale[1] estate received about 8 inches of ash, Chateaubelair about 6 inches, Petit Bordel[2] about 4 inches. Southward the coat of ash diminished to Peter's Hope, an estate on the west coast about ten miles southwest of the crater, where it ceased to be of importance. The beginning of this eruption was a mud-flow toward the site of Morne Ronde village.

Regarding Martinique, the telegrams state that the village of Morne Rouge has been destroyed and that the area of devastation has been extended five miles on the eastern side of Mt. Pelée. If the latter statement be true, nearly the whole northwestern section of the island, as shown in Plate XXXV must have been laid waste by the volcano, and the eruption of Pelée has risen already to the magnitude of that of the Soufrière. Morne Lacroix is reported to have disappeared altogether and the crater to have extended greatly toward the east. This may indicate that the vent under the new inner cone described in these pages has become partly clogged, and that the main activity has shifted to the vent mentioned (see p. 357) as being east of the Étang Sec at the base of the western face of Morne Lacroix. If this has taken place, as seems highly probable from the reported destruction of Morne Lacroix, the new inner cone acted as a dam in the great southwestern gash which played such an important part in the destruction of St. Pierre, so that the last eruptions came from a centrally located vent (like that of La Soufrière, St. Vincent) and the débris from the crater was distributed more symmetrically about the cone. The position of the great gash and neighboring cliffs with reference

ZrO_2	?
CO_2	None
P_2O_5	0.17
SO_3	0.24
Cl	None, or faint trace
S	(0.36) included in pyrrhotite below
NiO	None
MnO	0.21
BaO	Trace
SrO	None
Li_2O	Faint trace
Fe_7S_8 (?)	0.91
	99.67

[1] This is the estate mentioned in the footnote to page 334 as having been just outside the area devastated by the eruptions of May 7 and 18.

[2] The Petit Bordel estate is the one which I used as headquarters during part of my stay on St. Vincent.

to the vent on the western side of the Étang Sec, which was the most active center of eruption in May, June, and July, directed the blasts of the earlier eruptions toward St. Pierre and away from Morne Rouge. That directive factor having ceased to have force, through the growth of the inner cone and the (apparent) shifting of the center of activity to the eastern vent, Morne Rouge, a mile and a half nearer the crater than the middle of St. Pierre, came far within the area of destruction and received the full fury of an eruption.

The electrical phenomena attending these later eruptions of Mt. Pelée, also, are described as having been even more magnificent and terrifying than those observed in connection with the earlier explosions.

The sympathy in action between La Soufrière and Mt. Pelée, which was indicated in the eruptions of May, and the phenomena leading thereto, has been made more manifest by these later outbursts.

September 15, 1902.

EXPLANATION OF PLATE XXXVII.

Fig. 1.—La Soufrière, St. Vincent. Southwestern portion of the rim of the crater. The footprints on the crest are those of our party. See page 336.

Fig. 2.—La Soufrière. Southeastern portion of interior of crater. Column of steam rises from lake in bottom. View illustrates alternation of the beds of lava with those of tuff in the make-up of the island. See page 336.

FIG. 1.

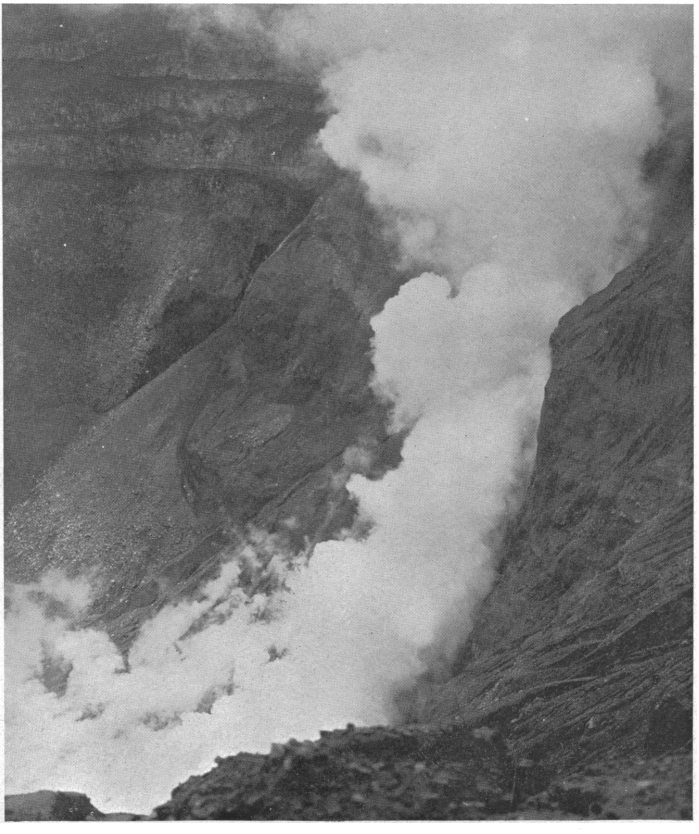


FIG. 2.

EXPLANATION OF PLATE XXXVIII.

La Soufrière, southwestern side. Ruins of the Wallibou sugar factory, the effect of the eruption. The cliff in the foreground is the indication of the landslide which carried the site of the village of Wallibou into the ocean. These ruins are shown almost in the middle of Plate XXXIV.

Photograph by J. C. Wilson.

RUINS OF THE WALLIBOU SUGAR FACTORY, ST. VINCENT.

EXPLANATION OF PLATE XXXIX.

Fig. 1.—La Soufrière, southeastern side. The Rabaka Dry River valley where it issues from the hills, showing bed of ashes where a gorge 200 feet deep existed before the eruption. From a distance looks like a glacier. See page 343.

Fig. 2.—La Soufrière, southeastern side. Trail to summit showing effects of volcanic blast. There was a bridle path on this ridge before the eruption. See page 341.

FIG. 1.

FIG. 2.

EXPLANATION OF PLATE XL.

Fig. 1.—La Soufrière, southwestern side. Valley of the Wallibou River, showing ash-beds 50 to 75 feet thick, and a secondary or superficial outburst of steam. See page 343.

Fig. 2.—La Soufrière, southwestern side. Another secondary outburst of steam in the Wallibou valley. This superficial eruption threw a temporary dam across the river and caused a mud-flow. See page 343.

FIG. 1.

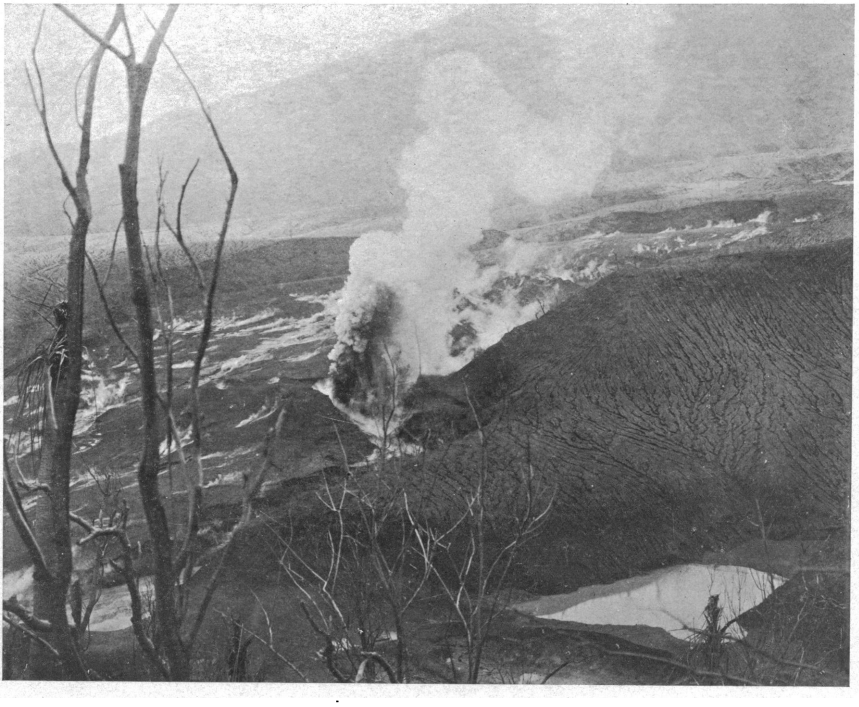


FIG. 2.

EXPLANATION OF PLATE XLI.

La Soufrière, southwestern side. The Richmond estate, showing the wind-drift surface of the newly-fallen volcanic ashes. The deposit here was from 2 to 4 feet in depth. The building was wrecked in the hurricane of 1898, and had been only partly restored before the eruption which put it into its present condition. Chateaubelair Island is in the background at the right. See page 343.

Photograph by J. C. Wilson.

THE RICHMOND ESTATE, ST. VINCENT.

EXPLANATION OF PLATE XLII.

Fig. 1.—La Soufrière. Valley of Wallibou River in the foreground. Dendritic drainage well illustrated on the divide between Wallibou and Trespé valleys. See page 344.

Fig. 2.—La Soufrière. Trail to summit at 1500 feet elevation showing mud-covered ridge with almost unaffected coating on the crest.

FIG. 1.

FIG. 2.

EXPLANATION OF PLATE XLIII.

Fig. 1.—Mt. Pelée, Martinique, from the west, before the eruption. Photograph by D. L. Elmendorf. See page 356.

Fig. 2.—Mt. Pelée from the west, showing the great crater. This photograph happens to have been taken from almost exactly the same position as the preceding, and a careful comparison of the two shows the changes wrought in the western side of the summit by the eruption. See page 356.

FIG. 1.

FIG. 2.

EXPLANATION OF PLATE XLIV.

Fig. 1.—Mt. Pelée. Southern rim of crater at about 3750 feet altitude.

Fig. 2.—Mt. Pelée. The inner cone of the crater, showing the scene of greatest activity. The crater rim in the foreground is 3950 feet above the sea. See page 356.

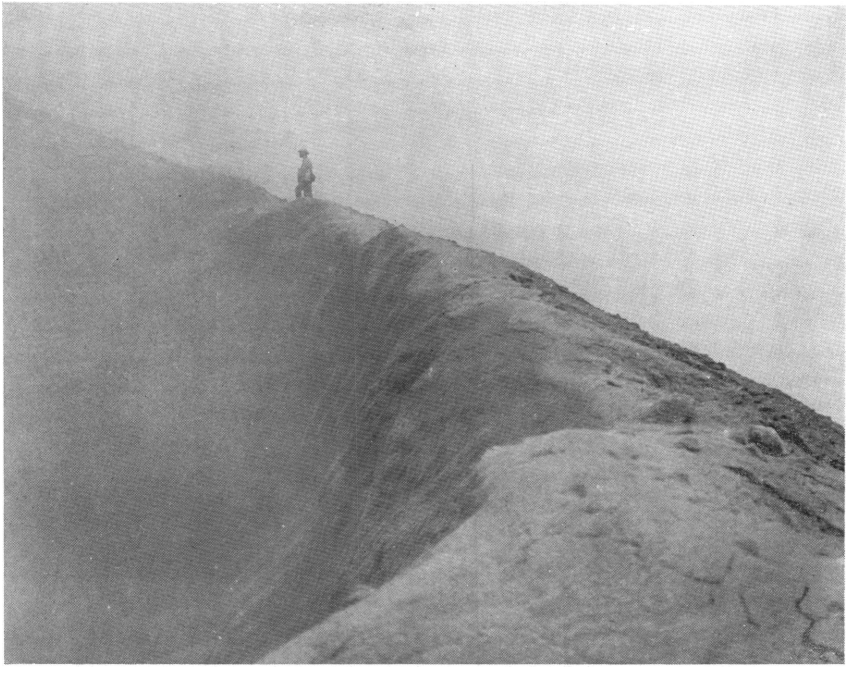


FIG. 1.

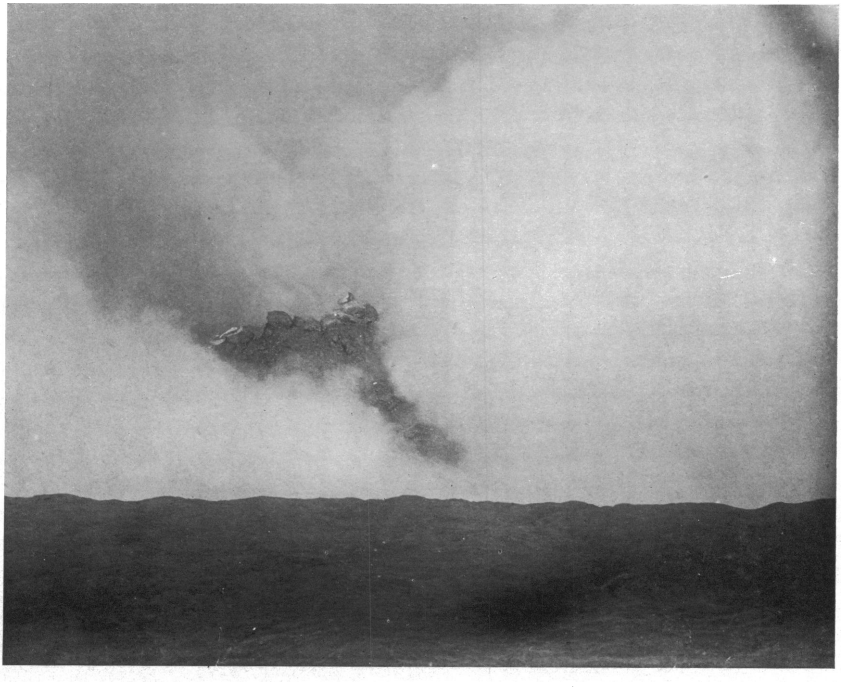


FIG. 2.

EXPLANATION OF PLATE XLV.

Fig. 1.—The ruins of St. Pierre from the south. The north and south walls have been injured by the eruption less than the east and west walls. Photograph taken June 14, 1902. Most of the destruction seems to have been wrought by the eruption of May 20. See page 365.

Fig. 2.—St. Pierre and portion of Rue Victor Hugo, May 21, 1902. It seems probable that many of the boulders in the foreground of the picture were thrown out from the volcano during this eruption. The heap in the middle of the picture, however, is composed mostly of rubble from the adjoining walls. See page 350.

FIG. 1.

FIG. 2.

EXPLANATION OF PLATE XLVI.

Fig. 1.—St. Pierre. Valley of the Roxelane or Rivière des Blanchisseusses in the northern part of the city, as it appeared May 22, 1902. See page 366.

Fig. 2.—St. Pierre. Statue of Notre Dame de la Garde, which was thrown from its pedestal by the volcanic blast. The statue is of iron, hollow, about 11 feet high, and lies on the brink of the bluff, with its base about 50 feet from its original position on the pedestal. See page 366.

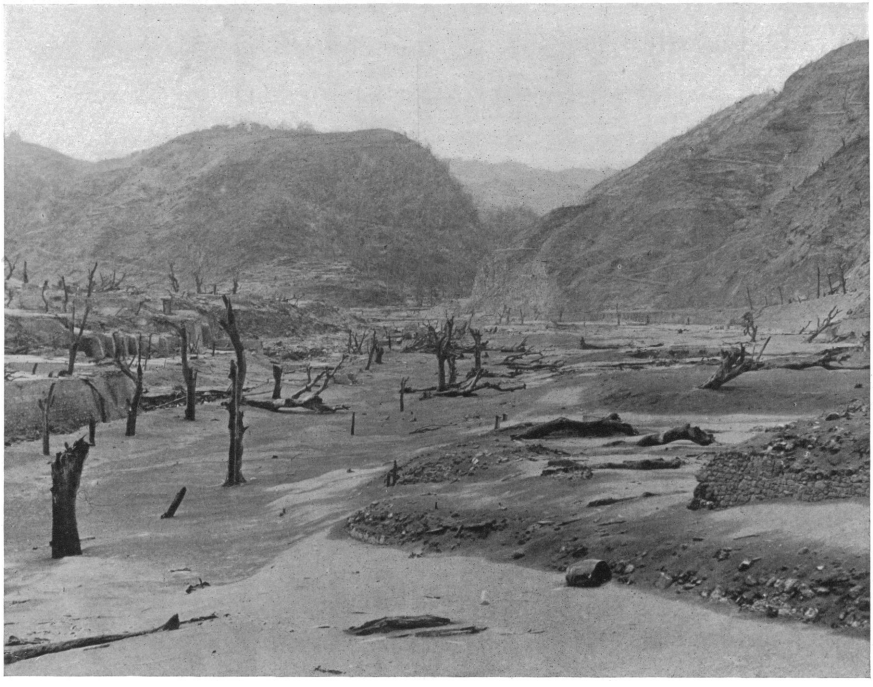


FIG. 1.

FIG. 2.

EXPLANATION OF PLATE XLVII.

Fig. 1.—St. Pierre. Ruins of the great distillery in the Fort Quarter of the city, showing the holes in the iron tanks, due to the volcanic bombardment. See page 349.

Fig. 2.—St. Pierre. Near view of one of the holes. The material of the tanks is quarter-inch boiler iron. See page 349.

Fig. 1.

Fig. 2.

EXPLANATION OF PLATE XLVIII.

Fig. 1.—Mt. Pelée, southwestern side. Mud streams of the Sèche-Blanche plateau at about 800 feet above the sea. See page 360.

Fig. 2.—Mt. Pelée, southwestern side. Ejected block on Sèche-Blanche plateau near sea coast. Block is about 30 feet long, 24 feet wide and 22 feet high. See page 348.

FIG. 1.

FIG. 2.

EXPLANATION OF PLATE XLIX.

Fig. 1.—Mt. Pelée, southwestern side. The gorge on the Rivière Sèche through the ash-beds near its mouth.

Fig. 2.—Mt. Pelée, southwestern slope. The bluff in the center of the view shows the horizontal striation due to the action of the volcanic sand-blast. See page 364.

FIG. 1.

FIG. 2.

EXPLANATION OF PLATE L.

Fig. 1.—Basse Pointe. View showing the extension of the delta and shore line by the great floods of May 8 and 27. The houses in the foreground stand nearly on the old shore line. See page 365.

Fig. 2.—Grande Rivière. Some of the great boulders left on the flood plain and in the channel of the river, above the village, by the torrents of May 8 and 11 and June 6 and 22. See page 365.

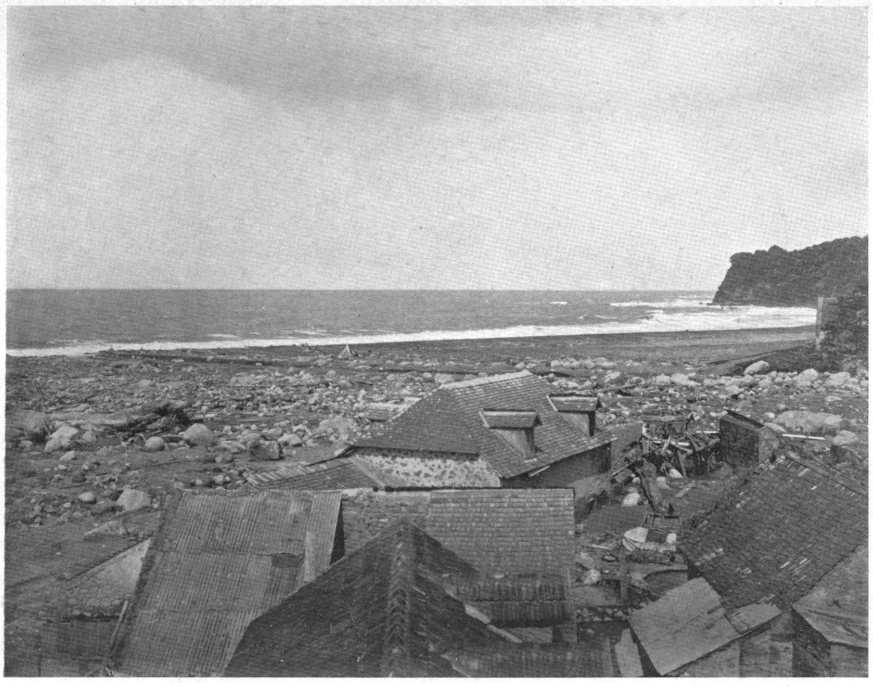


FIG. 1.

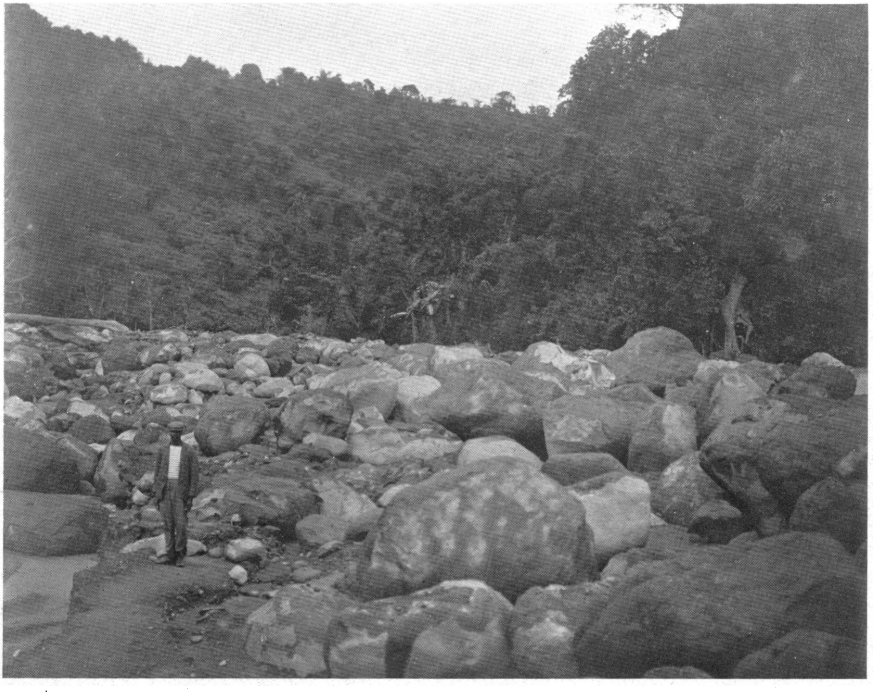


FIG. 2.

EXPLANATION OF PLATE LI.

Volcanic bomb from Mt. Pelée. The peculiar 'bread-crust' surface of this mass shows that it was thrown out of the volcano in a half-melted condition and was cooled in the air. Collected by the American Museum expedition near the site of the Guérin factory. See page 347.

'BREAD-CRUST' VOLCANIC BOMB, MT. PELÉE.

Height of specimen 2 feet 2 inches.