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

PART II.

The Changes in the Districts and the Subsequent History of the Volcanoes.

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[Plates 9–25.]

In 1902, Drs. Anderson and Flett had the honour of being commissioned by the Royal Society to visit the volcanoes of the Soufrière of St. Vincent and Montagne Pelée in Martinique, and Part I. of their Report on the eruptions of the volcanoes was published in the Philosophical Transactions for 1903.*

It was intended that Part II. should include an account of the subsequent changes in the deposits of volcanic ejecta observed on that visit, and also on the petrology of the specimens collected in 1902.

In the Spring of 1907, Dr. Anderson revisited the West Indies, but Dr. Flett being unavoidably detained in England by his official duties, Dr. Anderson is alone responsible for the field observations on the topography and geology, and also on the return of vegetation in the earlier portion of this Part II., while Dr. Flett contributes the petrology. (See the following paper.)

By the kind permission of Sir Daniel Morris, K.C.M.G., Mr. W. N. Sands, of the Botanical Gardens, St. Vincent, was able to accompany Dr. Anderson to the Soufrière, and make a collection of the flora which is gradually reappearing on the devastated area. These plants have been identified by him, and also, where necessary, by

* "Report on the Eruptions of the Soufrière in St. Vincent in 1902, and on a visit to Montagne Pelée in Martinique," Part I., by Tempest Anderson, M.D., B.Sc., F.G.S., and John S. Flett, M.A, D.Sc., F.R.S.E., 'Phil. Trans.,' A, vol. 200, pp. 353–553, Plates 21–39.

Sir DANIEL MORRIS. Thanks are also due to His Honour E. J. CAMERON, C.M.G., Administrator of St. Vincent, and to DUNCAN MACDONALD, Esq., of Wallilabu, for their kind assistance and hospitality, also to the Rev. T. HUCKERBY, of Chateau Belair, for much help in visiting the Soufrière, and for information regarding the eruptions subsequent to the great outbreak of 1902. The author's special thanks are also due to Professor T. G. BONNEY, F.R.S., and GEORGE YELD, Editor of the "Alpine Journal," for much kind advice and literary assistance.

The map in Part I., Plate 39, shows that the north end of the Island of St. Vincent is formed by the cone of the Soufrière volcano. In the summit of this mountain lies the principal or old crater, nearly a mile in diameter, from which the eruption took place in 1902. There is likewise a much smaller crater, the so-called "new crater," which was active in 1812 and may have been formed in that year. These two craters are surrounded to the north by a large crater-ring of older date, broken down towards the south, which has been referred to as the Somma Ring, since it bears the same relation to the working cone of the Soufrière as Somma does to Vesuvius. The whole mountain group was formerly known as Morne Garu, but the name has now been appropriated to another mountain about three miles to the south, also formed of volcanic material, but of much older date, which is separated from the Soufrière by a deep depression extending right across the island. The part of this depression on the eastern or windward side of the island is occupied by the Rabaka and other smaller streams, and is called the Carib country, while that on the western or leeward side is drained by the Wallibu and other streams, and is here referred to as the Wallibu district. In the 1902 eruption a certain amount of the ejecta overtopped the Somma Ring and descended some of the valleys to the north of it, but by far the greater portion was discharged into the above-mentioned transverse depression. The water from the crater lake was discharged at the beginning of the eruption down the Rabaka and Wallibu Rivers, the former of which it rendered impassable, and thereby cut off escape from the Carib country, where the greater part of the deaths occurred, while the solid and gaseous ejecta in the form of the incandescent avalanches and black clouds* descended to both sides of the island, and the most important geological phenomena were observed in the Wallibu district. These phenomena, including the incandescent avalanche into the Wallibu valley, the partial re-excavation of that valley by the river, the secondary explosions of steam and hot ash, the discharges of boiling mud, and the formations of new fans at the mouths of the rivers, have been fully described in Part I., p. 428, *et seq.*; as has been also the subsidence of part of the coast between the mouths of the Wallibu and Morne Ronde Rivers (Part I., p. 453, *et seq.*). This district was therefore the part to which attention was specially directed in 1907, with a view of observing the further progress of these changes and the return of vegetation.

* Called Nuée Ardente by the French Commission to Martinique, and later Nuée Péléenne. See Note, p. 298.

The Wallibu District.

The Wallibu valley, like its fellow, the Rabaka, though profoundly modified by denudation, is not primarily a valley of erosion, but a gap left between the mountains of the Soufrière and Morne Garu as they have been built up stage by stage. The slopes of Morne Garu to the south are formed of old tuff and occasionally lava, all dipping away from the centre of that mountain and with their surfaces sloping towards the valley more or less conformably to the dip. This was very evident when the surface was bare of vegetation in 1902 (Part I., Plate 29, fig. 2). The north slopes of the Wallibu district, including in that term the area drained by the smaller parallel rivers of the Wallibu Dry River, Trespé River, Morne Ronde, and others, all to the north of the Wallibu, are composed of a series of beds of a newer date formed by ejecta from the Soufrière. They dip away from the crater of that mountain and abut unconformably against the older beds of Morne Garu. They have been dissected into flat-topped plateaux (Plates 9 and 14) by the above-mentioned rivers, which run in deep gorges with steep and often precipitous sides. These gorges have again been filled in places by ejecta of later eruptions, and re-excavated in different degrees and sometimes not along the old lines, leaving plateaux and terraces of different ages and heights. The lower valley of the Wallibu is a good example of this.* The river as it descends from the mountains in a westerly direction turns abruptly to the south, and then to the west again, after which it flows by a straight course of almost two miles direct into the sea.

The south or proper left bank of this lower portion was before the eruption of 1902, and is now again, moderately sloping and diversified by side gullies, almost deserving the name of valleys, in the old beds of Morne Garu, which show a fairly advanced stage of denudation. The north bank, on the other hand, is cut from a plateau, flat topped in the greater part of its extent, but with a rounded hill at its eastern end, and a moderate slope towards the sea on the west above the sites of the Richmond Estate House and Wallibu Works. Its top slopes gently to the south-west, and there is a terrace on the opposite bank of the river, near the lower end of the valley, which forms a continuation of the same slope, and shows that the plateau was once continuous across the valley which has since been excavated. Unlike the sloping bank opposite, it presents towards the valley a precipitous face in places nearly 200 feet in height. In the 1902 eruption this part of the valley was filled by the incandescent avalanche to a depth of at least 100 feet in the upper part, and to a smaller extent towards the sea, and it was in this deposit of hot ash that the steam explosions, slips of hot ash, flows of boiling mud, and other secondary phenomena took place. They are illustrated in Part I., Plate 29, fig. 2, where a deep channel is in progress of re-excavation on the south side of the valley, while a large plateau of hot ash still occupies its north side.

* Part I., Map, Plate 39; Part II., Plates 9, 10, 11.

In 1907 almost the whole of this ash had been washed away, but a fragment remained in the shape of a terrace about 60 to 80 feet high, which showed the height to which the valley was originally filled (see Plate 10). It is situated on the north side of the valley, just below the abrupt turn to the west above mentioned, and is *in situ* except for a few partial landslides; the ash of which it is formed is unstratified and contains very few ejected blocks or fragments of any kind. The round hill behind it is the same as one shown to the left of the 1902 photograph in the middle distance. It was impossible to get a photograph from exactly the same position as before, since the ash bank on which the camera stood in 1902 has been all washed away, and the Wallibu plateau adjacent, when tried from several directions, proved inaccessible. The camera in 1907 was therefore placed on the floor of the valley in a similar position, but 60 to 80 feet lower. This floor, or more strictly terrace, as mentioned below, is all composed of water-sorted material, chiefly gravel and coarse sand, but with a good many blocks as big as a man's head. They represent ejected blocks and fragments of lava derived partly from the ash of 1902, and partly from older beds, the fine ash in each case having been washed away. The surface of the gravel bed showed marks of quite recent running water, and Mr. DUNCAN MACDONALD, who knows the place intimately, stated that during the last winter, 1906–07, the river ran along the foot of the north bank of the valley. When examined in March, 1907, it ran along the south side of the valley, and had already in those few months excavated a new channel about 30 feet in depth, as shown in Plate 11, which was taken from the top of the valley floor or terrace, the surface of which is shown in the previously mentioned Plate 9. The stratification as exposed in the side of this new valley is very distinct, and the sorting by water, mentioned above, is very evident. This gorge appears to have been excavated when the river was in flood, and as the water subsided and the excavating power became less, its channel in the bottom of the gorge became more tortuous, and it formed small meanders and left small terraces on its sides at different heights. This plate also shows the precipitous and inaccessible character of the north side of the valley where it is formed of the Wallibu plateau till it gets lower as it approaches the sea, and this is a characteristic specimen of the early stages of denudation in these ash beds.

The south side, on the contrary, is sloping, and its outline is characteristic of a more mature stage of denudation. This sloping character has enabled more numerous terraces of the new deposits to survive. Some low down by the side of the river consist solely of water-sorted material, while others show patches of ash in its original condition higher up the slope. In one or two cases it is possible to compare the two in juxtaposition (Plate 12, fig. 1), in which case the lower terrace of water-sorted material stands almost vertical where it has been undermined by the river in two stages; while behind it a mass of ash *in situ* shows most beautifully the marks of rain-water running over and down the surface. Further away again, the slopes of the old valley show denudation in a more mature stage.

Further up the mountain the remains of the avalanche became more abundant in the valley bottoms (Plate 13), and here they were also often better preserved, so that traces of the feather-pattern erosion, so noticeable in 1902,* were still visible on the surface. This was mainly due to the surface of these ash deposits, like those to be presently mentioned on the plateaux and on the ridges, having consolidated into a crust almost like a cement pavement which resists the action of the rain. Another very curious and, it is believed, novel point was observed with regard to these massive ash deposits. Instead of one stream re-establishing itself along the centre of the deposit, the tendency is for a new stream to form on each side at or near the junction of the new ash with the old valley walls, and as these streams deepen themselves, two new valleys are formed where only one previously existed, and the walls of each are composed on the one side of the new ash, and on the other of older tuff with occasional terraces of new ash. Sometimes the two valleys coalesce by the washing away of the central mass, but quite often the two remain distinct, as in the case of the Trespé River† and Wallibu Dry River to be mentioned shortly. The fact of this side formation of streams is clear; it is seen in the ravine just noticed, also in the upper Rozeau, and in several of the plates in Part 1, where, though not noticed at the time owing to its being then in an early stage, it is distinctly visible when looked for, but the cause is not so clear. It appears to be due to the fact that the water from the old slopes in running down into the original valley meets the soft new ash, and at once turns down along the valley and so starts the new stream, and it seems likely that the chief cause of its so turning is that the surface of the deposit tends to be higher along the middle of the valley than at the sides, the shape of the mass somewhat resembling a glacier, which it is well known is usually higher in the middle because of the more rapid motion of that part.

The Wallibu Dry River and Trespé River.—These are two small and short rivers to the north of and parallel with the lower part of the Wallibu valley, and both run in deep gorges in the floor of a wide valley bounded on the south by the Wallibu plateau. In 1902 both these gorges were filled with new ash to the level of the main valley floor, and the process of re-excavation of one of them is shown in Part I., Plate 30, fig. 2. It was noticed that this main valley was wider and more open than the Wallibu valley,‡ but no explanation was forthcoming at the time. Mr. DUNCAN MACDONALD now informs me that before the 1812 eruption the Wallibu River flowed down the Wallibu Dry River, and that its course was changed after that eruption. Mention has already been made of the Wallibu valley making an abrupt turn to the south and turning again to the west round the

* Part I., Plate 26 and Plate 28, fig. 1.

† I heard this river called also Cobrée. The confusion is due to these gorges being liable to be filled up and re-excavated in slightly different positions.

‡ Part I., p. 429.

end of the Wallibu plateau. The line of this upper part of the valley, if prolonged to the sea, passes to the north of the Wallibu plateau down the broad valley of the Wallibu Dry and Trespé Rivers, and is blocked opposite the east end of that plateau by a great deposit of ash, which has deflected the river into its present course (Plate 9). Below this obstruction the broad open valley can still be traced as described above, while its floor is now occupied by the two small river valleys above mentioned, divided by a plateau or ridge often only a few yards wide, and sometimes a mere knife edge. It is formed of ash different from and less consolidated than that composing the walls of the main valley, and its top is considerably lower than the Wallibu plateau. A closer inspection of the Trespé valley (Plate 12, fig. 2), where the narrow gorge has been emptied of the 1902 ash, now shows that the north wall is much higher than the south, and also formed of older and more consolidated tuff. If the sides of the picture were reversed, it might serve as a view in the Wallibu Dry River, the higher bank being in this case the Wallibu plateau to the south. It is thus clear that these two rivers are an example in a more advanced stage of the process which, as described, is now taking place in the ash of 1902 in the ravine above mentioned.

The Wallibu plateau is composed of ash older than that dividing the above two small rivers, but still comparatively new, and its flat top and precipitous sides, both north and south, proclaim it to be in an early stage of denudation, while the south bank of the Wallibu is composed of older tuff and lava, and shows a much more mature type of denudation, viz., sloping hills with rounded or ridged tops, and a good deal weathered into valleys or gullies. The same description would apply to the north face of the plateau, which is precipitous and obviously much less advanced in weathering than the slopes of the Soufrière on the opposite side of the valley to the north. The mass appears to be the remains of an avalanche or succession of avalanches of hot ash poured into the depression between the Soufrière and Morne Garu, on an enormously bigger scale than anything formed by recent eruptions. It would seem that the present bed of the Wallibu to the south, and the broad valley of the Wallibu Dry and Trespé Rivers to the north, are each the enlarged and deeply excavated development of the valleys that were formed at the sides of this prehistoric avalanche.

The Fans and Low Plateaux.—The part of the Wallibu district between the sea and the Wallibu plateau, and others like it, of comparatively old date, consist of a series of low plateaux and fans (Plate 14). These have been formed by a succession of discharges from the Soufrière, which are mostly unstratified, and have been partly or wholly consolidated into tuffs. They are much dissected by ravines cut by the rivers, and the materials brought down by these have formed fans and deltas consisting of water-sorted materials. Sometimes the rivers in the earlier stages of their cutting through the plateaux have deposited water-sorted beds on their surfaces, which are interbedded with those of ash *in situ*, rendering the structure more

complex, while the fans laid down in the earlier stages of denudation after an eruption are dissected by the rivers later on, leaving terraces at one or both sides which merge into the plateaux. The plateaux and fans thus pass insensibly one into another, but on the whole it will be convenient in this paper to restrict the term "fan" to the portion over which the river at present habitually flows at intervals, and reserve the term "plateau" for the more completed and generally higher portion over which such a flow no longer generally occurs.

In the eruption of 1902 the incandescent avalanche which came down the Wallibu, as soon as it had passed the deep part of the valley, spread like a fan over the plateaux to the north and south. To the south it turned round the lower end of the Richmond ridge, where it formed, along with water-borne material, a bar at the mouth of the Richmond River. This bar still exists, though much washed away. The river has cut a sinuous channel through it. The shore of the plateau, which in 1902 was sloping,* is now washed away into a steep cliff 30 or 40 feet high. There is only a narrow steep beach at its foot. The plateau at a little distance from the shore is about 50 feet in height, and the older portion further inland about 150 feet, or three times as much.

The fan of the Wallibu in 1902 extended beyond the coast line, and was very steep. Gushes of hot mud came down it,† and tended continually to build it up. In 1907 it scarcely extended beyond the coast line, and both have receded considerably. The fan is no longer steep, but has only a very gentle slope, as shown in Plate 14, which is taken from the plateau just mentioned. The river appears to wander frequently about this fan, as it does further up the valley. In March, 1907, it flowed at the south side of the fan, close under the above-mentioned cliff, and is consequently concealed behind it in the photograph. The avalanche, where it spread north towards the Richmond Estate House below the end of the Wallibu plateau, was of unequal thickness. This, in a good section on the north bank of the Wallibu fan, was from 10 to 20 feet, and, curiously, it was greater nearer the sea coast. The section exposed extended in places to below the old surface, and the line was marked by the vegetation which was returning in the old soil.

The plateaux to the north present similar features in the re-excavated river valleys. They show good sections of soft tuff, with a capping of new ash, generally from 10 to 20, or even more, feet in thickness, and the line of the old surface is here again visible by the return of vegetation. Except about the Wallibu House and Works, their surface is generally bare and consolidated into a crust.

The Wallibu Subsidence.—This took place along the shore north of the Wallibu and south of Larikai Point. The foreshore to a breadth of about 200 yards and a length of above a mile appears to have subsided into deep water by a sort of submarine landslide, a secondary effect of the earthquakes connected with the eruption.

* Part I., Plate 24, fig. 1.

† Part I., Plate 23, fig. 2.

Further slides are reported to have taken place at the times of the eruptions in September, 1902, and March, 1903, but this is not very certain. The cliffs in this part are higher than further south, but present similar structural features, viz. :—tuff capped with new ash (Plate 14). A new beach is forming along the base, the materials of which appear to be furnished partly from the cliffs, partly by that brought down by the rivers. The gorges cut through this plateau are often very narrow, and their steep sides show fine sections of the tuffs and ash beds.*

The Soufrière.

The Upper Slopes.—The upper slopes of the mountain are chiefly formed of beds of tuff like the lower parts, but contain perhaps a larger proportion of ejected blocks which naturally fell in greater abundance nearer the crater. They are much cut up into deep ravines which are separated by the ridges, the slopes of which are often very steep, as described in Part I.† Even in 1902 the new ash, which had never been thick on these slopes, was in great part washed away, and it was only on the ridges and in some of the valley bottoms that any considerable amount of that ash remained, and this process, of course, has gone on ever since.

The ash on the ridges still remains, and its surface is consolidated into a thin but hard crust similar to that on the plateaux. This extends generally only to a width of a few feet, and often not more than one or two. On each side of the ridge where the ash has been washed away the old soil has been exposed, and it would doubtless also have been in a great measure removed if it had not been held together by the roots of plants which, as mentioned below, were in many cases not killed. Even when dead they no doubt held the soil together to a large extent while the new vegetation has been re-establishing itself.

The old Carib track to the summit ran along one of these ridges (Plate 22, fig. 2), and the consolidated ash forms in most parts an excellent footpath along the former lines. It is true that in places the ridge has been carried away by landslides, but a comparatively small amount of labour would suffice to restore it to a perfectly useful condition. The path for a considerable distance overlooks the upper part of the Rozeau valley, which extends nearly to the summit of the mountain, and this is a good example of a high valley in which extensive ash deposits were formed. It was here that Mr. T. M. Macdonald saw explosions in the earlier stages of the eruption, and these were supposed to proceed from parasitic craters, *i.e.*, side branches of the main chimney. The place was pointed out to me by his brother in 1907. It was impossible to approach it closely except at unjustifiable risk, but an examination from a distance of perhaps 100 yards revealed nothing but a hollow in a bed of ashes, which no doubt was merely the locality of a secondary explosion in the hot ash like those

* Plate 12, fig. 2. In lower Trespé valley.

† Part I., Plate 31, fig. 2, and Plate 35.

described in Part I., p. 438. This body of ash, which is well seen from near the Maroon tree about half way up the mountain, presents one of the best examples of the rounded character of the deposit in its original state, where, as mentioned above, it was higher in the middle than at the edges.

The Crater.—In 1902 we ascended to the lip of the crater twice, from the south-west and south-east sides respectively, by the old Carib track which led from Chateau Belair, *viâ* Wallibu, on the leeward side to lot 14 and Georgetown on the windward side of the Island, but owing to the summit being in cloud on each occasion we saw only rare glimpses of the interior. In 1907 I was more fortunate, and during part of the time I was on the summit the air was perfectly clear, though the clouds came down before I had an opportunity of examining the new crater. The topography of the old crater is still correctly represented on the Admiralty chart. The crater is approximately circular, nearly a mile in diameter at the rim, and with a lake in its bottom (see Plate 15).

The walls in the greater part of their height are nearly vertical, and consist of alternate layers of tuff and compact rock, all dipping outwards from the crater. The latter beds are chiefly lenticular in section and columnar or subcolumnar in structure, the columns being as usual arranged at right angles to the surfaces of cooling. Probably they are chiefly lava flows, but some may be intrusive sheets. It was impossible to get near enough to examine their surfaces of contact with adjacent beds. There is a very prominent dyke to the north-west of the crater and a smaller one to the west of it, which cut through several of the massive beds referred to, so that, as intrusive action has undoubtedly occurred, the results might be horizontal sheets as well as vertical dykes. One of the horizontal beds mentioned above, situated in the north-west wall of the crater, is especially massive. It must be several hundred feet thick and is distinctly columnar. At the foot of the almost vertical cliff is a broad bench or beach, specially well marked on the north and east side of the crater. The Rev. T. Huckerby, of Chateau Belair, who has ascended the mountain many times, is quite clear that it was formed by the ejecta of the small eruption of March, 1903. It has suffered much erosion by rain and other agents of subaerial erosion, and a talus is forming on it in places by falls from the cliffs above.

The topography of the crater lake also corresponds with that marked on the Admiralty chart, and the sheet of water appears to be a trifle over half a mile in diameter. Mr. Huckerby thinks it is at a somewhat lower level than before the eruption, but Professor Karl Sapper's measurements render this doubtful.* The water is of an uniform light green colour and does not boil or steam in any part. The mottled appearance in Plate 15 is due to reflections from the clouds. The lake is not in any way divided, and no secondary cone is visible. If any exists it must be below the water level. There is one spot near the foot of the crater wall on the south side where vapour escapes occasionally in small quantity, and

* See p. 291.

another still less evident on the east. Neither is sufficiently conspicuous to appear on the photographs. Thus all the deeper parts of the crater bear evidence of the severity of the eruption of 1902, since it appears that any loose deposits previously existing there have been entirely blown out, and that the small bench or talus mentioned above is of subsequent formation. The upper parts of the walls of the crater are on the whole less precipitous than those lower down, and are in places, especially on the south and south-west, covered with a deposit of new ash apparently only a few feet thick (Plates 16 and 18). It dips towards the crater at the angle of repose between 30° and 40° and has been much denuded by the rain. There are only a few places, however, where it is sufficiently continuous to obscure the solid beds, and where these are visible ash and tuff predominate over lava, the reverse of which is the case lower down. On the north the wall is considerably higher than on the south, and the precipitous portion extends higher up. The beds of tuff, which are here particularly well developed, contain many large ejected blocks (Plate 17). This abundance of ejected blocks to the north-east of the crater agrees with the observation of Mr. T. M. Macdonald during the eruption of 1902, that most of the stones thrown out went to windward, so that the direction appears to have remained unchanged from an earlier period. The figure to the right is standing on a lower portion of the rim (Gap A in several plates) near the point where the Carib track begins to descend in a south-easterly direction to the windward side of the island, and through this gap, no doubt, the black cloud and avalanche descended which devastated the Carib country.

This lip of the crater is usually quite narrow, generally only a few feet, occasionally a few yards, wide, as shown in Plate 16. It is mostly composed of a bed of new ashes a few feet thick, almost everywhere consolidated on the surface into a crust, generally less than an inch thick, as in the case of the ridges lower down. Where this crust is entire it has preserved the rest of the bed from erosion, but whenever it has been broken through, the whole of the deposit has generally been washed away, and this is particularly noticeable on the outer slopes, where the beds of new ash lie conformably on the old ones and weather off in successive layers. The lip is by no means regular or uniform in height. It is highest to the north. Besides the gap just mentioned (Gap A), it presents three well-marked gaps, B, C, and D, of which B is shown in Plate 16, and D, the more westerly, in greater detail in Plate 18. B and C are on the south of the crater; of these the more westerly, C, is somewhat the lower, and both are lower than A. It was doubtless through them, and presumably through the lower one especially, that the water of the crater lake and the incandescent avalanche descended into the Wallibu and Rabaka districts.

The other gap, D, Plate 18, occurs more to the west, where the lip of the crater joined the Somma ridge; as the whole of this part of the rim of the crater is much higher than the southern portion, the bottom of the gap, deep as it is, still

remains higher than B and C. This gap, D, leads down in the direction of Larikai and Morne Ronde. It was lowered considerably during the eruptions of the autumn of 1902, and this accounts for the greater deposits in the Larikai valley in the later eruptions. The Somma Ring (Plate 18) is seen to consist of beds of lava and tuff dipping outwards from the crater, conformably with the outer slope of the mountain. The whole of the interior of the crater is still quite bare and without any trace of returning vegetation. A few small patches of moss appear on and about the rim, and in somewhat greater abundance on the slopes outside. This is worth notice, for Mr. JAMES ANDERSON, in 1784 (Part I., p. 461), found moss covering the inside of the crater and in great abundance on the cone at the confines of the grassy region and the barren, so that the conditions are presumably becoming similar to those which existed at that time, and the vegetation will eventually be as it was before the eruption of 1902.

The Carib country was not visited*, but as far as could be judged from a distant view from near the top of the Soufrière, vegetation was returning in a manner similar to that in the Wallibu district, and Mr. SANDS, who has since visited the district, assures me that this is the case. He states that there is water in the upper reaches of the Rabaka River, though it all sinks into the ground lower down, so that none reaches the sea. The old bed of the river has become blocked about a mile from the sea and a new course has been formed to the north of it. The restoration of the water supply to the district, by the repair of the old conduit, is under consideration.

The difference between the character of the eruptions of the Soufrière and Montagne Pelée, mentioned in Part I., p. 533, appears to have continued since 1902, the outbursts from the former volcano being generally less frequent but more violent than those from the latter.

THE RETURN OF VEGETATION.

Confining our attention for the present to the Wallibu district, it may be stated generally that the whole of the country north of Morne Garu was devastated in different degrees. The limit of the zone of devastation extended right up to the summit of Morne Garu, and the line followed the main ridge in a westerly direction almost to the sea, before reaching which it diverged so that the Richmond Plantation Works were included, but the south bank of the river was not materially injured (Plate 19). Within this area the bottoms of the valleys, which were covered by the incandescent avalanche, had their vegetation utterly destroyed. In other places, where the hot ash was only deposited in a thin layer, the roots were in many cases not killed outright and are now throwing up new shoots and leaves, though the large trees are almost universally killed, except in a few sheltered situations.

* Arrangements had been made to return by what was then advertised as the last voyage of the Intercolonial Service of the Royal Mail Company.

The localities may now be discussed more in detail. The conditions at the Richmond Plantation Works may be taken as a type of those of all the low ground near the limit of devastation. The incandescent avalanche swept down the Wallibu valley and spread out over the old fan or plateau at its mouth, it then turned south round the lower end of the Richmond ridge and destroyed the Richmond Works and all the vegetation near them. The ash still remains to a depth of two to six feet in different parts, and the old roots are completely buried and thoroughly destroyed, but the avalanche was confined to the bottom of the valley, and none of its effects are visible on either side. The black cloud which accompanied the avalanche either did not keep to the ground beyond the ridge behind the Works or had lost most of its heat, and on this slope there are Gru Gru palms (*Acrocomia sclerocarpa*), which though injured are recovering, and one silk cotton tree (*Eriodendron anfractuosum*) at the Works is still alive (Plate 19). In other places, however, further to the east, some trees are killed, but this appears to be the limit of devastation. The surface of the ash near the Works has not consolidated, but is rapidly breaking up under the influence of plant roots, and humus is being formed. The chief new plants are Castor Oil (*Ricinus communis*), which grows in luxuriant masses along and around the ruins of the Works, and a plant, Cattle Tongue (*Pluchea odorata*), which has already formed flourishing bushes taller than a man (Plate 20, fig. 1). Besides these, Indigo (*Indigofera Anil*), Sensitive Plant (*Mimosa pudica*), Guinea Grass (*Panicum maximum*), *Eupatorium odoratum*, and two grasses (unnamed) were also noticed. On the hill sides, grasses and a few trees, such as Gru Gru palm (*Acrocomia sclerocarpa*) above mentioned, Walnut (*Andira inermis*), Fiddle Wood Tree, and *Ficus* sp. Near the river the Rozeau Grass (*Gynerium saccharoides*) is also growing luxuriantly to a height of 12 or 15 feet (Plate 20, fig. 2).

At the foot of the seaward slope of the Richmond ridge is a fan, or plateau, which was covered several feet thick with the incandescent avalanche, the end of which is mentioned above as extending up the valley as far as the Richmond Works (Plate 21). Here the surface has consolidated into a crust nearly an inch thick, almost like a concrete pavement, and where this crust is perfect no vegetation can spring up; where, however, it is broken up, as along the small water courses, Silver Ferns (*Gymnogramme calomelanos*), grasses and young Plucheas are getting hold and their roots are spreading into the harder parts on each side. In places also the crust is being broken up by the trampling of horses and cattle, and the process of return of vegetation is thereby being hastened. The lower end of Richmond ridge above this fan was only slightly affected.

Further to the north along the coast there are several other plateaux on which the vegetation is making similar progress (Plate 14). They are much cut up by ravines, in the precipitous walls of which, and in the sea cliffs, the old soil is generally exposed at a junction of the old tuff and new ash above it, and this line is often marked by a band of luxuriant growth from the old roots. The Wallibu Plantation (Part 1, Plate 25,

fig. 2) was situated on one of these plateaux below the end of the main Wallibu plateau. The vegetation is here more advanced than on the surrounding flats, and it had almost concealed the aqueduct, which is such a conspicuous object in the 1902 plate; Bamboo (*Bambusa vulgaris*) is growing luxuriantly and the other plants are practically the same, and their growth is about as much advanced, as at the Richmond Plantation.

In the Wallibu valley vegetation has made little progress, the floor being composed of ash and gravel which is still liable to re-arrangement by every flood, but on the south slopes leading up to the Morne Garu range the return has been considerable. The surface is still studded with the charred and bleached skeletons of trees, which appear to have been killed universally, with the single exception of a small lateral valley north of the lower part of the Richmond ridge, where a few palm trees in a sheltered position have recovered. The shrubs and herbaceous vegetation, which were all burnt level with the ground, are gradually returning, in many cases from the old roots, since the removal of the thin covering of ashes by the rain. The north wall of the Wallibu valley is precipitous and only recently relieved of its covering formed by the incandescent avalanche, and is still almost bare of vegetation. The top of the Wallibu plateau was entirely devastated. The trees remain only as bleached trunks except a few which have recovered in sheltered positions at the ends and south edge of the plateau (Plates 9, 10, 11). The dead trunks show that the ash was never more than a few feet thick at the most, and the whole is now covered with a luxuriant growth chiefly from the old roots.

In the smaller gorges to the north, such as the Wallibu Dry River and Trespé discussed above, vegetation is making more progress than in the Wallibu. Their precipitous sides are becoming densely covered with Silver Ferns (*Gymnogramme calomelanos*) and creepers such as Ipomœas, besides grasses and herbaceous plants (Plate 22, fig. 1).

Along the slopes of the Soufrière, of which the ridge followed by the old Carib track may be taken as an example, the return of vegetation is very marked. All the trees without exception are killed and their stumps are becoming covered with Ipomœas and other creepers, while, the ash having been much washed away, except along the ridges, the old soil is mostly exposed (Plate 22, fig. 2) and the vegetation is returning chiefly from the old roots and their progeny. In the lower part, as for instance where the track rises steeply out of the Trespé valley, the vegetation is so luxuriant as to form a tropical jungle dense enough in places to require the use of a cutlass to effect a passage through it (Plate 23, fig. 1). At about this height are masses of Rozeau (*Gynerium saccharoides*), *Heliconia Bihai*, Tree Fern (*Cyathea arborea*), a few trees, and a large number of shrubs and herbaceous plants, grasses and creepers (Ipomœas chiefly), and the same flora continues up to the Maroon Tree, which is at a height of about 1000 feet.

At about 800 feet Tree Ferns (*Cyathea arborea*) become very abundant and large

sheets of them are common (Plate 23, fig. 2), and generally it may be said that vegetation is luxuriant up to a height of about 1000 feet, abundant up to 1500, and very sparse above that height, with only a few grasses and silver ferns; higher up nothing but mosses and lichens are found.

At the lower lip of the crater and just inside it mosses and lichens only are found. The mosses have been identified at Kew as: *Pogonatum tortile*, P. BEAUV., and *Philonotis tenella*, JAEG., and the lichen as *Stereocaulon* sp.

On the higher slopes of the Carib country vegetation is much the same as on the leeward slopes at about the same elevation.

The coast north of Morne Ronde and Larikai Point was only examined from a canoe, but on this side of the mountain vegetation appeared to be returning in a manner similar to that on the more accessible parts. Most of the plants were the same as at Richmond and Wallibu, and the Trumpet Tree (*Cecropia peltata*) and Bois Flot (*Ochroma lagopus*) were also noticed.*

THE HISTORY OF ERUPTIONS AFTER MAY, 1902.

The Eruption of September 3 *and* 4, 1902.—Through the courtesy of His Honour C. J. CAMERON, Administrator of St. Vincent, and Sir DANIEL MORRIS, of the Imperial Agricultural Department, and other officials, I have been allowed access to reports by Mr. POWELL, of the Botanical Gardens, St. Vincent; Professor RADCLIFFE HALL, Professor LONGFIELD SMITH, and Mr. ALLAN, the Revenue Officer of Chateau Belair. The Rev. T. HUCKERBY, of Chateau Belair, Mr. MACDONALD, and the Rev. JAS. DARRELL have also furnished notes. From these sources the following account is condensed.

After the eruptions of May, 1902, the crater remained quiescent, but earthquakes were noticed at the Botanical Gardens on July 17th and 21st, and by the Rev. T. HUCKERBY at Chateau Belair on the 9th, 19th, 20th, 23rd, 30th, and 31st of the same month. The shock of the 17th occurred at 9.45 a.m., as noted by Mr. POWELL, and was preceded by a noise rather like a bomb exploding. The movement was up and down, and the duration about six or eight seconds; that of the 21st took place at 1.10 a.m. The movement was from north to south, and the duration also six or eight seconds.†

A party who visited the Soufrière on the 12th of August saw small openings (fumaroles) on the lip of the crater from which steam and small pebbles escaped.‡

On September 3, from 6 a.m., a series of explosions commenced, which increased in violence as the day wore on, and at 9 p.m. the detonations became very loud. The

* The return of vegetation on Krakatoa presents many points of similarity. 'Treub. Annal. Jard. Botan. Beutenjorg,' 7, 1887–8.

† Mr. POWELL'S Report, September 12, 1902.

‡ 'Sentry,' August —, 1902.—Some of the newspaper cuttings do not retain the date of issue.

eruption reached its climax about 2 o'clock in the morning of the 4th. A black cloud alive with electric displays stretched itself from the north to the south of the island; at 3 a.m. the detonations had become less regular, and at 3.55 a.m. an earthquake was noticed at Chateau Belair, and also at the Botanical Gardens, where the explosions were considered louder than in May, the "din" being described as terrific. From this time the eruptions became less violent, though slight rumblings continued throughout the day till 5.30 p.m. It was noticed during the eruption that material like mud flowed from the crater down the Larikai valley. There was a heavy fall of ash on the leeward side of the island. Beginning as a thin layer at Barualli, it gradually increased to five to nine inches at Chateau Belair, where several buildings were injured by the heavy fall, which consisted of dust, lapilli, and black stones. Very little ash fell at Georgetown, or the windward side, and the mountains in the middle of the island showed no change in appearance. Mr. POWELL made an official visit to some native allotments on the leeward side of the island, about four miles south of the volcano, in order to estimate the damage. At Rosebank, on the seashore, the thickness of the deposit was about three inches. It consisted of coarse ash and pieces of pumice stone up to three inches in diameter, with solid stones of the size of gravel and occasionally larger. For $1\frac{1}{4}$ miles inland the damage to the native provision grounds was very great, but for the next mile much less. No lives were lost.*

On Sunday, September 21, there was a sharp, but short explosion, very striking in appearance. The people were much frightened, and asserted that there was a greater accompaniment of "fire" than on previous occasions. Part of the red glow, however, may be attributed to the setting sun.†

On September 18 the telegraph cable to the north, which had been repaired only the previous day, was again interrupted.

On Friday, September 22, Mr. HUCKERBY‡ made an ascent of the Soufrière. For some distance, whilst crossing the Wallibu valley, he had to walk ankle deep in mud. On the lower ridges he found a plentiful supply of fine ash. About 400 feet below the summit a large number of newly ejected blocks were lying about in all directions. Great changes had taken place within the crater. He estimated it to be 150 feet deeper than it was immediately after the eruption of the 7th of May. A considerable amount of ash was banked up against the northern wall and part of the eastern side, which had become almost perpendicular, while a large portion of the Larikai (W.) side had been blown away and the lip lowered several feet. A fissure had been formed on the southern lip, from which steam was slowly ascending. The bottom of the crater contained a small lake of stone-coloured liquid, which was constantly boiling up and sending forth clouds of steam.

* Mr. POWELL'S Report, September 12, 1902.

† Letter from Mr. MACDONALD, of Wallilabu.

‡ Rev. T. HUCKERBY, in a letter to Dr. ANDERSON.

Mr. HUCKERBY noticed after the eruption that further subsidences had taken place north of the mouth of the Wallibu River, as had happened in the May eruption.

The Eruption of October 13 *and* 14, 1902.—This appears to have been the most severe eruption since May, 1902. Mr. HUCKERBY writes*:—"On the 1st and 13th of October there were electric displays over the crater, and on the night of the 12th a lunar halo was observed. The 13th and 14th were days of intense heat, and several earthquakes were felt at the northern end of the island. At about 8 p.m. on October 14, slight rumblings were heard, and clouds of dust-laden steam were ejected from the crater, but everything passed off very quickly. At midnight the activity recommenced and violent detonations disturbed the people of the district. At 12.30 a.m., what appeared to be a ball of fire presented itself over the crater, followed by a flow of red-hot matter down the Larikai side of the mountain. At the same time a mist-like circle appeared over Chateau Belair. At five minutes to two, stones began to fall in Chateau Belair and continued for about two hours. The electrical displays were terrible to behold, and the thunder cannonaded with a deafening roar. Mud began to fall at 2 o'clock. I noticed four earthquake shocks, the two at 3.22 a.m. and 4 a.m., respectively, being the heaviest and most prolonged. The detonations became irregular between 4 and 5 o'clock and died away gradually. At 8 o'clock in the morning the crater was sending forth volumes of dust-laden vapour, which action continued until the 17th. Stones, some probably two pounds in weight, were picked up at Chateau Belair on the morning of the 15th. Most of the ejecta were carried out E. and N.E. of the island. The Carib country was covered with large stones and coarse material."

The débris fell chiefly upon the windward side of the island. The Carib country, as it had been previously utterly devastated, did not attract much attention, but Mr. POWELL† visited the still inhabited districts and noted the amount of damage. At Kingston there was from $\frac{1}{8}$ to $\frac{1}{4}$ inch of ash. Further north it gradually increased in thickness. At Gregs and Union Estates 2 inches were measured, and at Park Hill 3 to 4 inches, while at Georgetown and Mount Bentinck the depth was 6 to 8 inches. Much damage was done to the provision grounds of the natives in all the localities, which the newspapers describe as utterly ruined. The ash was very hot, but apparently from the heat of the sun. The dust was carried as far as Barbados, where detonations were heard, and samples were collected at the Government Laboratory, and also by the U.S. Weather Bureau, and the Rev. N. B. WATSON, St. Philips. Professor RADCLIFFE HALL gives the amount collected at the Laboratory as follows:—

	Tons per acre.
October 16, from 9 a.m. to 11 a.m., at the rate of	0·48
11 a.m. to 1 p.m. „	2·10
1 p.m. to 3 p.m. „	1·34
Total from 9 a.m. to 3 p.m. „	3·92

* In a letter to Dr. ANDERSON.

† POWELL, Report of October 24, 1902.

He also collected samples at Rosebank and Hastings, where the amount from 8.45 a.m. to 4 p.m. on October 16 was 4·49 tons per acre.*

Mr. POWELL and a party ascended the mountain on October 28, 1902, and found that the old crater was discharging volumes of steam and that numerous cones of ashes were being thrown up to a height of 30 or 40 feet from a fissure close under the southern wall.† The lake was boiling near the centre. The steam as it rose was carried along the south-eastern wall to the eastern edge of the crater, where it became visible to observers in the low country and created the erroneous impression that the new crater was in eruption.

On Wednesday, November 26, 1902,‡ there was a considerable flow of mud down the Rabaka River. The ash avalanches of the May eruptions had completely blocked its bed, and the ejecta of the subsequent eruptions had doubtless contributed their quota. As a result there was no water in the channel, and this in spite of the heavy rainfall of five months. On November 26 the stream at last got vent, and two raging, steaming torrents descended the valley. One of these destroyed the remains of the Rabaka Sugar Works, and for the last mile before reaching the sea the old course has been blocked up and the river now runs in a new channel to the north of the old one. It is supposed that a lake had formed in the higher reaches of the river which at last had got vent, but details are wanting.

Mr. HUCKERBY writes§: "Detonations were heard on the 19th and 22nd of October and on the 6th, 11th, and 24th of November, 1902. On the 26th of November there was a minor eruption and a small quantity of ash and lapilli fell at Georgetown and Chateau Belair. On the 22nd of January, 1903, at 12 noon, there was again a minor eruption with a projection of very dark steam and a little ash. Detonations were heard on the 22nd, 24th, 26th, and 28th of January and on the 6th of February. Steam was emitted from the crater on the 13th, 14th, and 28th of February."

Professor SAPPER, of Tübingen,‖ ascended the Soufrière on February 6, 1903, with the Rev. T. HUCKERBY, of Chateau Belair, and paid a visit to both the new and the old craters, this apparently being the first to the new one since the eruption. They found that owing to landslides into the crater the gap above the Larikai valley was deepened. They had considerable difficulty in crossing it, and in order to do this had to descend some distance. Dr. SAPPER made a plan of the crater and found that no material alteration had taken place in its shape from that indicated on the English Admiralty Chart. The diameter in every direction was about 1320 metres (4331 feet),

* 'The Agricultural Reporter,' October 20, 1902.

† 'Sentry,' October 31, 1902.

‡ 'Barbados Advocate,' December 3, 1902.

§ In a letter to Dr. ANDERSON.

‖ "Der Krater der Soufrière von St. Vincent," von KARL SAPPER, 'Centralblatt für Mineralogie,' Stuttgart, 1903, pp. 369–373.

but the north wall being higher than the south the plane of measurement was inclined in that direction, so that on a level the shape was really somewhat oval, with the long diameter from the W.N.W. to E.S.E. The lake was also oval, with its diameter in the corresponding direction. Its length on February 6 was 540 metres (1772 feet), its breadth 340 metres (1116 feet), and the height above the sea-level 585 metres (1919 feet),* which agreed almost exactly with that given on the chart (1930 feet). The water was boiling in the centre and also at the south-east corner. The district between the Somma wall and the two craters was deeply covered with ejecta. The new crater was filled up almost flat. It had a small shallow lake (about 70 metres (230 feet) in diameter) towards its eastern side, with water marks which showed that it had been bigger. The saddle, which previously separated the new from the old crater, had disappeared, probably owing to landslides. Fumaroles were found in the crater rim in the gap leading down to the Larikai valley and also one somewhat more to the east above the head of the Rozeau valley.

Professor LACROIX made the ascent along with Madame LACROIX, Ensign DEVILLE, Professor HOVEY, and the Rev. T. HUCKERBY of Chateau Belair, on March 3, 1903, *i.e.*, before the last considerable eruption, and has published his observations in the 'Annales de Géographie.'† The following is an abstract of the parts of his paper which relate to matters that have occurred since the May eruption. He mentions that banks of hot ash and terraces still remain in the Wallibu valley, and that steam explosions still occasionally take place from them.‡ These banks render the river valleys somewhat narrower than before. He saw from his boat, when off the mouth of the Richmond River, an explosion of hot mud take place from the crater of the Soufrière, and he observed the sudden descent of a torrent of mud in the high Rozeau valley, probably caused by a shower. At a height of about 600 metres the ground was covered by large lapilli, the product of the eruption of September, and ejected blocks and bombs were common. They were often partly buried in the lapilli into which they had fallen. He mentions the gap at the head of the Larikai ravine, and was informed by Mr. HUCKERBY that it had been enlarged by the eruption of October, 1902. Avalanches were falling from the walls of the crater, and there was a talus at their base. Large ejected blocks of old rock were more common at the rim of the crater, particularly at the east, than they were lower down. At first, when M. LACROIX gained the edge of the crater, the water of the lake was tranquil, and had the appearance of yellow steaming mud. The least agitation of any part caused it to assume a more grey colour. Suddenly from the centre of the lake there rose a mass of mud of inky blackness, entangling blocks of rock.

* These measurements appear to have been carefully made. HOVEY gives 600 metres; most of the other observers also give figures, but as they are merely estimates I have not quoted them.

† "Les Dernières Éruptions de Saint-Vincent," Mars 1903, A. LACROIX, 'Annales de Géographie,' tome xii., 1903, No. 63 du 15 Mai 1903.

‡ They appear to have ceased about this time.

After some seconds it reached to the level of the edge of the crater, and then rose to a height of several hundred metres. M. LACROIX succeeded in taking a photograph* which shows an outline like sheaves of rockets, mixed with puffs of white vapour, which soon gained predominance and hid the rest from view. The mass of mud, which rose noisily, fell heavily back again with a deafening roar. Then a new column of vapour, larger than the former, rose from the bottom of the crater and filled it.† The party received a heavy shower of mud. Several other explosions of different degrees occurred while the members were on the summit. The explosion was seen from Castries in St. Lucia, and was sufficiently conspicuous to cause inquiries as to its nature to be made by telegraph.

Professor HOVEY was one of the same party who visited the crater on March 3, 1903, and he crossed the mountain to the windward side a few days later. He remarks‡:—"Considerable alterations have taken place since my former visit 8 months previously. The eruptions of May had left the leeward side coated with a deposit of very fine-grained material, which formed a cement-like mud under the influence of the rain; but the deposit on the windward side was of a coarser nature. Now, the surface to leeward is covered with gravel which has more or less completely hardened into a compact surface. This gravel is composed not only of small fragments from a quarter to half an inch in diameter, but also of numberless bombs. These bombs vary in size from that of a pea upwards, the largest observed were between 2 and 3 feet across. On the windward side the gravelly deposit had not been compacted, but is soft to walk upon. Within the district from Richmond to Windsor Forest on the leeward, no vegetation is to be seen except such as has sprung up along the sides of the gullies which cut through the new deposit into the old soil. On the windward side the slopes of the mountain have been much more generally freed from ash than on the leeward, and considerable vegetation is to be seen on the slopes of the ravines and gorges. The crests of the ridges and the lower slopes, however, are still covered with a coating of bare ash." He mentions the rapidity with which erosion has taken place since the eruption, and estimates the amount that has been carried out to sea from the valley of the Wallibu alone at 25,000,000 tons, without counting that from the surrounding slopes.

Eruption, March 21 to 30, 1903.—The Rev. T. HUCKERBY writes as follows§:—"From the 15th to the 18th of March the heat was intense. At 5 o'clock of the morning of the 18th three lunar halos were visible. On the morning of the same day a halo circled the sun. At about 9 o'clock the same night we were disturbed by

* LACROIX, 'Montagne Pelée,' pp. 53–54 and 176–7, Plates 21, 22.

† LACROIX, 'Montagne Pelée,' Plate 22.

‡ 'Sentry,' St. Vincent, March 1903. 'American Museum Journal,' July 1903. 'Comptes Rendus,' ix., Congrès Géol. Internat. de Vienne, 1903, "The 1902–3 Eruptions of Mont Pelée, Martinique, and the Soufrière, St. Vincent," by EDMUND OTIS HOVEY.

§ Letter to Dr. ANDERSON.

very loud detonations, the earth trembled severely. I immediately went outside, to see if the Soufrière were showing any signs of an eruption. Everything seemed calm and quiet on the northern end of the island, but looking in the direction of the harbour (Chateau Belair), I noticed three horizontal rings of vapour, one within the other.*

"On the 21st large volumes of steam were emitted from the crater, and early the following morning detonations and rumblings were heard. At 7.25 a.m. the explosive period of the eruption commenced, the usual black cloud, cauliflower in shape and fringed with various colours, rose to a tremendous height and then passed away in all directions. The regular detonations and explosions ceased about 10 o'clock. Occasionally, during the day, noises proceeded from the crater, as if some great monster were in distress. There were three earthquakes between 7 and 8 in the morning, and one at 9 o'clock. After the detonations and explosions had ceased, the crater continued to send forth dust-laden vapour, without cessation, right on to the 30th of March. On the last-named date I visited the coast as far as the Larikai valley. Very little ejecta had fallen at Wallibu. At Morne Ronde there was a depth of 4 inches of new grey dust. At the opening of the Larikai valley there was a fall of $6\frac{3}{4}$ inches. Further along the coast, at the bottom of the Larikai ravine, there was a depth of 20 feet of new ejecta, indicating that there must have been a considerable flow from the western lip of the crater. A bomb, found in a heated condition on the top of a deep layer of ash, proved to be 75 lbs. in weight. Between 8 and 9 o'clock on the night of the same day the whole of the crater seemed as if it was lighted up by electricity. I concluded that the bottom of the crater was in a luminous condition and reflected its glow on everything around and on the cloud above. The light lasted for a few minutes and was followed by the ordinary emissions of dense clouds of steam.

"On the 31st I started on a trip round the island. I found that the material distributed on the windward side of the island was very different from that which had fallen on the leeward side. The deposit on the leeward side, except in the Larikai ravine, was consistently grey dust, while on the windward side, ash, pumice, and large pieces of dull chocolate-coloured material preponderated. The pumice, which I had picked up at Owia, has the appearance of a pink sponge.

"At the beginning of April I again visited the Soufrière. The inside of the crater presented an entirely different appearance, the bottom was filled up to about the old water level, with chocolate-coloured ash. In the centre of this new deposit was a comparatively narrow hole, which I concluded was the mouth of the funnel. The southern lip had been raised by the outflowing dust. A large portion of the north-eastern wall had been blown out and a fair number of fissures, which had formed in the new deposit of the crater, were throwing up a large amount of steam.

* Two such concentric rings were also seen at Chateau Belair on August 30, 1902, before the eruption of September 3.—(Mr. CHASTENET, quoted by Mr. MACDONALD in a letter to Dr. ANDERSON.) See also the eruption of October 13, 14, *supra*.

"I have made many visits to the Soufrière since the occasion mentioned above. The hole in the centre of the new deposit has gradually widened, and, I suppose, will ultimately take up the whole width of the bottom of the crater. Conditions are rapidly becoming normal, and in a few years' time the mountain will once again be covered with verdure and beauty."

Mr. POWELL* reports, on March 24, that the depth of black dust was about half an inch at Park Hill. At Three Rivers and Mount William it was about three-quarters of an inch deep and coarser in grain. It contained many considerable pieces of an inch and upwards in size. The cocoa trees were here a good deal damaged. At the experiment station, near Georgetown, it was coarser still, more cinder-like, and pieces of 3 inches or more in diameter were common. The sugar-canes and other plants were much injured. At Dickson's Village, which is in an exposed position above Georgetown, the ash was 2 to 3 inches deep and larger cinders more abundant still. From Georgetown northward the country "presented one blackened waste." At Turema, about 5 inches of dust were measured. On the whole, there appears to have been a light fall of dust over all the island south of Georgetown and Chateau Belair, a moderate fall on the leeward coast north of this, except in the Larikai ravine, where there was a deposit, in places, 20 feet thick; and a fairly uniform layer of a few inches thick over the Carib country, north of Georgetown. The heat-absorbing properties of the last fall were considered to render it more detrimental than the deposits of the former eruptions.

The dust was carried by the wind to Barbados. On Sunday, the morning was clear till about nine, when a dense black cloud came rolling up from the west, the surface wind being easterly at the time. Dust began to fall about 11.15 and it continued to do so more or less heavily up to about 1 o'clock, after which it slackened and ceased altogether at 5 o'clock. When the gloom was deepest, the day was darker than on either of the previous occasions of a fall, viz., the 7th of May and the 16th of October, 1902. During the midday service lamps were lighted in the various places of worship. The dust appears to have taken about two hours in traversing the distance of 111 miles. The amount as estimated by Mr. LEWTON BRAIN and Mr. R. D. ANSTEAD, of the Imperial Department of Agriculture, from observations made at Bay Mansion, was $2\frac{1}{2}$ tons to the acre. It will be remembered that the total fall on May the 7th was 17·58 tons per acre, and that on October 16 about 3·92 tons per acre. The cloud appeared to be denser towards the north, and at Codrington House, two miles to the north of Bridgetown, the fall was 6·52 tons per acre.† Since this eruption the crater has been practically quiescent.

* Curator to the Commissioner of Agriculture.

† 'Agricultural News,' March 28, 1903, No. 25.

Montagne Pelée in Martinique.

When we visited Martinique in 1902, it was "our intention to make merely such reconnaissances as would enable us in a general way to ascertain the points of difference and of similarity between the outburst of Mont Pelée and that of the Soufrière, and to see what light the phenomena in Martinique threw on the events which had happened in St. Vincent,"* and this being understood, we had the advantage of a friendly conference with Professor Lacroix, the Chief of the French Commission, who most courteously discussed his observations and conclusions with us. These he has since embodied in a monumental volume published by the Academy of Sciences,† and we have already indicated the chief points of difference and similarity between the two volcanoes, both in the preliminary and full report, so that it now only remains to compare the history of the two volcanoes since the great eruption, and to note the changes which, during a visit in March, 1907, I observed to have recently taken place in the crater and the slopes of the mountain, especially the region of the Rivière Blanche, and, since Professor Lacroix's great work is not very accessible to English readers, to draw attention to one or two of the most remarkable phenomena described in it.

The Crater and the Spine.—The great spine which has formed so peculiar and novel a feature in the eruption of Montagne Pelée had no counterpart in the Soufrière of St. Vincent, and this constitutes the most important difference between the outbreaks of the two volcanoes, which in other respects were so remarkably similar. When we visited Martinique in 1902, there was in the upper part of the mountain, at the head of the valley of the Rivière Blanche, a great "triangular fissure,"‡ or V-shaped gap, out of which, on July 9, we saw the descent of an incandescent avalanche, which was the counterpart of that which destroyed St. Pierre. Through that gap, as the trade-wind clouds momentarily dispersed, we caught occasional glimpses of a bank of large loose angular blocks of stone at a high temperature, which rolled down at intervals, accompanied by the discharges of volumes of dust-laden steam. We also saw several times for a few moments a large pointed rock, reaching to a height of perhaps 100 feet, or more, above the top of the dome of stones, but as we were ignorant of the exact topography of the locality, which was not accurately marked on the official maps, we could not ascertain for certain that it was more than an unusually large crag on the further lip of the crater, and accordingly did not particularise it in the report. This uncertainty as to the topography has now been cleared up. The map in Professor Lacroix's book (p. 120) correctly represents the

* Preliminary Report. 'Roy. Soc. Proc.,' vol. LXX., 1902, p. 439; and Part I., p. 478.

† 'La Montagne Pelée et ses Éruptions,' par A. Lacroix, Paris. Masson et Cie., 1904.

‡ Part I., p. 491, called "cleft" in the Preliminary Report, pp. 440, 441, and "Echancreur en V" by Lacroix.

topography as I observed it in March, 1907, and it is now certain that the bank of stones was the surface of a new cone, or dome, which was in process of being built up in the Étang Sec, which, in this eruption at any rate, was the working crater of the volcano.* The dome has never shown any crater of explosion on its summit and appears to be comparable, for instance, to such masses as the Domite Cones of the Auvergne. The pointed rock rose from its summit. It now appears that this rock had been independently seen three days previously, viz., on July 6, by a French party under Professor LACROIX, and by an American party under Professor JAGGAR, and that photographs had been obtained by both, which, though very indistinct, enabled useful diagrams to be drawn.† It is certain that this rock occupied much the same position on the summit of the dome as the spine did later, and one of its surfaces showed "long striated smooth slopes" like the later spine. It does not appear, however, to have been the identical spine, for its smooth surface faced westward instead of eastward, as did the corresponding surface of the latter. JAGGAR thinks it was an early stage of the same phenomenon; LACROIX thinks, on the contrary, that it was part of a "bourgeonnement" (budding) of lava (LACROIX, p. 41) and that its shape was due to the splitting off and falling away of the surrounding portions, and this view is supported by the craggy condition of the summit of the dome shown in photographs taken in October before the upraising of the spine, which commenced in earnest in November.

The French Commission commenced systematic observations from the Morne des Cadets early in October, using first an alidade and then a theodolite, and on November 3 the measured height of the summit was 1343 metres (4406 feet). LACROIX considers that the growth of the spine commenced on the night of the 3rd to 4th November, 1902,‡ and on November 24 it had reached a height of 1575 metres (5167 feet) above sea-level, or a growth of 230 metres in 20 days, *i.e.*, at the average rate of over 10 metres a day. This was the first maximum height; from that time a series of falls gradually reduced the total height till February 6, 1903, when only 1424 metres (4672 feet) were registered, or a net loss of 151 metres (495 feet), and this in spite of a continued rise of the remainder of the spine. From February 7 a new period of growth commenced, though less rapid than the former; on March 25 the former maximum of 1575 metres was again reached and soon surpassed, and from May 10 to 31 and from June 25 to July 6 the height was continuously above 1600 metres (5249 feet). The absolute maximum reached was 1608 metres (5276 feet) on July 4, 1903, or 257 metres above the former summit of the mountain, and

* The other small lake on the summit, the Lac des Palmistes, if a crater at all, was not in action in 1902, and its place is now occupied by a plain of *débris* and ejected blocks, including many bread-crust bombs.

† LACROIX, p. 114. JAGGAR, "The Initial Stages of the Spine on Pelée," 'American Journal of Science,' vol. xvii., January, 1904.

‡ LACROIX, *loc. cit.*, p. 121 *et seq.*

about 600 metres (1969 feet) above the former level of the crater lake of the Étang Sec from which it sprung.*

This cone or dome appears to have been formed of viscous lava partially or wholly solidified in places, and this mixture would be in a condition, by the sudden disengagement of the vapour and the shattering of the partially solidified rock, to give rise to, or at any rate take part along with, other discharges from the chimney in the formation of the incandescent avalanches and other forms of "nuées ardentes"† which have been observed. The avalanche seen by us certainly contained a number of large blocks of a brighter red colour and apparently of a higher temperature than the rest of the material in it, and these presumably had come from the dome. LACROIX considers that the "nuées ardentes" observed by him proceeded from the surface of the dome, and especially from a patch on its south-west flank near the base. They did not issue from any well-marked crater on its summit.

The spine itself seems, as we might have expected, to have been formed of very similar material to the dome. LACROIX speaks of a carapace, or shell, on its surface, which often was detached in flakes (fendillement), disclosing an interior at a high temperature which he describes as consisting of porous matter with driblets (bavure) of molten lava exuding from the intervals and cracks. Portions were frequently detached with the emission of "nuées ardentes." There was no great central passage. The surface of the spine was scratched and grooved by friction against the walls of the volcanic chimney out of which it rose. Its shape at first was angular, but it was almost cylindrical in its later stages, probably because the prominences in the chimney were gradually worn off, and its diameter was estimated by LACROIX at 150 metres. He calculates that if the spine had not undergone any crumbling and falling (ecroulement) between November 3, 1902, and July 4, 1903, it would have attained an altitude of at least 2200 metres (7218 feet), and the total height of the column extruded must have been about 850 metres (2789 feet), or, say, 2800 feet.‡ The careful measurements regularly taken showed that it diminished in height solely by flaking and falling, and that at no time did it sink again into the chimney when it had once risen. It appears clear, therefore, that both the dome and the spine were formed by molten matter, with perhaps some inclusions of blocks torn from the walls of the passage, being forced up from below into the volcanic chimney, that this matter was at first sufficiently plastic to spread out and form the dome, and that as cooling gradually took place, parts solidified and broke up into large blocks, from some of which the vapours escaped

* These estimates depend on earlier measurements, the accuracy of which cannot be depended upon to within a few metres.

† The term "Nuées ardentes," as used by LACROIX, appears to include both the "Incandescent Avalanches" and "Black Clouds" described in Part I. He now prefers the term "Nuée Peléenne" as more general. ('L'Éruption du Vésuve en Avril 1906,' p. 12, par A. LACROIX; 'Revue Générale des Sciences des 30 Octobre et 15 Novembre 1906.') Both Dr. FLETT and I prefer our old terminology as more precise.

‡ LACROIX, 'Montagne Pelée,' p. 132.

quietly, while other parts exploded into minute fragments with sudden escape of vapour and descended the mountain as "nuées ardentes," accompanied often with a mixture of the larger fragments. It is impossible to say exactly the depth to which this breaking up and liberation of the vapours extended. As the whole gradually cooled and became consistent, and as further material was forced up from below, the upper portion no longer spread out into a dome, but was forced up "en masse" as a spine, though it still retained veins of pasty or liquid material spreading through it. This forcing up from below by fluid pressure was clearly the main mechanism of the ascent, but LACROIX thinks that the pressure of the veins of semi-fluid lava might be an accessory cause of the ascent and especially of the lateral swelling and flaking off of the crust. It is impossible to deny the existence of this cause, since it has been postulated that the dome was formed in this way in the early stages of the eruption, but it clearly became much less important later on. Some authors have suggested that the spine was an old plug formed in the chimney, by the materials left there at the close of an earlier eruption. There is no proof whatever of this theory and it does not accord well with the transition from the formation of the dome to that of the spine, nor does it account for the high temperature of the central parts of the spine with its veins of still semi-fluid lava, or for the flaking off of the crust and emission of "nuées ardentes" as the veins of lava came to the surface.

I made two ascents of the mountain in March, 1907, and on the second occasion the cloud lifted for a few moments and enabled me to get a photograph which showed the stump of the spine rising out of a cone of talus surrounding it, and obviously formed of its ruins (Plate 24). At the line of junction of the spine and the talus was a ring of very active fumaroles from which steam and other vapour was escaping with a loud roar, obviously from under considerable pressure. The clouds closed in again before it was possible to complete the examination, but the photograph shows the spine to consist of a sort of volcanic agglomerate of blocks of various sizes, similar to what I imagine the structure of the dome to have been.

The Wall of the Crater.—The talus extended in every direction up to the walls of the crater, and had in a great degree filled it up. On the south-west side was the above-mentioned **V**-shaped gap where the talus had overtopped the former crater ring and extended down to the valley of Rivière Blanche. On the east and south-east the crater was least filled. Its wall continued uncovered from the side of the gap to beyond the remains of Morne Lacroix, to an average depth of probably above 100 feet. It was almost vertical throughout all this extent. The valley formed between it and the talus appeared to extend, but at a decreasing depth, round the north of the dome.

The resemblances between the valleys of the Wallibu in St. Vincent and the Rivière Blanche in Martinique, and the phenomena observed in those valleys respectively, are summed up in Part I., p. 489, and the changes which have since occurred serve chiefly

to increase the resemblances and minimise the differences. Thus in March, 1902, there was in the latter valley a number of fumaroles, some of which were active enough to have led to the supposition of their being parasitic craters. Further examination has satisfied Professor LACROIX of their superficial nature, *i.e.*, their origin in the deposits of hot ash, and their consequent similarity to those in the Wallibu.* They are all now cool and extinct except one group, which I had the pleasure of visiting in company with M. GUINOISEAU, Adjutant in charge of the Observatory of Morne des Cadets. They are situated at a height of about 1350 feet above the sea, on the low ridge between the Rivières Blanche and Claire, which here flow down one broad valley apparently much in the same way as two rivers often occupy each one side of a big old valley in St. Vincent. The ridge itself is perhaps 50 feet higher than the valley on each side, and broad in proportion. It consists of fragmentary ejecta of the 1902 eruption, including a good many large blocks. The temperature of the fumaroles had been as high as 300° C. last year, but was gradually decreasing. M. GUINOISEAU found it to be about 230° C. at the time of our visit. This group is the only one about the nature of which any doubt now exists, but it appears most probable that its origin, like that of the others, is superficial.

The differences between the two valleys are not by any means so great as the resemblances, and they appear to be all traceable to two causes, viz., the repeated, or rather, the at one time almost constant, passage of the incandescent avalanches, and the fact that owing to the configuration of the crater these all descend through the V-shaped gap right down the valley on which they spend their whole force. Thus the denudation of the deposits is in a somewhat less advanced stage than in the Wallibu, and the bedding somewhat more complicated owing to an alternation of water-sorted beds with those of fresh ash. Moreover, apparently owing to the very direct course of the valley from the V gap to the sea, and its steep inclination, the number of large ejected blocks even in the lower part of the valley is much greater than in the corresponding part of the Wallibu. This is only what might have been expected when I recall the stones which we saw descending by leaps and bounds in the incandescent avalanche of July, 1902. They were large enough to be visible at a distance of several miles and distinctly a brighter red than the rest of the avalanche material.

In this connection also ought to be mentioned another phenomenon, which though not altogether absent in St. Vincent is much more conspicuous in Martinique, viz., a scoring and grooving of the rocks of the sides of the Blanche valley. The part I specially noticed was a cliff nearly 200 feet high in the ridge between the Blanche and Sèche Rivers and perhaps half a mile nearer the sea than the active fumaroles above mentioned. The valley here is somewhat narrower than higher up, and much narrower than lower down, and it is just the part where the avalanches might be

* LACROIX, p. 400.

expected to attain their greatest speed. The whole rock is scored and grooved in a way recalling glacial scratches, but I have scarcely ever seen any due to that cause so well marked. These scratches, I since find, have been noticed by LACROIX and HOVEY in other parts of the valley.* The rock is a tuff containing many blocks of very hard andesite, so many that it might almost be called an agglomerate. The body of the tuff itself, on the contrary, in which the blocks are embedded though tenacious is soft enough to be cut with a knife, yet the hard stones have been planed off level with the rest of the mass. Nothing could show more vividly the amount of force applied, and the suddenness of its application.

Owing to the cause previously mentioned very few of the upper valleys received any hot ash, but any which did so present a most striking similarity to those in St. Vincent. Thus a photograph of the upper Rozeau valley in St. Vincent is practically indistinguishable from one of the upper Falaise in Martinique. Both were deeply filled with hot ash in the early stages of the eruption, in which explosions were seen to take place that were supposed to proceed from parasitic craters. In both cases what we see are not really true craters, but merely examples of places where secondary steam explosions took place in the hot ash as previously so often mentioned in the Wallibu district. In Martinique the rains, associated with the eruption, swept down such quantities of coarse débris as to form a delta in a few hours (Plate 25, fig. 4).

The Return of Vegetation.—Vegetation has returned in a manner and to an extent strikingly similar to what has taken place in St. Vincent. Thus, at a height of 1500 feet, on the east side of the mountain, where the ascent is usually made from Vivé, practically all the trees are killed and their trunks remain as bare stumps, while a luxuriant vegetation is growing up chiefly from the old roots (Plate 24). Large sheets of ferns are particularly noticeable. The ferns extend considerably higher, viz., to about 2000 feet, where they give way to grasses, while towards the summit only a few mosses and lichens are found. The slopes above Morne Rouge, as far as could be observed from the road, were in a similar condition. At Morne Rouge village the deserted gardens are full of luxuriant tropical growth, so full that most of the gates cannot be opened; partly no doubt in consequence of being embedded in ash, but principally owing to the new plants, which have grown up since the place has been left to run wild.

At St. Pierre the principal street, along which is one of the chief roads in this part of the island, has been cleared of ash and débris. The ruins of the houses on each side are still embedded in ash and covered by a dense jungle of tropical vegetation.

The valley of the Rivière Blanche and the district between it and St. Pierre is the only part which is still bare of vegetation, and this is no doubt due to the passage down it of the repeated "nuées ardentes."

* LACROIX, p. 217; HOVEY, 'Preliminary Report,' p. 363.

THE GENERAL SEQUENCE OF VOLCANIC PHENOMENA, ETC.*

In addition to the volcanic and seismic occurrences noticed under this heading, mention ought to be made of the great eruption of the volcano of Santa Maria in Guatemala, on October 24, 25, 26, 1902, news of which had scarcely arrived in Europe at the time when Part I. went to press. Owing to the extremely remote and inaccessible position of the volcano the eruption did not attract the notice it deserved, it was not examined at the time by any English or American man of science, although Professor KARL SAPPER, of Tübingen, has published an account.†

This eruption was of the same explosive type as those of St. Vincent and Martinique, but much more violent. An entirely new crater about three-quarters of a mile in its longer diameter was formed, and the south side of the volcano (which was supposed to have been extinct) was blown away.

I venture in conclusion to submit the following speculation as to the depth of the volcanic foci beneath St. Vincent and Martinique. The chimneys of the two volcanoes appear to have some connection underground as may be inferred from the following considerations. The eruptions have been repeatedly either simultaneous or so nearly so that the difference in time might be accounted for by the magma being delayed in travelling through a devious and perhaps branching passage or system of passages, blocked in different degrees by various obstructions. The eruptions have been of the same type, viz., explosive without the effusion of lava, and of a rather special variety of that type, the Pelean.‡ The chemical composition of the ejecta is not more different than could be explained by the interaction between the magma at a high temperature and the walls of the passages, supposing them to intersect various strata. It seems, therefore, natural to conclude that the two volcanoes are at the ends of two branches of one common passage, and it is not unreasonable to suppose that these branches divide at an angle not very obtuse and consequently at a great depth. If the two volcanoes were supplied from a comparatively superficial laccolite or intrusive sheet of molten matter extending widely under the whole district at no very great distance below, why did not an eruption also take place in the Island of St. Lucia, which is in a direct line between the two volcanoes and in which there is an active Soufrière, or through the sea bottom, which attains a depth of 10,000 feet both on the Atlantic and Caribbean side of the chain of islands?

* Part I., p. 532.

† Dr. KARL SAPPER, 'In den Vulcangebieten Mittelamerikas und Westindiens,' Stuttgart, 1905, and several smaller articles.

† I visited and examined the volcano in January, 1907, and have published an account of this visit in the 'Geographical Journal,' April, 1908.

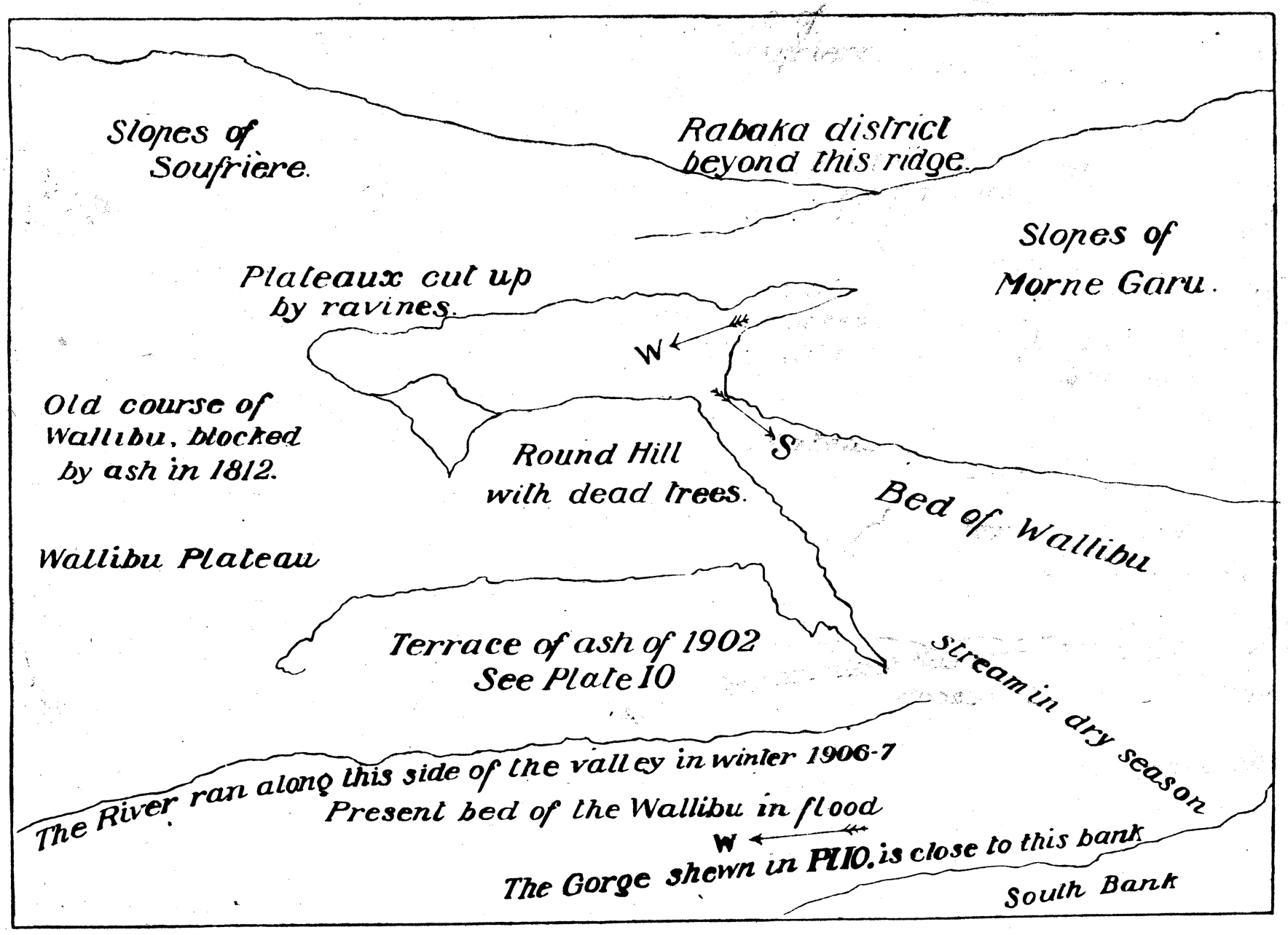
‡ For a discussion of this see Part I., p. 499, and for the details of the coincidence of these eruptions see p. 532.

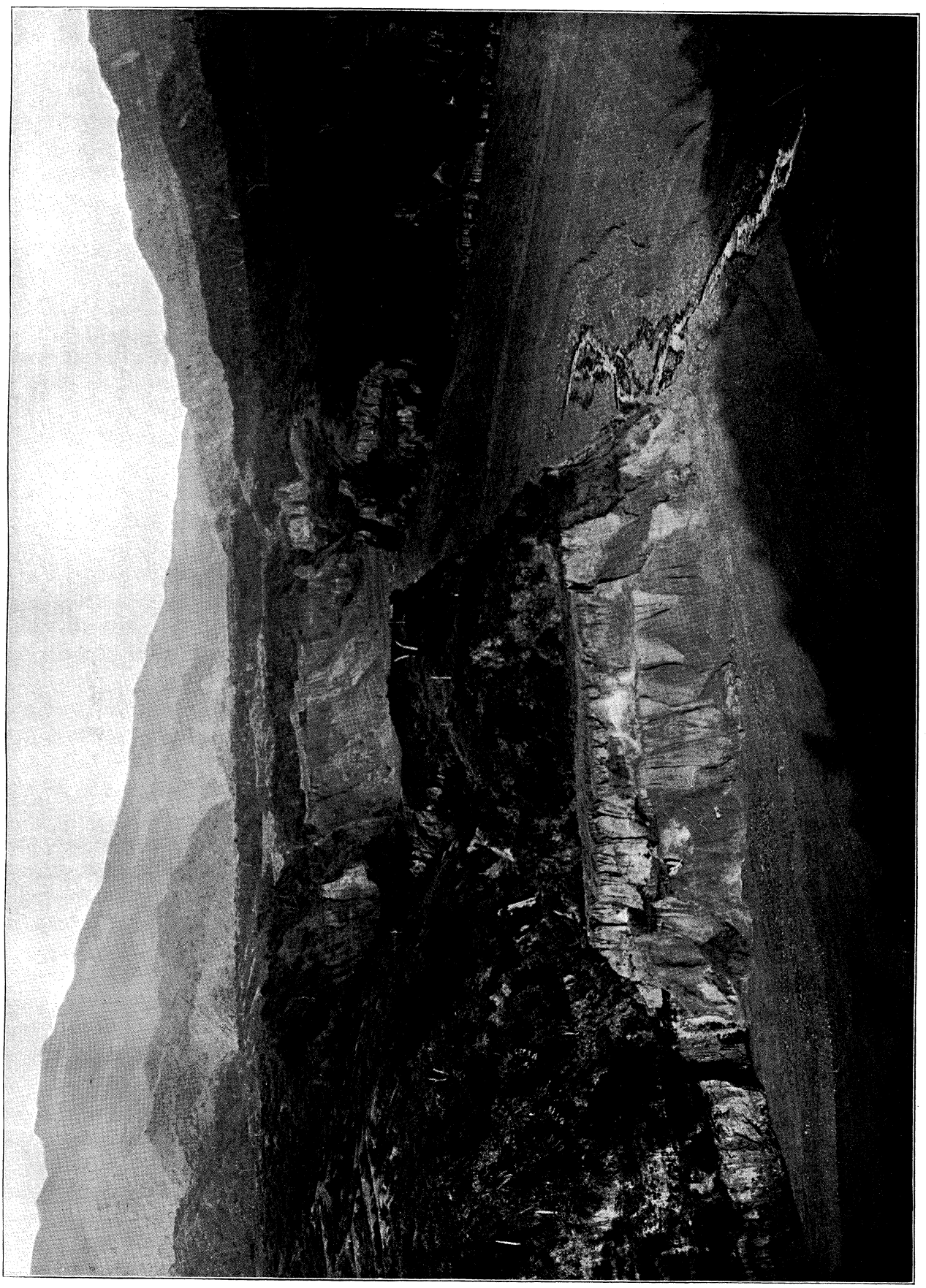
LIST OF ERRATA

IN PART I. ('PHIL. TRANS.,' A, VOL. 200, p. 353).

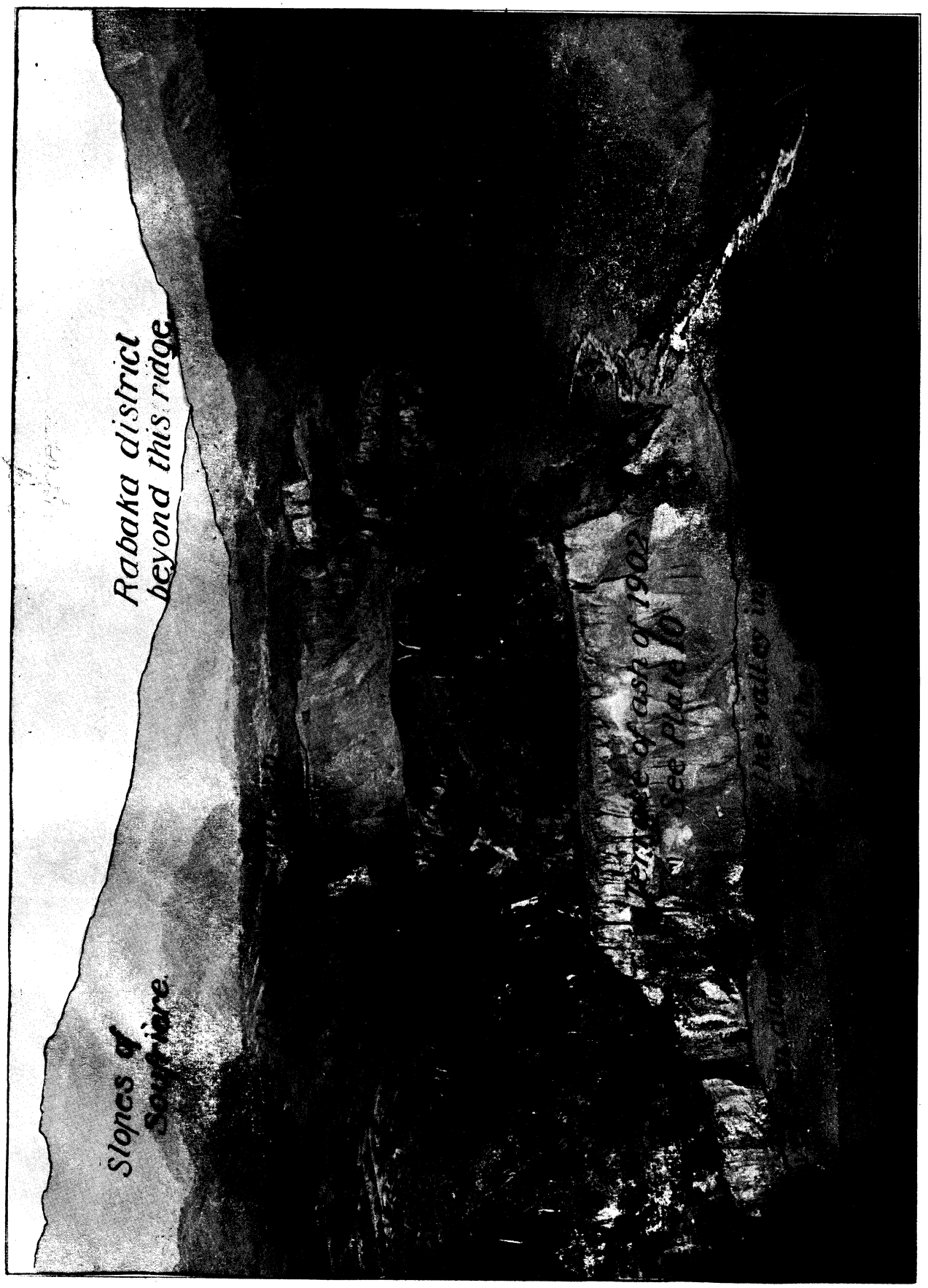
Page 361, line 31, *for* "north" *read* "south"
„ 362, „ 12, „ "indicates" *read* "indicate"
„ 378, „ 26, delete brackets ( )
„ 392, „ 18, *for* "ontburst" *read* "outburst"
„ 393, „ 28, „ "sand," *read* "sand"
„ 400, „ 11, „ "builing" *read* "building"
„ 404, „ 30, „ "Wallibu" *read* "Wallilabu"
„ 406, „ 5, „ "Wallibu," „ "Wallilabu"
„ 407, „ 26, „ "where," *read* "where"
„ 412, „ 11, delete $\delta\gamma-$
„ 414, „ 26, *for* "Wallibu," *read* "Wallilabu"
„ 435, „ 10, „ "Plate 21," *read* "Plate 31"
„ 452, „ 12, „ "pointin goutward" *read* "pointing outward
„ 471, „ 5, „ "has" *read* "had
„ 480, „ 4 from bottom, *for* "p. 11" *read* "Plate II"
„ 497, „ 5 „ „ „ "on" *read* "in"
„ 509, „ 6 „ „ „ "The" *read* "the"
„ 532, „ 9 „ „ „ "Ruez-Altenango" *read* "Quezaltenango"
„ 535, „ 25, *for* "1776" *read* "1766"
„ 543, „ 4 from bottom, *for* "SOWTRAY" *read* "SOWRAY"

„ 413 is incorrectly numbered 418

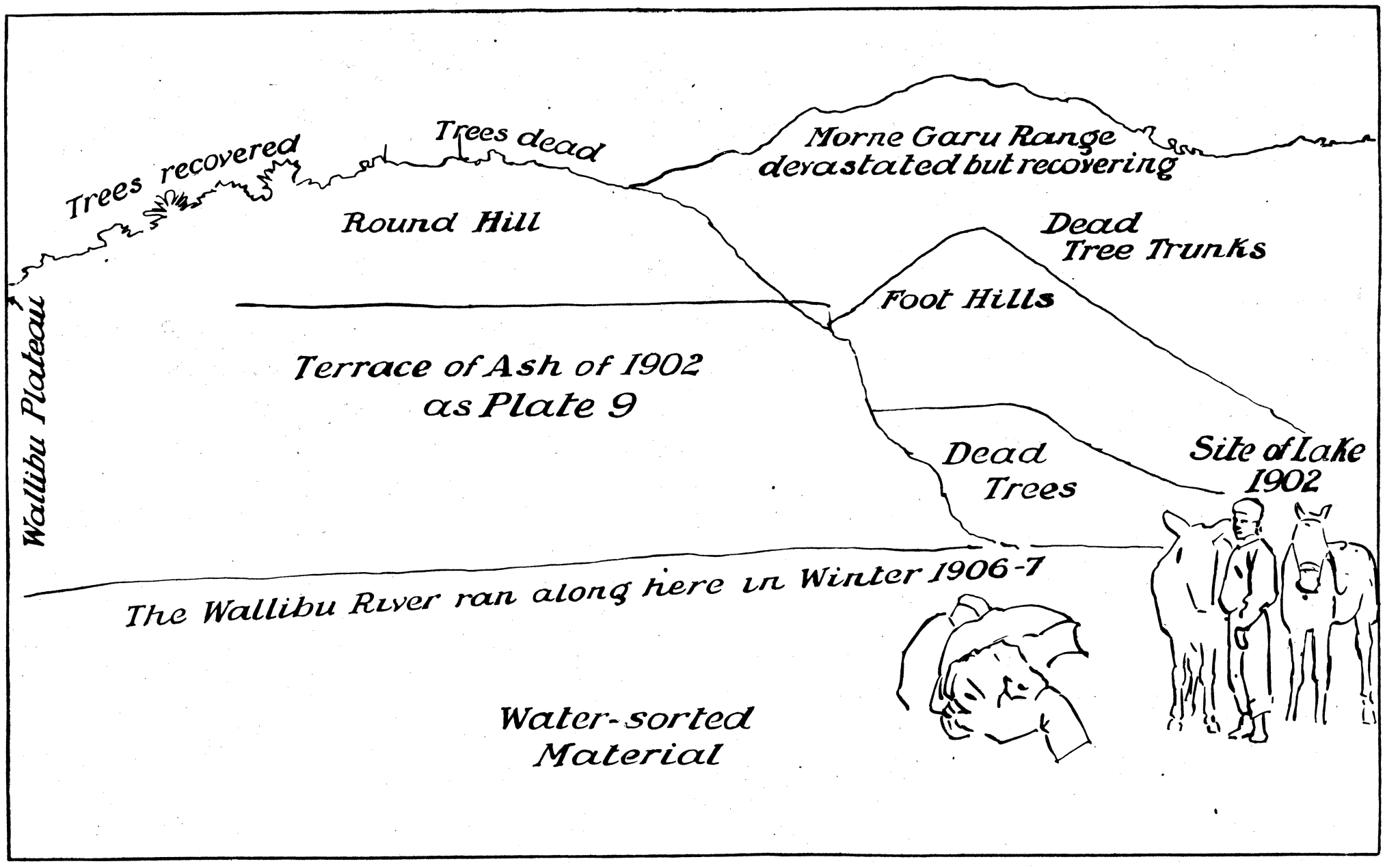

Slopes of Soufrière.
Rabaka district beyond this ridge.
Slopes of Morne Garu.
Plateaux cut up by ravines.
W
S
Old course of Wallibu, blocked by ash in 1812.
Round Hill with dead trees.
Bed of Wallibu
Wallibu Plateau
Terrace of ash of 1902
See Plate 10
Stream in dry season
The River ran along this side of the valley in winter 1906-7
Present bed of the Wallibu in flood
W
The Gorge shewn in Pl.10. is close to this bank
South Bank

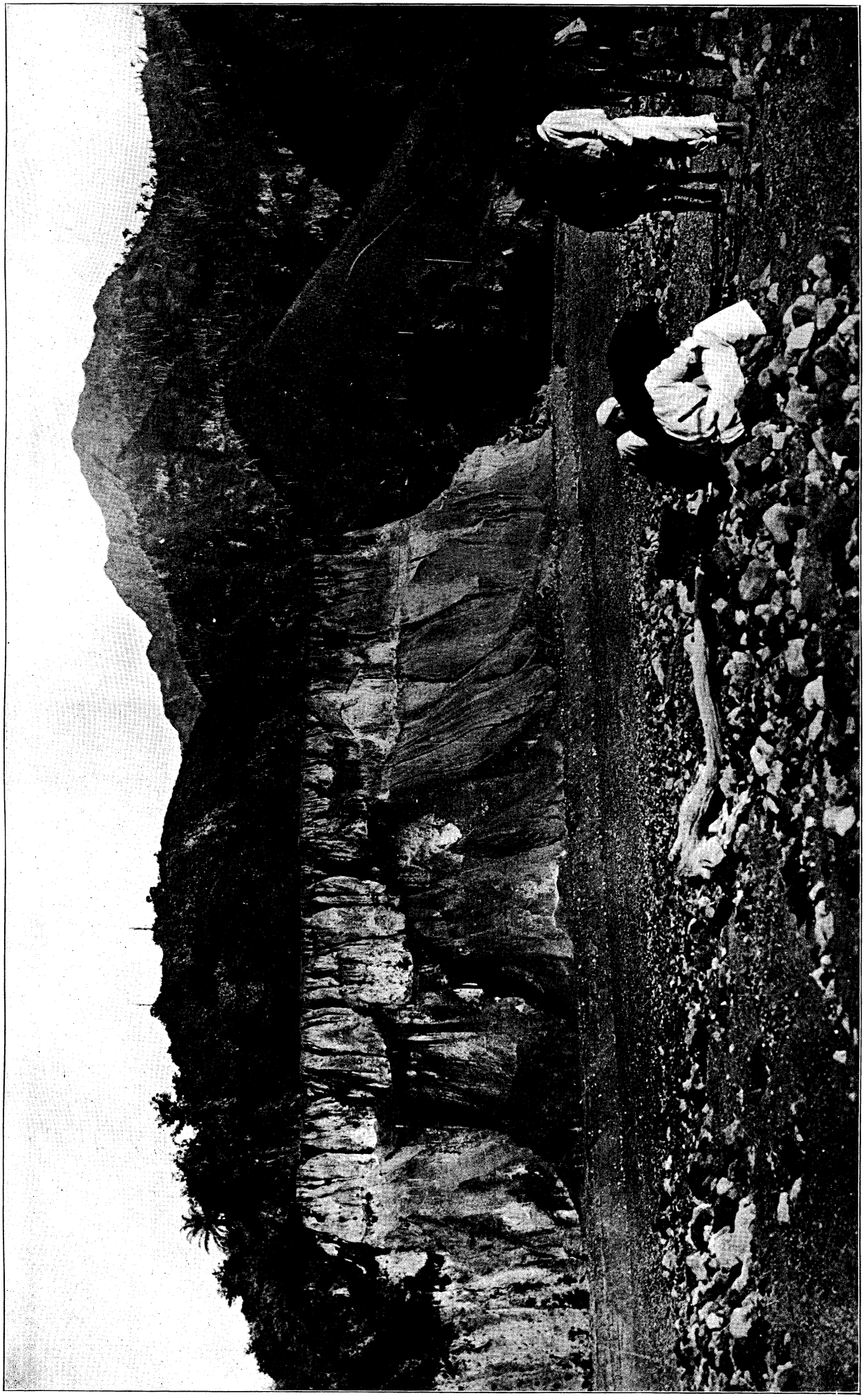


Lower Wallibu district, from Richmond Ridge, near Bunker's Hill.

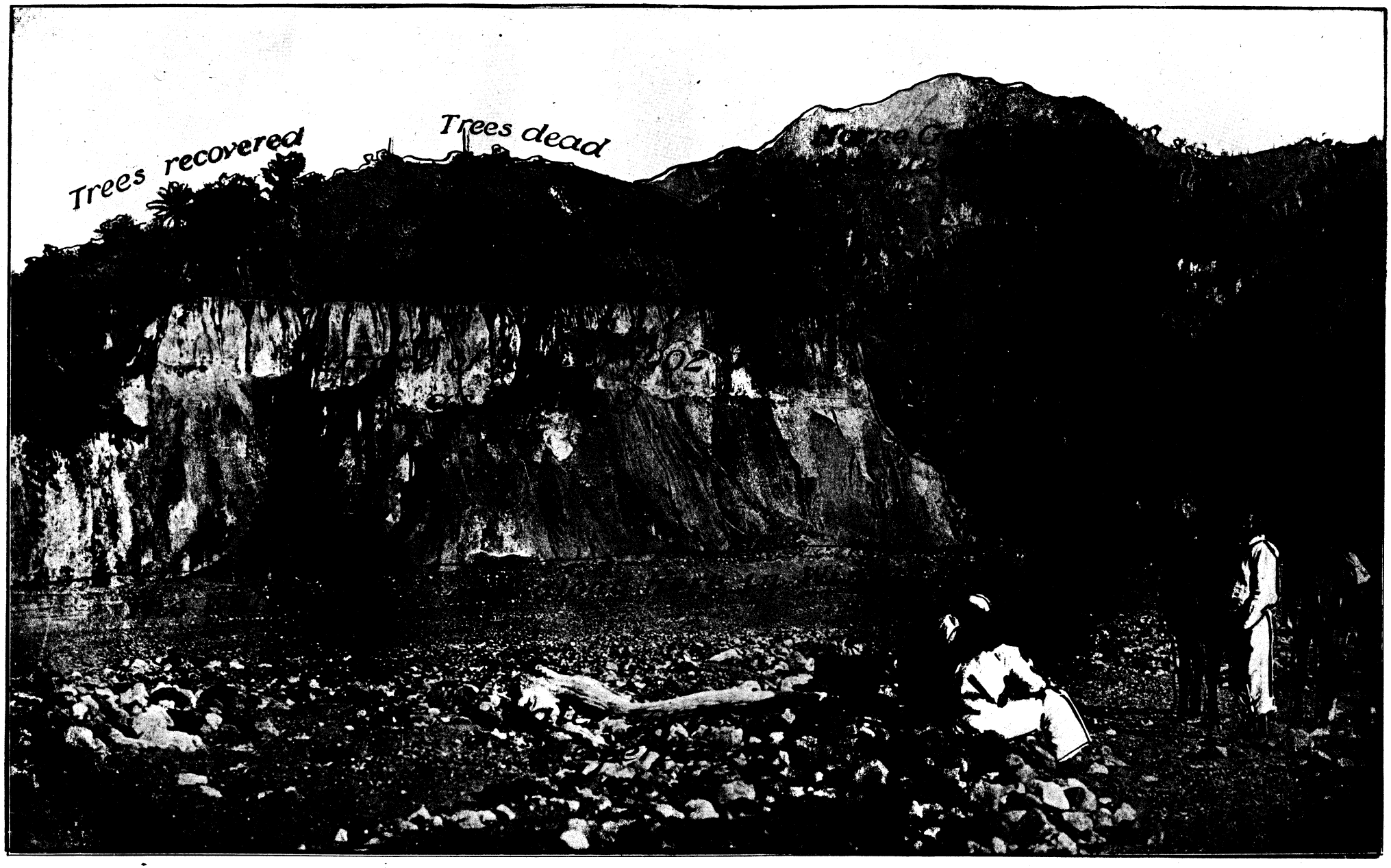


Lower Wallibu district, from Richmond Ridge, near Bowden's Hill.

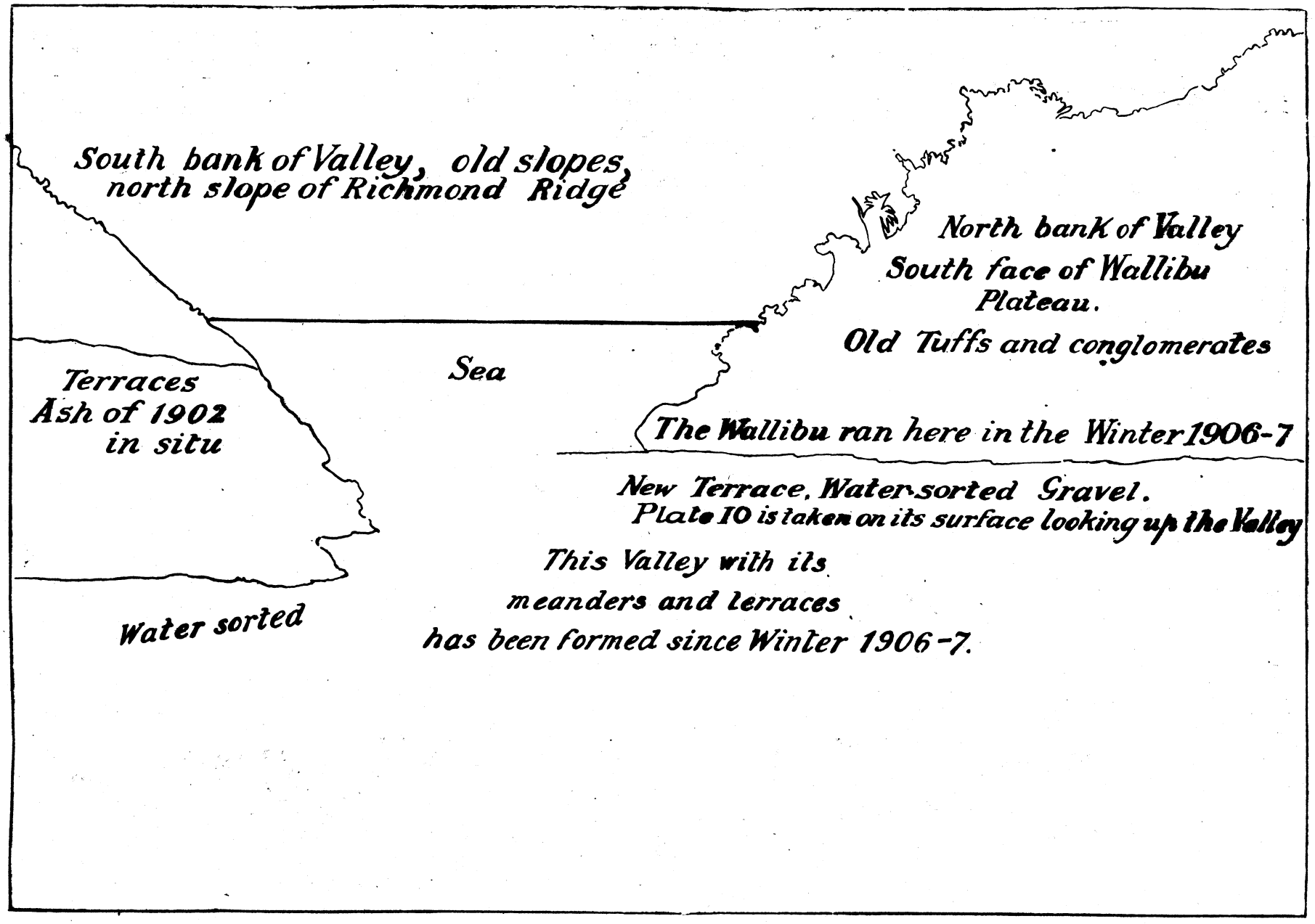

Trees recovered
Trees dead
Morne Garu Range
devastated but recovering
Round Hill
Dead
Tree Trunks
Foot Hills
Wallibu Plateau
Terrace of Ash of 1902
as Plate 9
Dead
Trees
Site of Lake
1902
The Wallibu River ran along here in Winter 1906-7
Water-sorted
Material

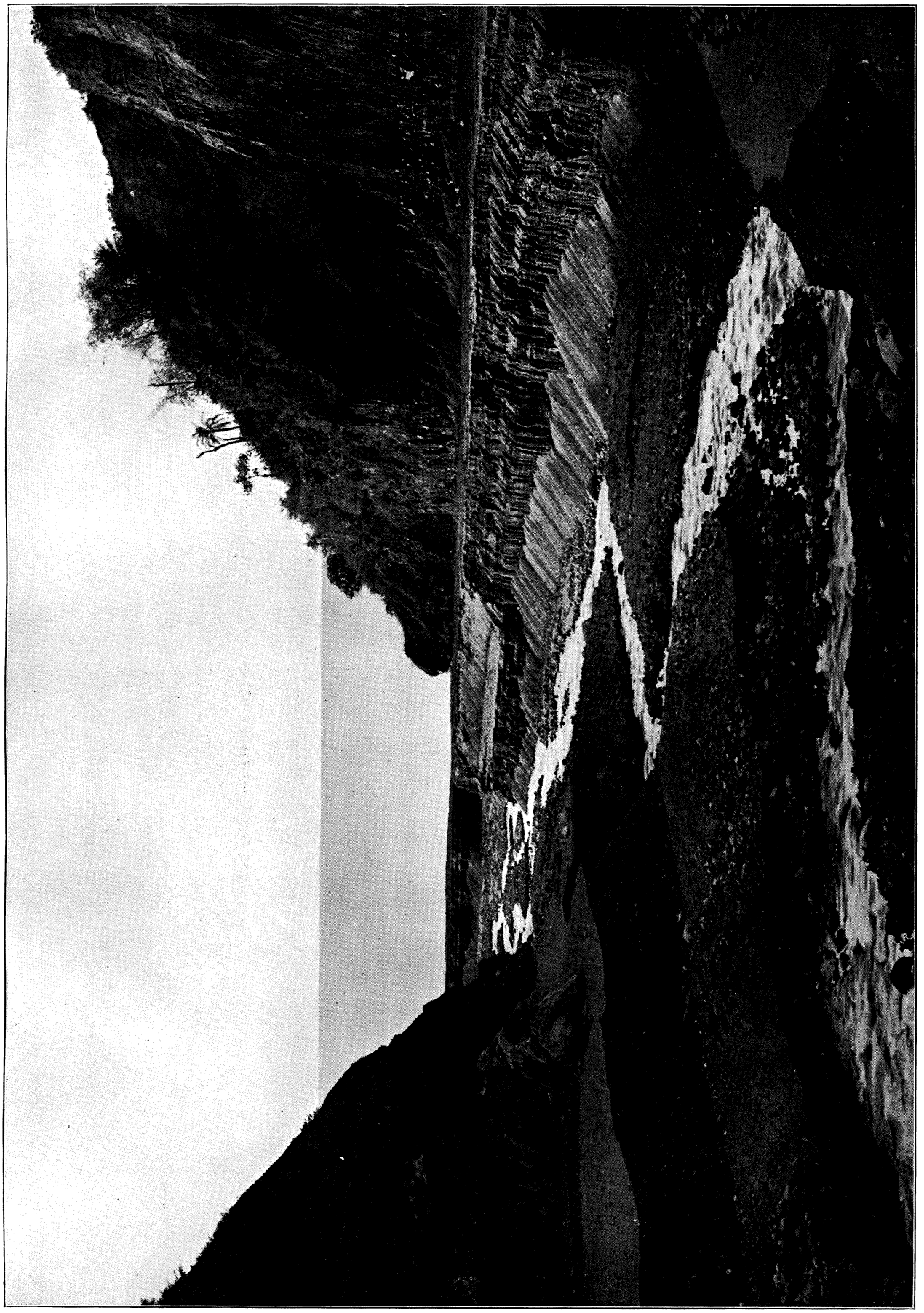


Terrace of new ash, North bank, Lower Waihibu Valley.

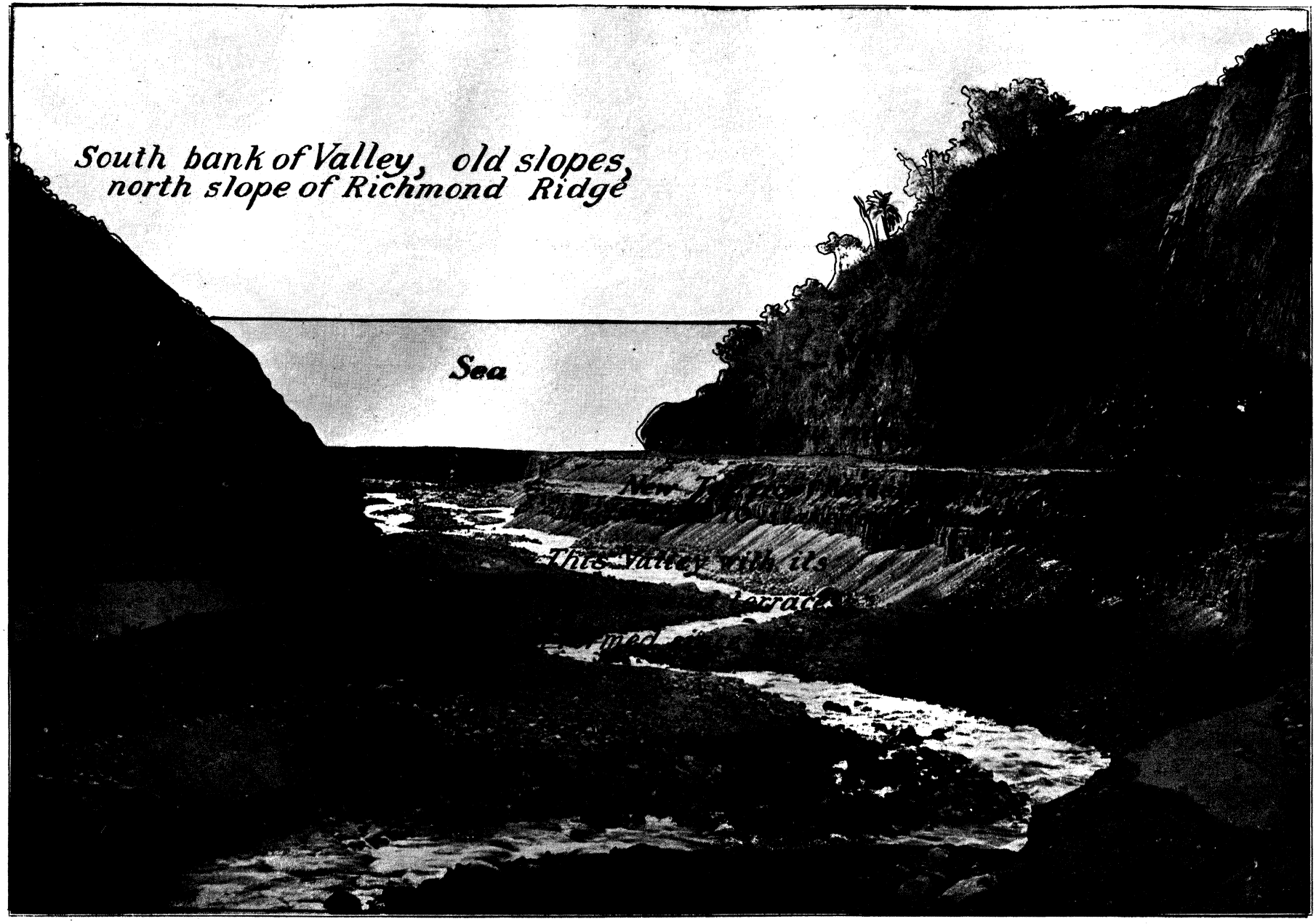


Terrace of new ash, North bank, Lower Wallibu Valley.

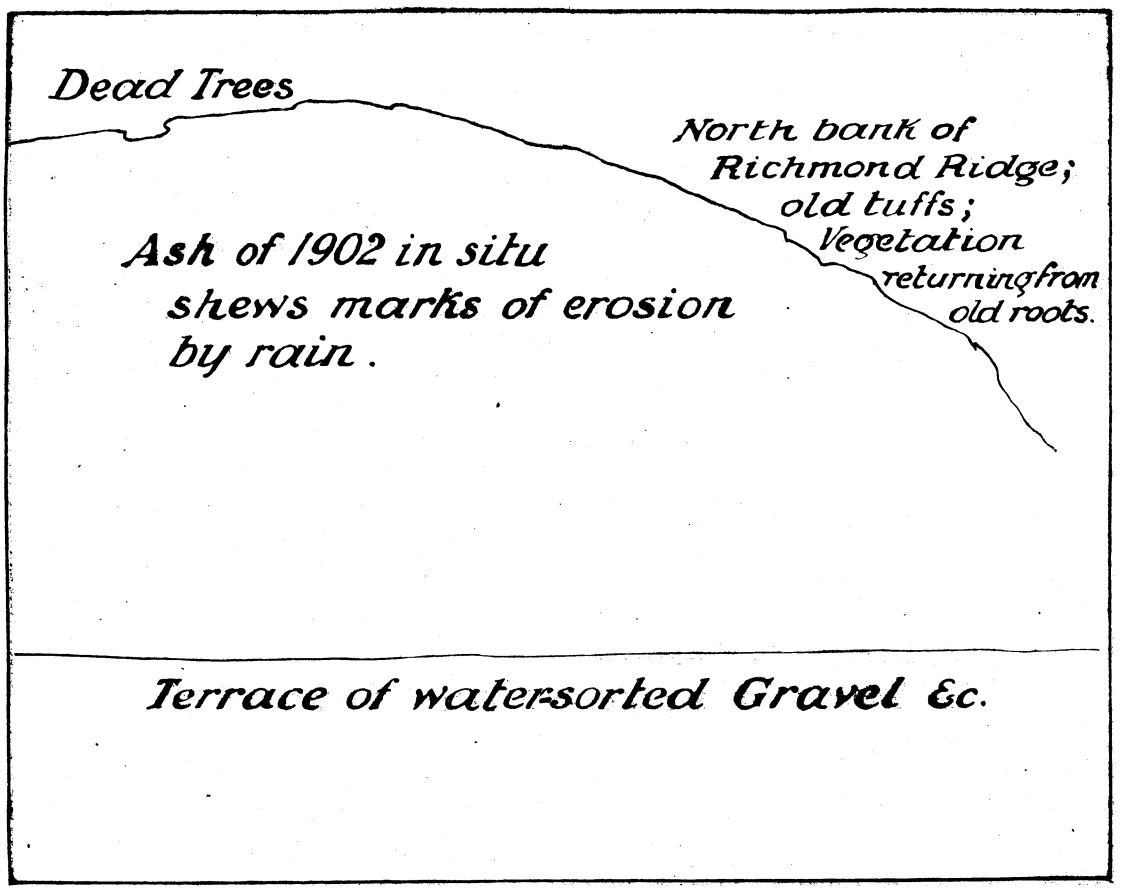

South bank of Valley, old slopes,
north slope of Richmond Ridge
North bank of Valley
South face of Wallibu
Plateau.
Old Tuffs and conglomerates
Sea
Terraces
Ash of 1902
in situ
The Wallibu ran here in the Winter 1906-7
New Terrace, Water-sorted Gravel.
Plate 10 is taken on its surface looking up the Valley
This Valley with its
meanders and terraces
has been formed since Winter 1906-7.
Water sorted

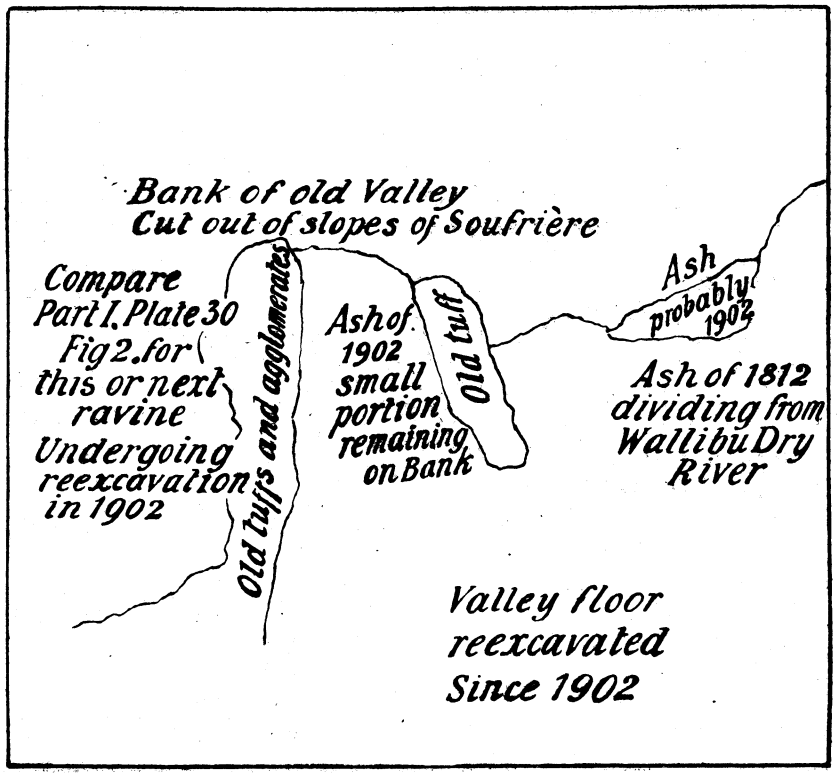


Lower Wallibu Valley, looking West, towards the sea.



Lower Wallibu Valley, looking West, towards the sea.


Dead Trees
North bank of Richmond Ridge; old tuffs; Vegetation returning from old roots.
Ash of 1902 in situ shews marks of erosion by rain.
Terrace of water-sorted Gravel &c.


Bank of old Valley Cut out of slopes of Soufrière
Compare Part I. Plate 30 Fig 2. for this or next ravine Undergoing reexcavation in 1902
Old tuffs and agglomerates
Ash of 1902 small portion remaining on Bank
Old tuff
Ash probably 1902
Ash of 1812 dividing from Wallibu Dry River
Valley floor reexcavated Since 1902

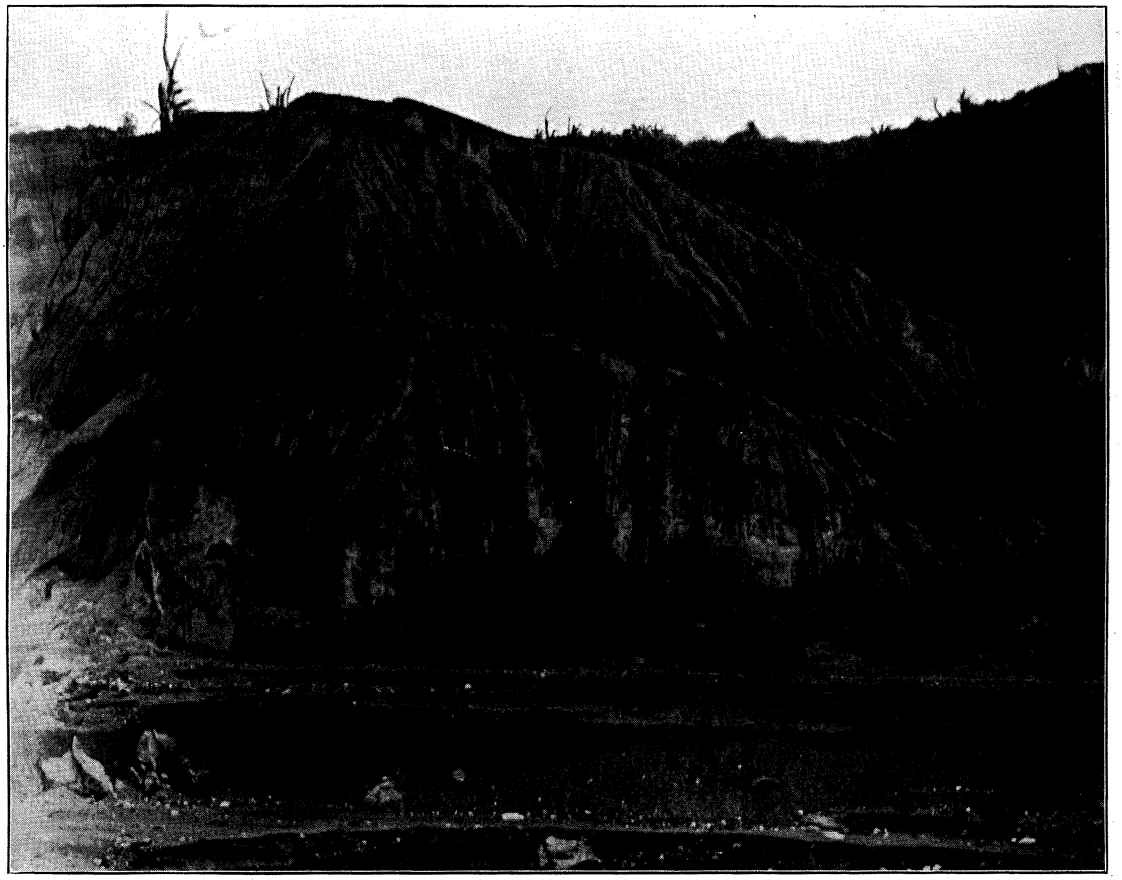


Fig. 1. *Terraces on South bank of Lower Wallibu.*

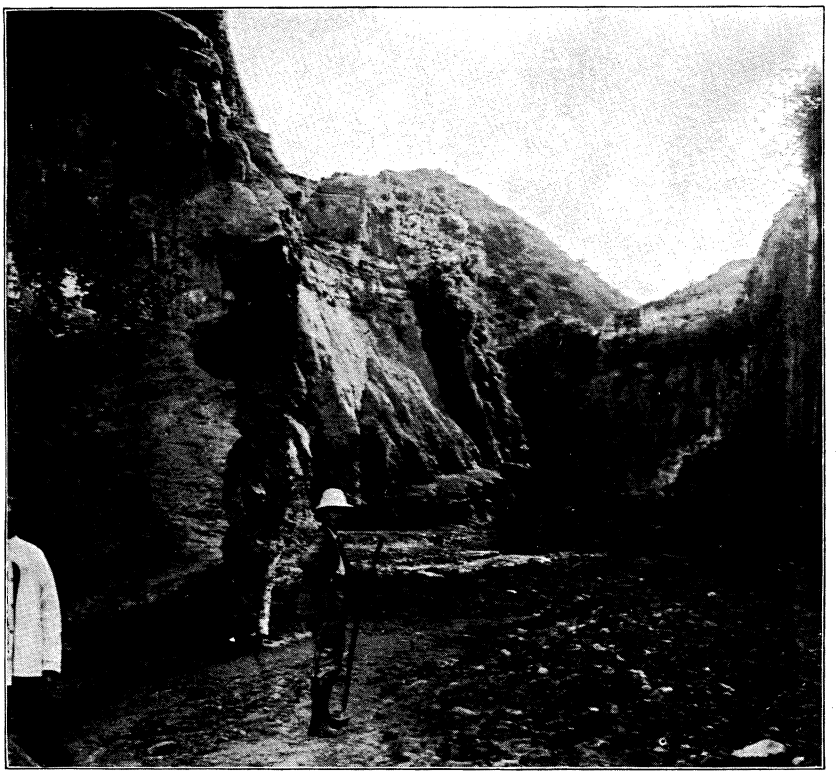


Fig. 2. *Trespé Ravine.*

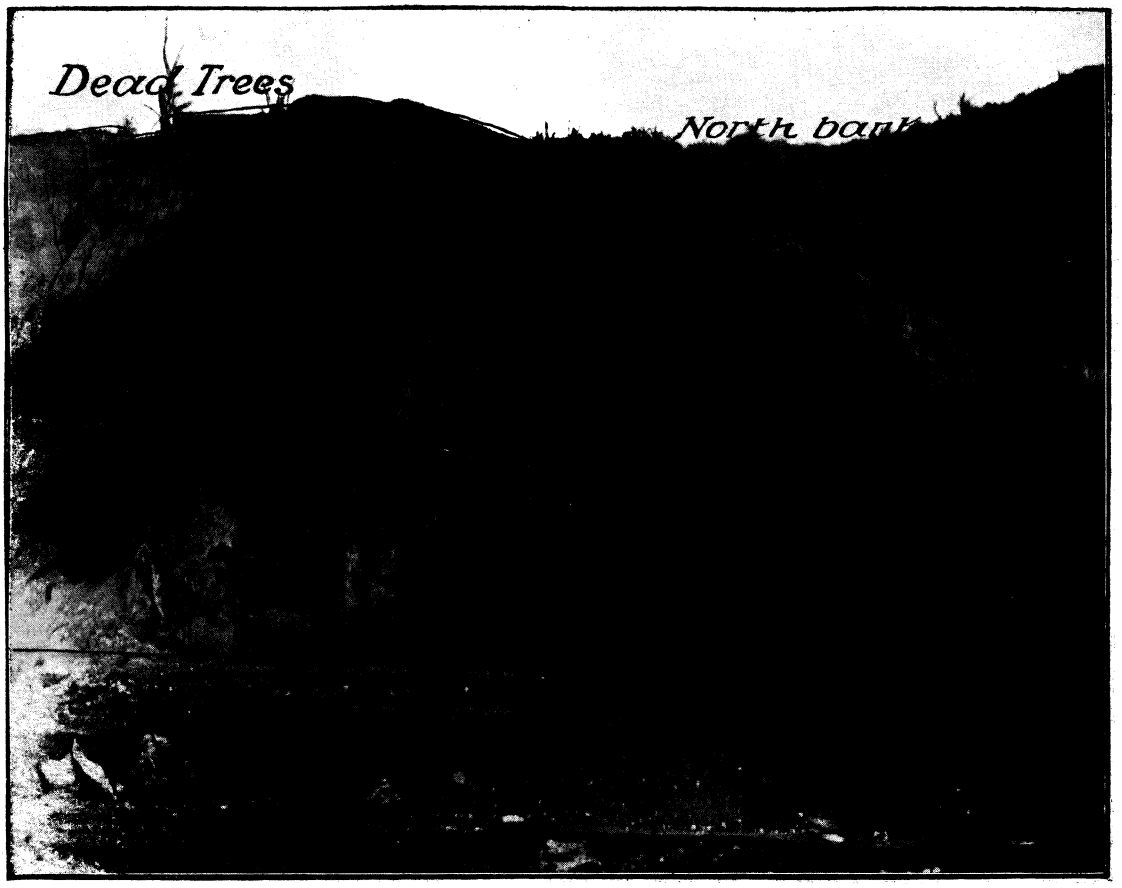
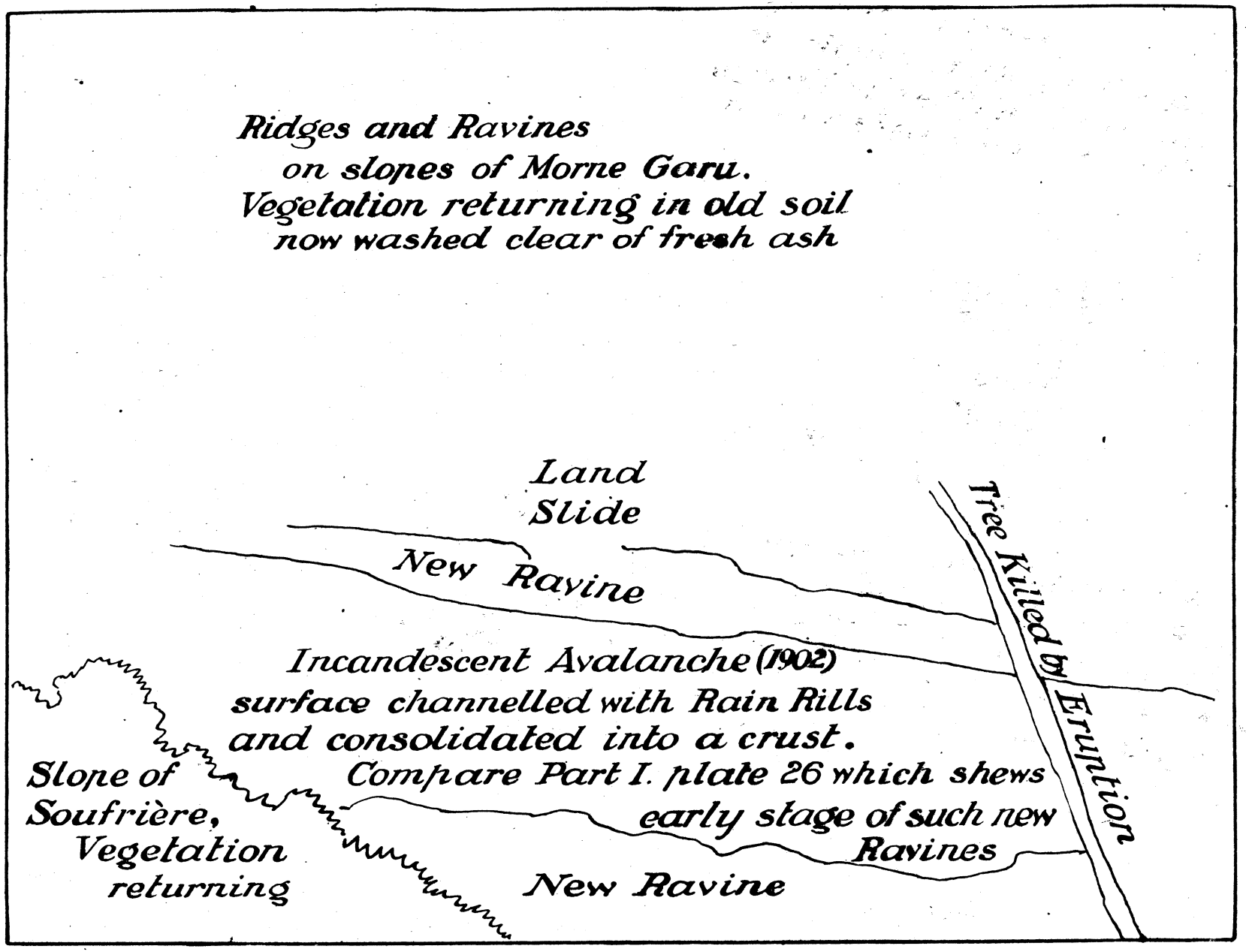
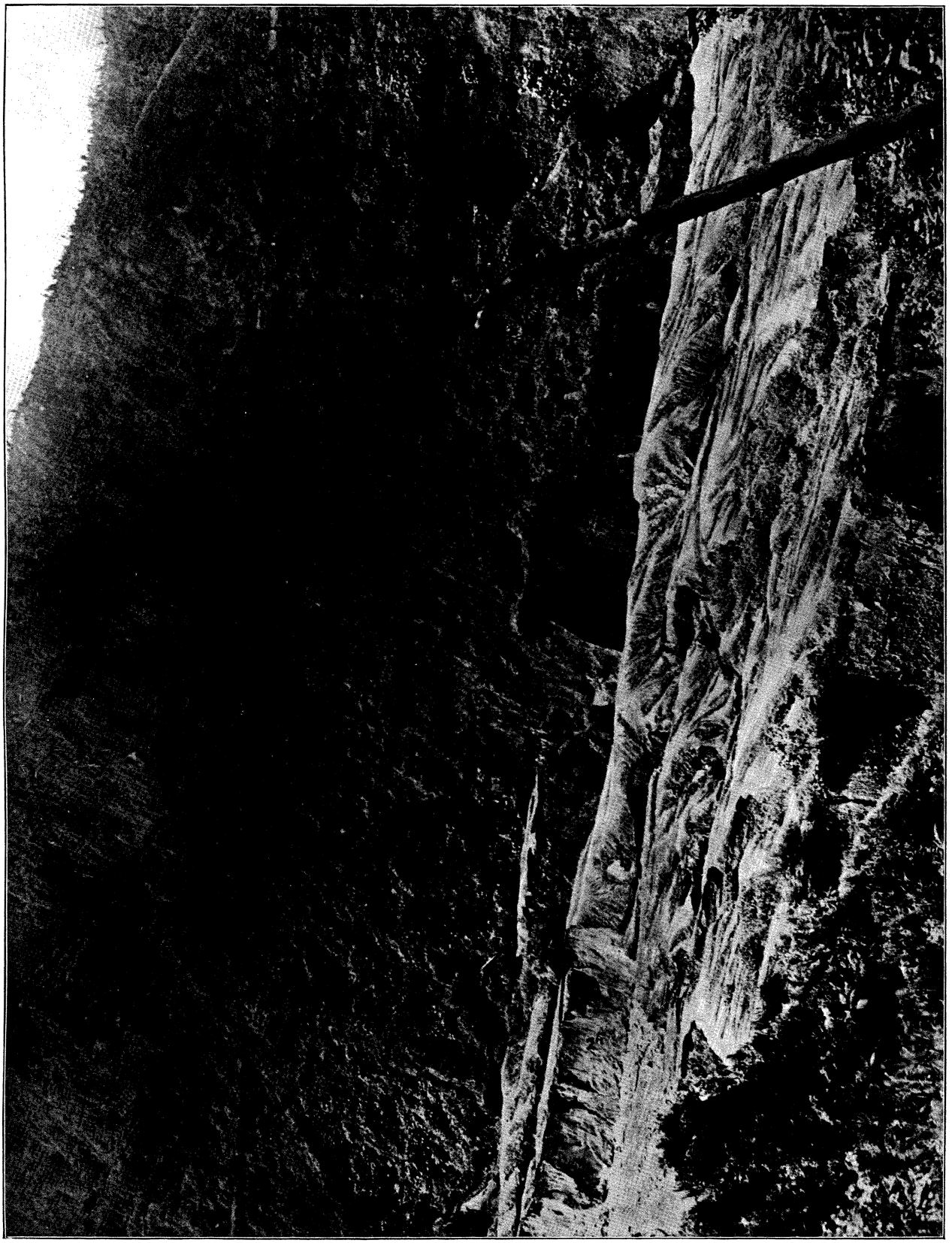


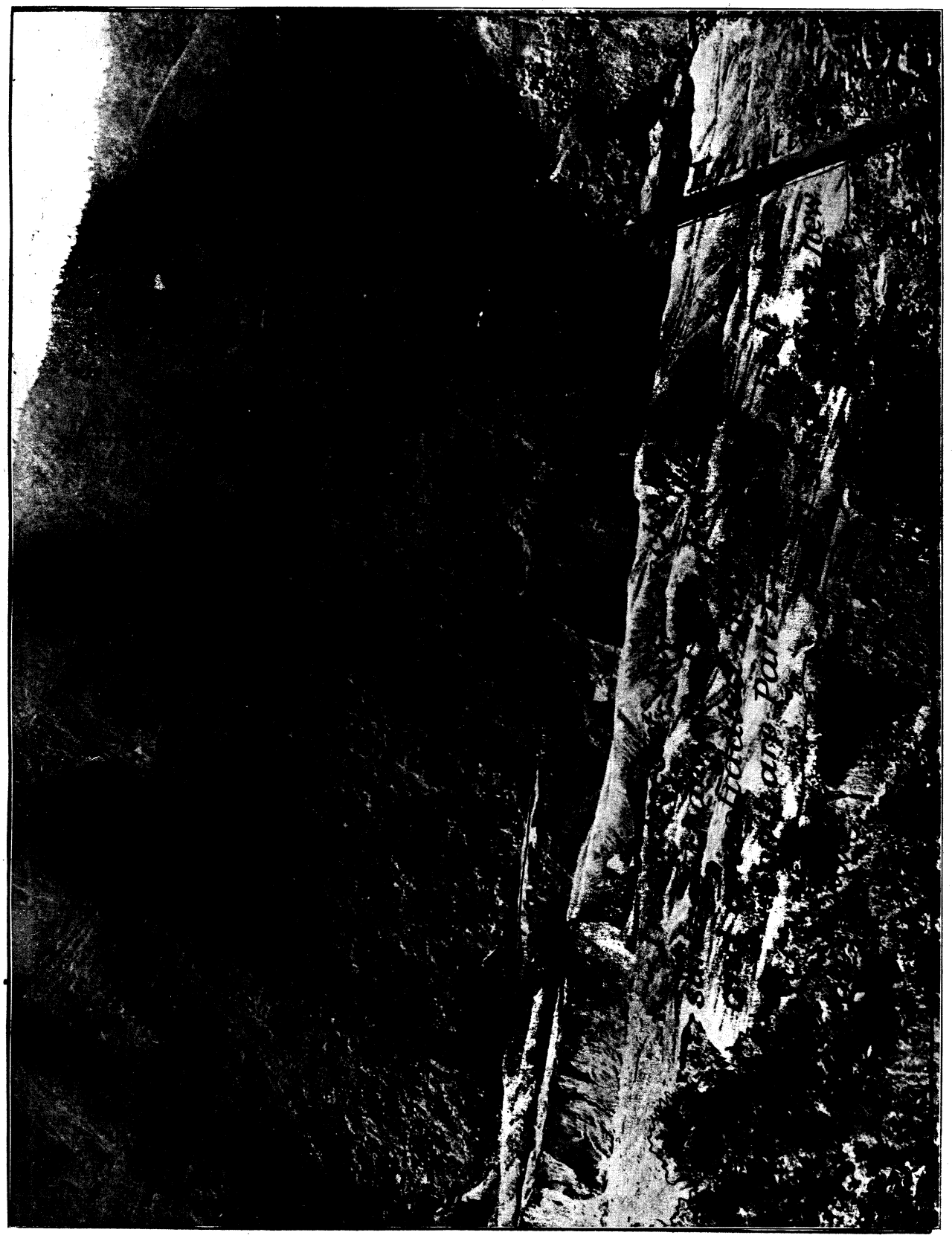
Fig. 1. *Terraces on South bank of Lower Wallibu.*

Fig. 2. *Trespé Ravine.*

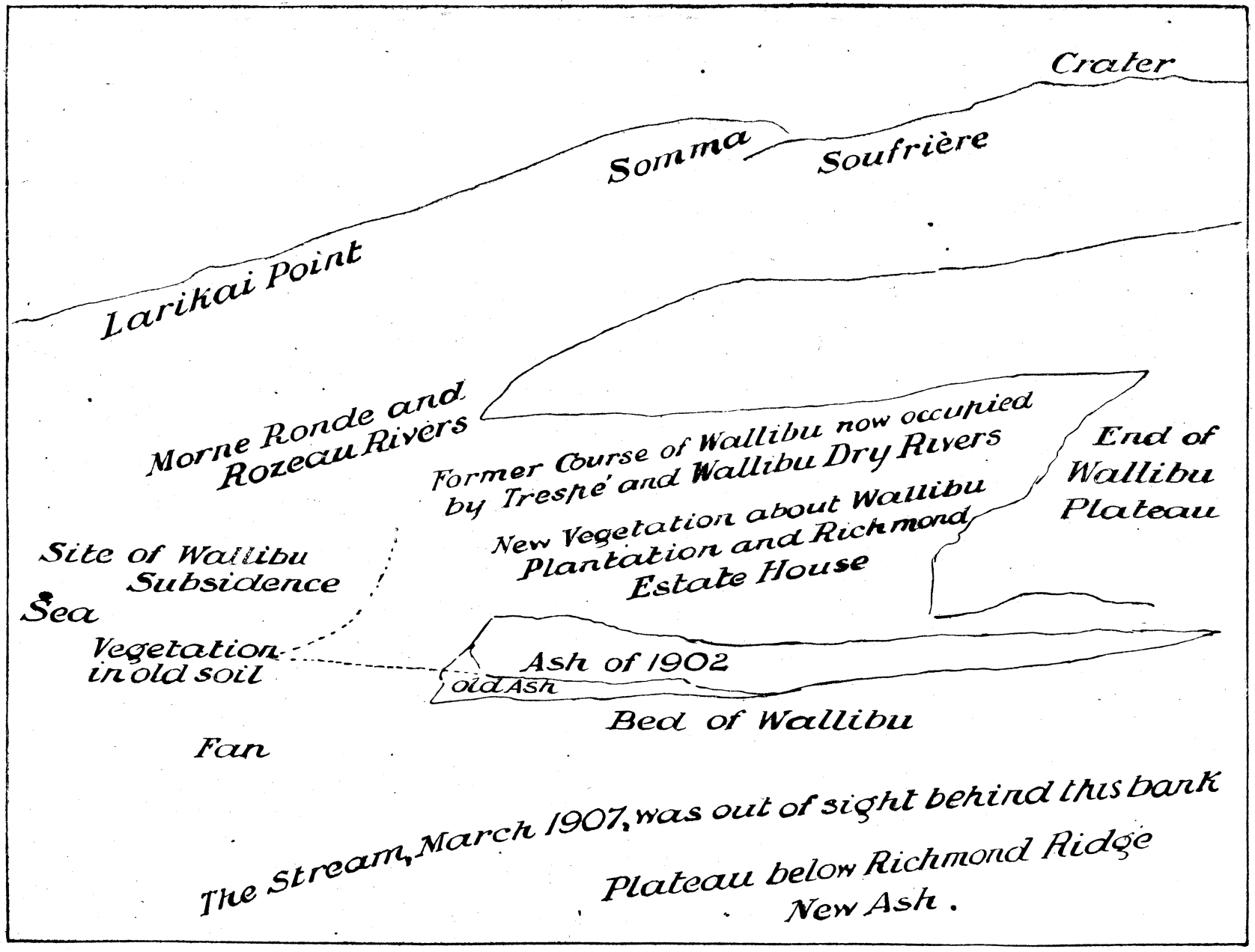

Ridges and Ravines
on slopes of Morne Garu.
Vegetation returning in old soil
now washed clear of fresh ash
Land
Slide
New Ravine
Tree Killed by Eruption
Incandescent Avalanche (1902)
surface channelled with Rain Rills
and consolidated into a crust.
Compare Part I. plate 26 which shews
early stage of such new
Ravines
Slope of
Soufrière,
Vegetation
returning
New Ravine

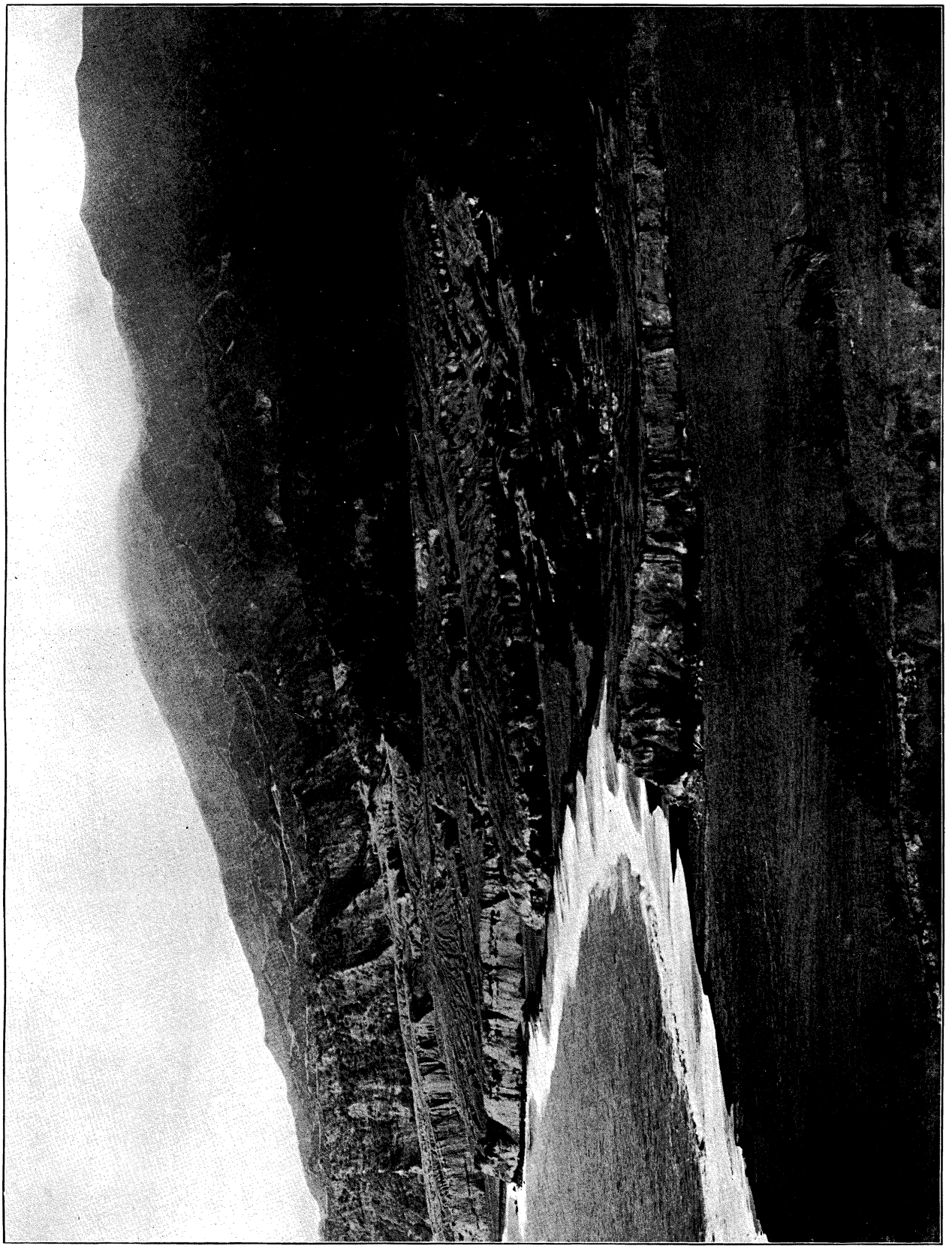


Ravine on Soufrière, Upper Trespé Valley.

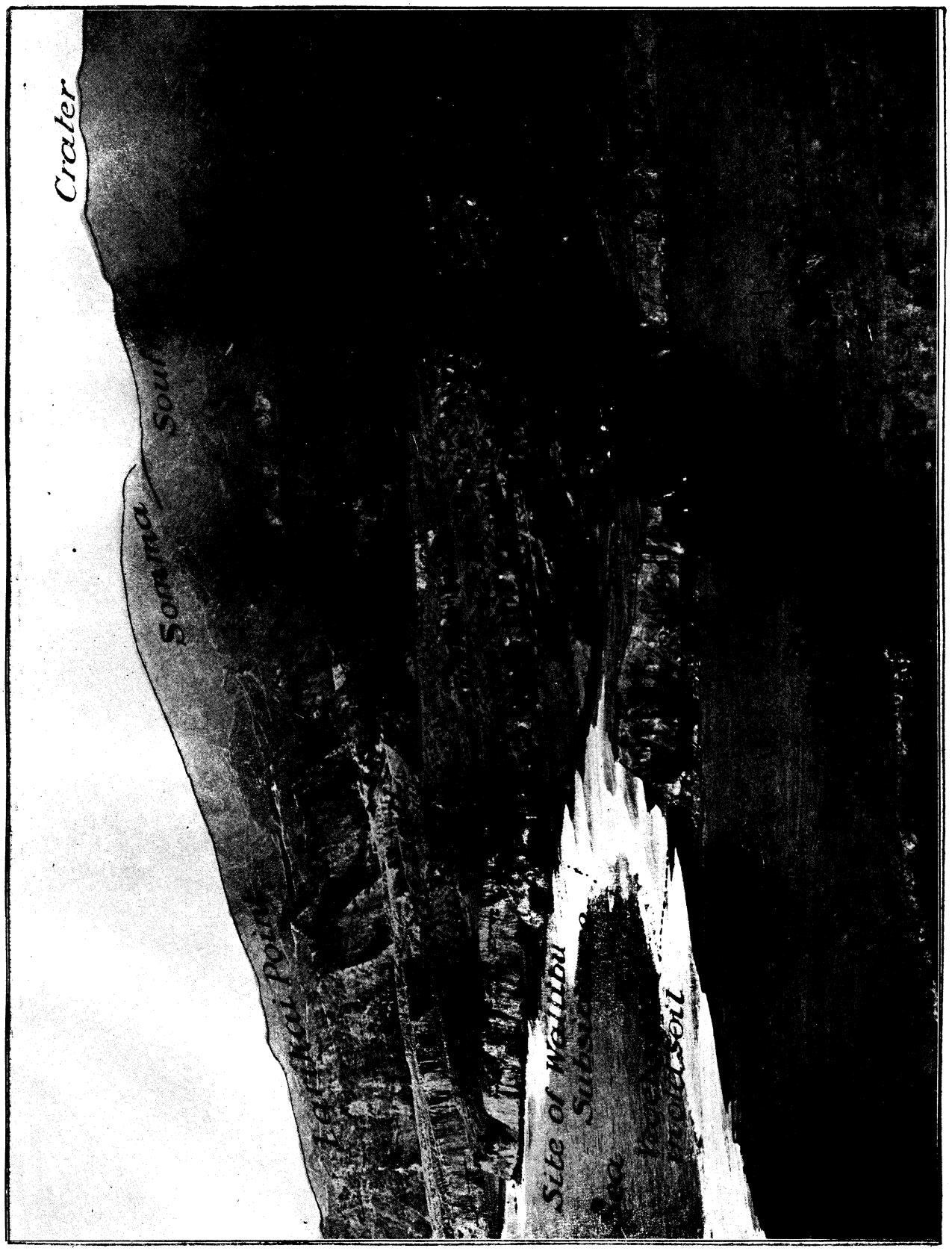


Ravine on Soufrière, Upper Trespé Valley.

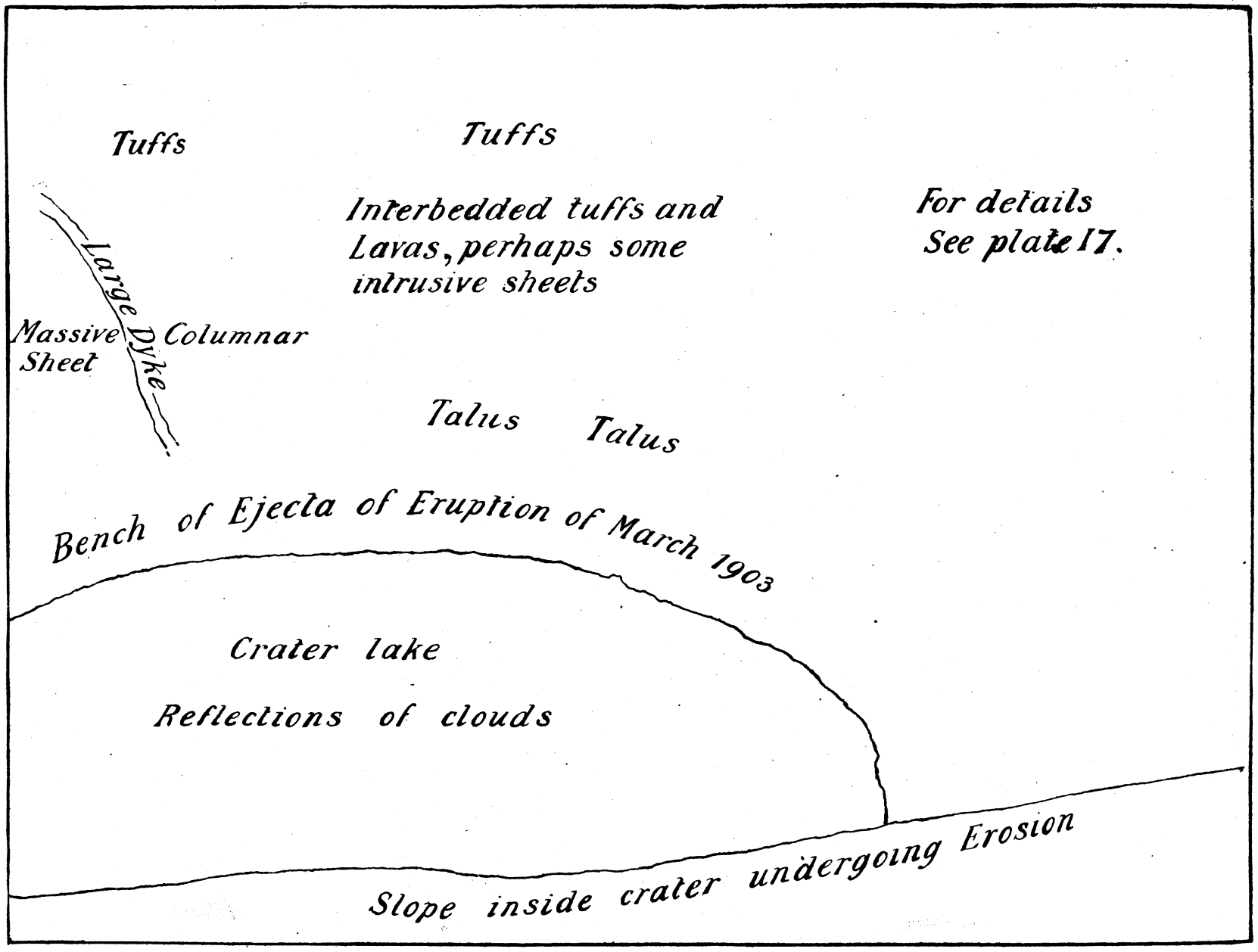

Crater
Somma
Soufrière
Larikai Point
Morne Ronde and Rozeau Rivers
Former Course of Wallibu now occupied by Trespé and Wallibu Dry Rivers
End of Wallibu Plateau
New Vegetation about Wallibu Plantation and Richmond Estate House
Site of Wallibu Subsidence
Sea
Vegetation in old soil
Ash of 1902
old Ash
Bed of Wallibu
Fan
The Stream, March 1907, was out of sight behind this bank
Plateau below Richmond Ridge
New Ash.

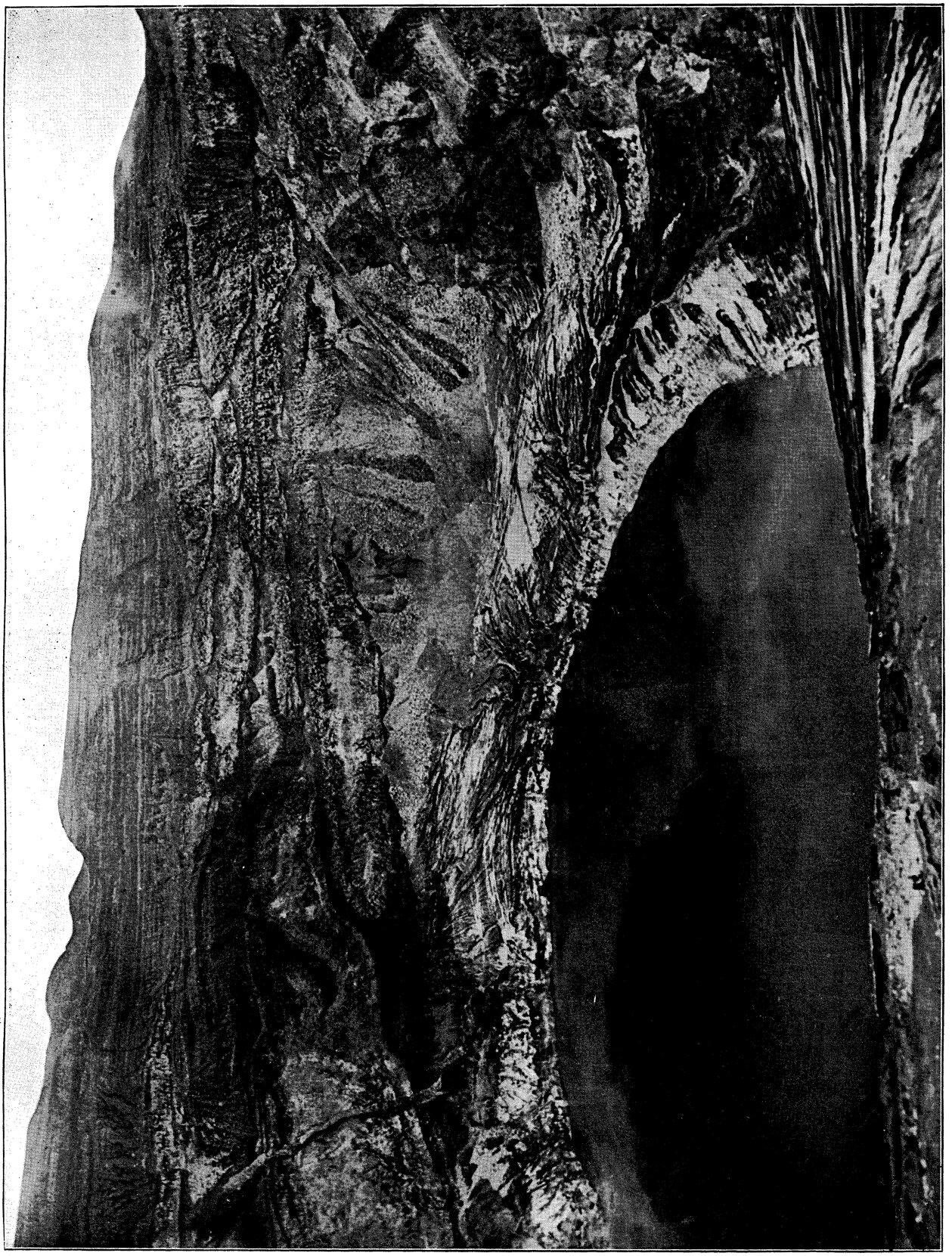


Mouth of Wallibu, from Plateau below Richmond Ridge.

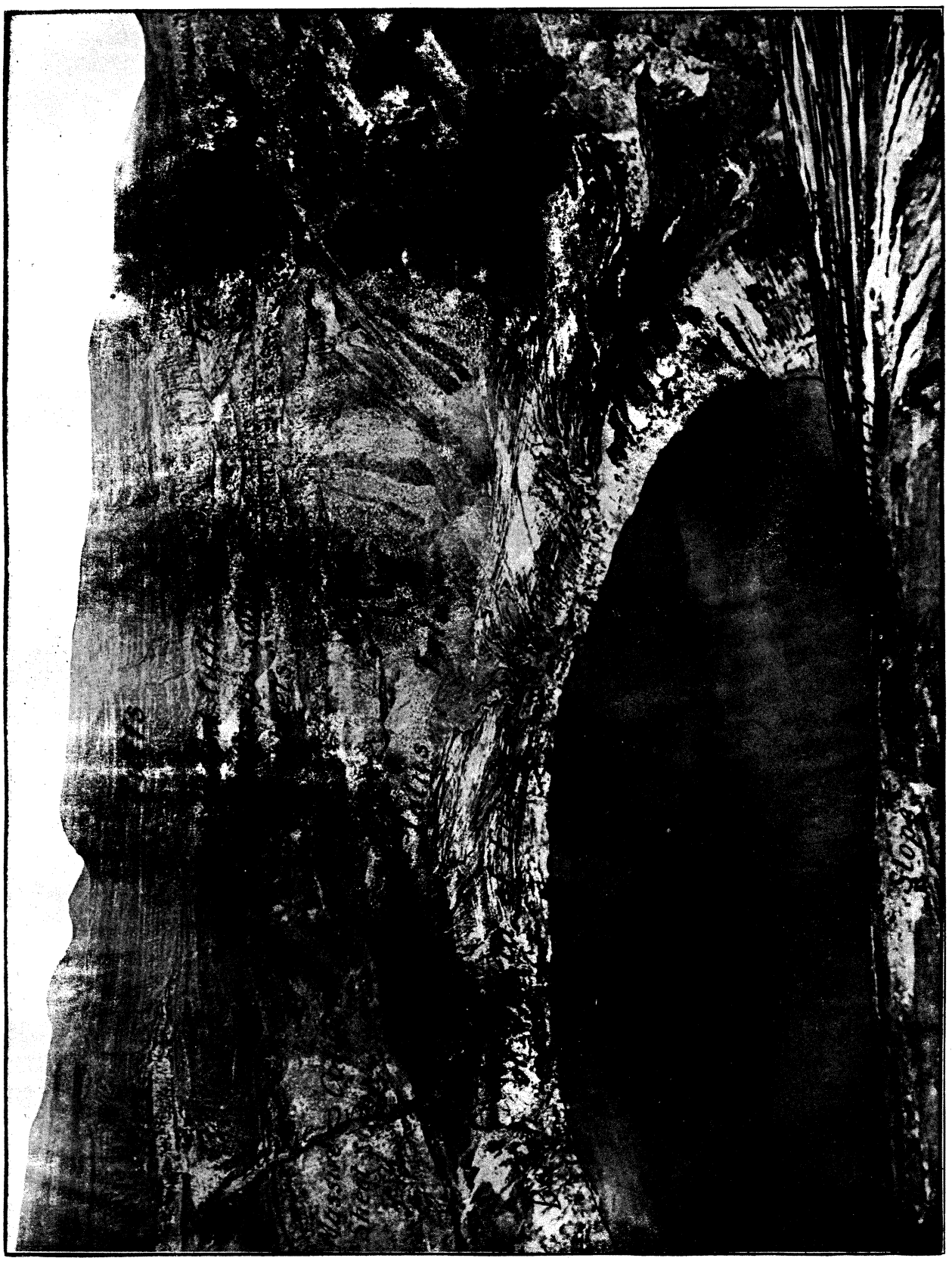


Mouth of Wallibu, from Plateau below Richmond Ridge.

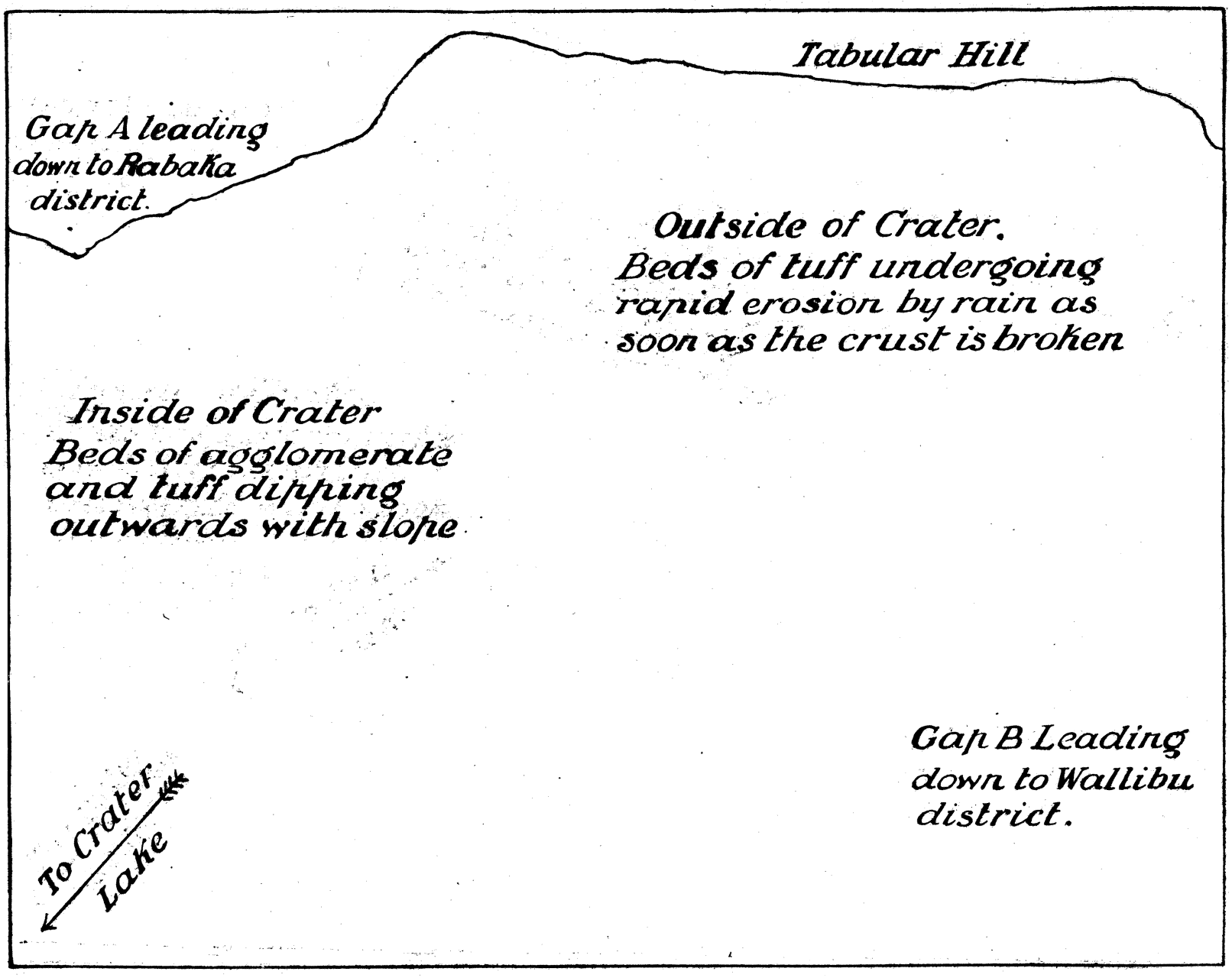

Tuffs
Tuffs
Interbedded tuffs and Lavas, perhaps some intrusive sheets
For details See plate 17.
Large Dyke
Massive Columnar Sheet
Talus
Talus
Bench of Ejecta of Eruption of March 1903
Crater lake
Reflections of clouds
Slope inside crater undergoing Erosion

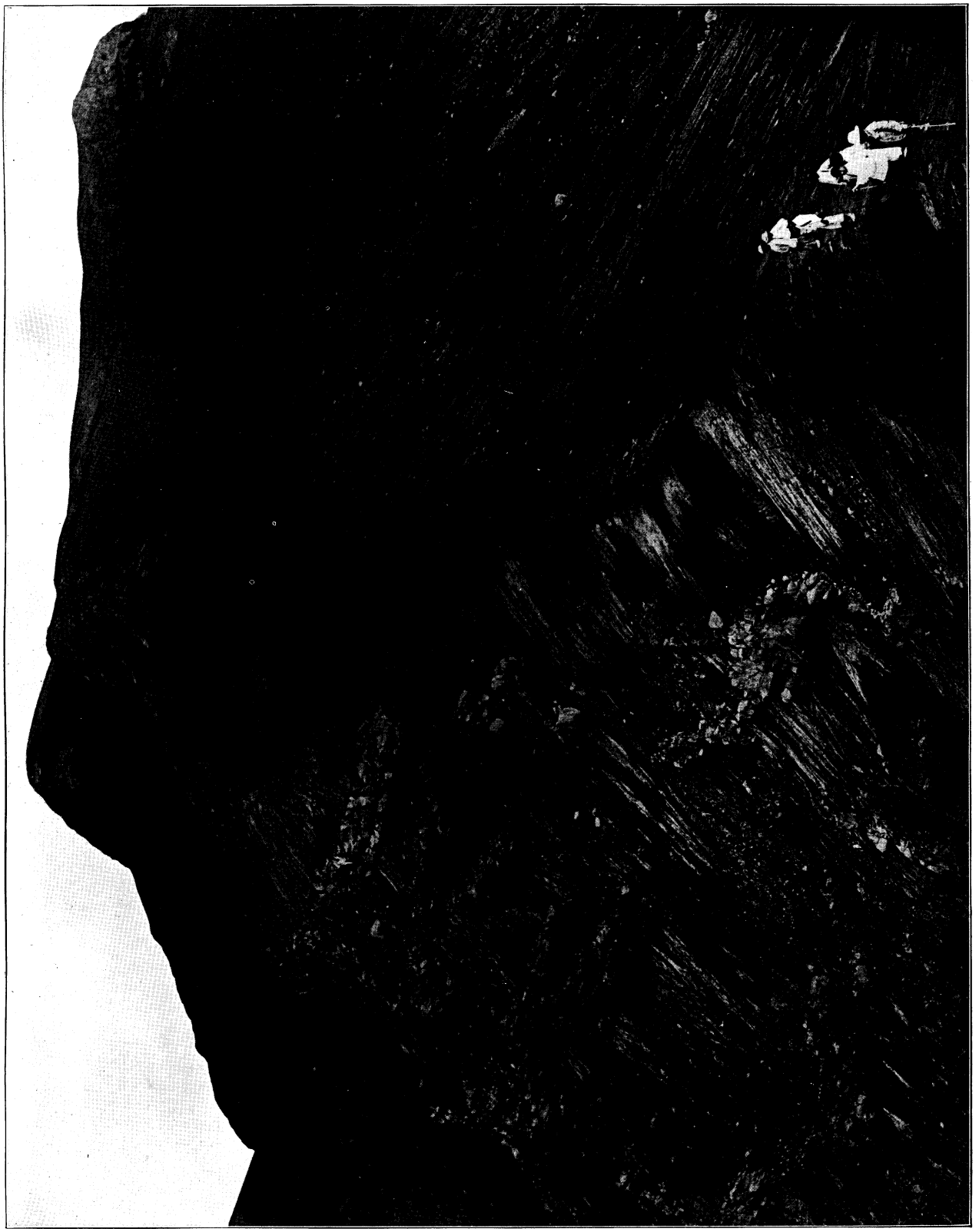


The Crater of the Soufrière, from the South-west lip.

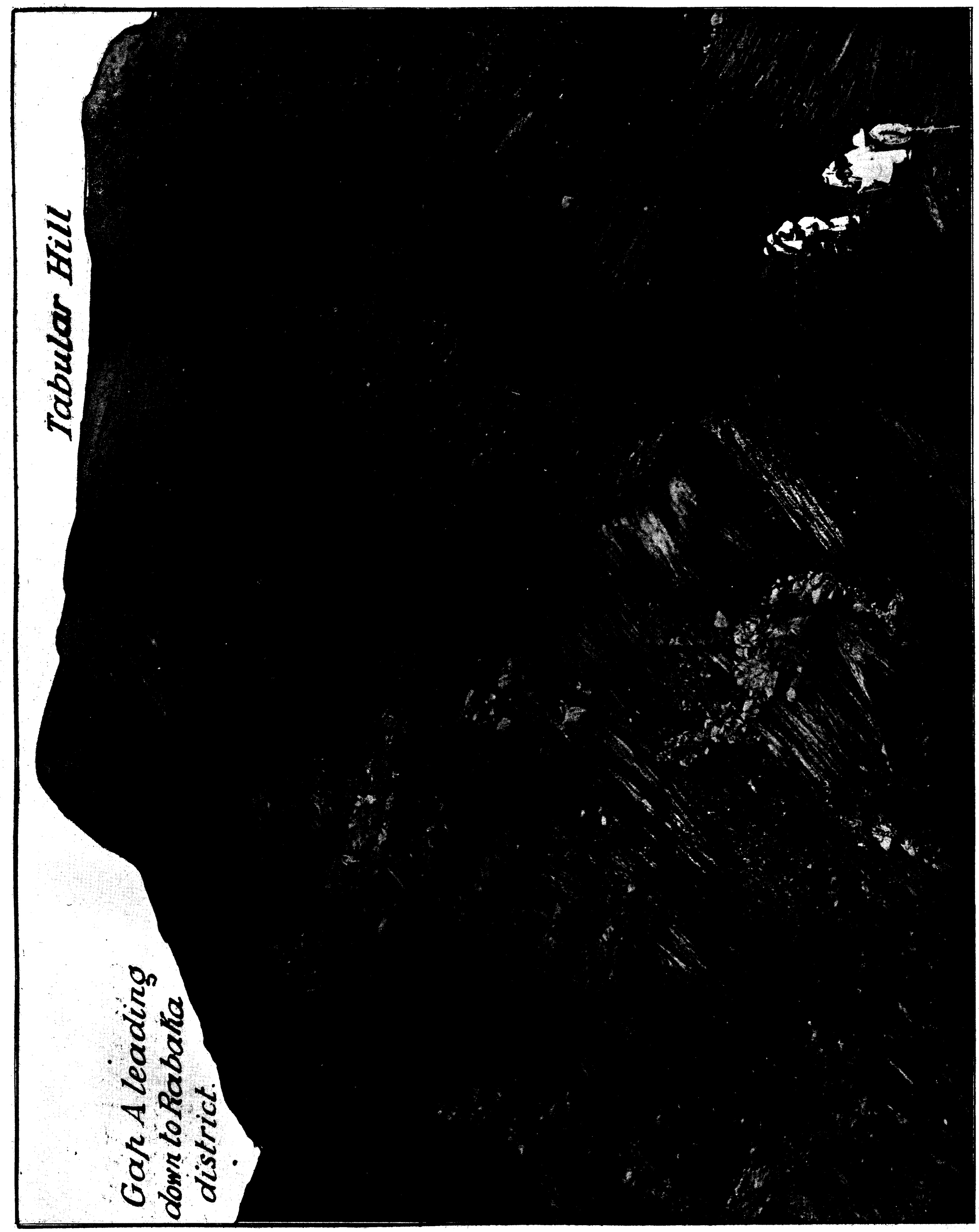


The Crater of the Soufrière, from the South-west lip.

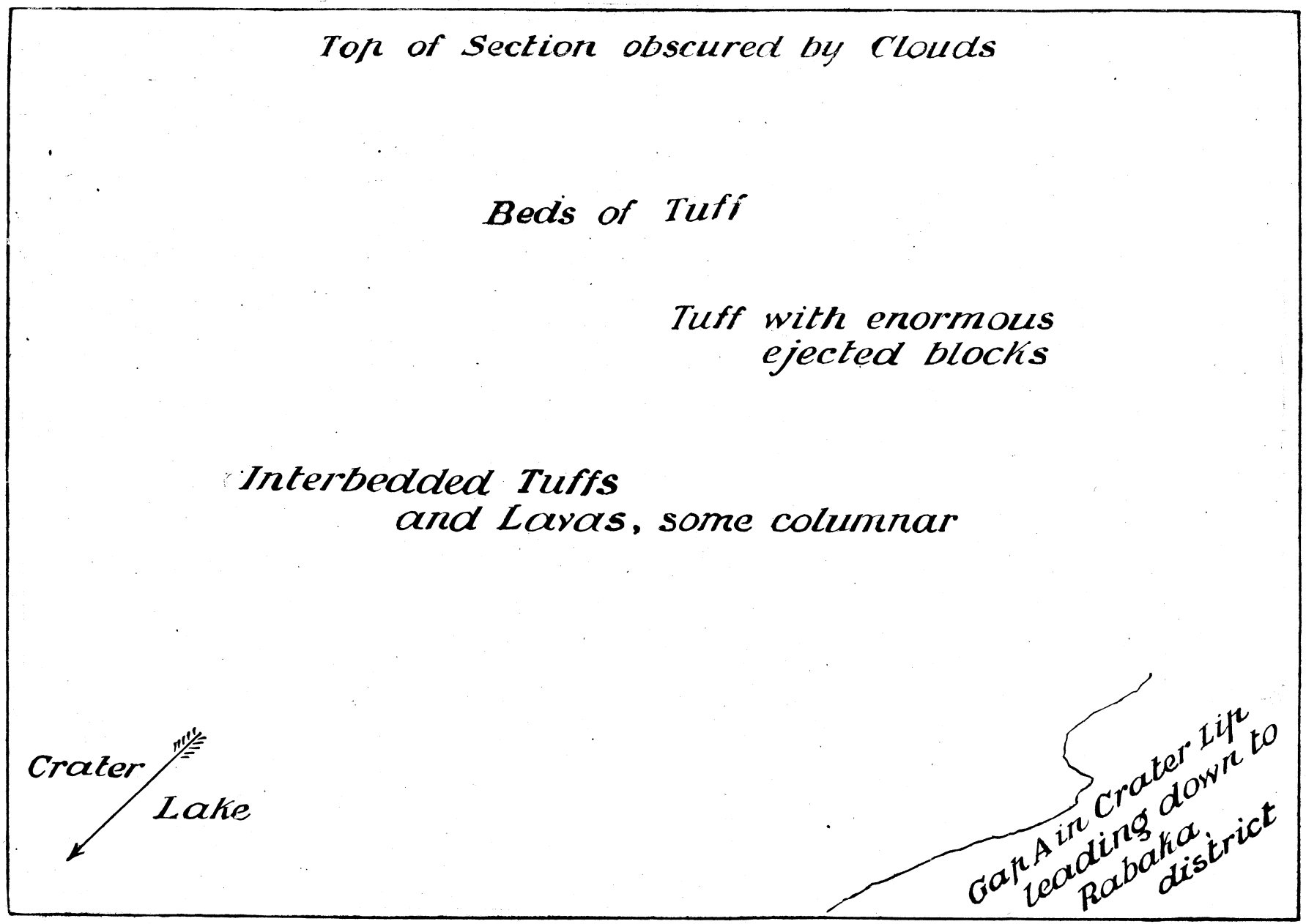

Tabular Hill
Gap A leading down to Rabaka district.
Outside of Crater. Beds of tuff undergoing rapid erosion by rain as soon as the crust is broken
Inside of Crater Beds of agglomerate and tuff dipping outwards with slope
Gap B Leading down to Wallibu district.
To Crater Lake

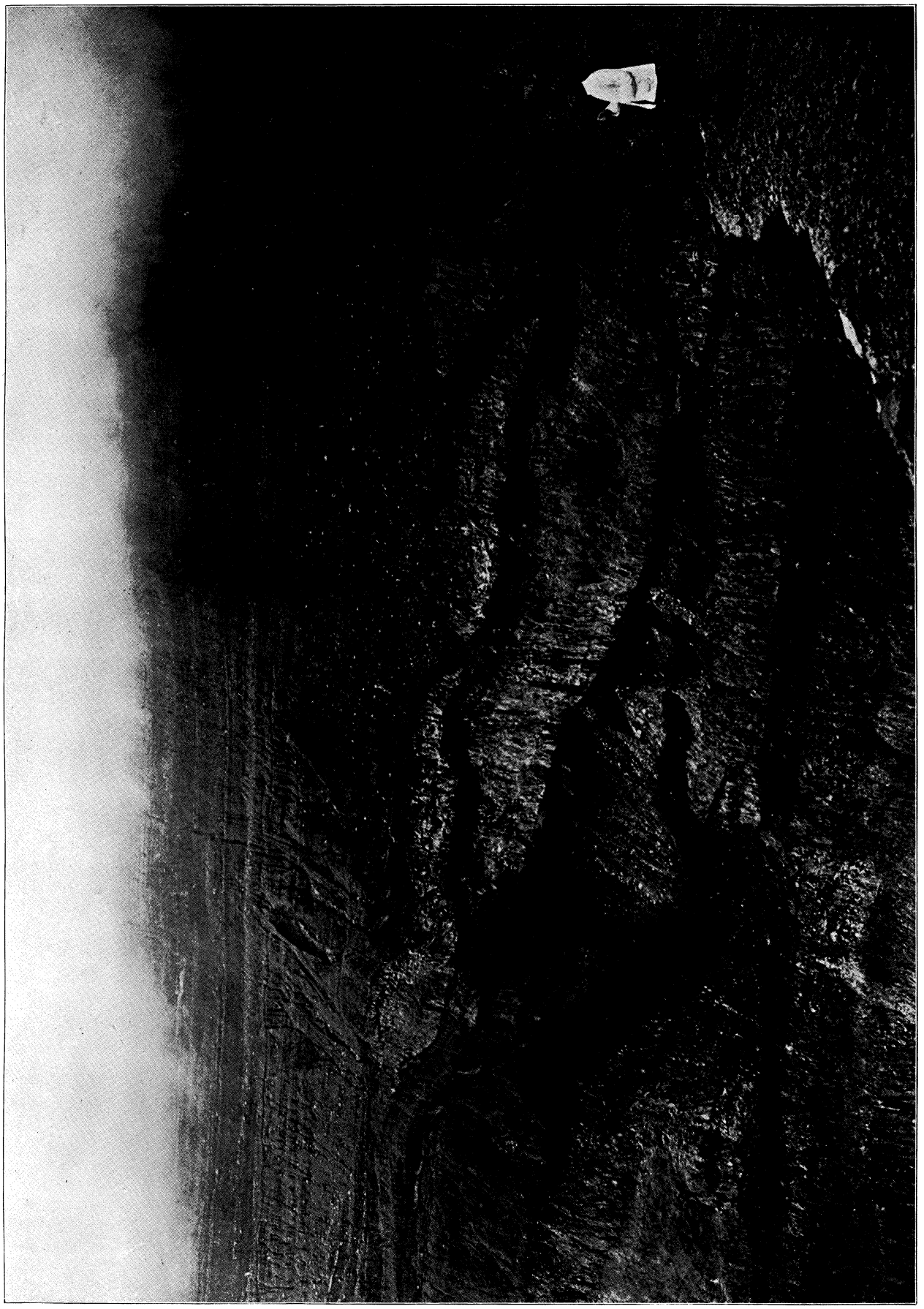


Crater of the Soufrière; south lip, from West.

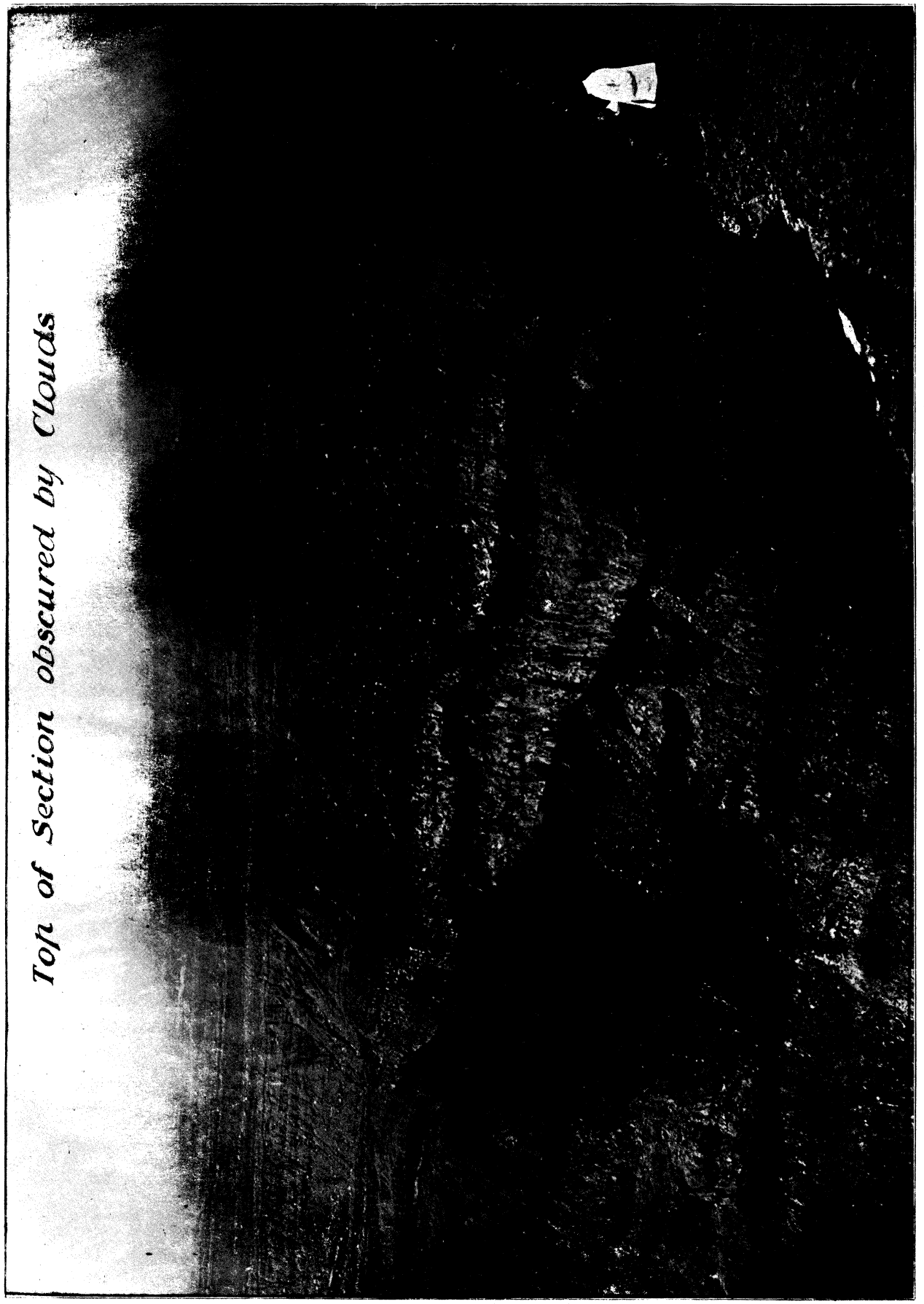


Crater of the Soufrière; south lip, from West.

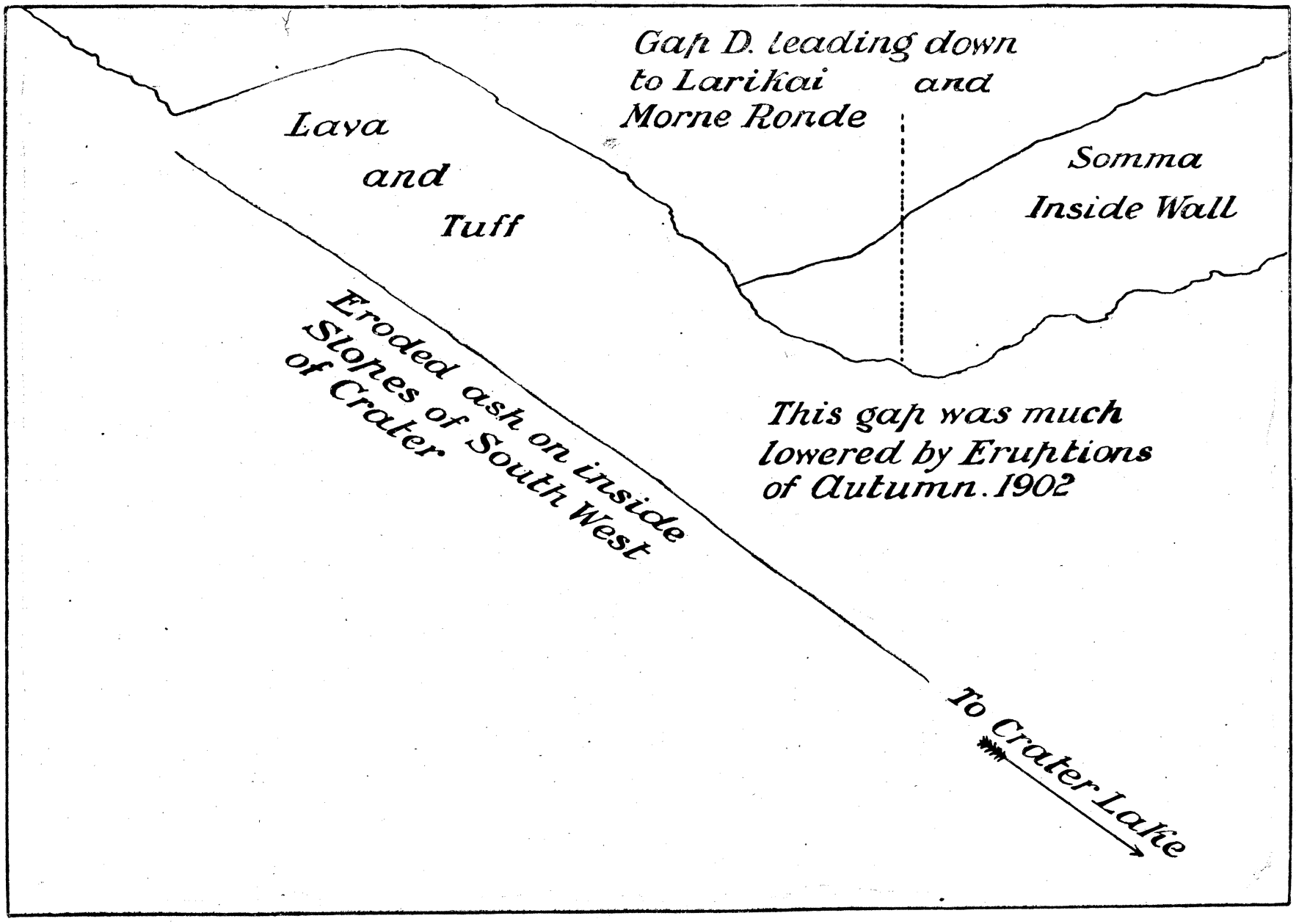

Top of Section obscured by Clouds
Beds of Tuff
Tuff with enormous ejected blocks
Interbedded Tuffs and Lavas, some columnar
Crater Lake
Gap A in Crater Lip leading down to Rabaka district

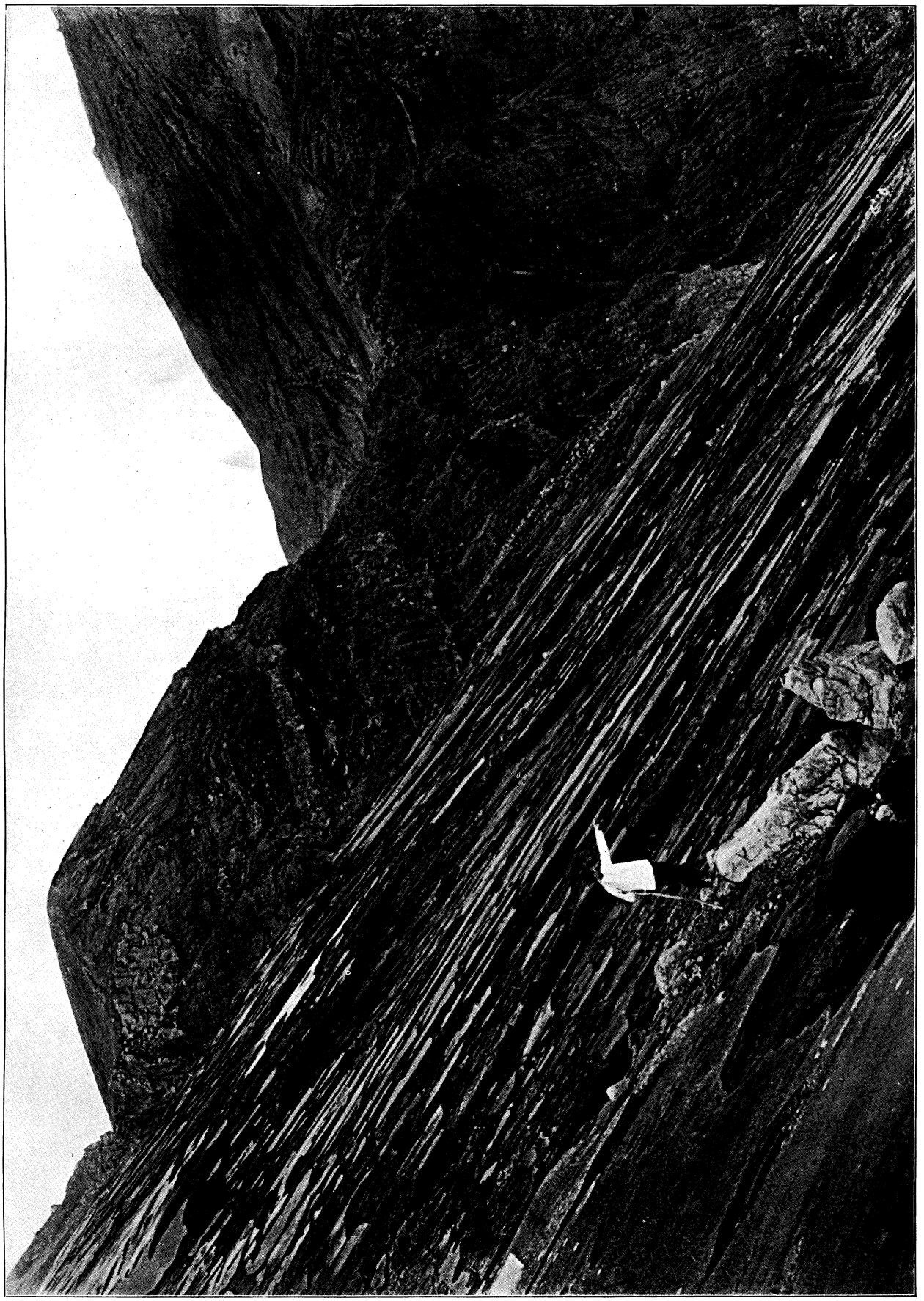


North wall of Crater, Eastern end.

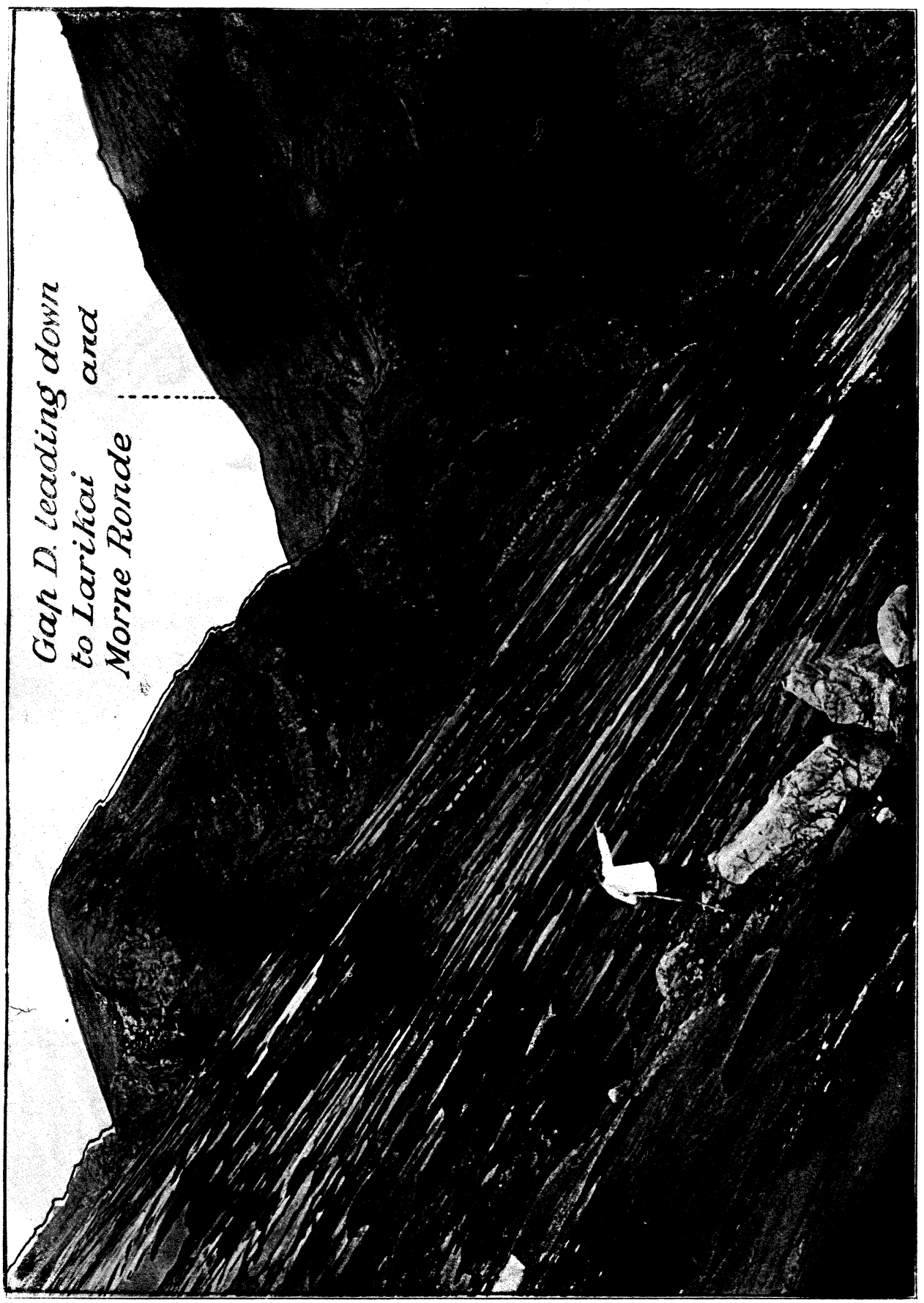


North wall of Crater, Eastern end.

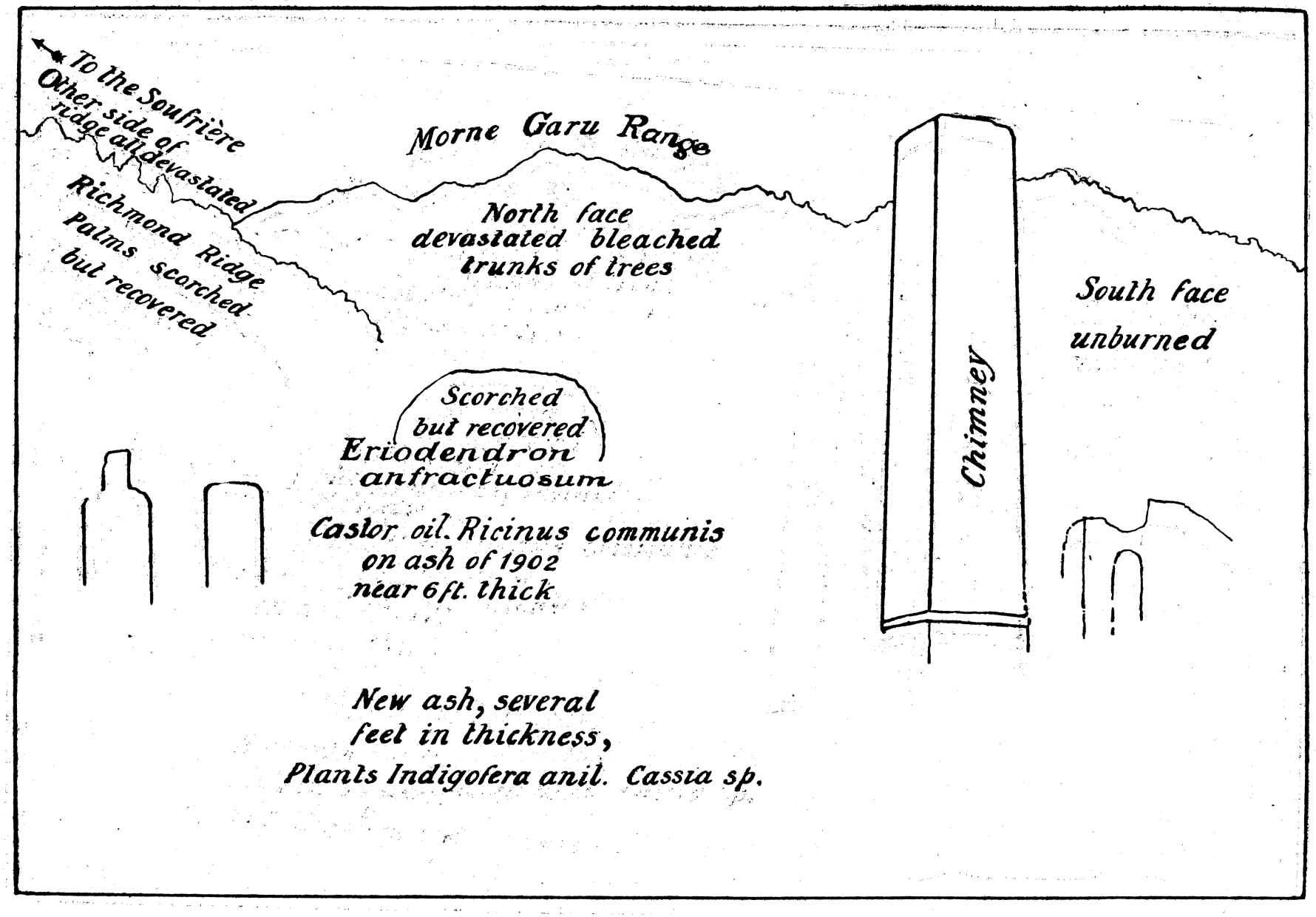

Gap D. leading down to Larikai and Morne Ronde
Lava and Tuff
Somma Inside Wall
Eroded ash on inside Slopes of South West of Crater
This gap was much lowered by Eruptions of Autumn. 1902
To Crater Lake

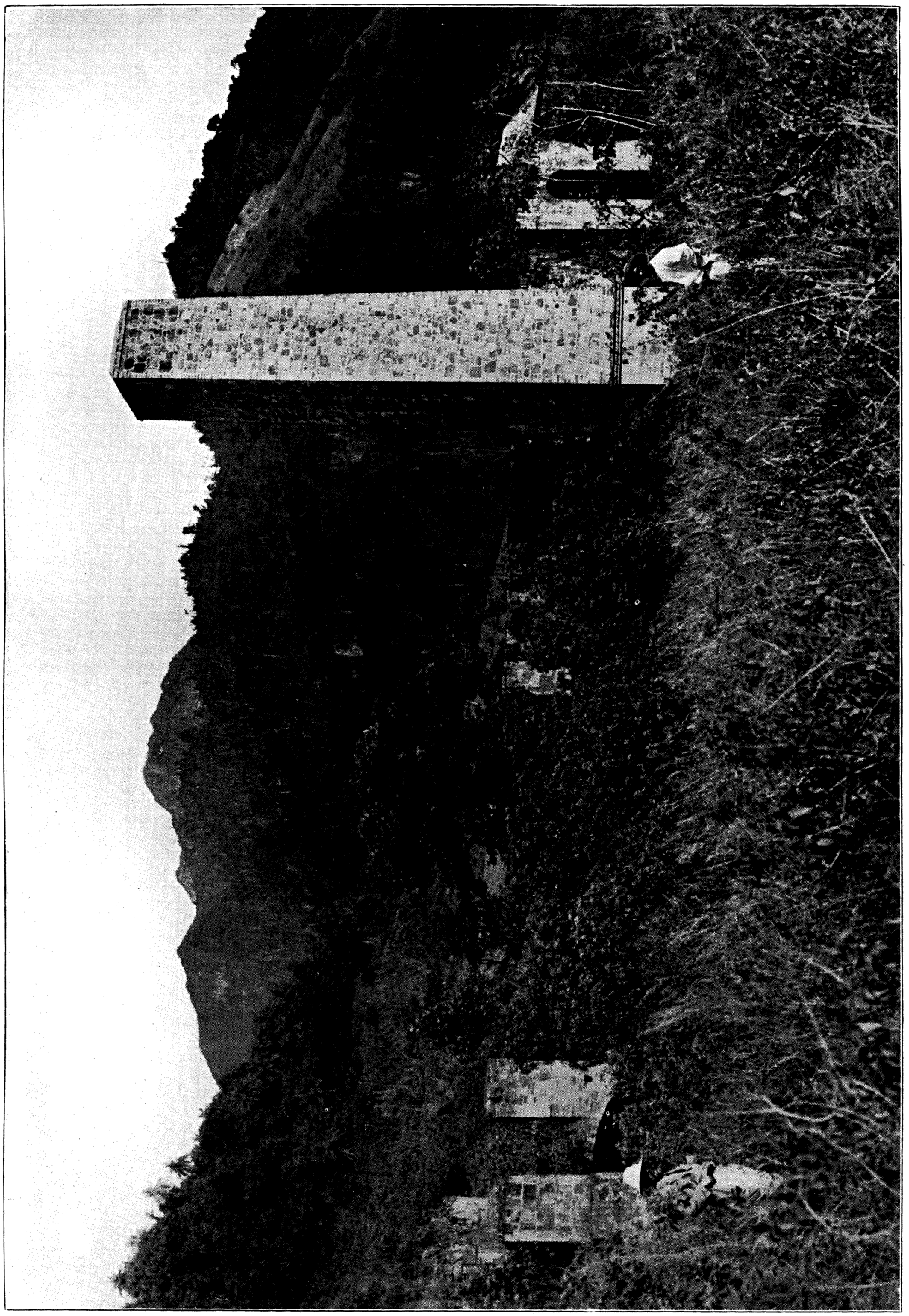


West lip of Crater.

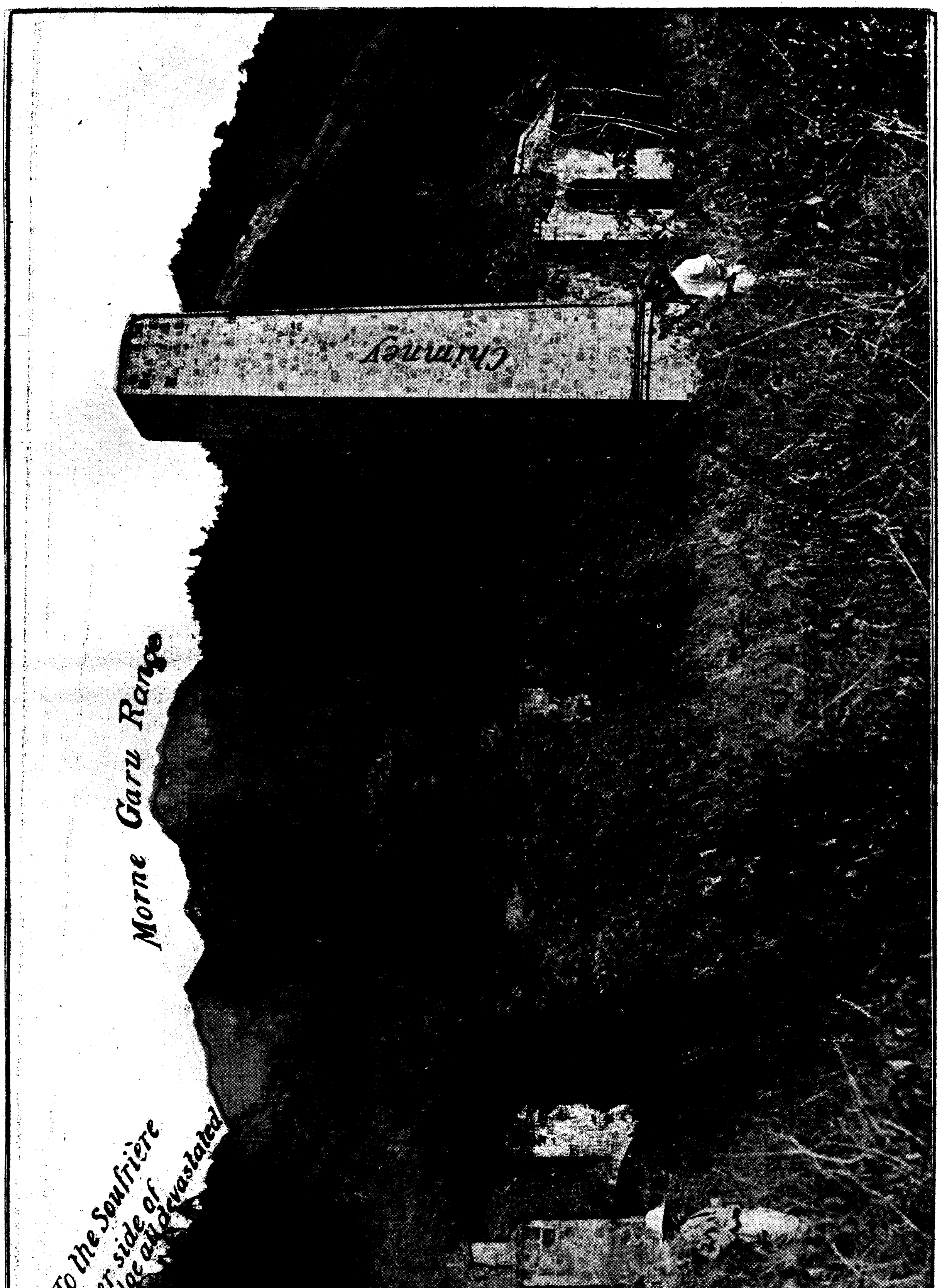


West lip of Crater.

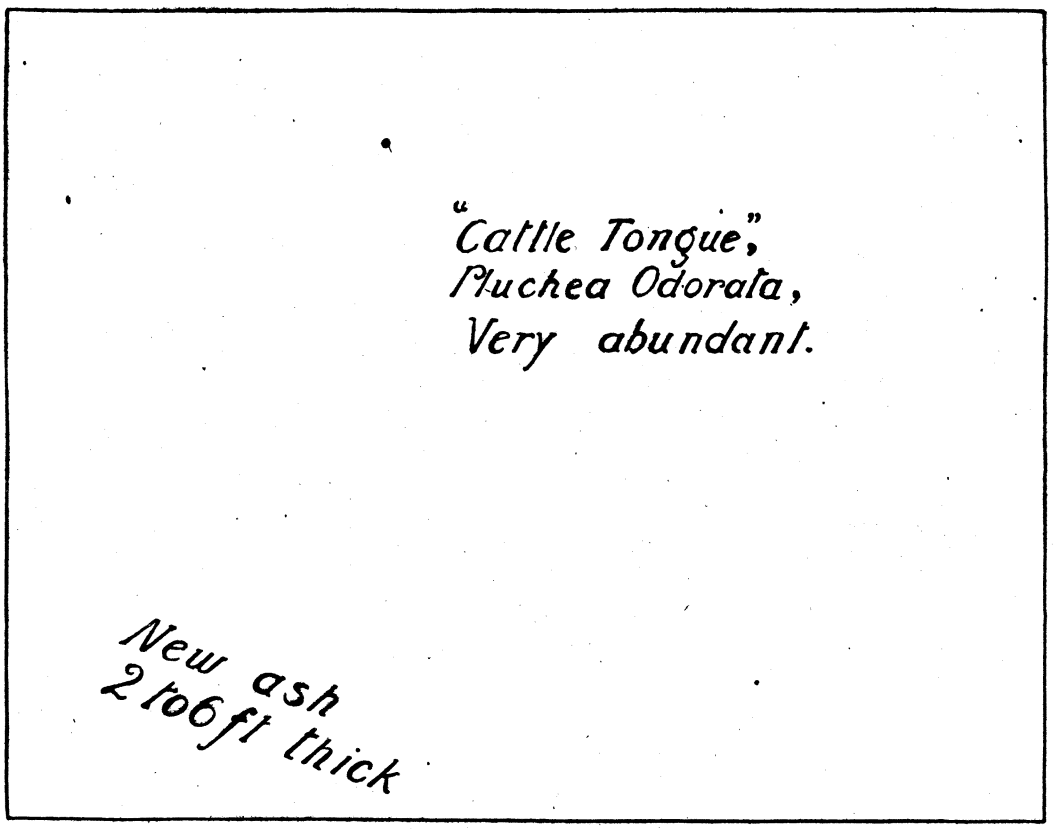

To the Soufrière
Other side of ridge all devastated
Richmond Ridge palms scorched but recovered
Morne Garu Range
North face devastated bleached trunks of trees
Chimney
South face unburned
Scorched but recovered
Eriodendron anfractuosum
Castor oil. Ricinus communis
on ash of 1902
near 6ft. thick
New ash, several feet in thickness,
Plants Indigofera anil. Cassia sp.

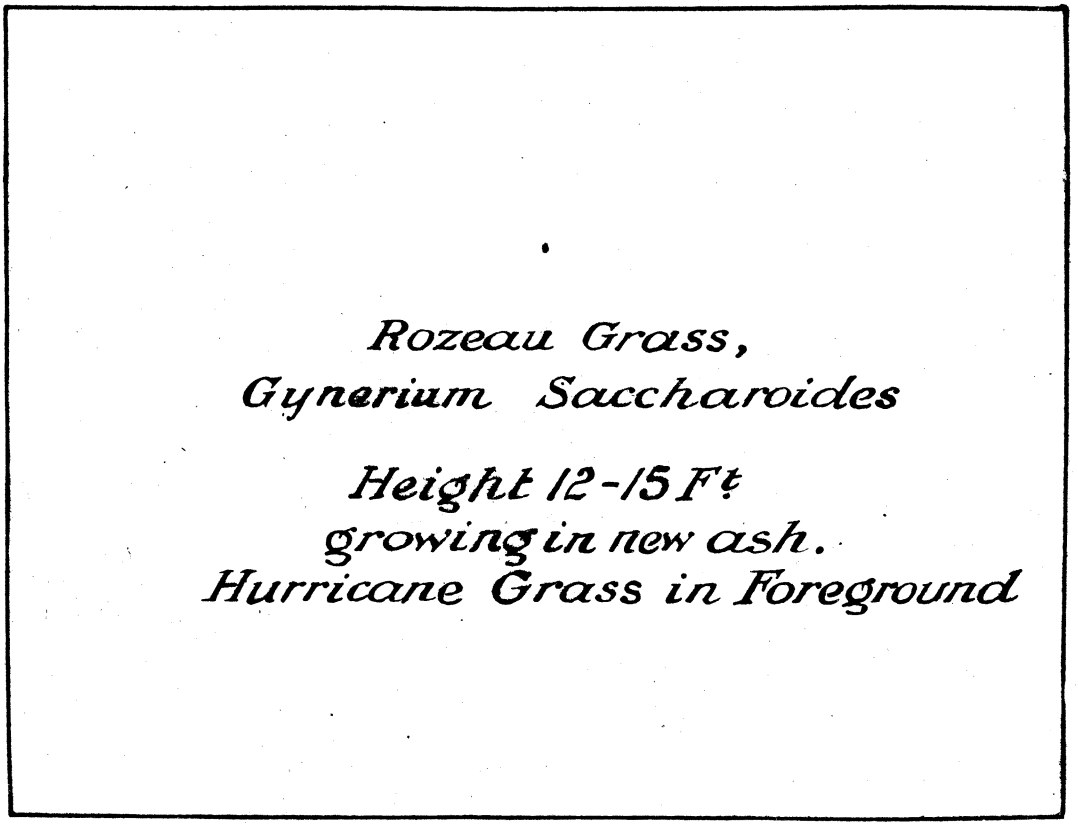


Richmond Plantation Works, 1907, *from the West.*



Richmond Plantation Works, 1907, *from the West.*


"Cattle Tongue",
Pluchea Odorata,
Very abundant.
New ash
2 to 6 ft thick


Rozeau Grass,
Gynerium Saccharoides
Height 12-15 Ft
growing in new ash.
Hurricane Grass in Foreground

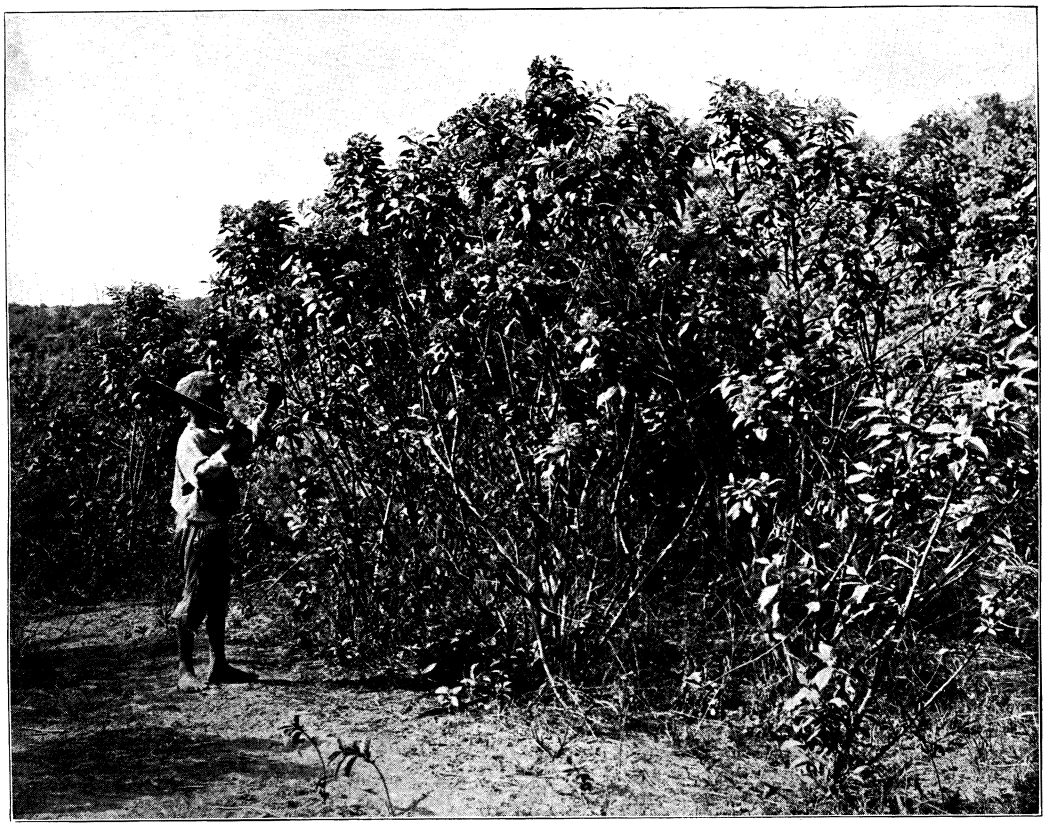


Fig. 1. *Near Richmond Works*, 1907. (Pluchea Odorata.)

Fig. 2. *Near the River, Richmond Works.*

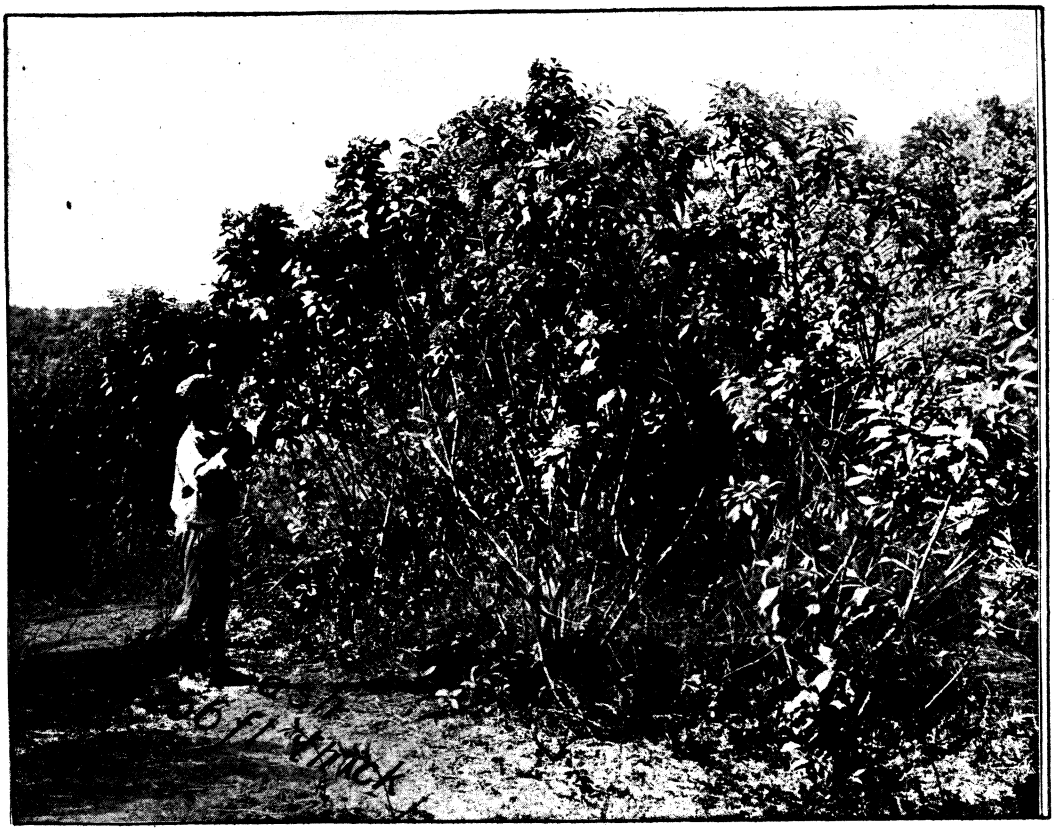


Fig. 1. *Near Richmond Works*, 1907. (Pluchea Odorata.)

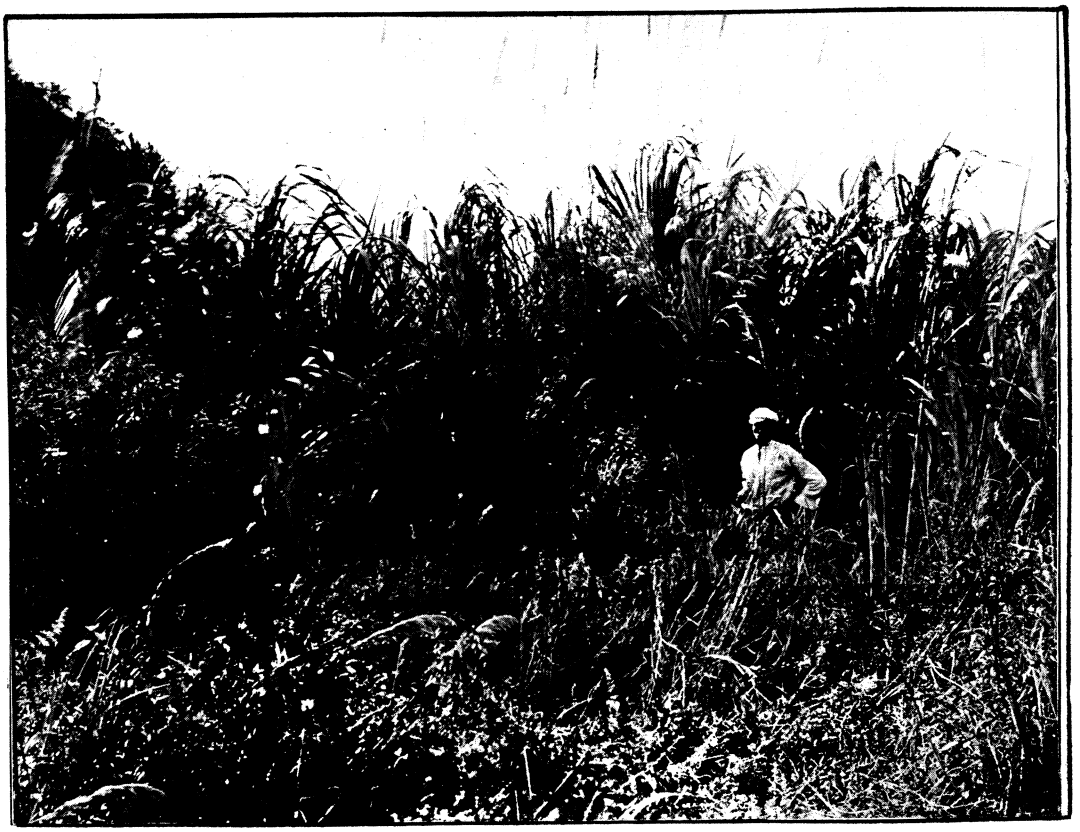
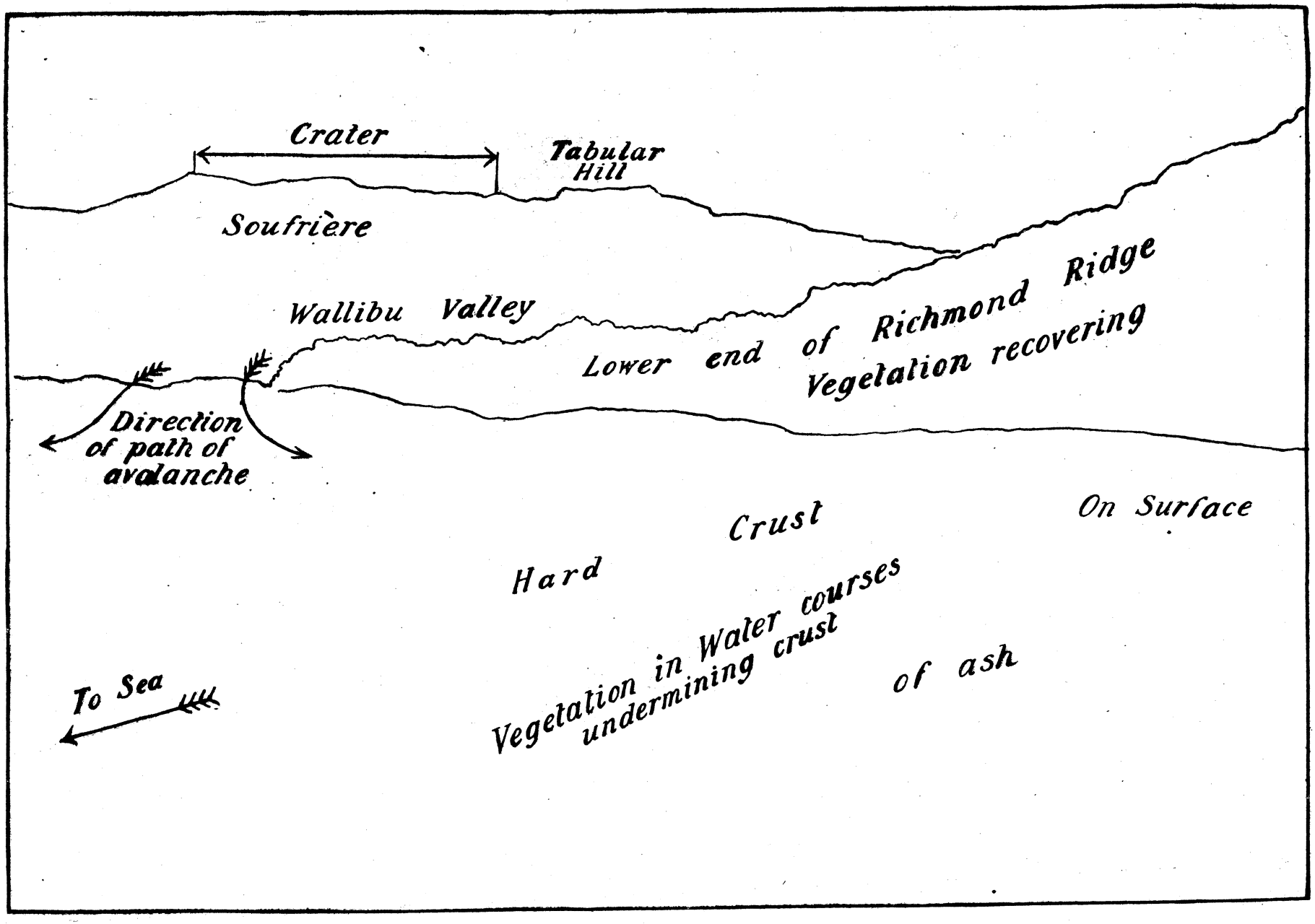
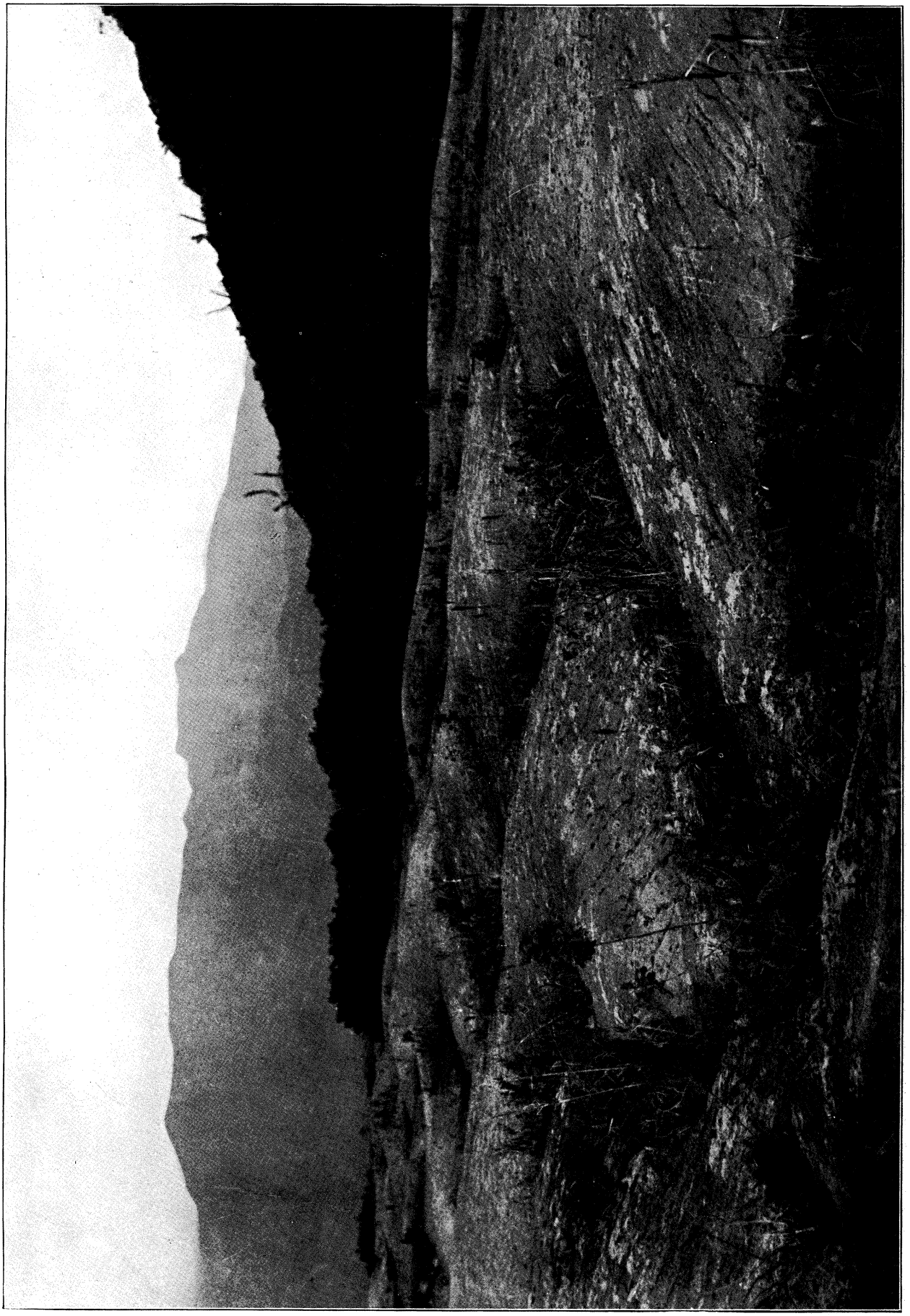
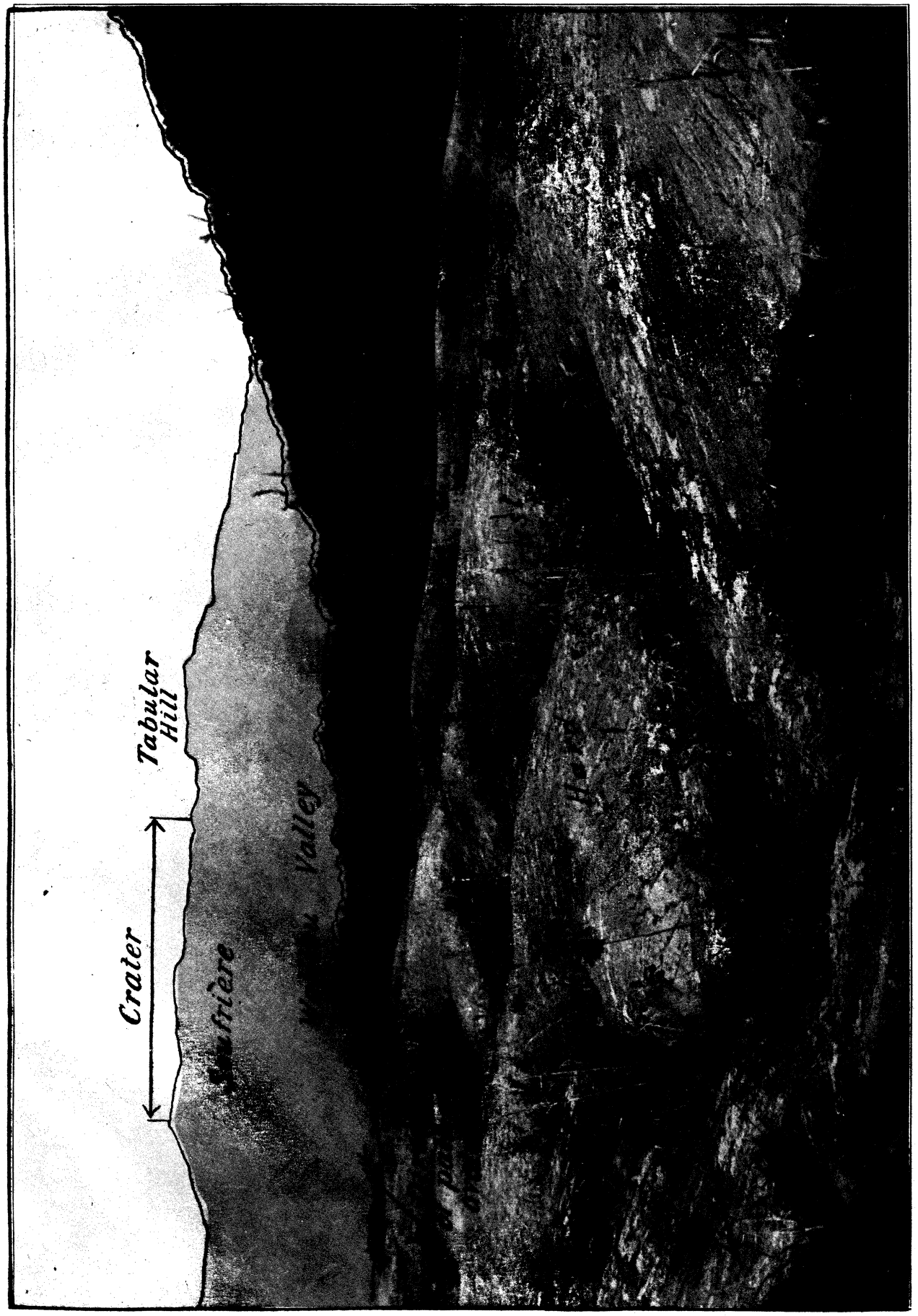


Fig. 2. *Near the River, Richmond Works.*

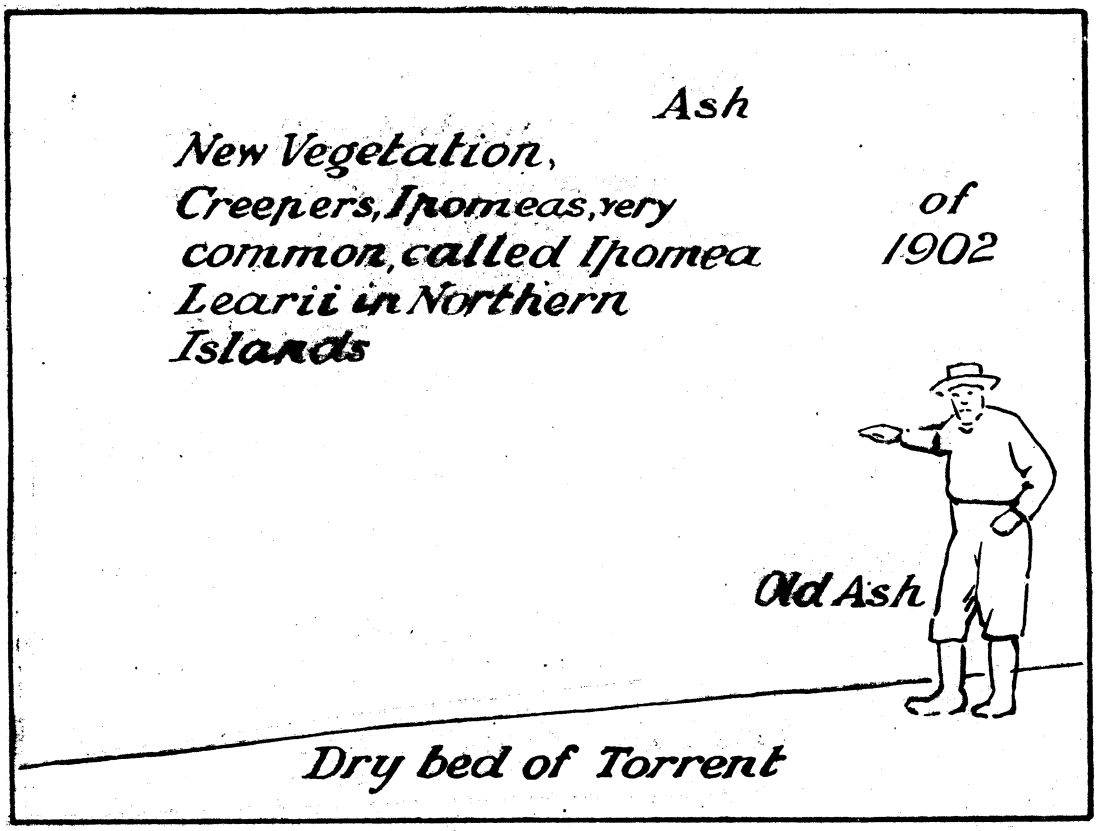

Crater
Tabular Hill
Soufrière
Wallibu Valley
Lower end of Richmond Ridge
Vegetation recovering
Direction of path of avalanche
On Surface
Crust
Hard
Vegetation in Water courses undermining crust
of ash
To Sea



The Avalanche, below end of Richmond Ridge.



The Avalanche, below end of Richmond Ridge


Ash
New Vegetation,
Creepers, Ipomeas, very
common, called Ipomea
Learii in Northern
Islands
of
1902
Old Ash
Dry bed of Torrent

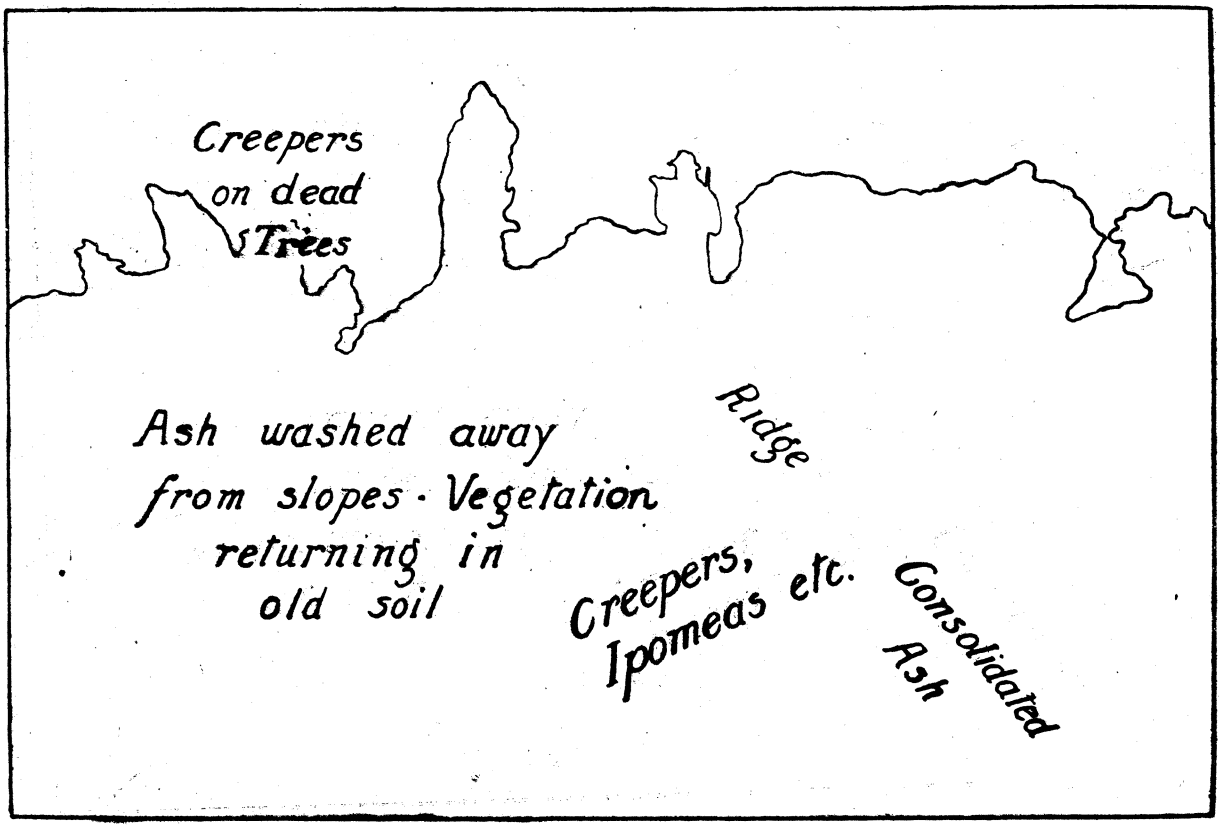

Creepers
on dead
Trees
Ash washed away
from slopes · Vegetation
returning in
old soil
Ridge
Creepers,
Ipomeas etc.
Consolidated
Ash

Fig. 1. *North Wall of Trespe Valley.*

Fig. 2. *A Ridge on the Soufrière at about* 600 *feet.*

Fig. 1. *North Wall of Trespe Valley.*

Fig. 2. *A Ridge on the Soufrière at about* 600 *feet.*

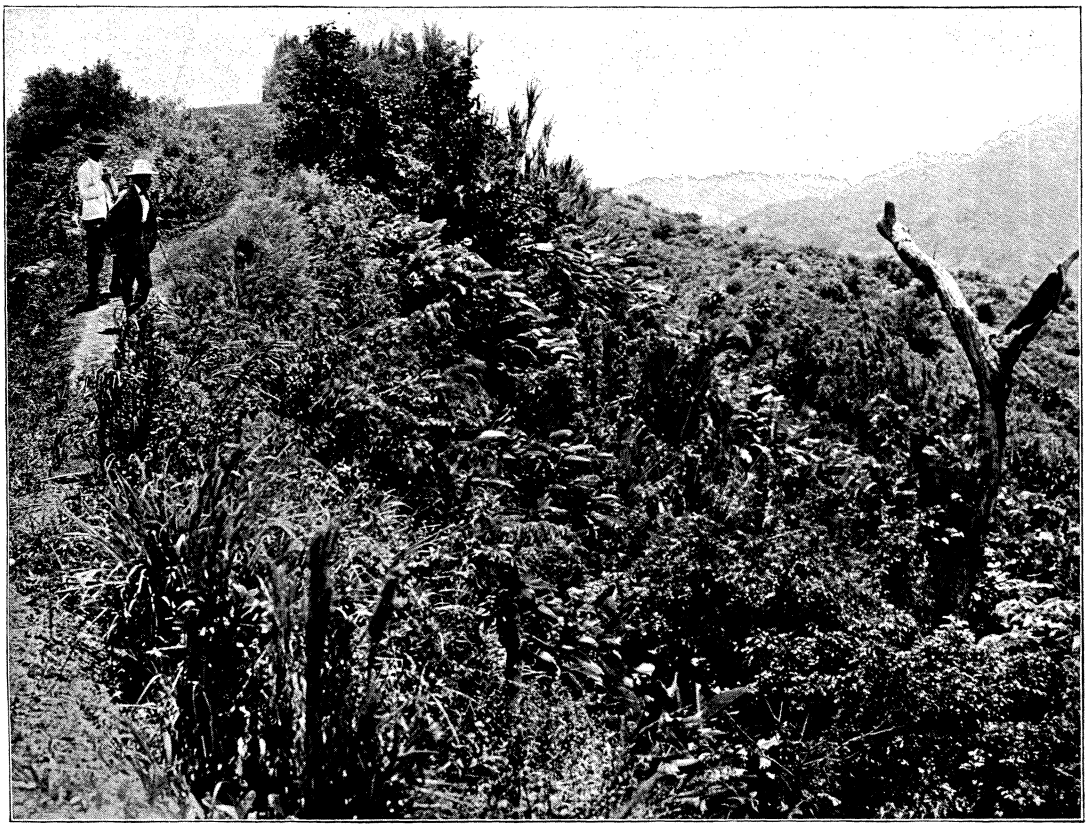


Fig. 1. *South Slopes of Soufrière at about* 600 *feet.*

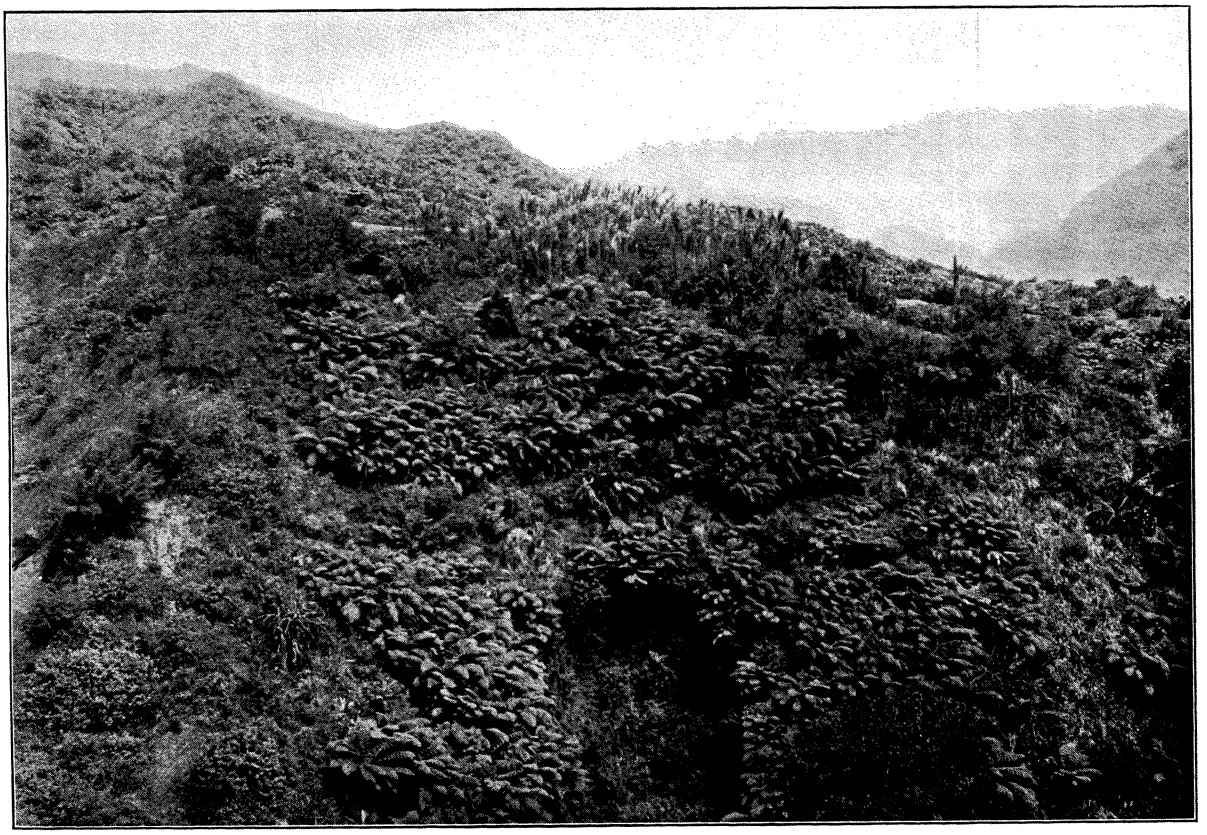
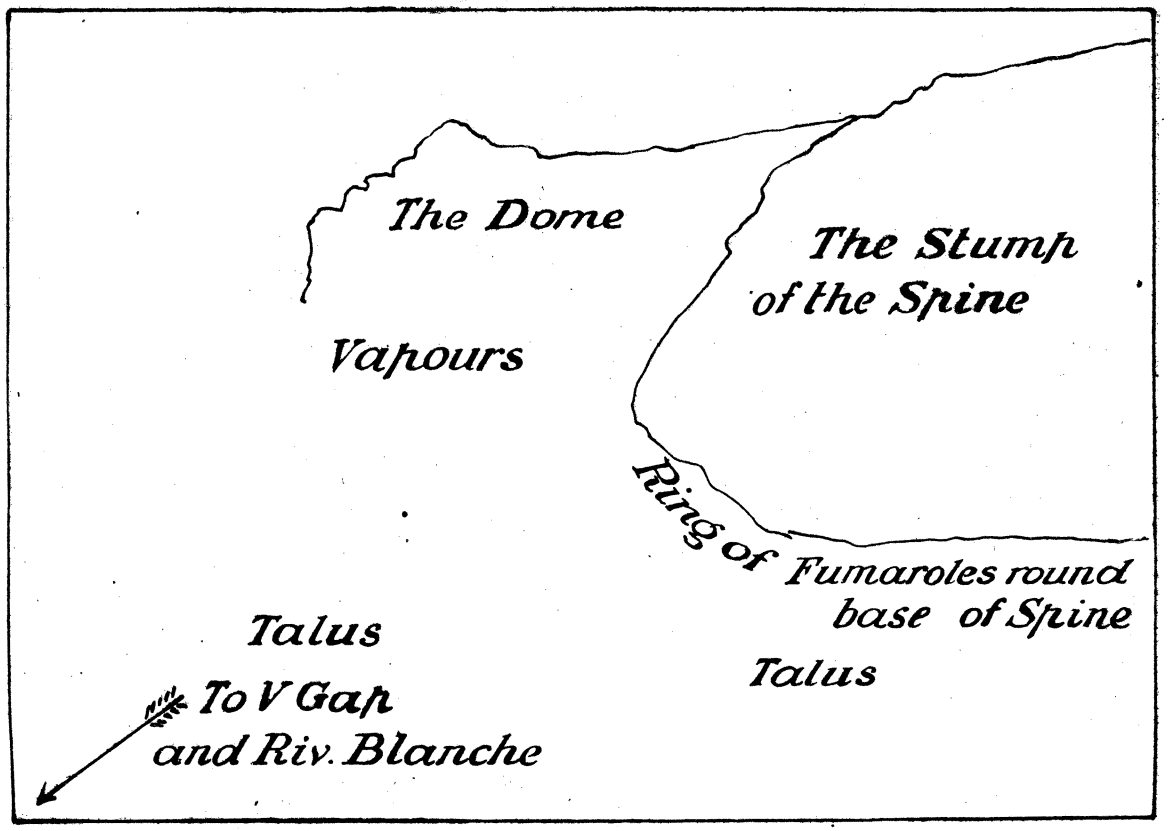
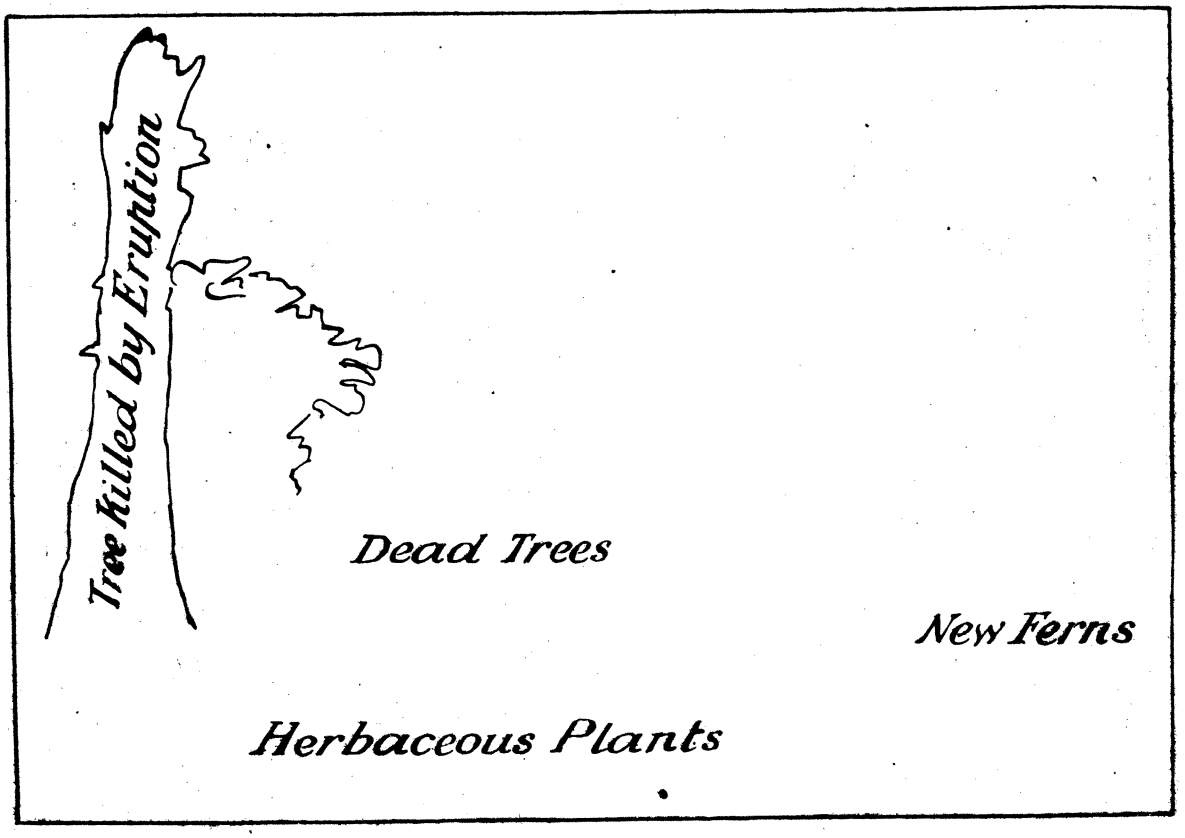


Fig. 2. *Slopes of Soufrière at about* 800 *feet.*


The Dome
The Stump of the Spine
Vapours
Ring of Fumaroles round base of Spine
Talus
Talus
To V Gap and Riv. Blanche


Tree killed by Eruption
Dead Trees
New Ferns
Herbaceous Plants

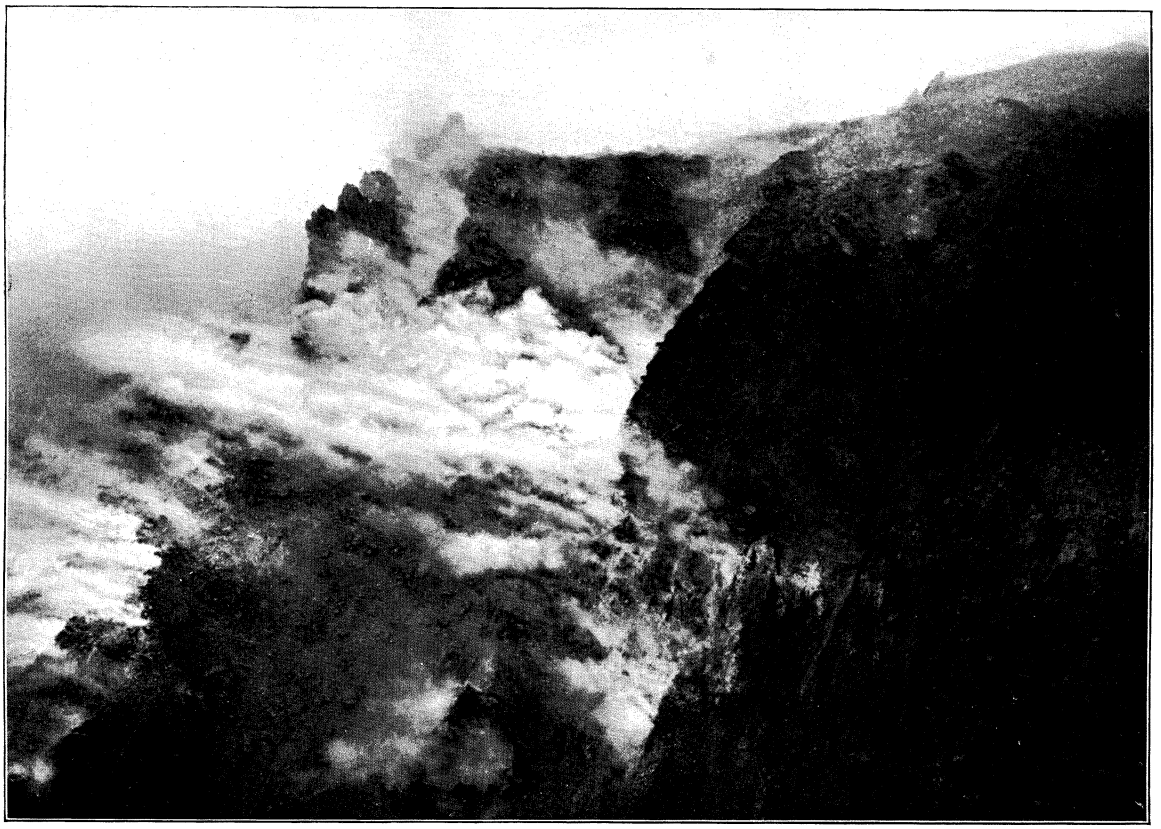


Fig. 1. *The Crater of Montagne Pelée, March* 13, 1907.

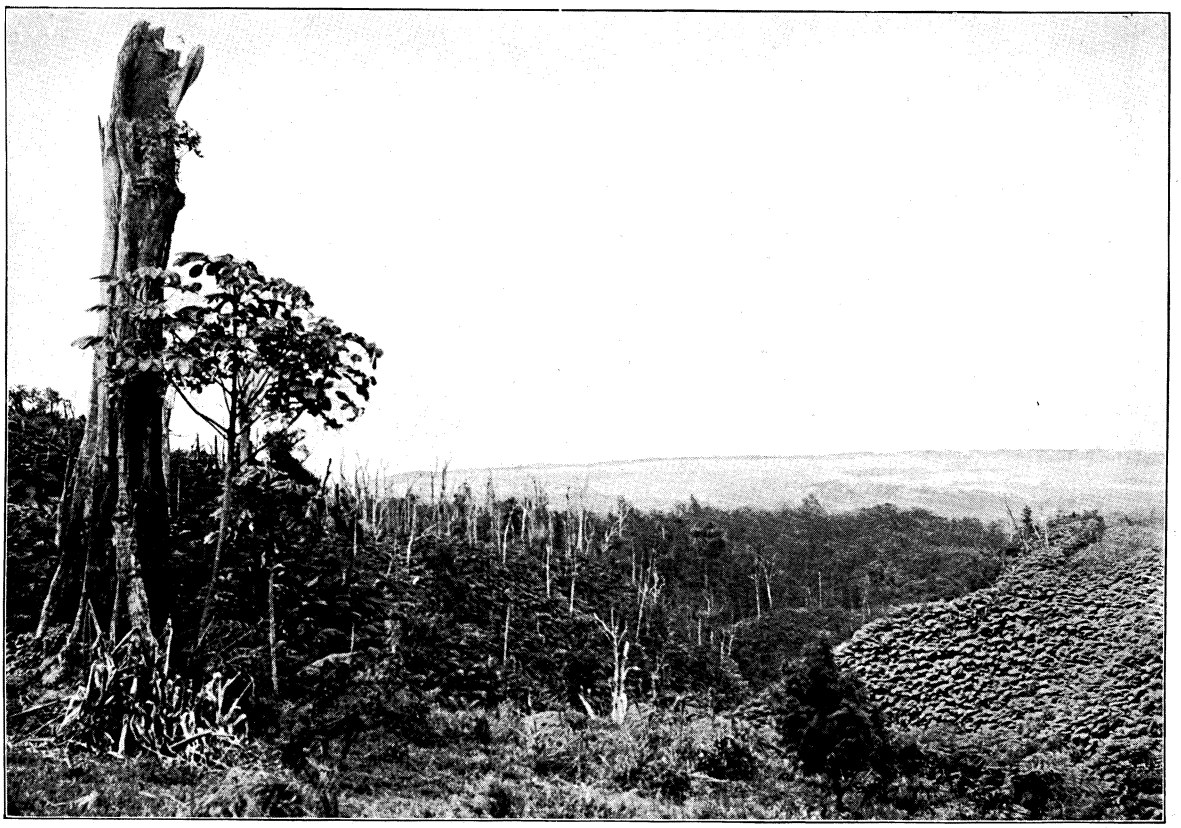


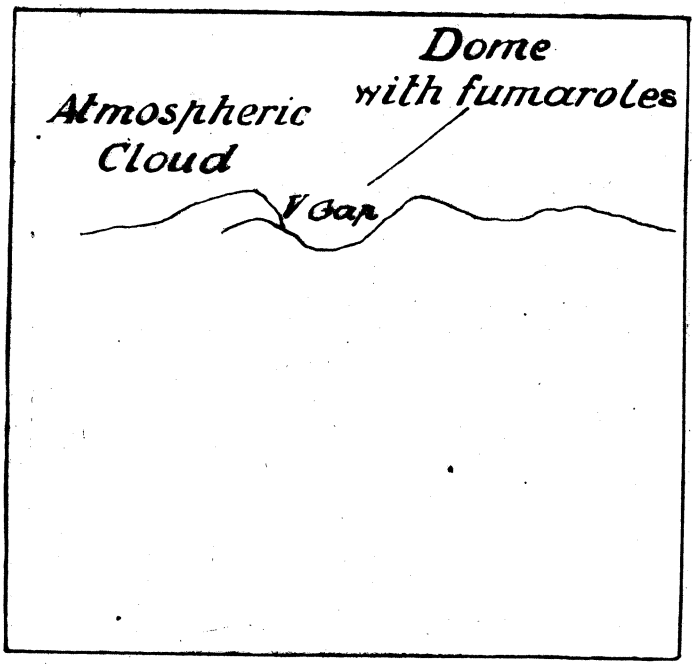
Fig. 2. *On Montagne Pelée, North side, at about* 1500 *feet.*

Fig. 1. *The Crater of Montagne Pelée, March* 13, 1907.

Fig. 2. *On Montagne Pelée, North side, at about* 1500 *feet.*

Tuff containing large blocks

Tuff containing large blocks



Blocks transported by torrential rain

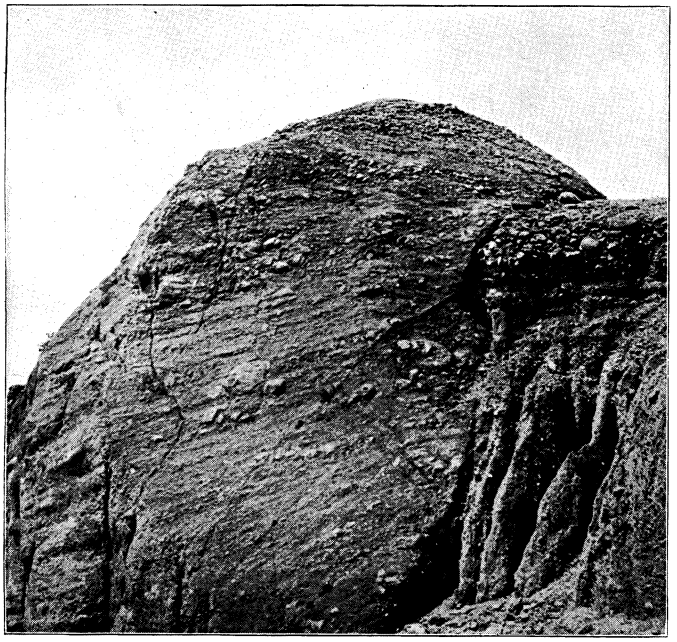


Fig. 1. *Tuff-agglomerate, scored by avalanches. General view.*

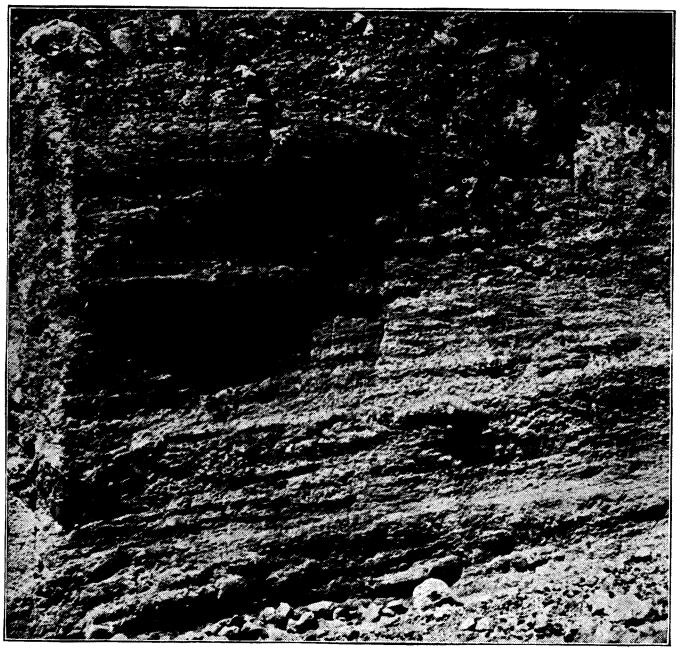


Fig. 2. *Details beyond left corner of Fig.* 1.

Fig. 3. *Valley of Rivière Blanche, from near shore.*

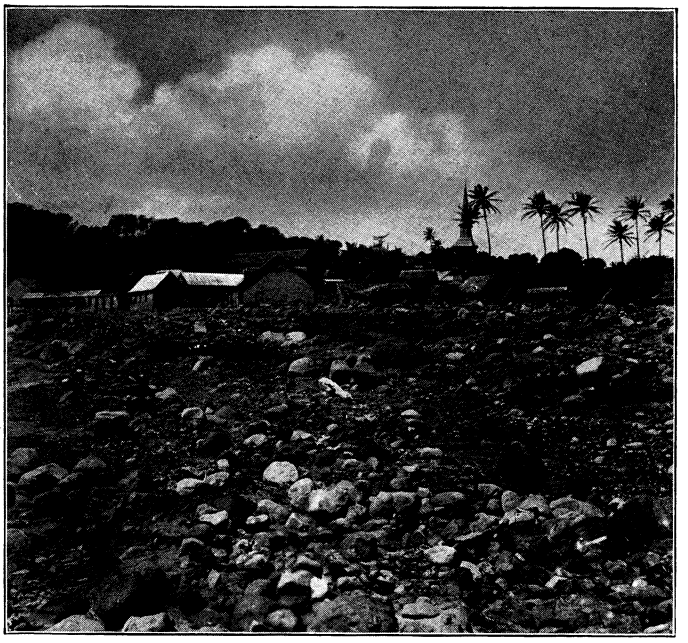
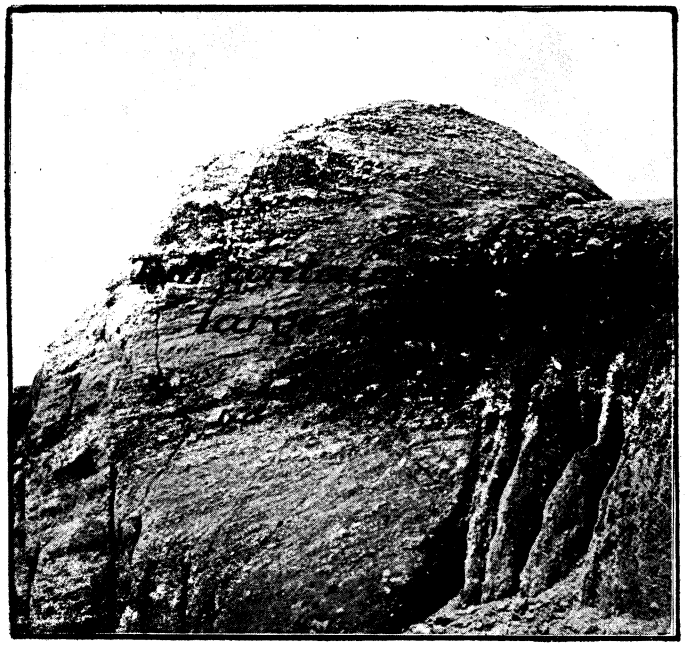


Fig. 4. *The new Delta at Basse Pointe.*



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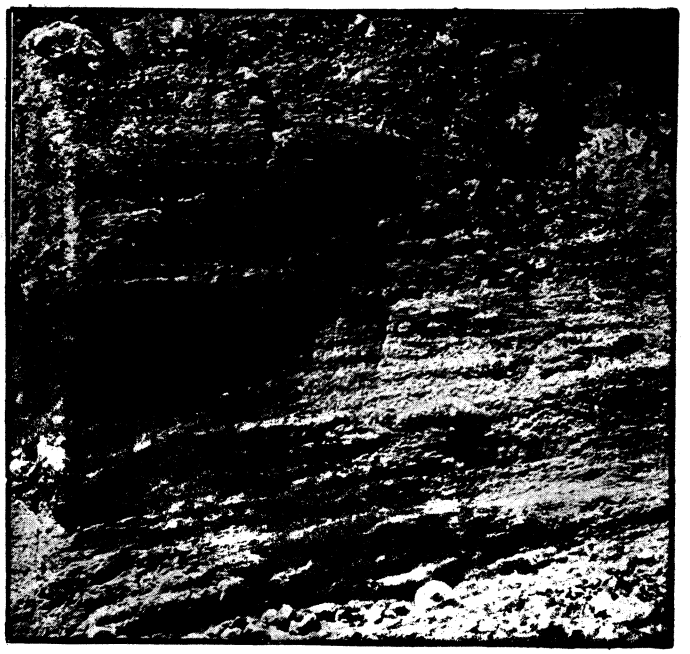


Fig. 2. *Details beyond left corner of Fig.* 1.

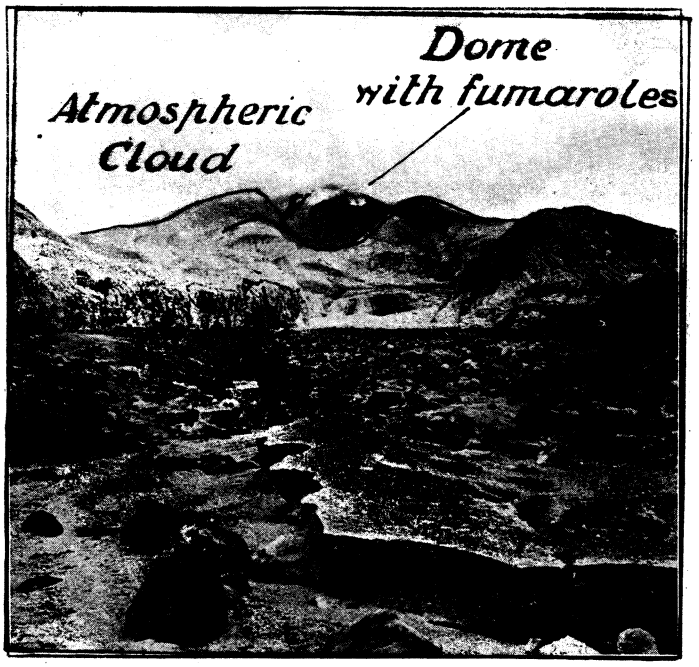
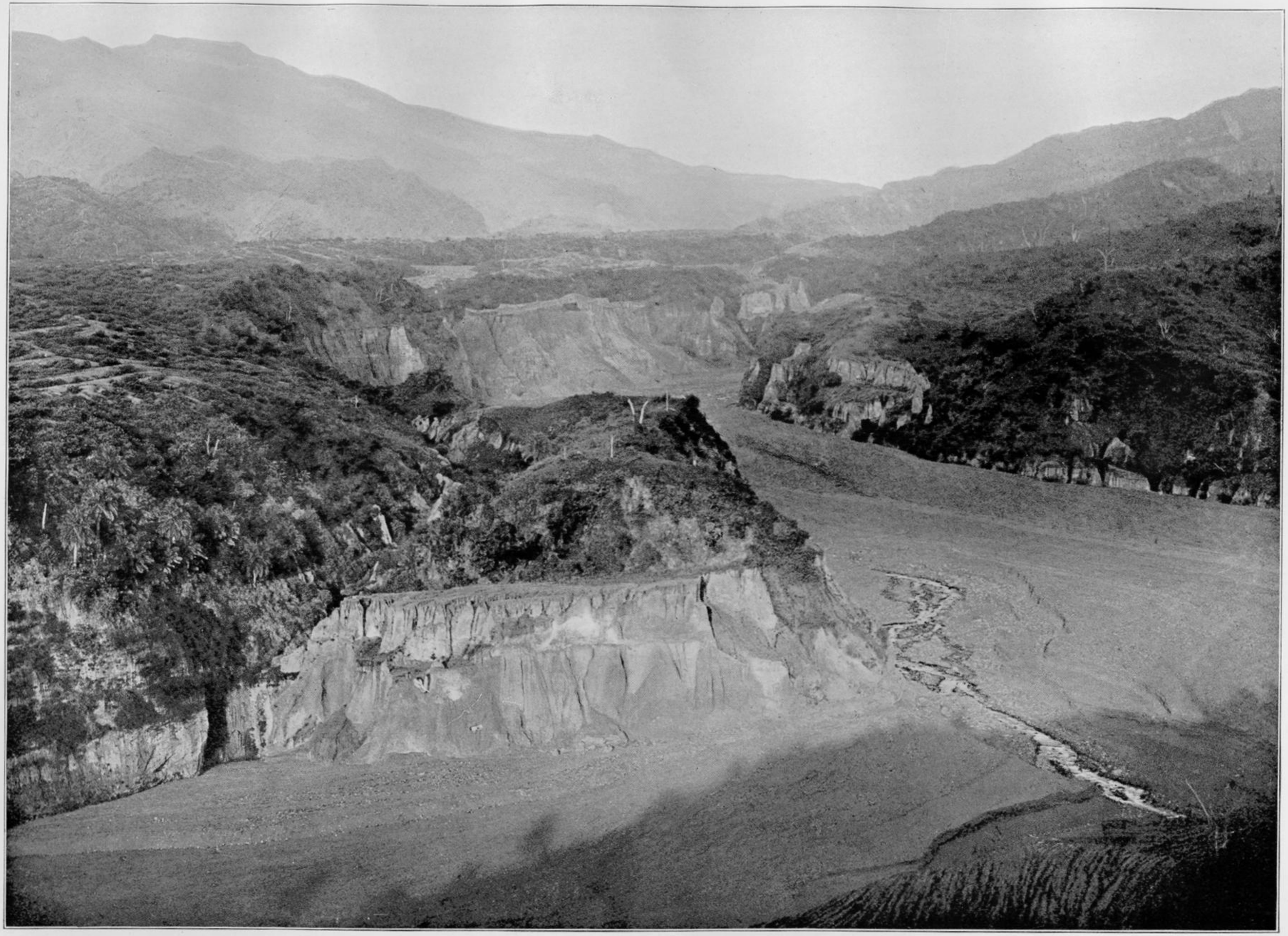
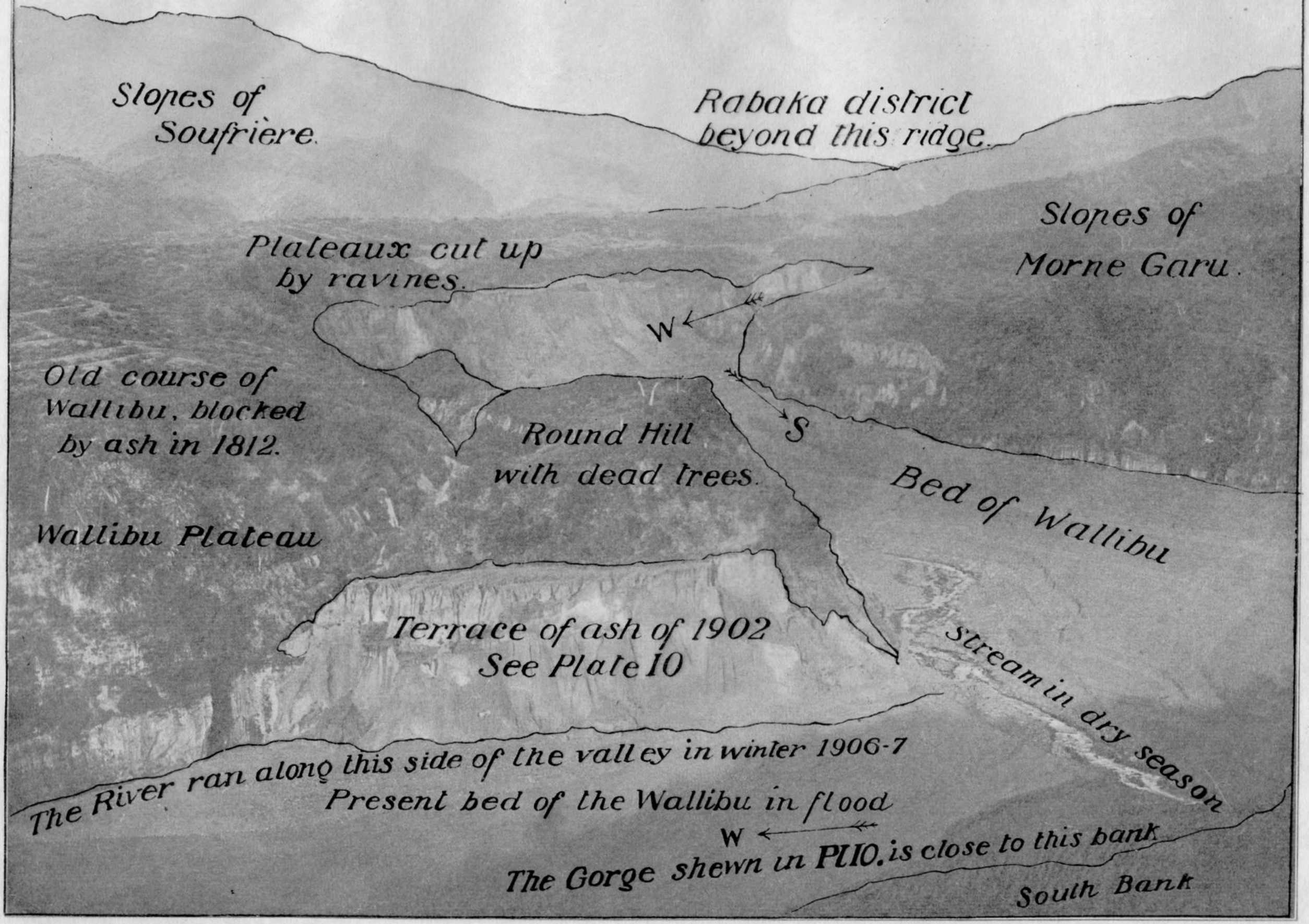


Fig. 3. *Valley of Rivière Blanche, from near shore.*

Fig. 4. *The new Delta at Basse Pointe.*

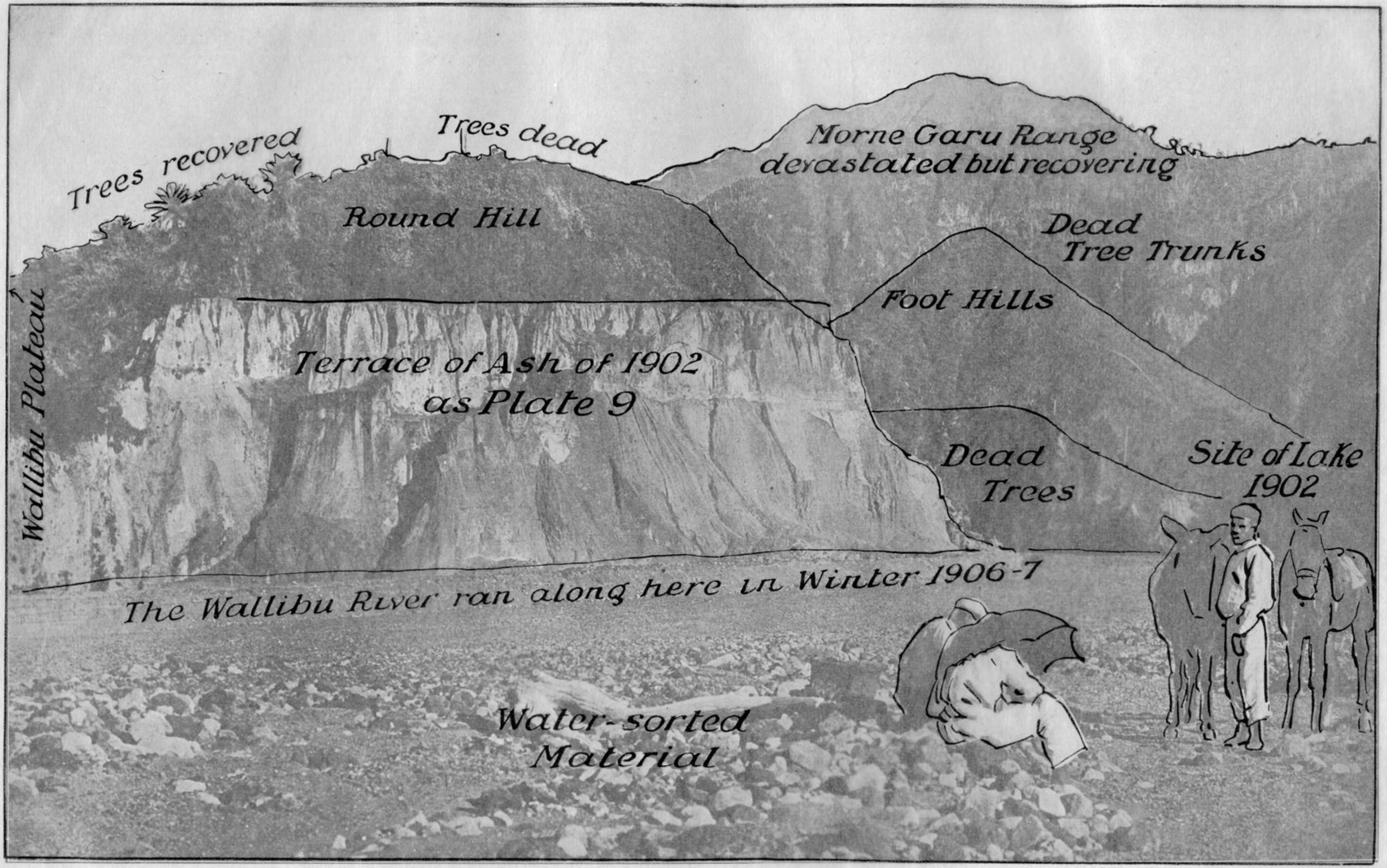


Lower Wallibu district, from Richmond Ridge, near Bunker's Hill.



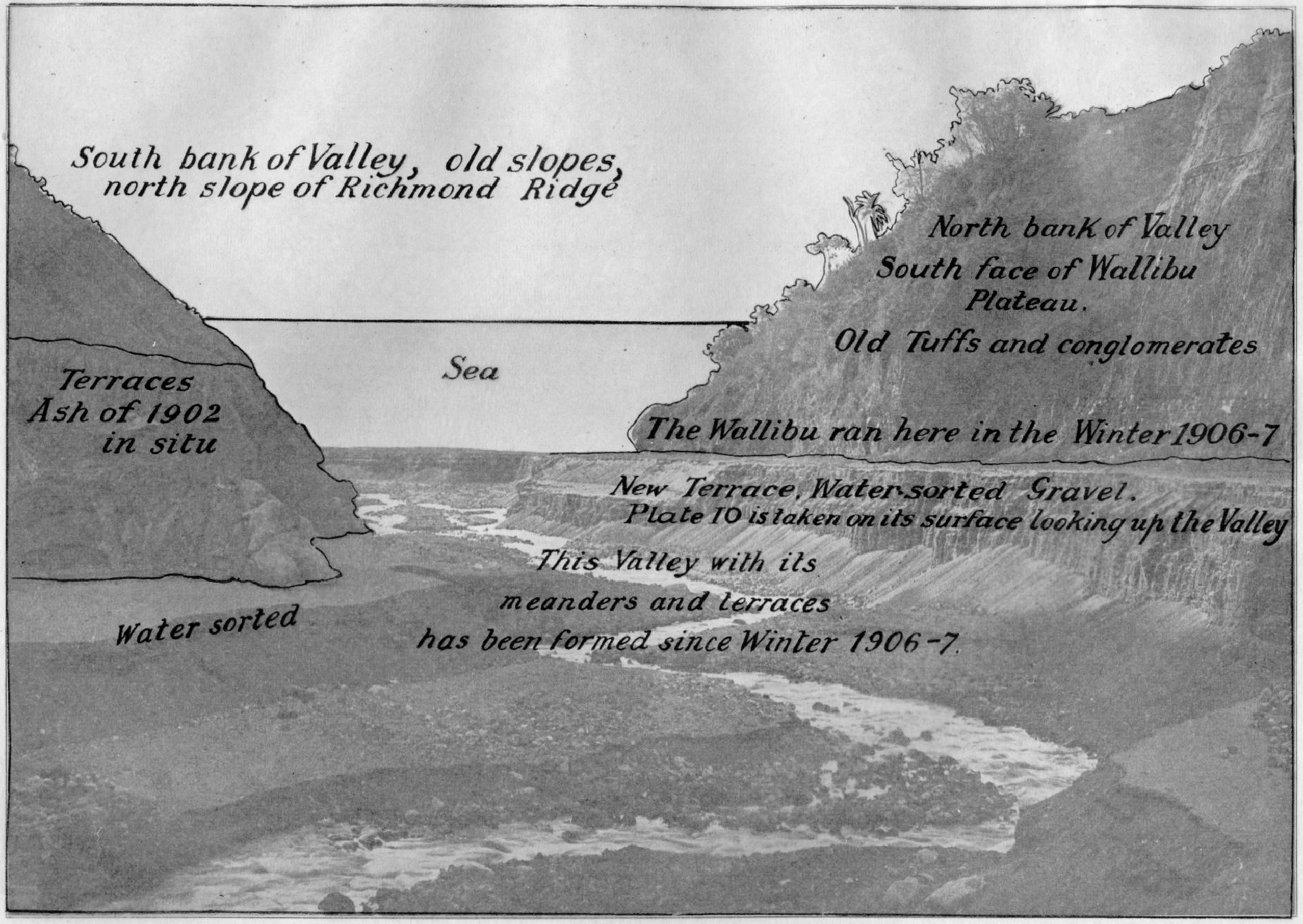
Lower Wallibu district, from Richmond Ridge, near Bunker's Hill.

Terrace of new ash, North bank, Lower Wallibu Valley.



Terrace of new ash, North bank, Lower Wallibu Valley.

Lower Wallibu Valley, looking West, towards the sea.



Lower Wallibu Valley, looking West, towards the sea.

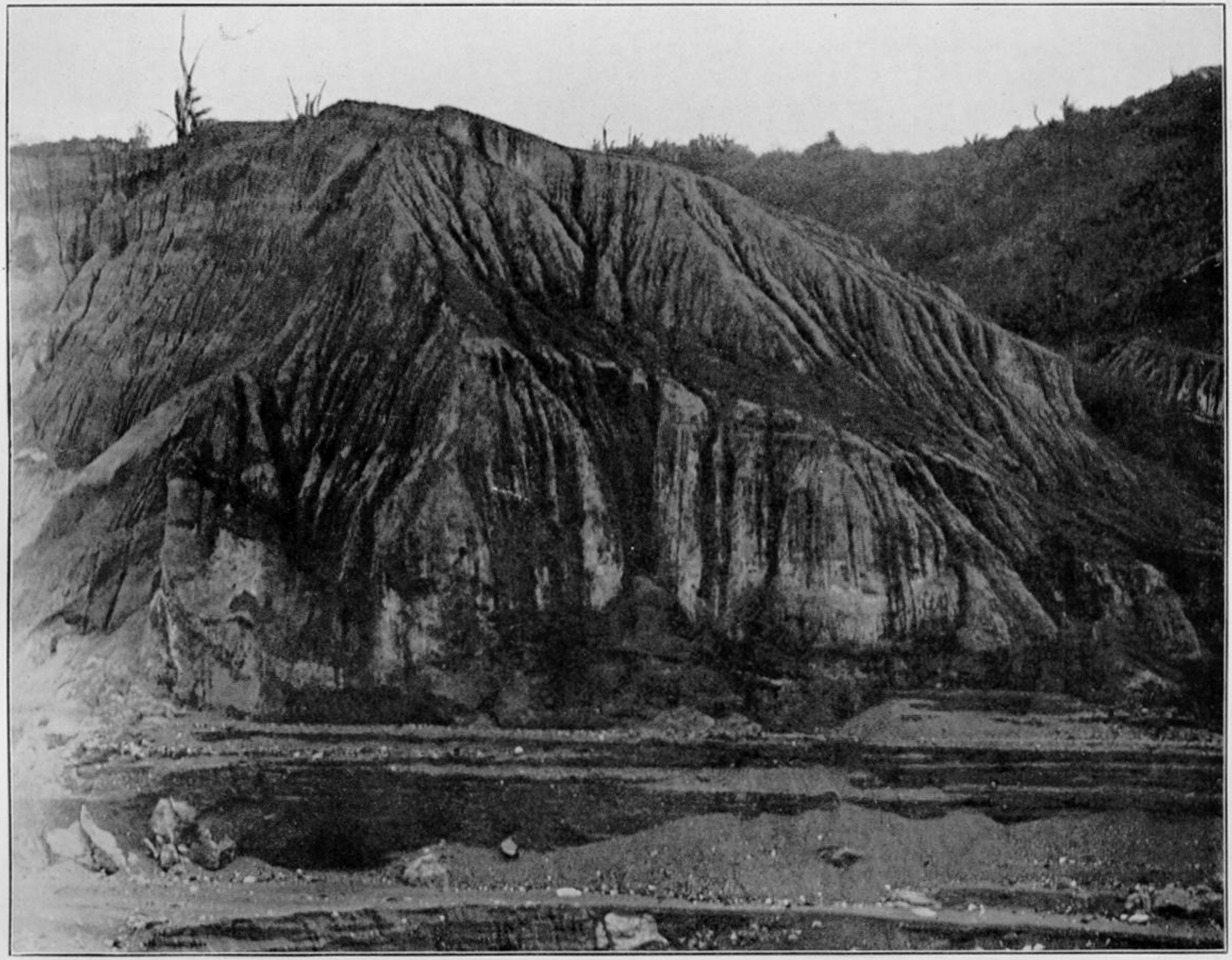


Fig. 1. *Terraces on South bank of Lower Wallibu.*

Fig. 2. *Trespé Ravine.*

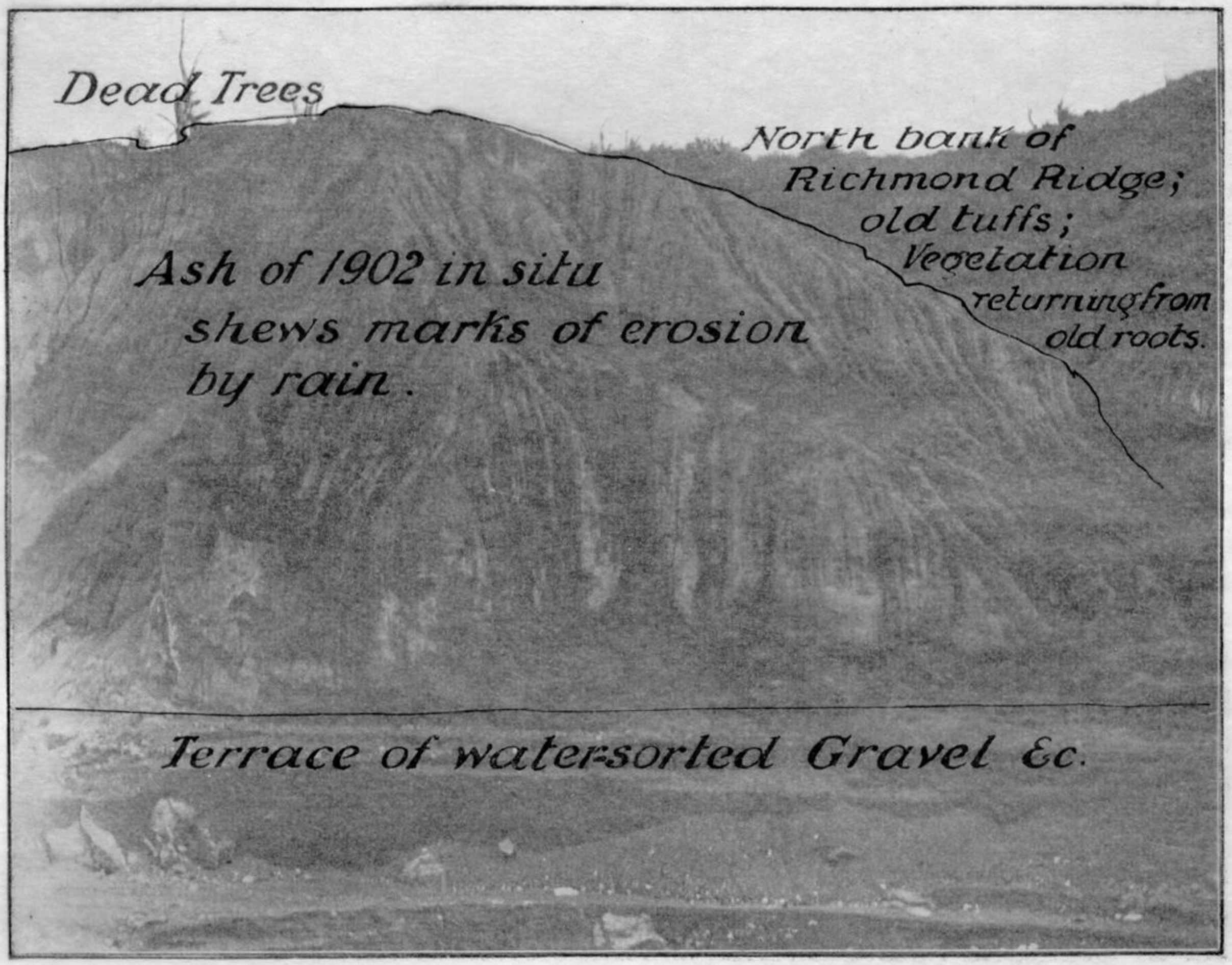


Fig. 1. *Terraces on South bank of Lower Wallibu.*

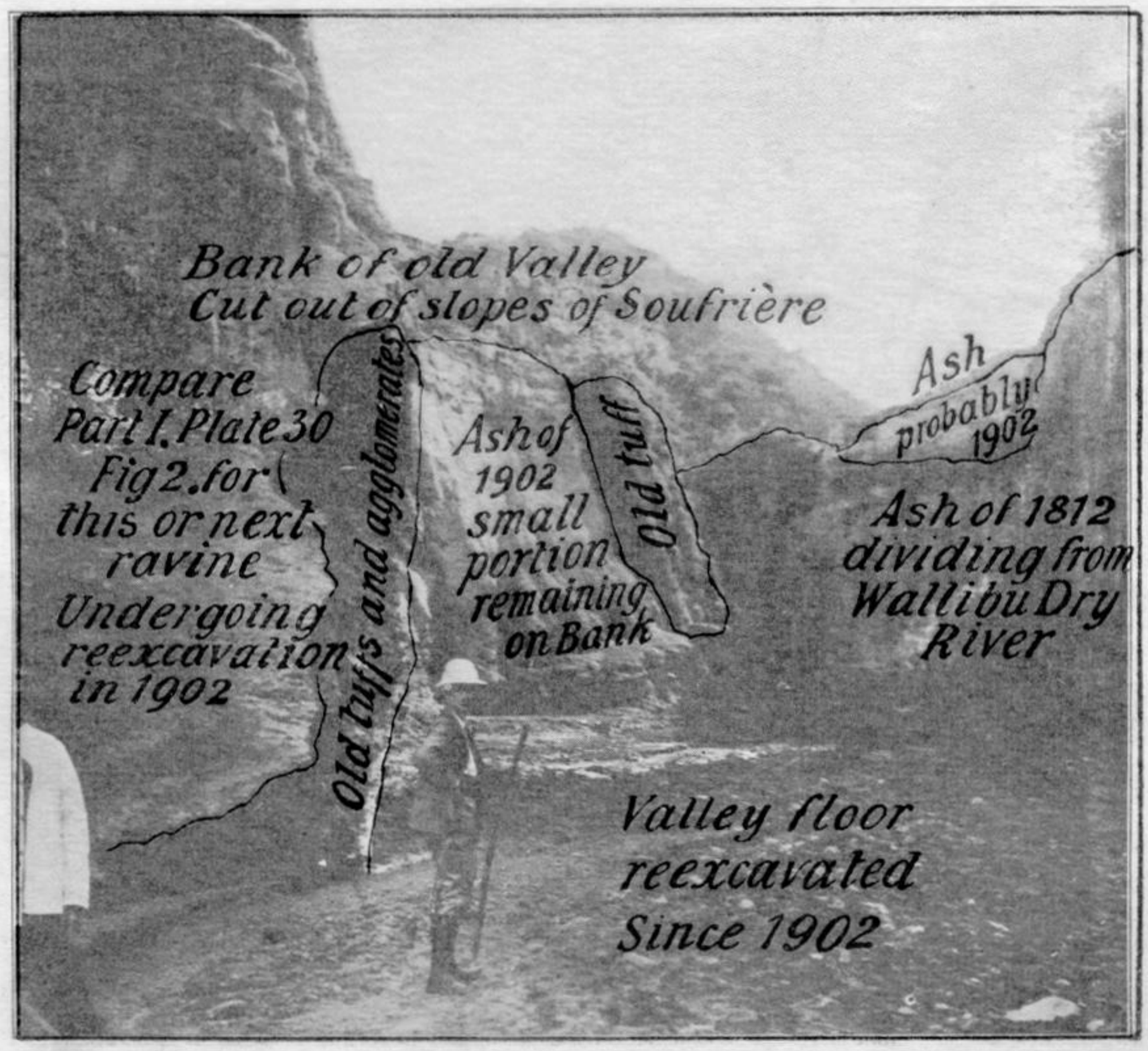
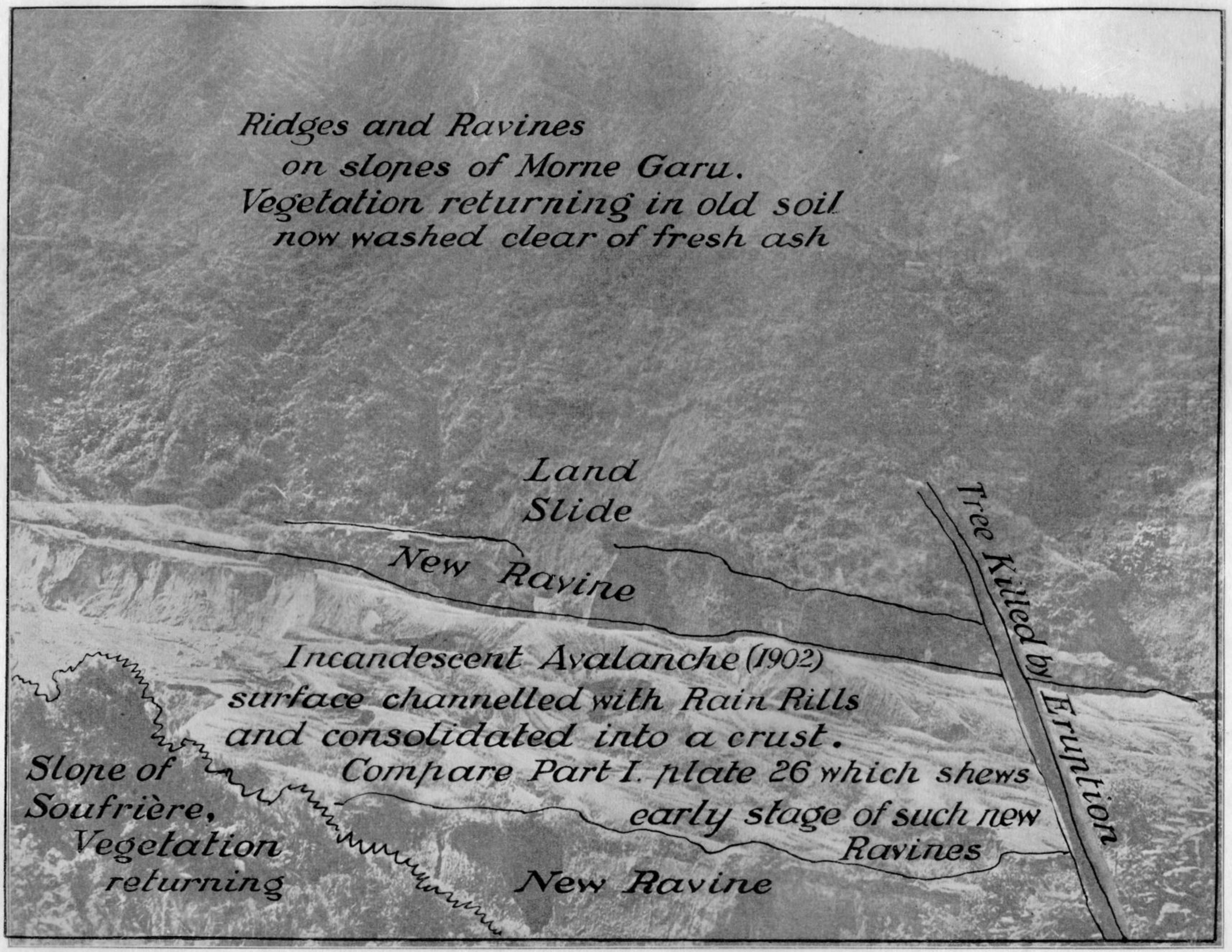


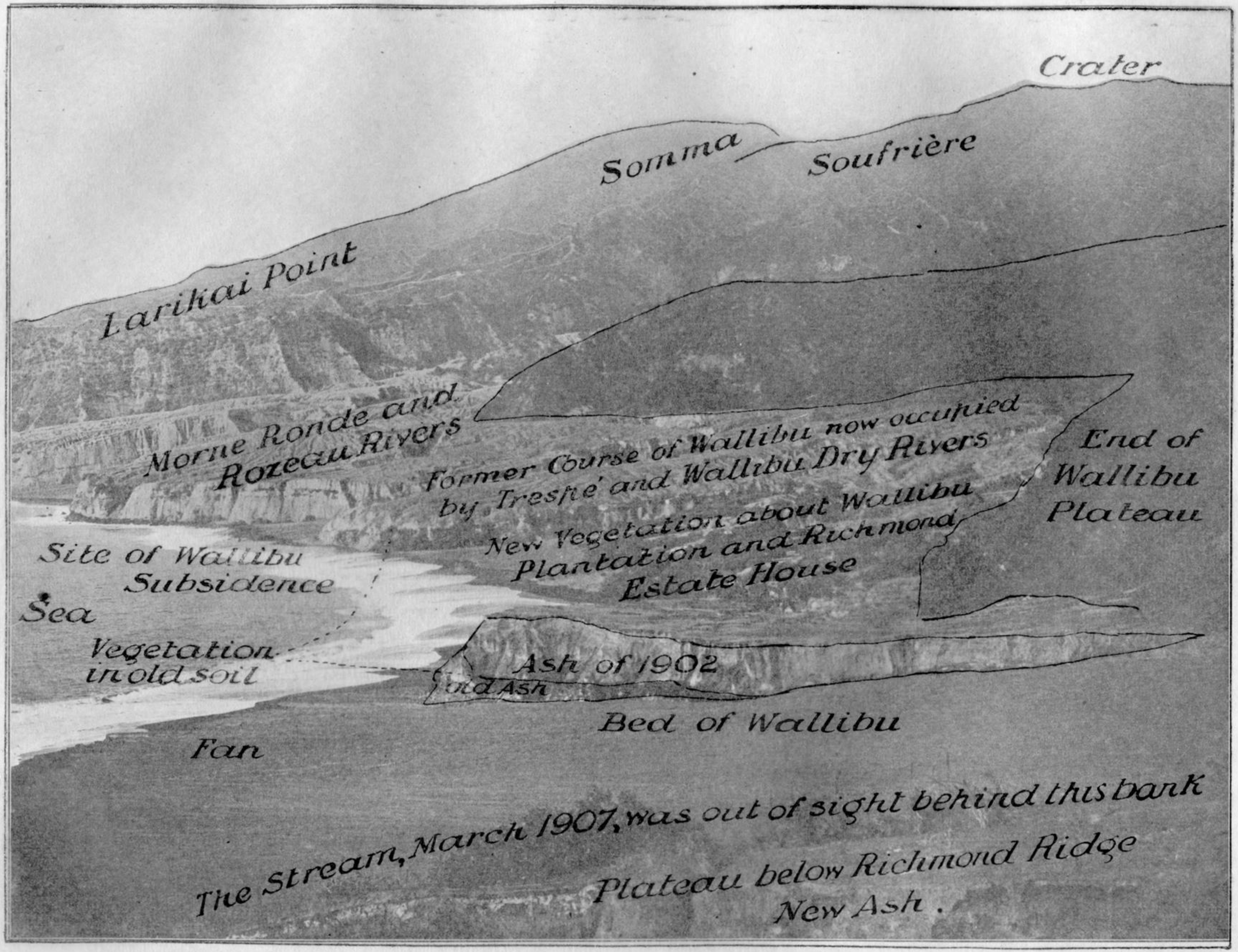
Fig. 2. *Trespé Ravine.*

Ravine on Soufrière, Upper Trespé Valley.



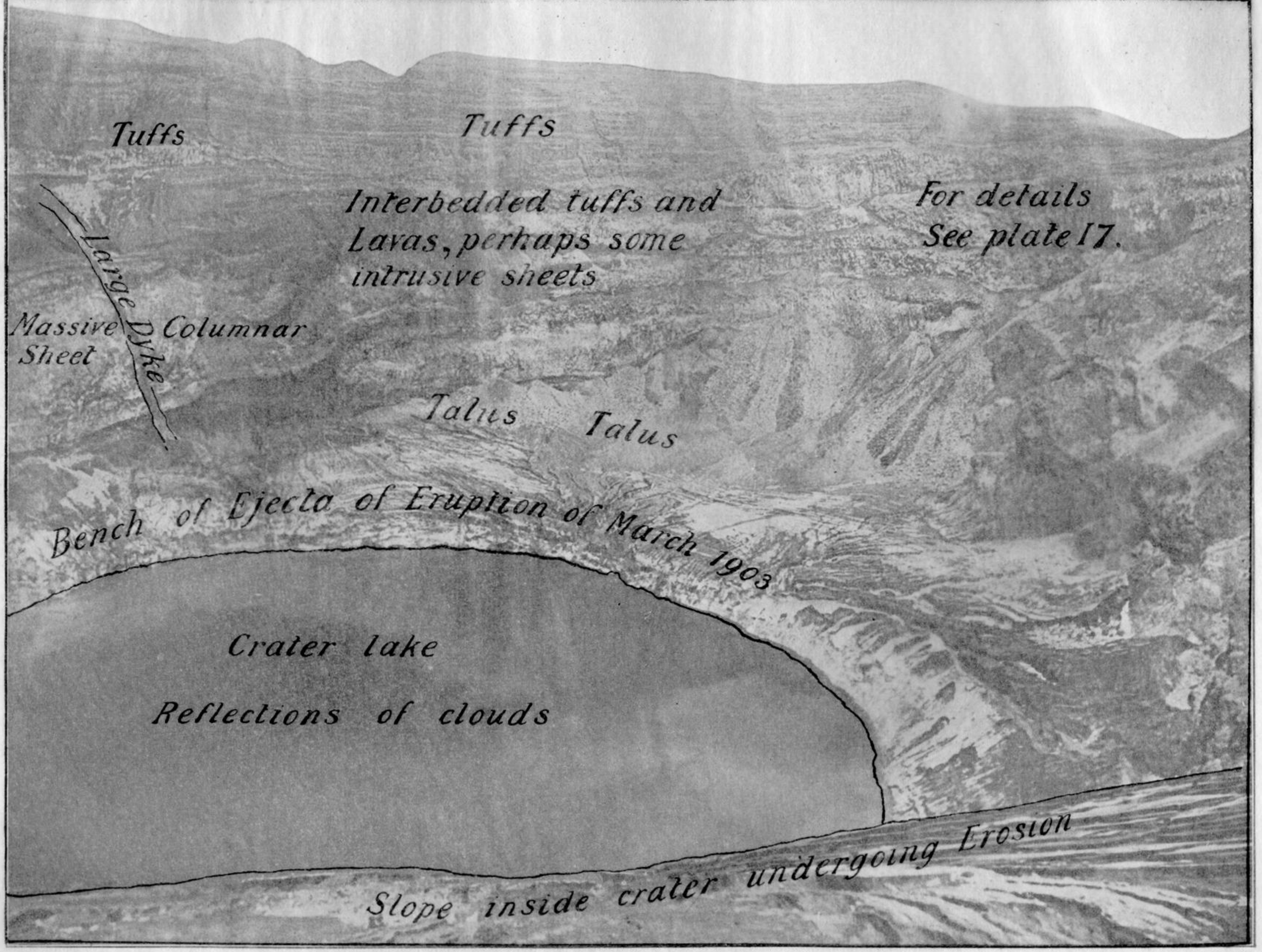
Ravine on Soufrière, Upper Trespé Valley.

Mouth of Wallibu, from Plateau below Richmond Ridge.



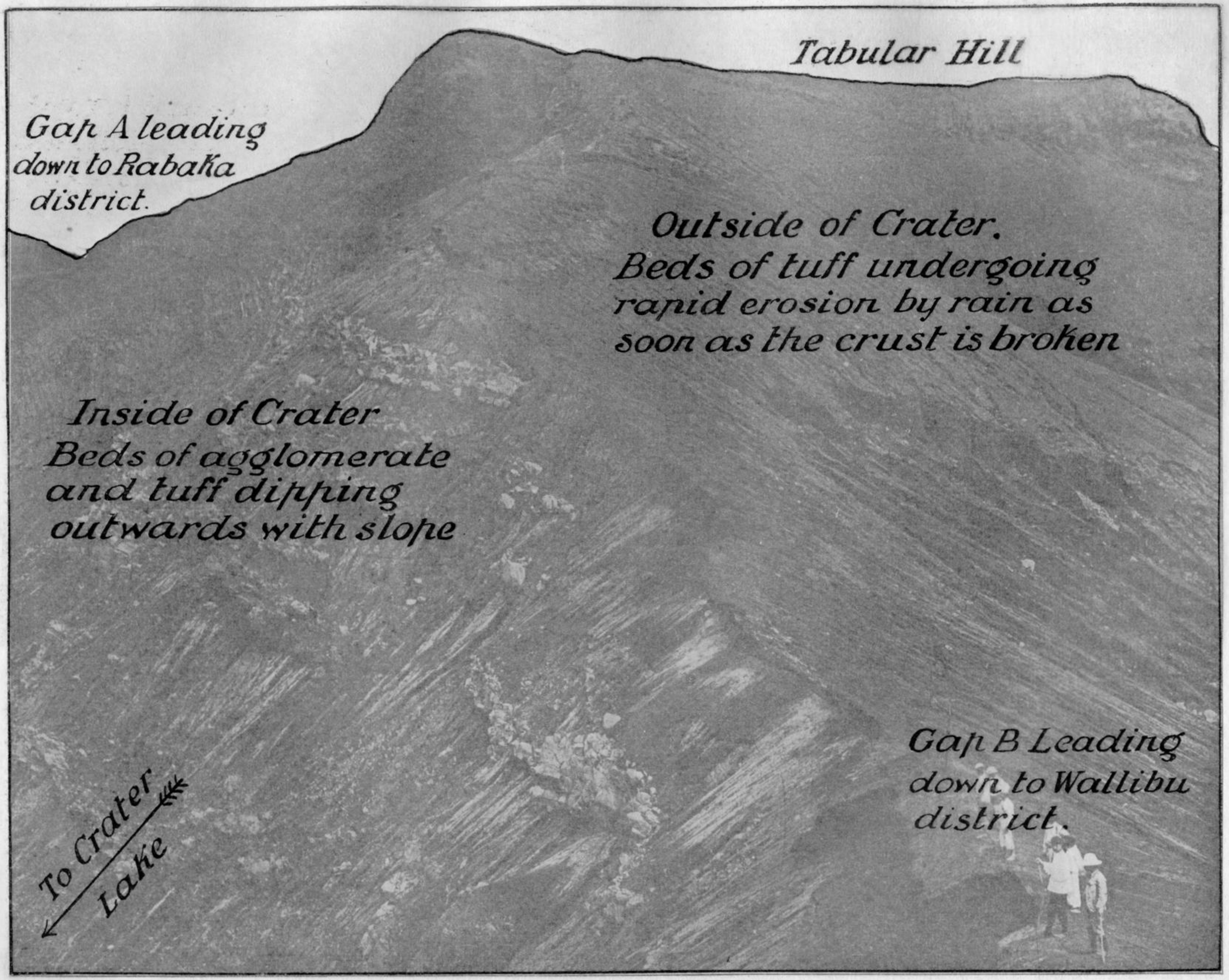
Mouth of Wallibu, from Plateau below Richmond Ridge.

The Crater of the Soufrière, from the South-west lip.



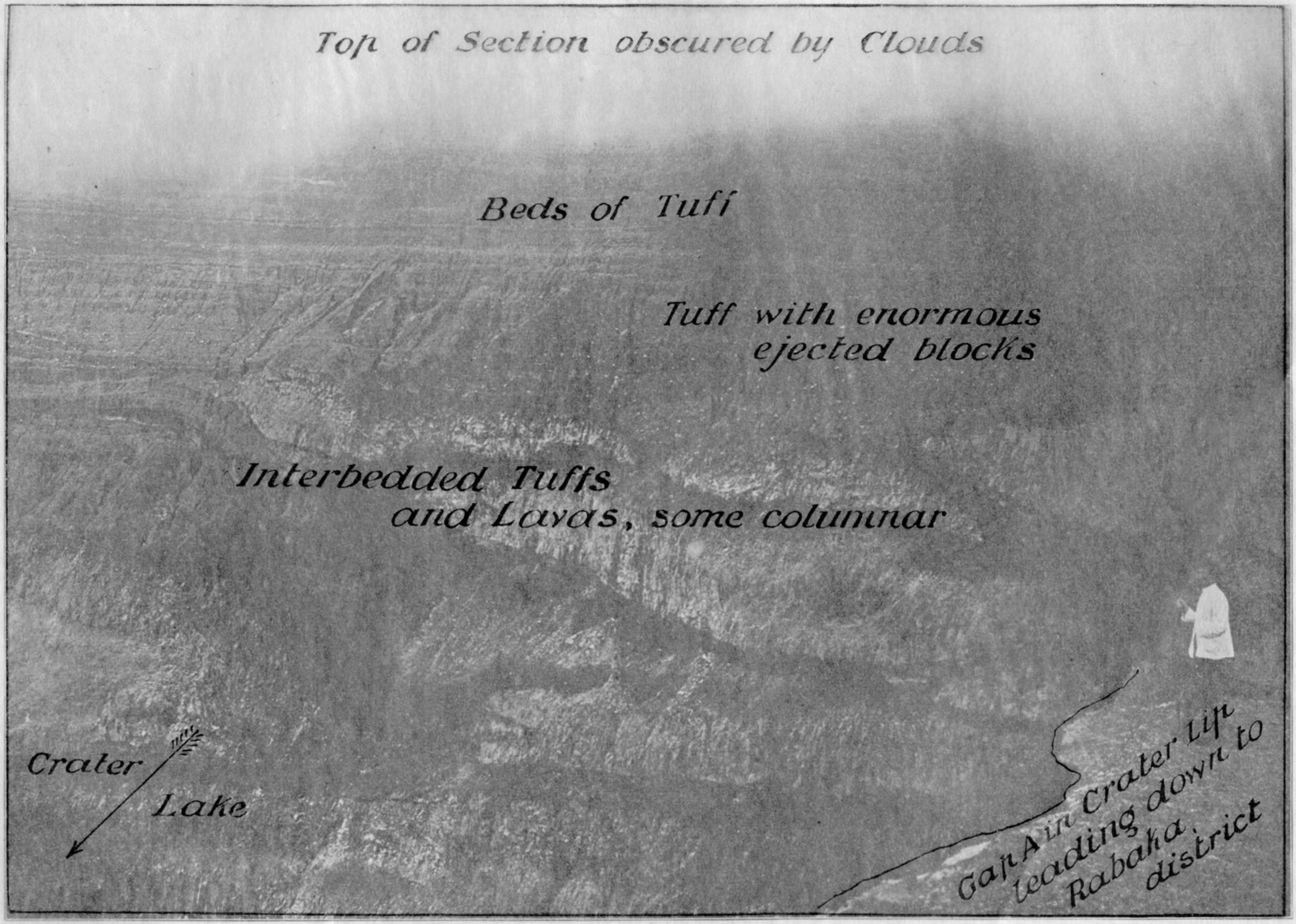
The Crater of the Soufrière, from the South-west lip.

Crater of the Soufrière ; south lip, from West.



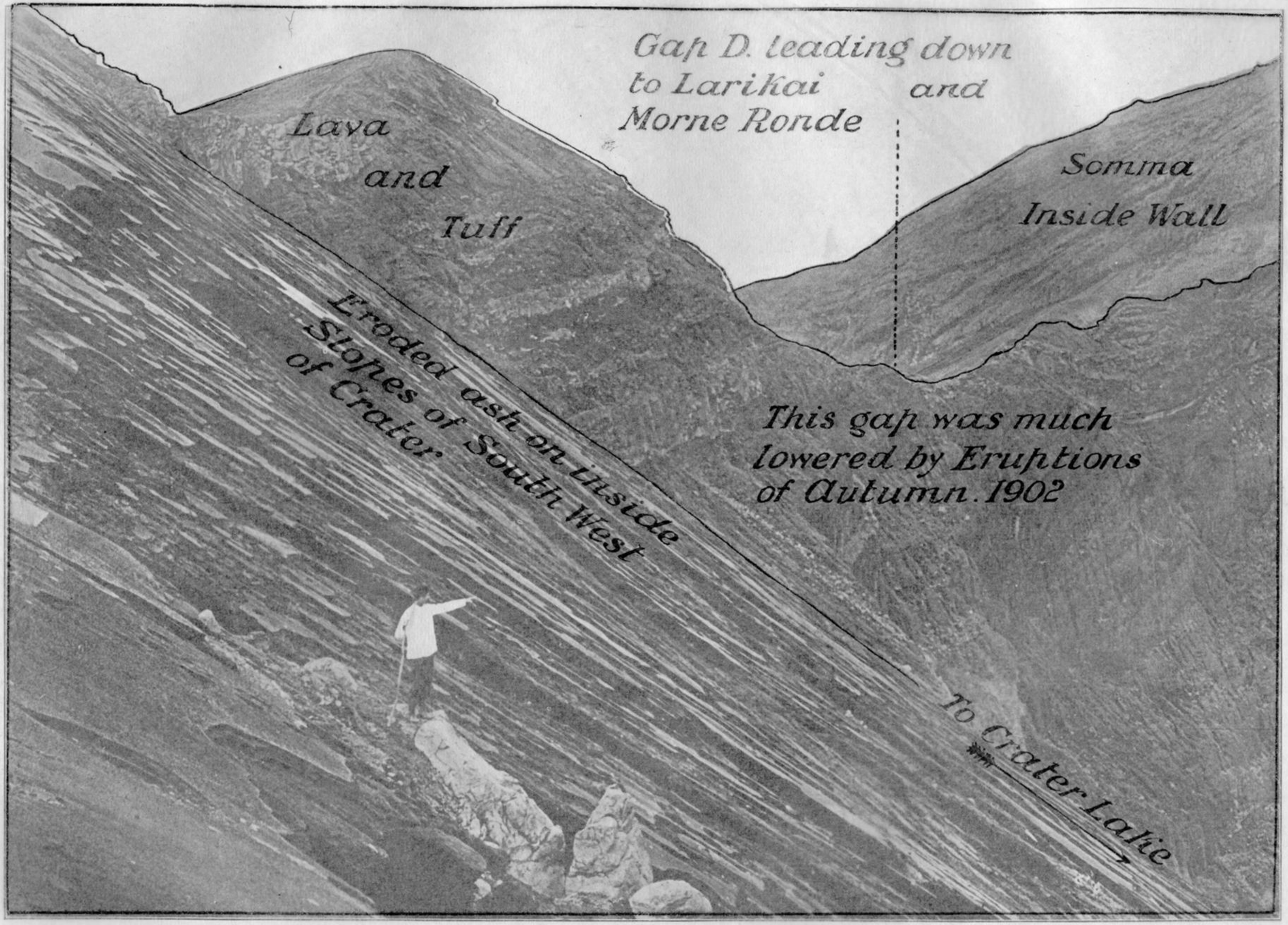
Crater of the Soufrière; south lip, from West.

North wall of Crater, Eastern end.



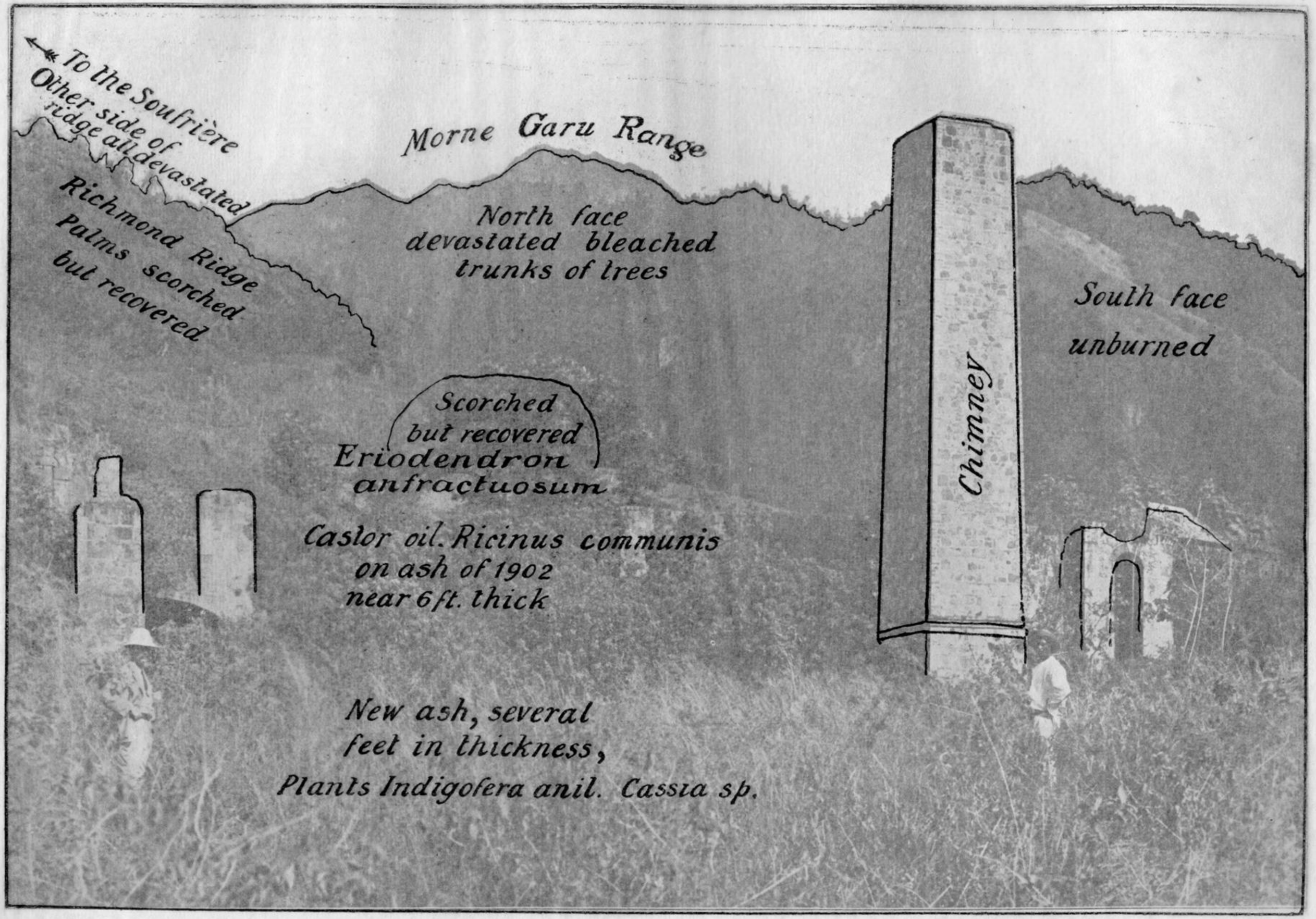
North wall of Crater, Eastern end.

West lip of Crater.



West lip of Crater.

Richmond Plantation Works, 1907, *from the West.*



Richmond Plantation Works, 1907, *from the West.*

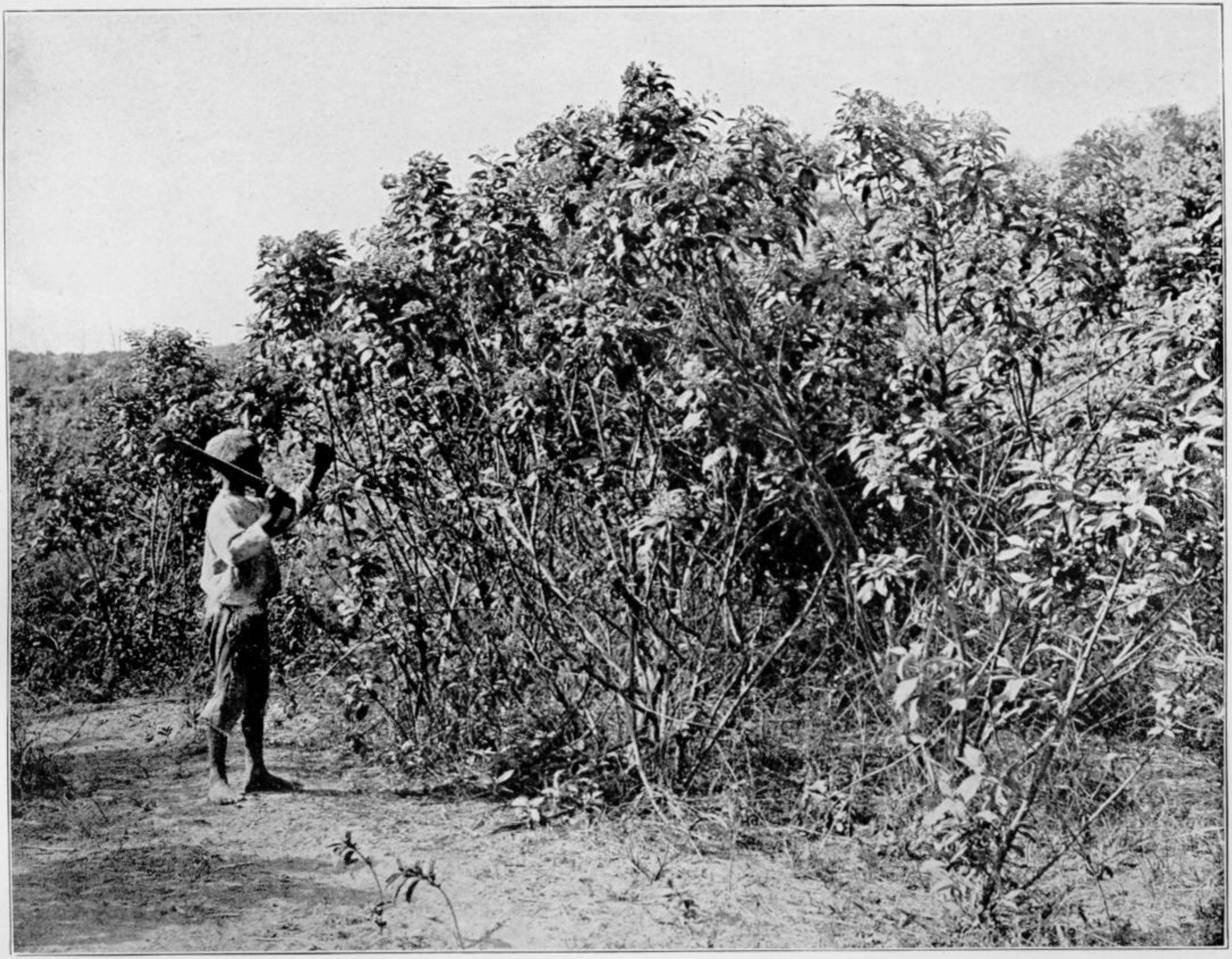
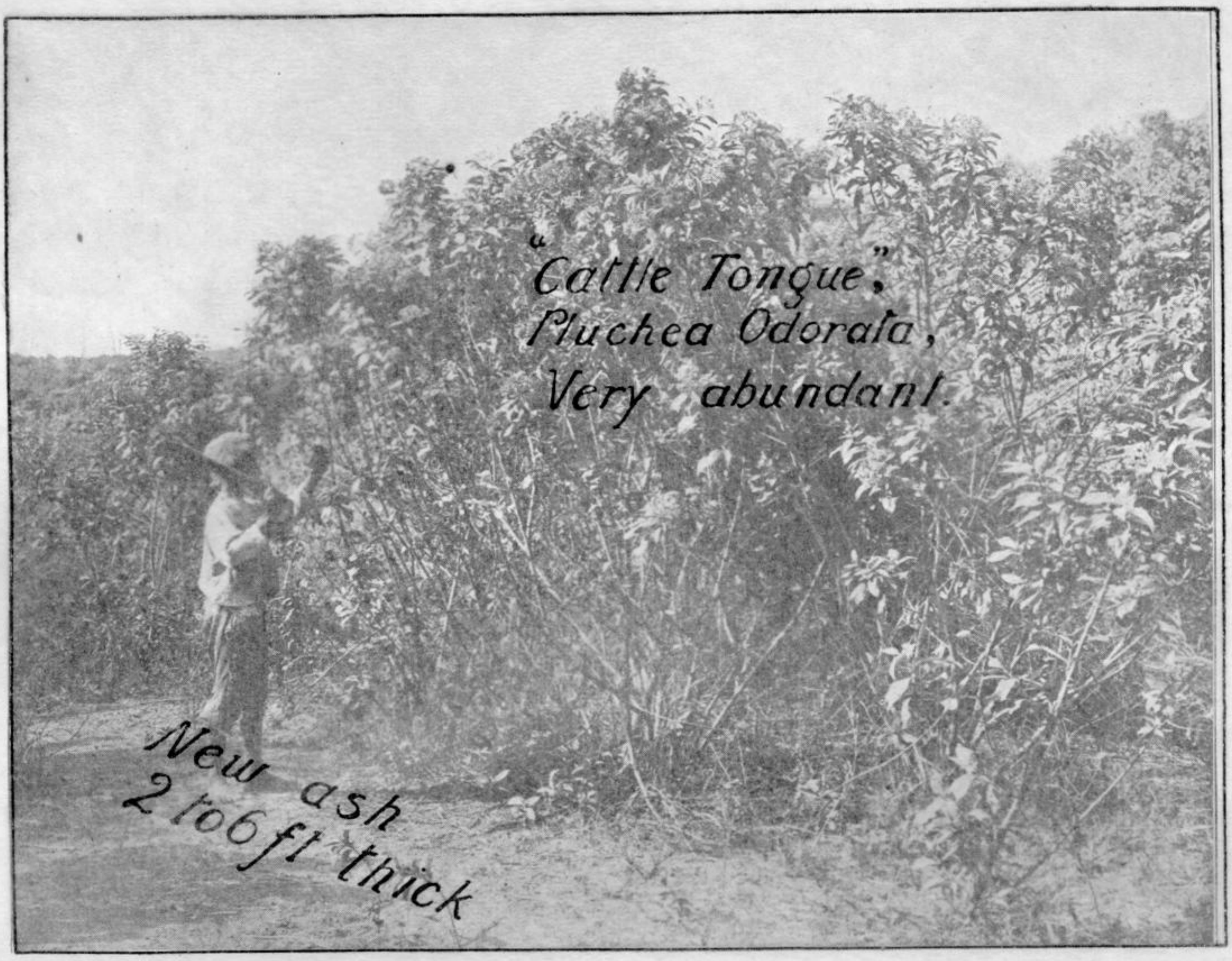


Fig. 1. *Near Richmond Works*, 1907. (Pluchea Odorata.)

Fig. 2. *Near the River, Richmond Works.*



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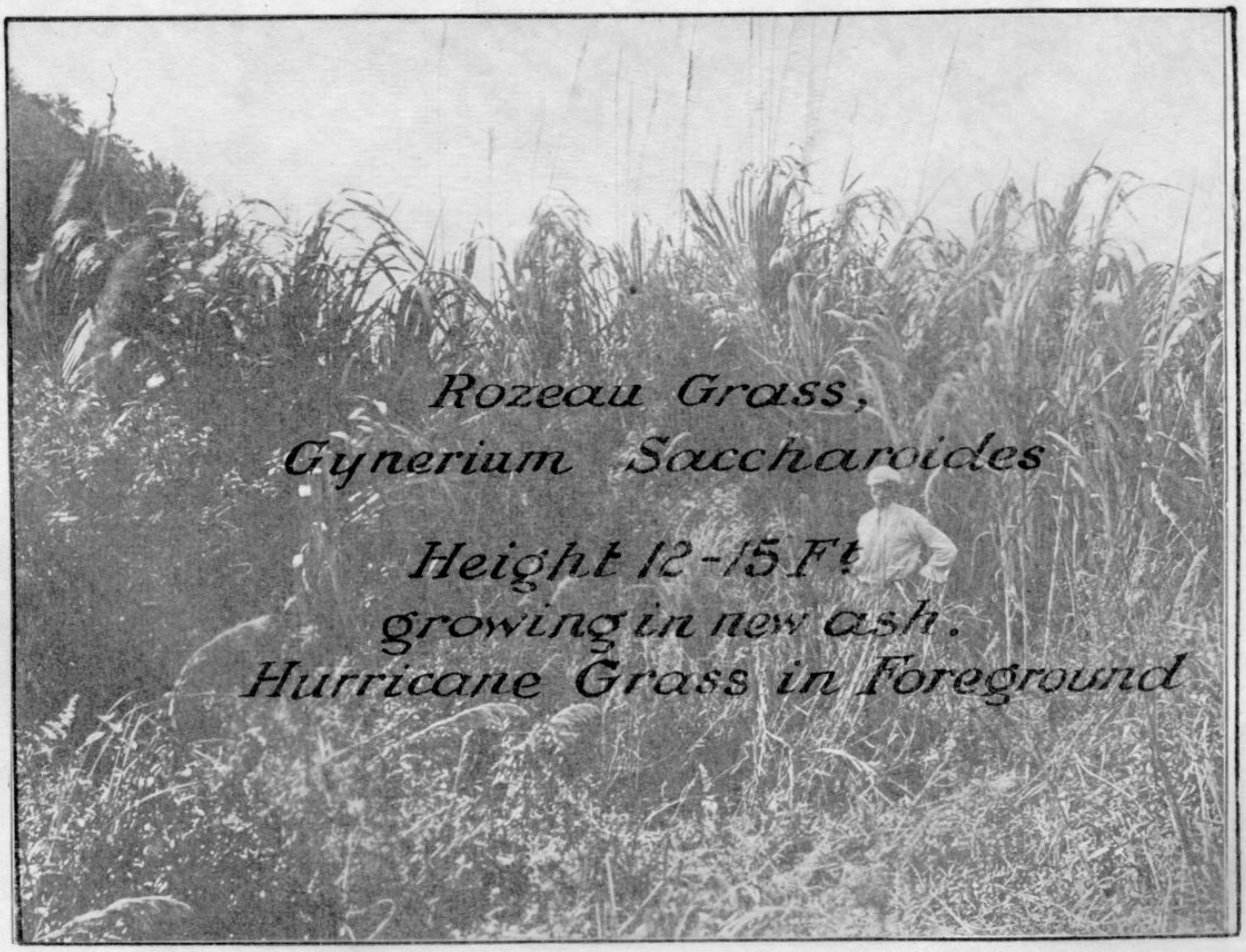
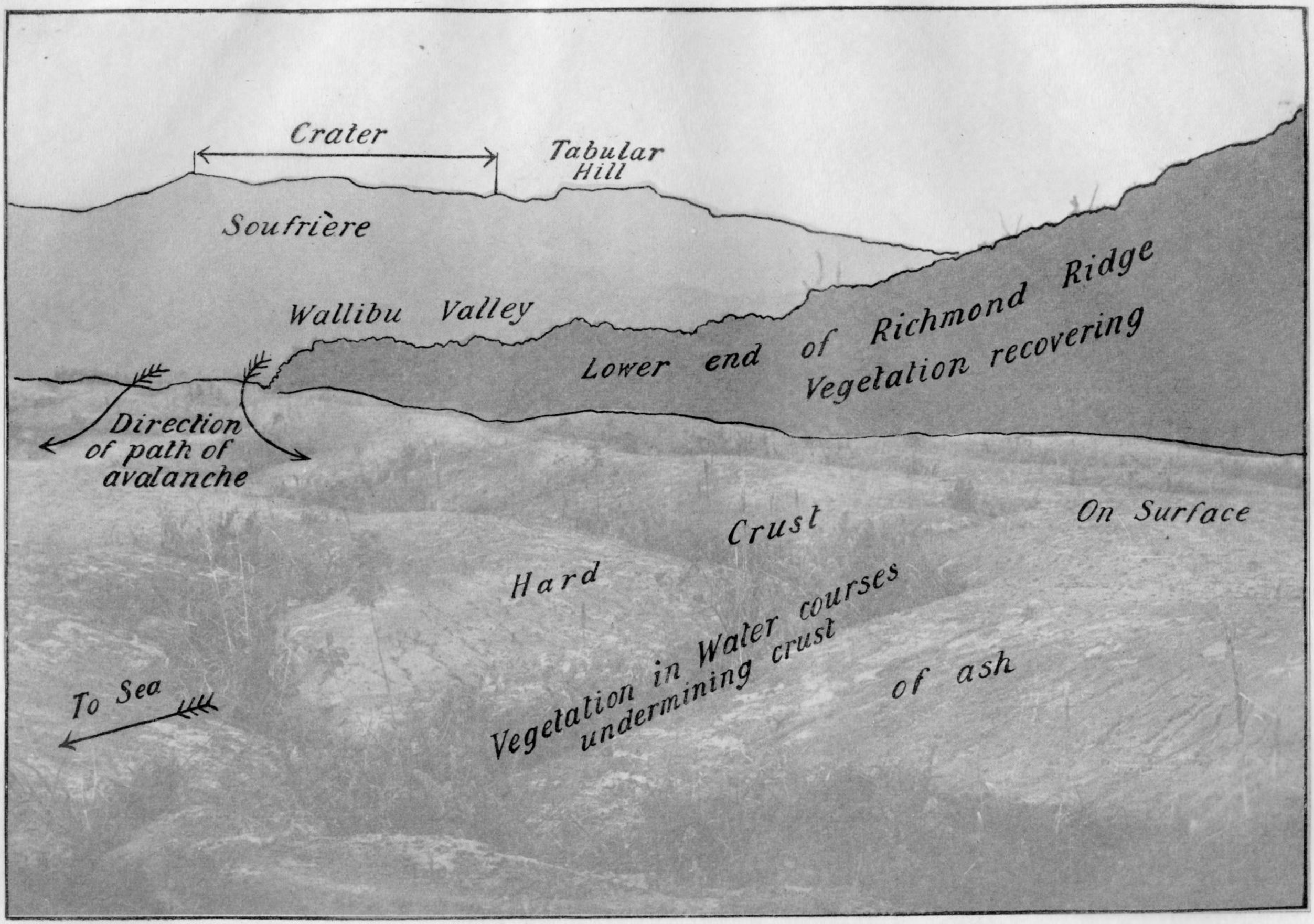


Fig. 2. *Near the River, Richmond Works.*

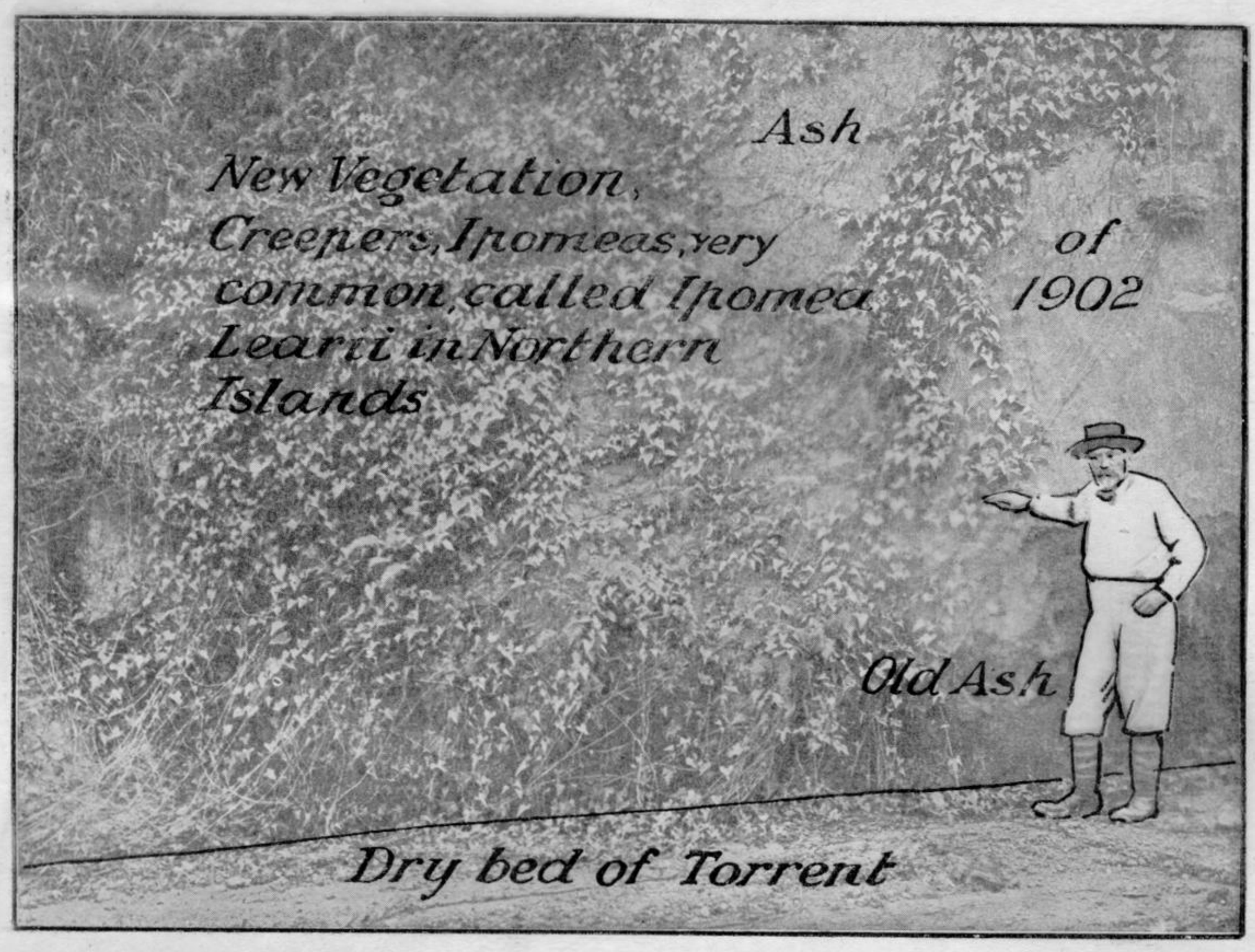
The Avalanche, below end of Richmond Ridge.



The Avalanche, below end of Richmond Ridge.

Fig. 1. *North Wall of Trespe Valley.*

Fig. 2. *A Ridge on the Soufrière at about* 600 *feet.*



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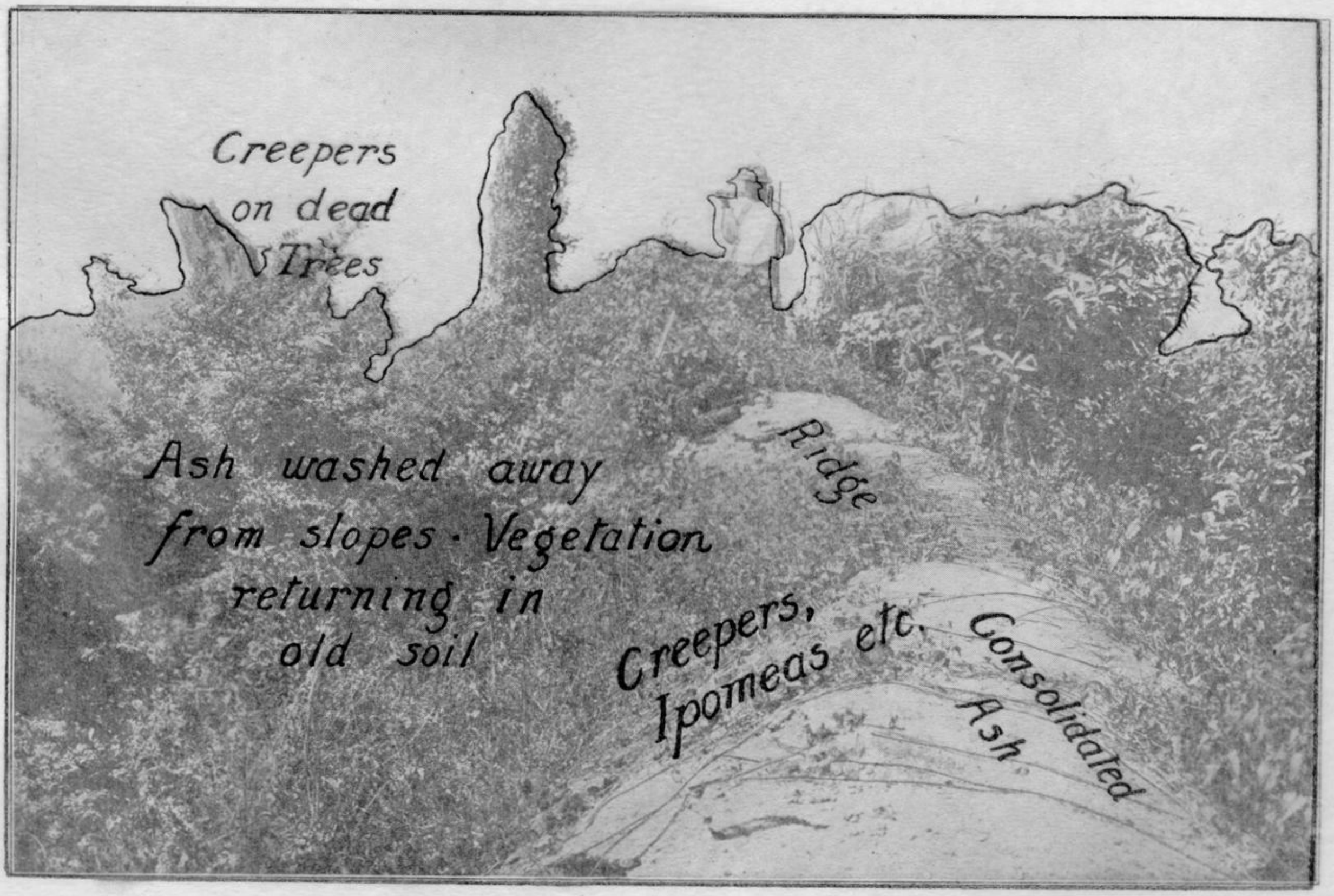


Fig. 2. *A Ridge on the Soufrière at about* 600 *feet.*

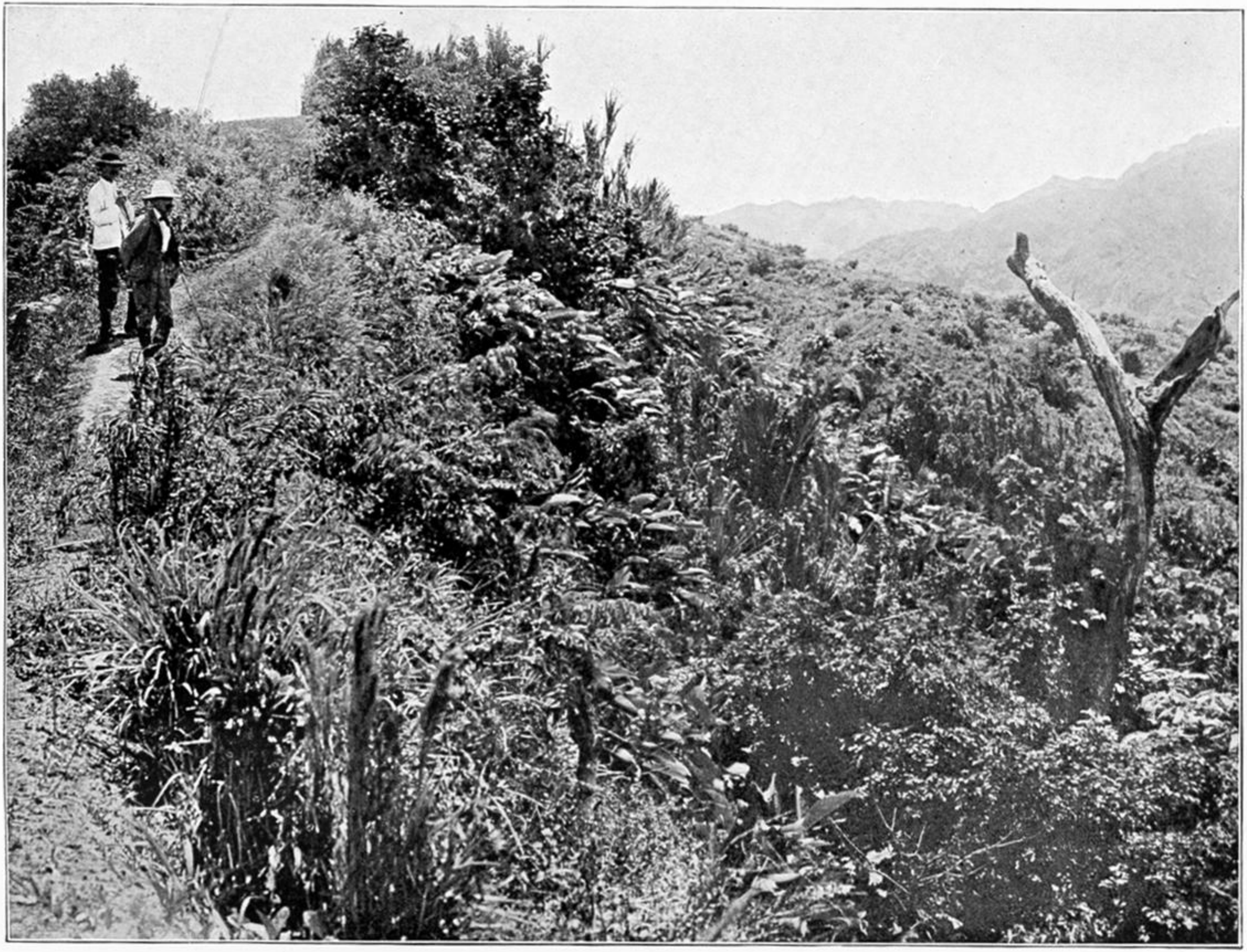


Fig. 1. *South Slopes of Soufrière at about* 600 *feet.*

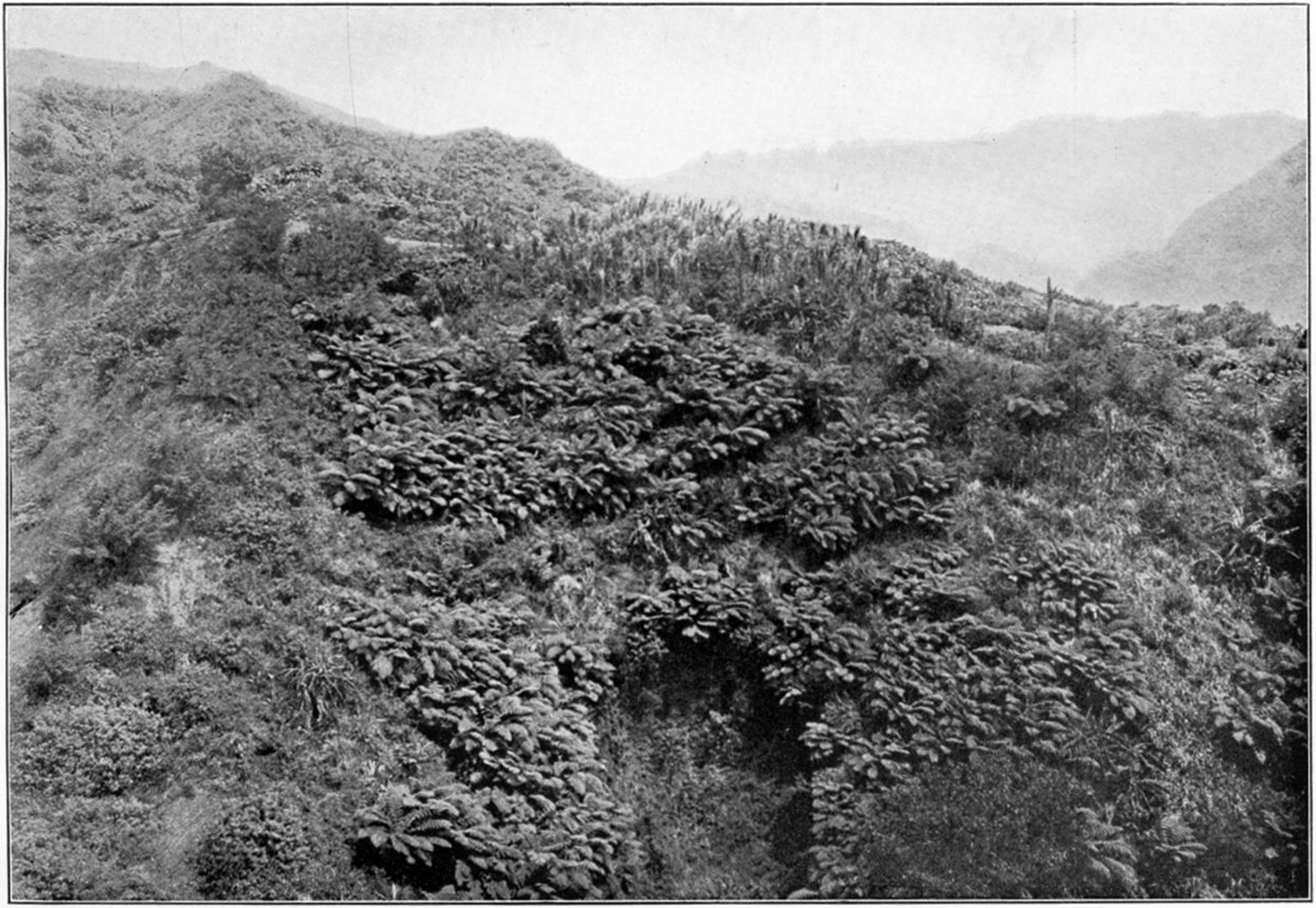


Fig. 2. *Slopes of Soufrière at about* 800 *feet.*

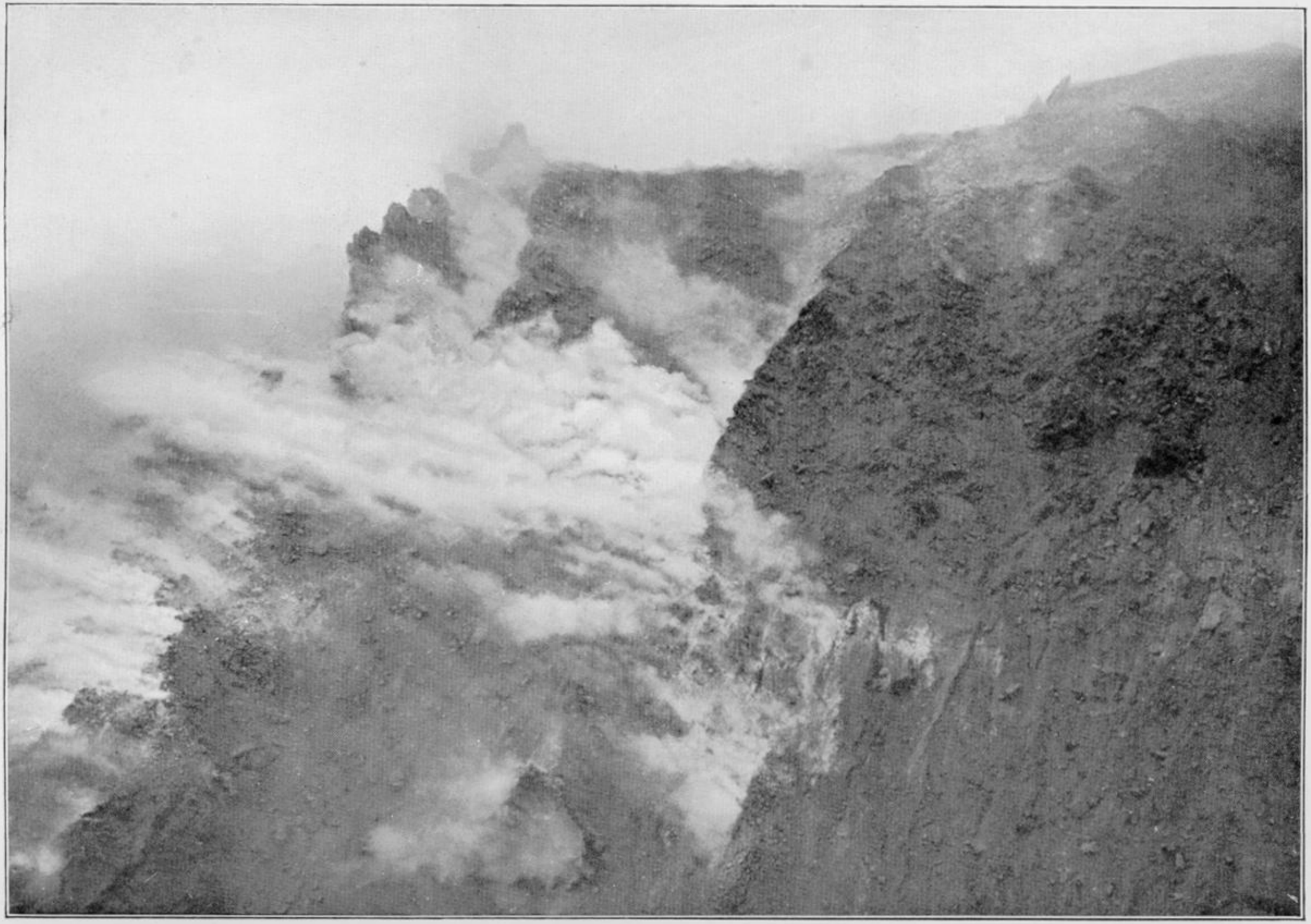
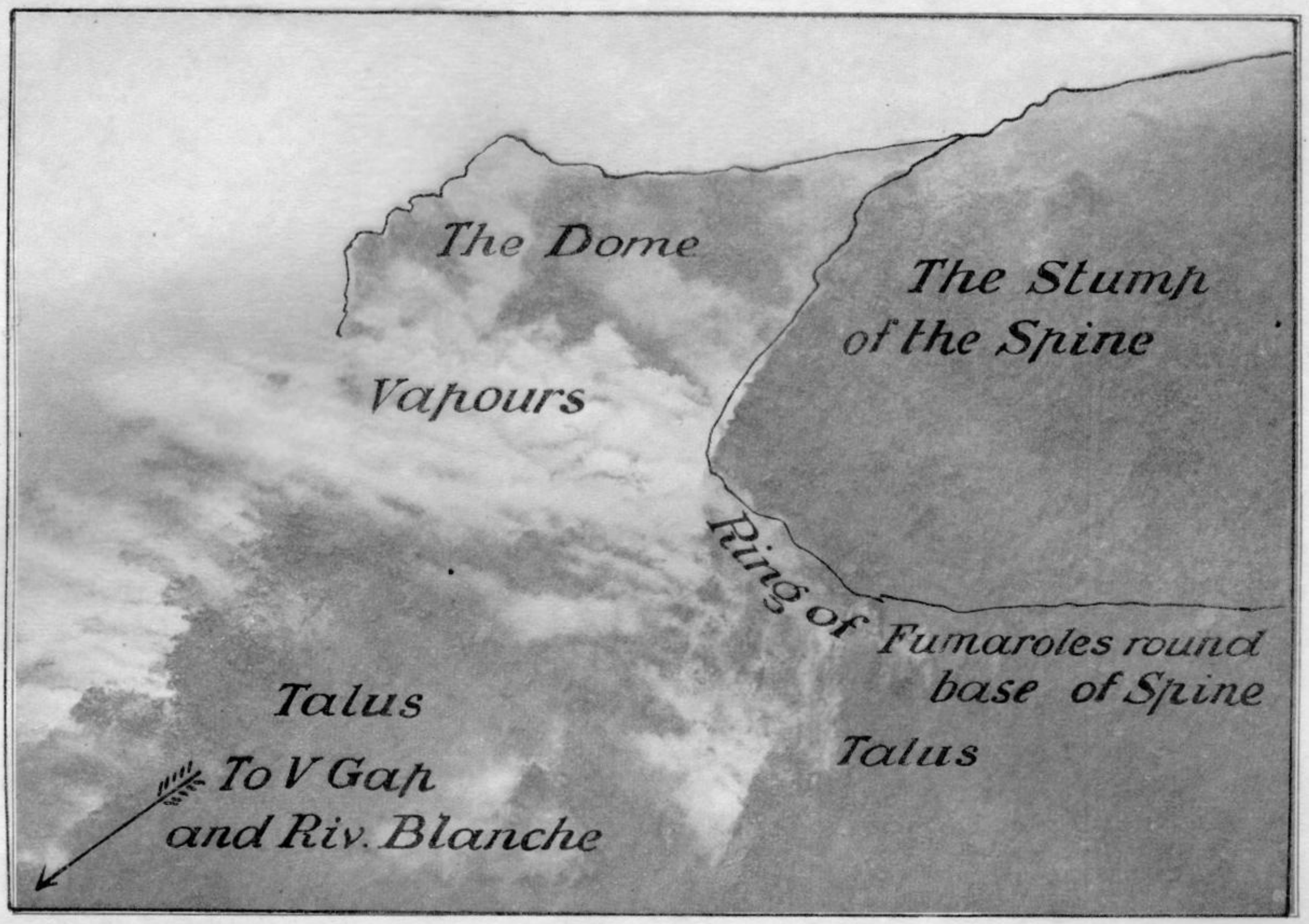


Fig. 1. *The Crater of Montagne Pelée, March* 13, 1907.

Fig. 2. *On Montagne Pelée, North side, at about* 1500 *feet.*



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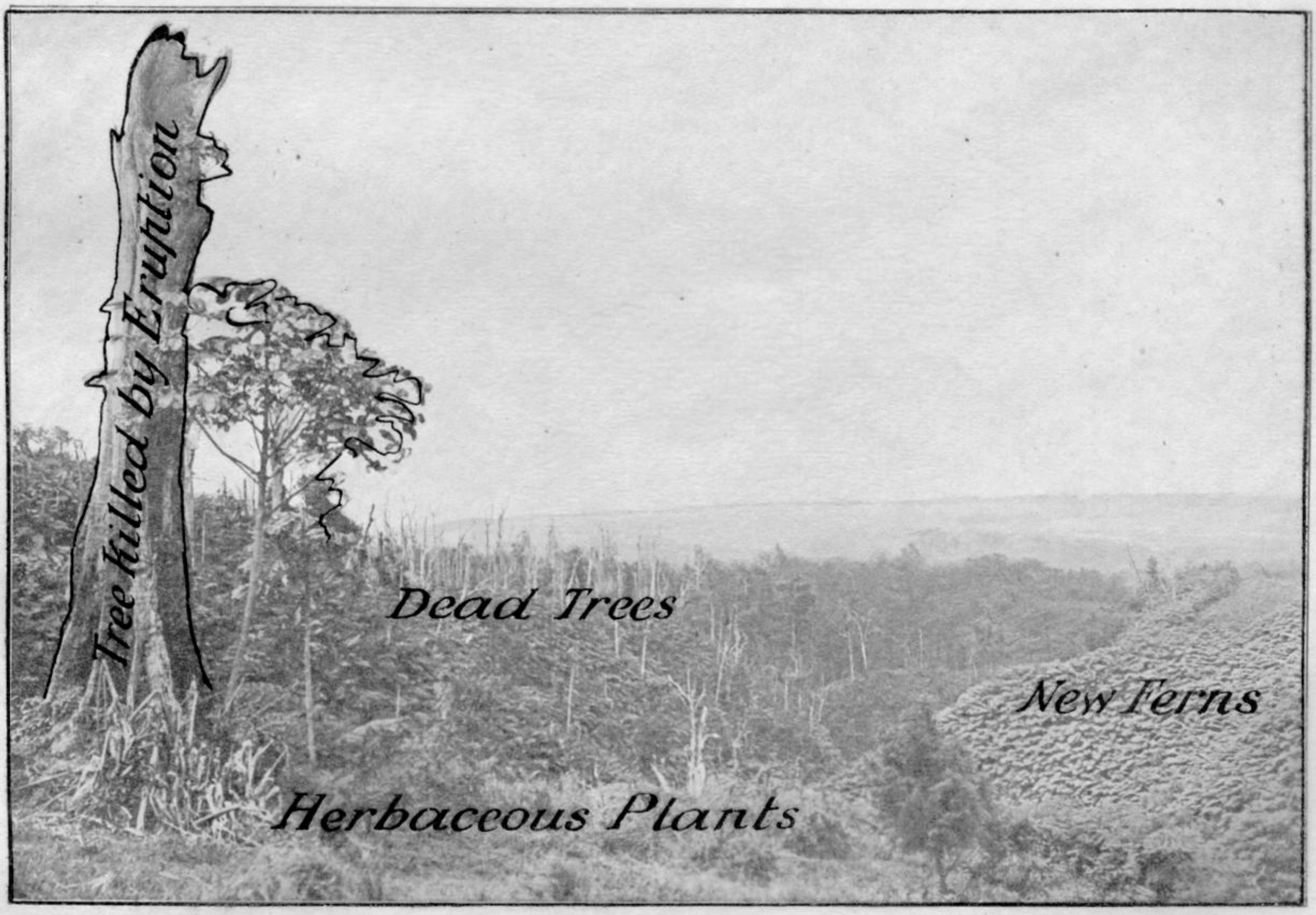

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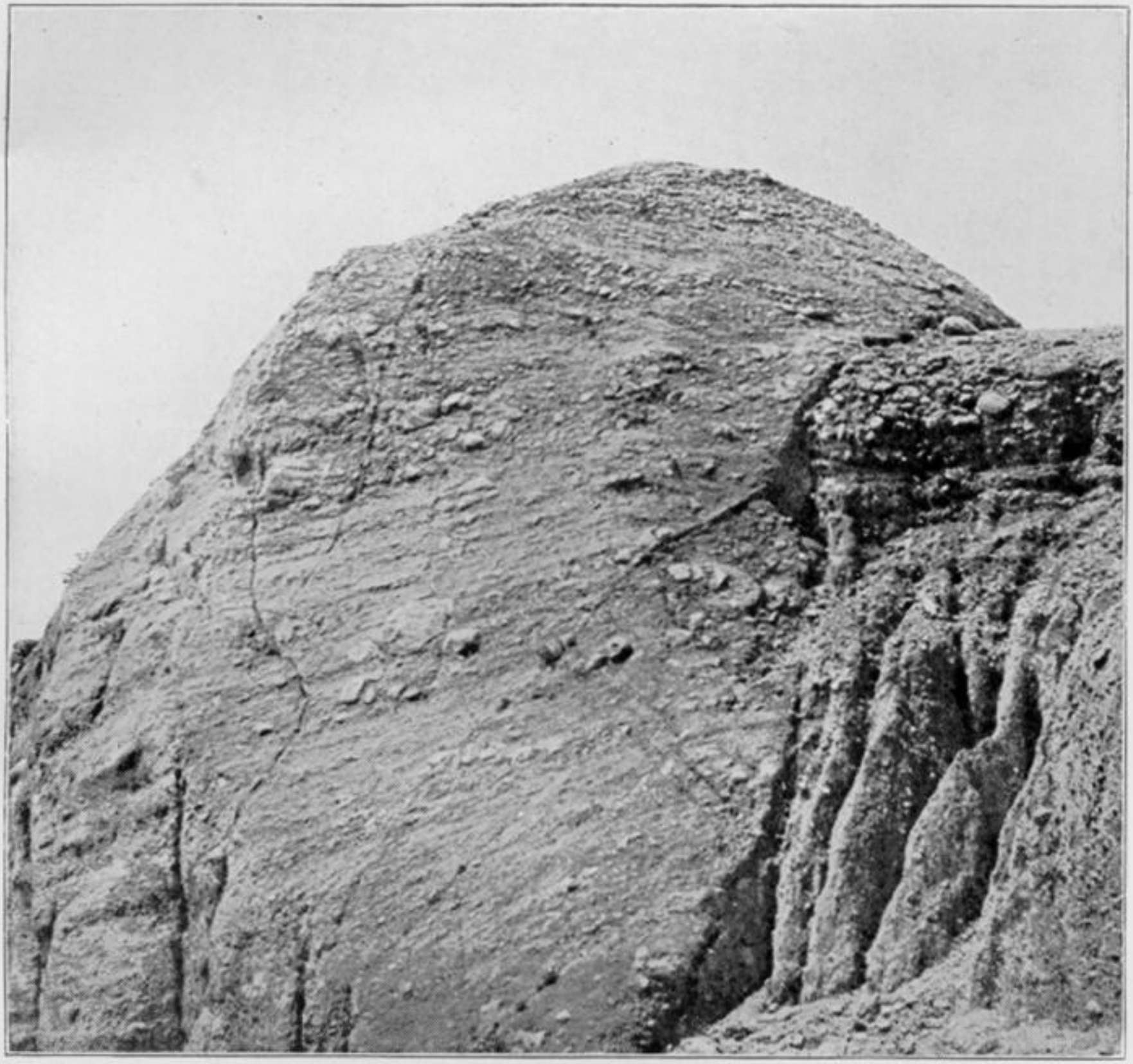


Fig. 1. *Tuff-agglomerate, scored by avalanches. General view.*

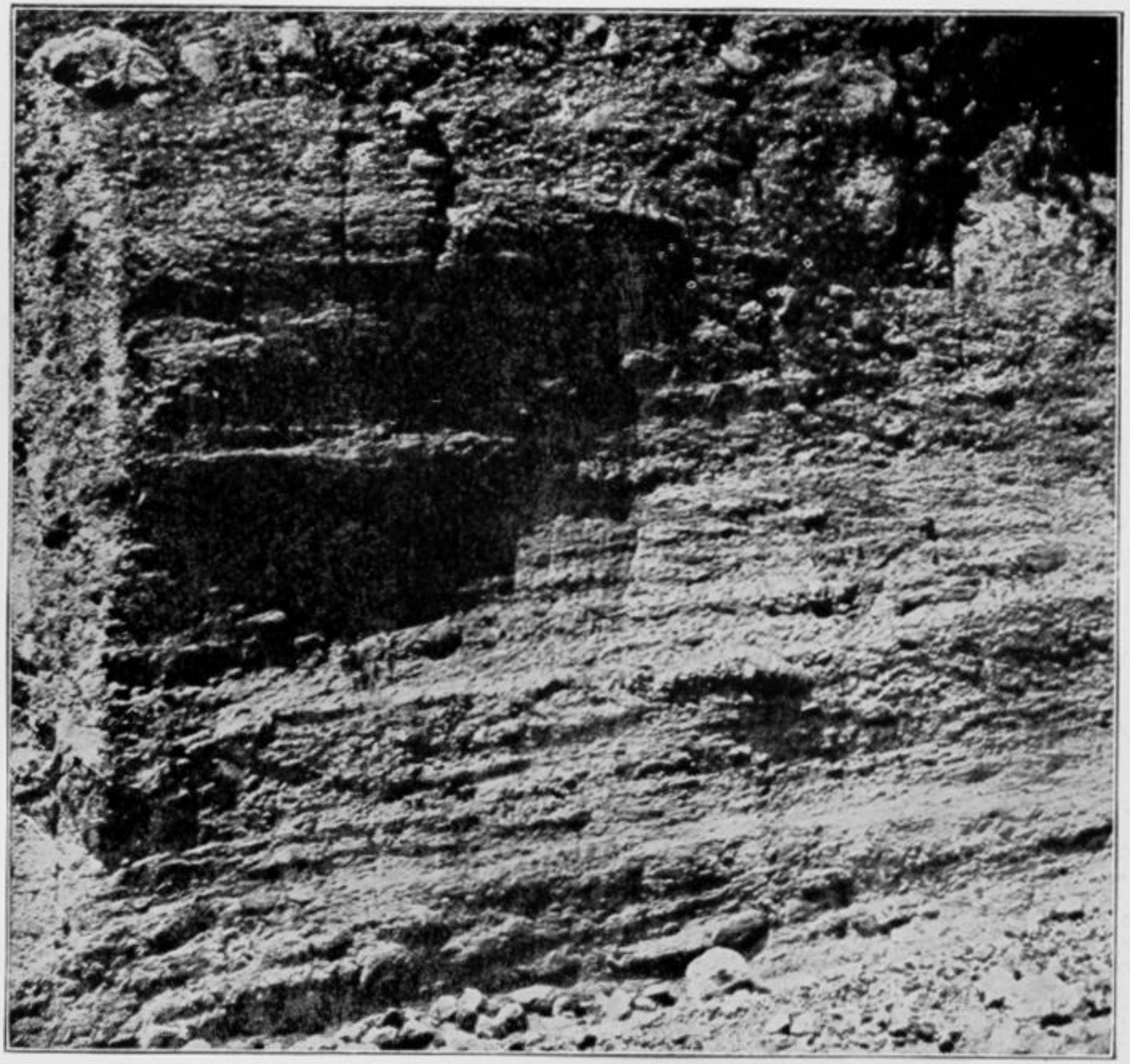


Fig. 2. *Details beyond left corner of Fig.* 1.

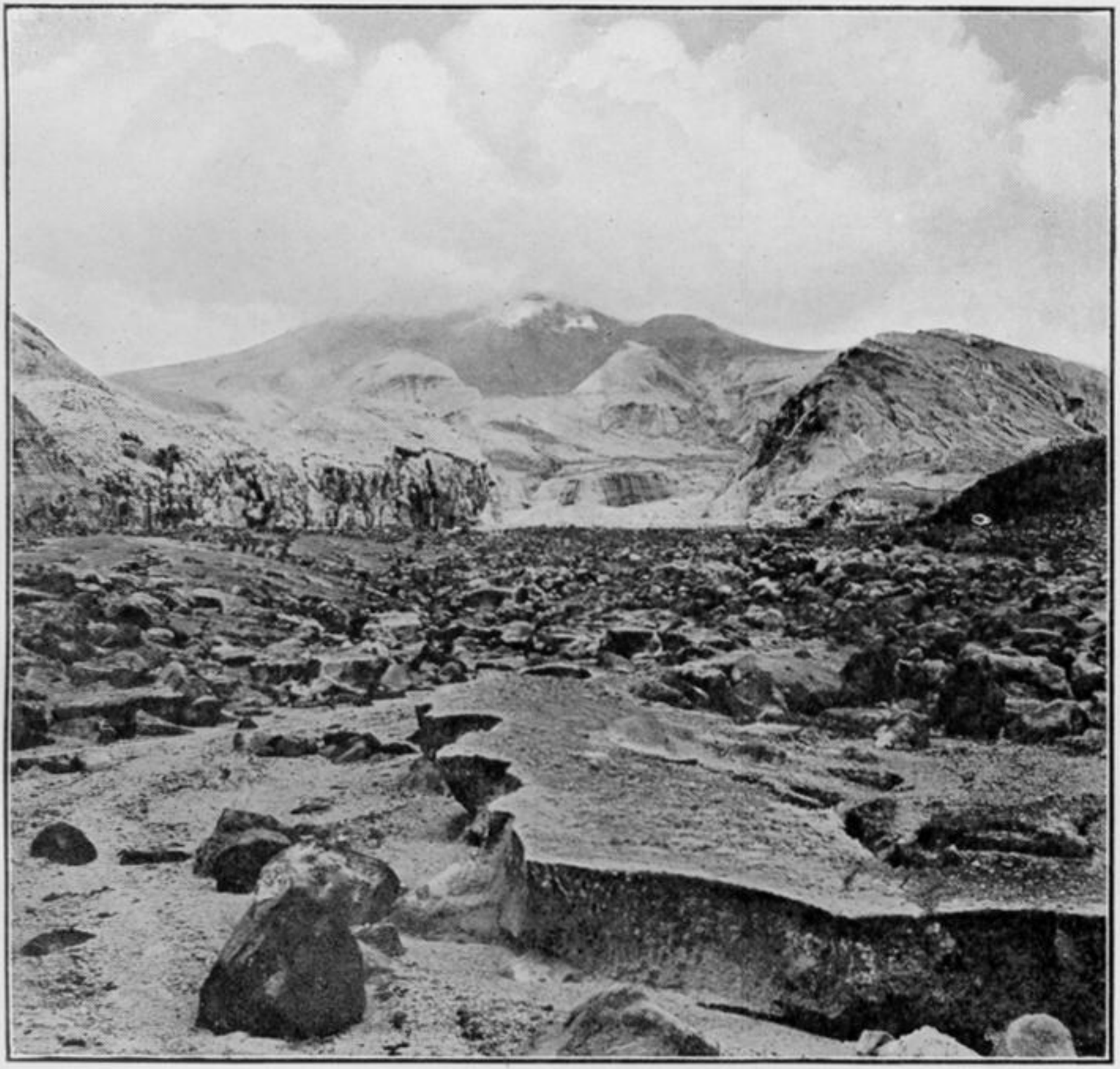
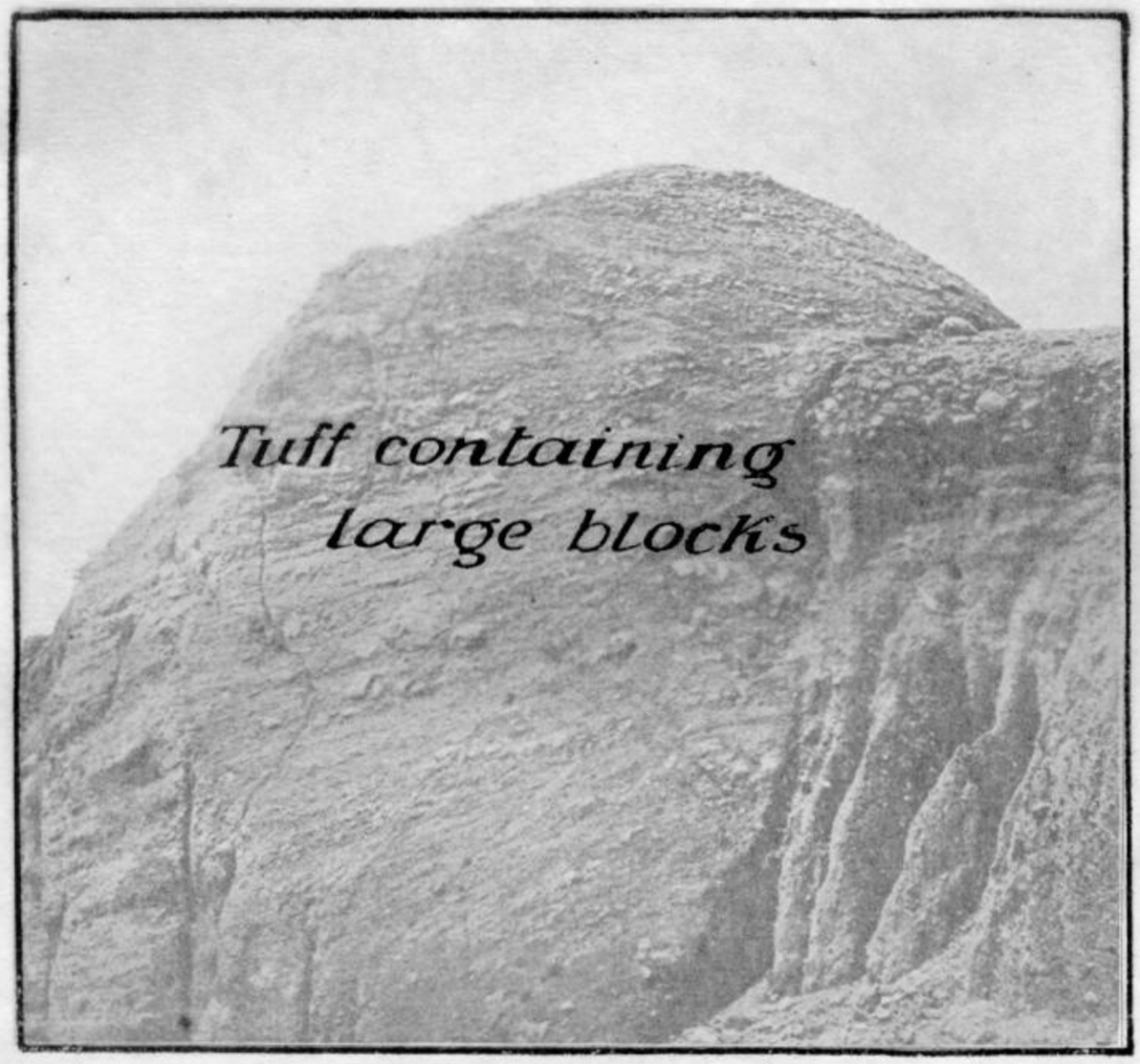


Fig. 3. *Valley of Rivière Blanche, from near shore.*

Fig. 4. *The new Delta at Basse Pointe.*



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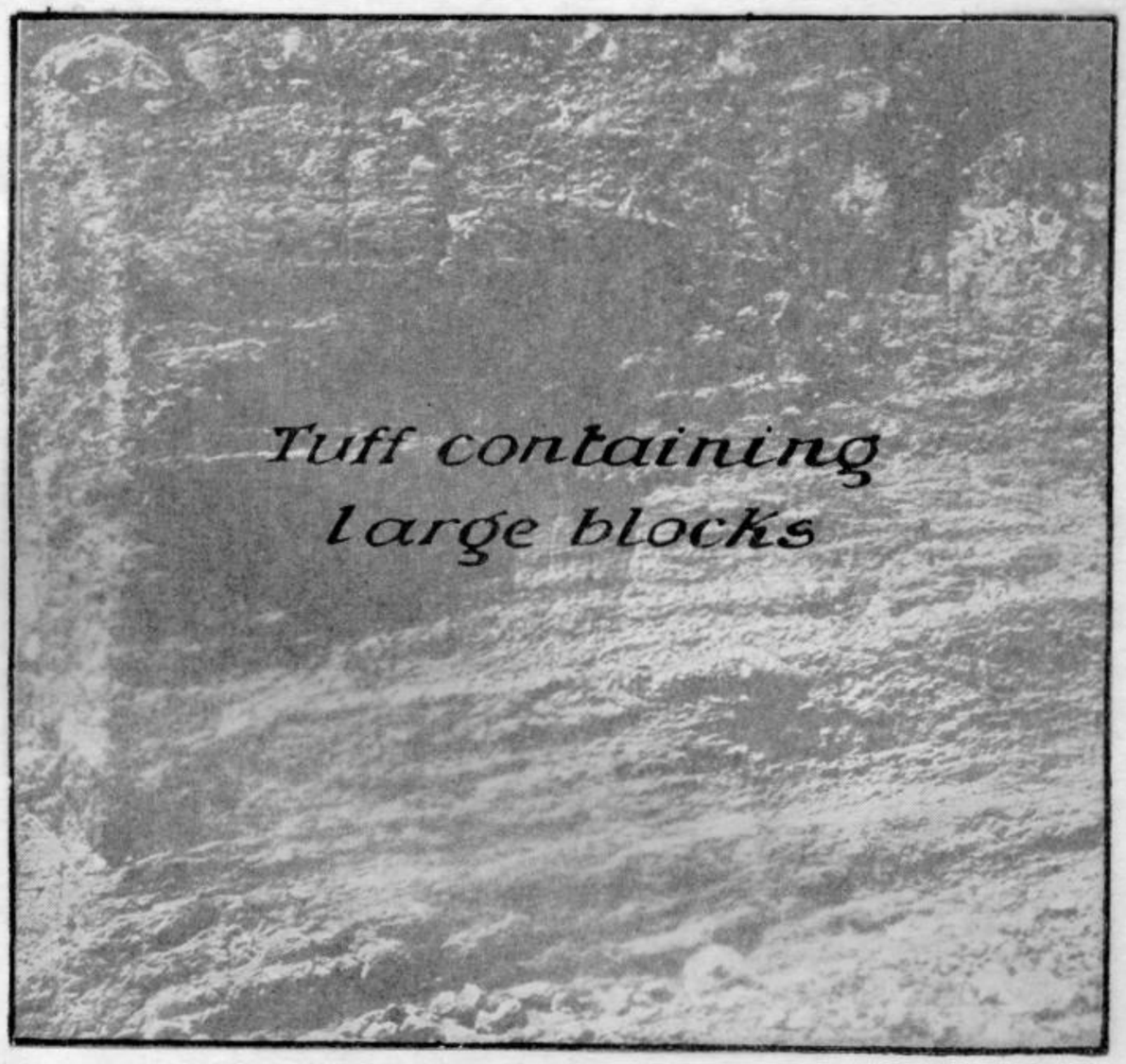


Fig. 2. *Details beyond left corner of Fig. 1.*

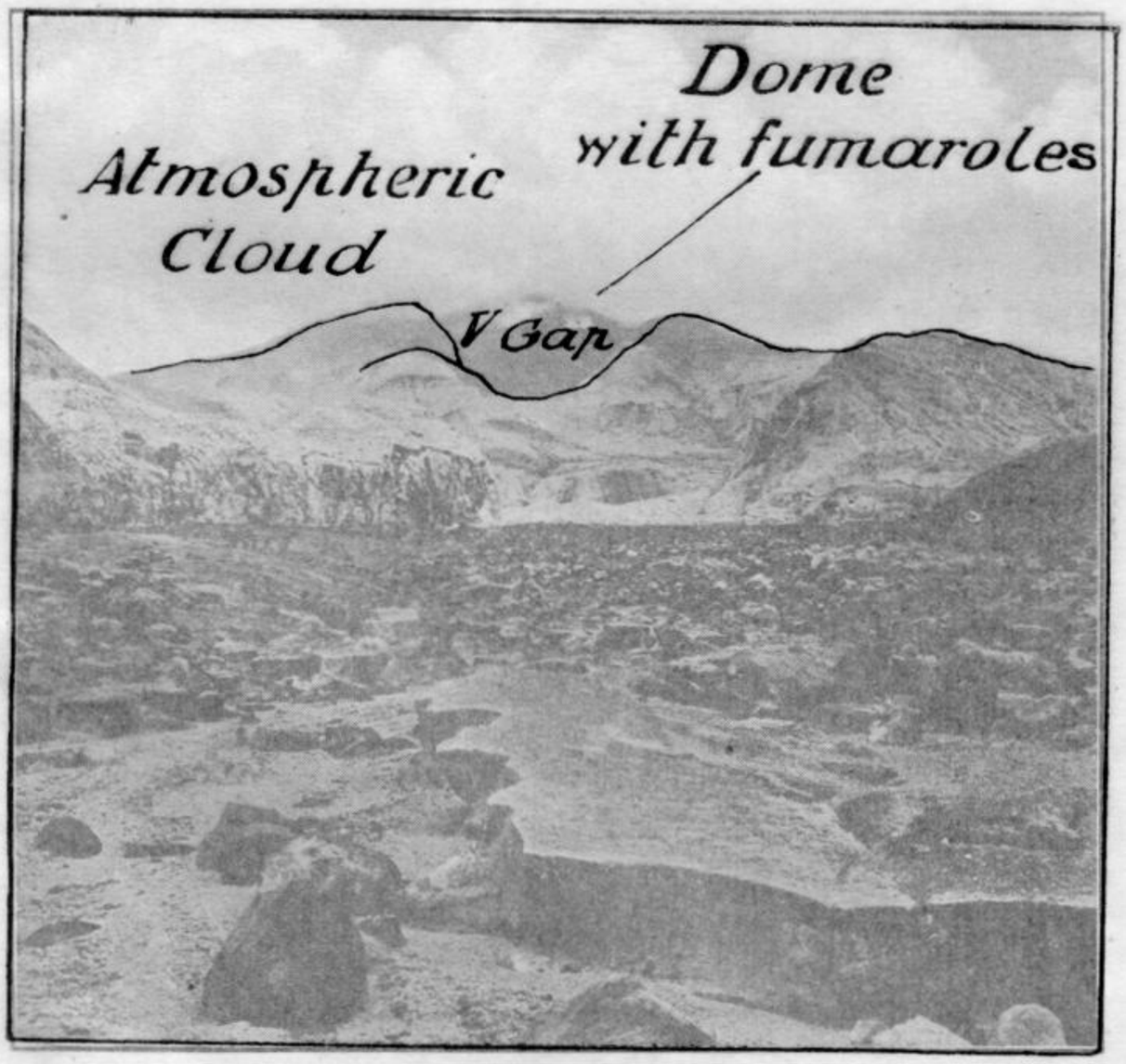
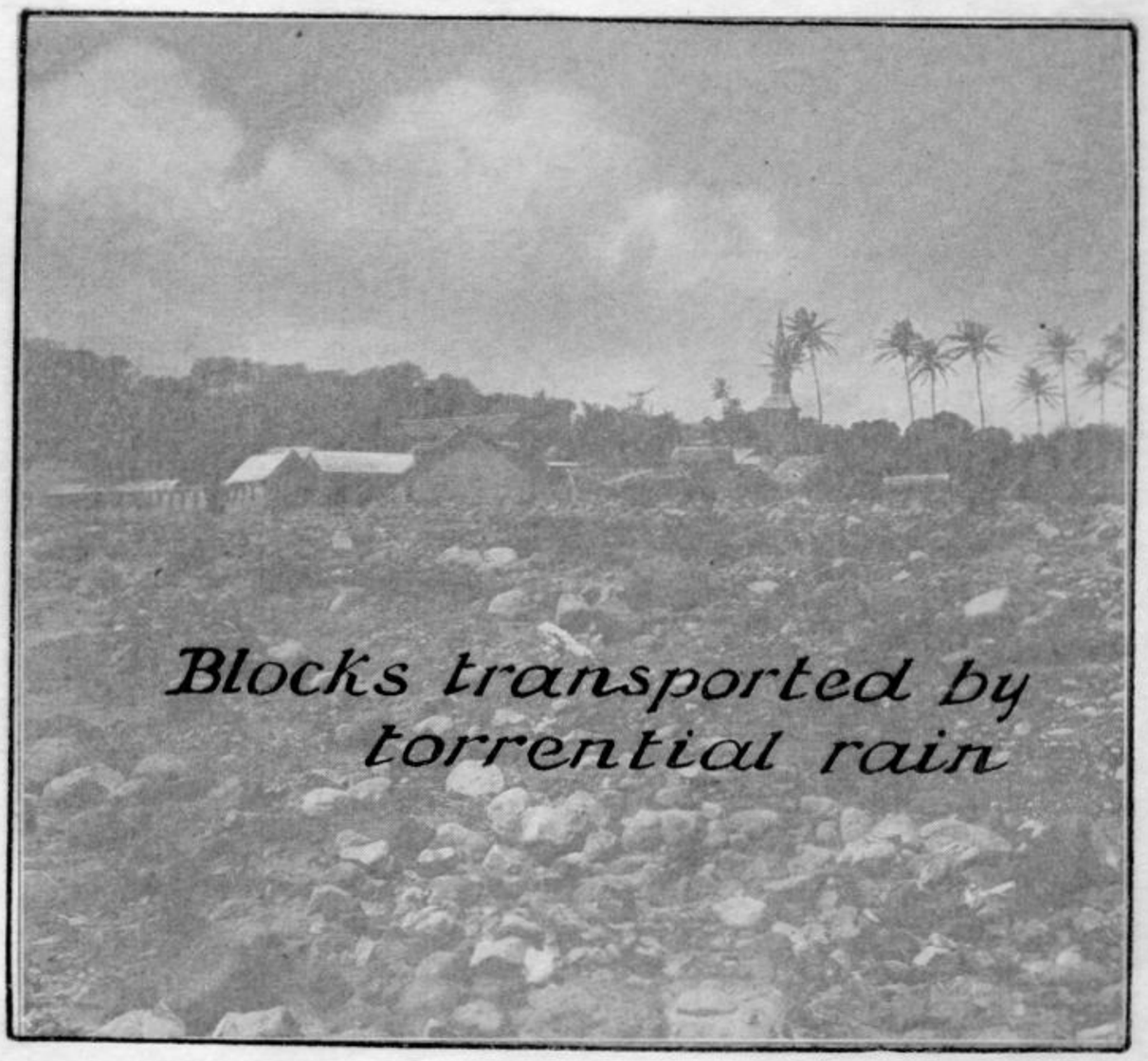


Fig. 3. *Valley of Rivière Blanche, from near shore.*



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