The Volcanoes of Guatemala
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THE VOLCANOES OF GUATEMALA.*

By Dr. TEMPEST ANDERSON.

I spent nine months, including the winter of 1906–7, among the volcanoes of Mexico, Guatemala, and the West Indies. The first and last named groups are comparatively well known, while those of Guatemala, though equally, if not more important, have, owing to their remote and inaccessible position, scarcely attracted the attention they deserve from English geologists, though they have been described by a French commission under Dollfus and Montserrat † in 1868, and more recently by Prof. Karl Sapper, ‡ of Tubingen. They consist of a row of giant cones averaging 10,000 to 12,000 feet in height, roughly parallel with the Pacific coast. As viewed from the deck of a Pacific mail steamer they present a most imposing appearance, for though really at a distance of 50 miles from the coast, their whole height is visible at once, as no other range of mountains intervenes, the coast being a belt composed of Quarternary beds which only rise into low foothills. These foothills, the Costa, are covered with coffee plantations, from which the well-known Guatemala coffee is largely produced.

None of these volcanoes is habitually in eruption, like Izalco in Salvador, or Stromboli in the Lipari islands; on the contrary, their

* Royal Geographical Society, January 13, 1908. Map, p. 588.

† 'Voyage Géologique dans les Republiques de Guatemala et de Salvador.' Par MM. Dollfus et E. de Montserrat. Paris: Imprimerie Imperiale. 1868.

‡ 'Mittelamerikanishe Reisen und Studiên.' Dr. Karl Sapper. Vieweg. Braunschweig. 1902. 'In den Vulkangebeiten Mittelamerikas und Westindiens.' Dr. Karl Sapper. Stuttgart: E. Nägele. 1905. Also several smaller articles, of which the following especially deals with this district, and has been freely quoted: 'Die Vulcanischen Ereignisse in Mittelamerika,' in Jahre 1902. Karl Sapper. 'Neuen Jahrbuch für Mineralogie, etc.,' 1904, Bd. I. Stuttgart: Nägele.

eruptions usually take place only after intervals of many years, even centuries, during which the volcano is quiescent and may appear extinct. Then a terrific explosive eruption occurs in which discharges of ash and fragmentary material predominate, though the outflow of lava is not unknown, and the whole country for miles round is devastated. The cones are in most cases separated by an interval from those adjacent in the chain, and, where the vent has shown a tendency to shift and form parasitic or subsidiary cones, the new opening has usually been nearer to the Pacific ocean. An apparent exception to this rule mentioned by Dollfus and Montserrat was the case of Santa Maria, 11,480 feet, and Cerro Quemado. The former is an old volcano, and was supposed to be extinct. The latter, adjacent but further inland, is more recent, and had been active in 1785, when it poured out some large flows of andesitic lava. In 1902, after a severe earthquake which almost destroyed the adjacent city of Quezaltenango, Santa Maria opened out an enormous new crater, nearer the sea than its old one, and of course than that of Cerro Quemado, and is thus no longer an exception to the general rule.

This eruption is so important in relation to those of the Soufrière in St. Vincent, and Montagne Pelée in Martinique, that the associated phenomena deserve special mention.

On January 18, 1902, there was a severe earthquake.

On February 26 an unusual tidal wave was observed along the coast of Salvador and part of Guatemala.

On April 18 a very severe earthquake almost destroyed the town of Quezaltenango, and caused subsidences at Ocós.

On May 7 and 8, the great eruptions of St. Vincent and Martinique, on the other side of the Caribbean Sea, burst into full activity, after premonitory signs lasting a few days.

On May 10, Izalco in Salvador, to the south of Guatemala, resumed activity after 15 months' quiescence.

On June 25, Masaya, in Nicaragua, after forty-three years' inactivity, resumed slight activity, which continued for several weeks, and the neighbouring crater of Santiago showed similar signs, as did also Momotombo, which had been at rest for many years. Colima, in Mexico, above 700 miles distant, also showed signs of awakening energy. These phenomena culminated in the great outbreak of Santa Maria on October 23 and 24, and following days. I and my colleague, Dr. Flett, have elsewhere fully discussed the general sequence of these volcanic phenomena.* The details of the above must now be discussed separately.

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* Anderson and Flett. 'On the Eruptions of the Soufrière, etc.' Part I. *Phil. Trans.*, Series A, vol. **200**, 1903, pp. 532. Parts II. and III., 1908, will contain the later history, the petrology, and a bibliography.

The Earthquake of January 18, 1902.

Guatemala has always been considered a district particularly subject to earthquakes, especially at the changes of the seasons in April, May, and October, November, but they had been less frequent than usual for some years before 1902.

On January 18 a severe shock was felt widely over the Republic. San Martin, a village near Quezaltenango, had some houses thrown down; and at Ocós, on the Pacific coast, three parallel ridges, sloping gently towards the sea, but steep towards the land, were formed in the sand. List, quoted by Sapper,* writes, "Just as at any moment one may see a wave break on the shore, so the volcanic breaker remained modelled in the sand of Ocós." The ridges were in general parallel to the coast-line, and could be traced for a distance of about an English mile. The earth-waves passed through a coffee shed, and some of the steel pillars had sunk 2 feet. The waves on the pier are described as having a length of 25 to 30 metres, and a depth of 25 to 30 cms. As showing the strength of the shock, it is mentioned that two locomotives, weighing 20 tons each, were moved 6 feet in the direction of the earth push. Similar appearances were observed on the Mexican coast near San Benito. Sapper considers the earthquake tectonic in character, *i.e.* caused by readjustments of the Earth's crust, in this case probably a slip somewhere under the Pacific.

The earthquakes of April 18 were considered by List at Ocós to be of the same nature as that of January 18, *i.e.* tectonic. In that of April 18, the sinking of the sand continued further inland than in January. Sapper does not consider it clear whether it was a general sinking of the coast or merely a local sinking of the sand inland due to the shaking. At Quezaltenango the shock was especially violent. Mr. Walter S. Ascoli,† who was on the spot, relates that while he was quietly reading about 8.20 p.m., without the slightest warning or premonitory tremor, the Earth began to sway violently, and the ornaments in the room all lost their balance and fell to the floor. This oscillation continued for twenty seconds, then suddenly the motion became vertical and much more violent. Later on the shocks seemed to come from all directions. Loud "retumbos" (underground noises) were heard. Scarcely a single house or building in the town remained habitable, and those on the slopes of the Cerro Quemado, consisting chiefly of *adobe* (*i.e.* dried mud), were entirely destroyed. As showing the violence of the shocks, the church of San Sabastian, which was built soon after the Spanish

* Sapper, 'Neues Jahrbuch,' *ut sup.*, p. 49.

† In a letter to Dr. Anderson. Much information has also been obtained from Mr. A. H. Gehrke, of Rösing Bros., London and Guatemala; Don Carlos Moesly, of Helvetia; Herr John Lisser, of Retalhuleu; besides Sapper's works; to all of whom my thanks are due.

occupation, and had resisted all the earthquakes since that time, was completely ruined. Mr. Ascoli considers that the deaths in Quezaltenango really exceeded one thousand, though reported at a much smaller number. This earthquake was very widespread. It was felt from the city of Mexico, and even San Francisco, as far as Salvador, especially along the Pacific slope, the coffee zone at the foot of the volcanic range having suffered severely, but it was curiously local. It was probably most severe at Quezaltenango and San Pedro and along the high lands to Sololá, but some villages within a few miles of the former town escaped almost entirely, and so did Totonicapam, only a few miles north of Sololá. It was noticed that brick houses suffered more damage than those built of stone, and these again more than those with wooden frames; while the native ranchos, built of poles covered with thatch, bound together with bands made of creepers, suffered scarcely at all. Many landslips were traced to the shock.

After April 18 a series of small earthquakes occurred, and on September 23, another severe one. Rockstroh, who visited the damaged districts after the occurrence,* considers the three earthquakes of January 18, April 18, and September 23 all tectonic; while List, who observed them all personally at Ocós, considers the last of quite a different character to the others. The smaller ones were probably volcanic, and connected with the approaching outbreak of Santa Maria. Some were more local in their distribution, and more severe towards the Salvador frontier. They may have been connected with the renewed activity of Izalco.

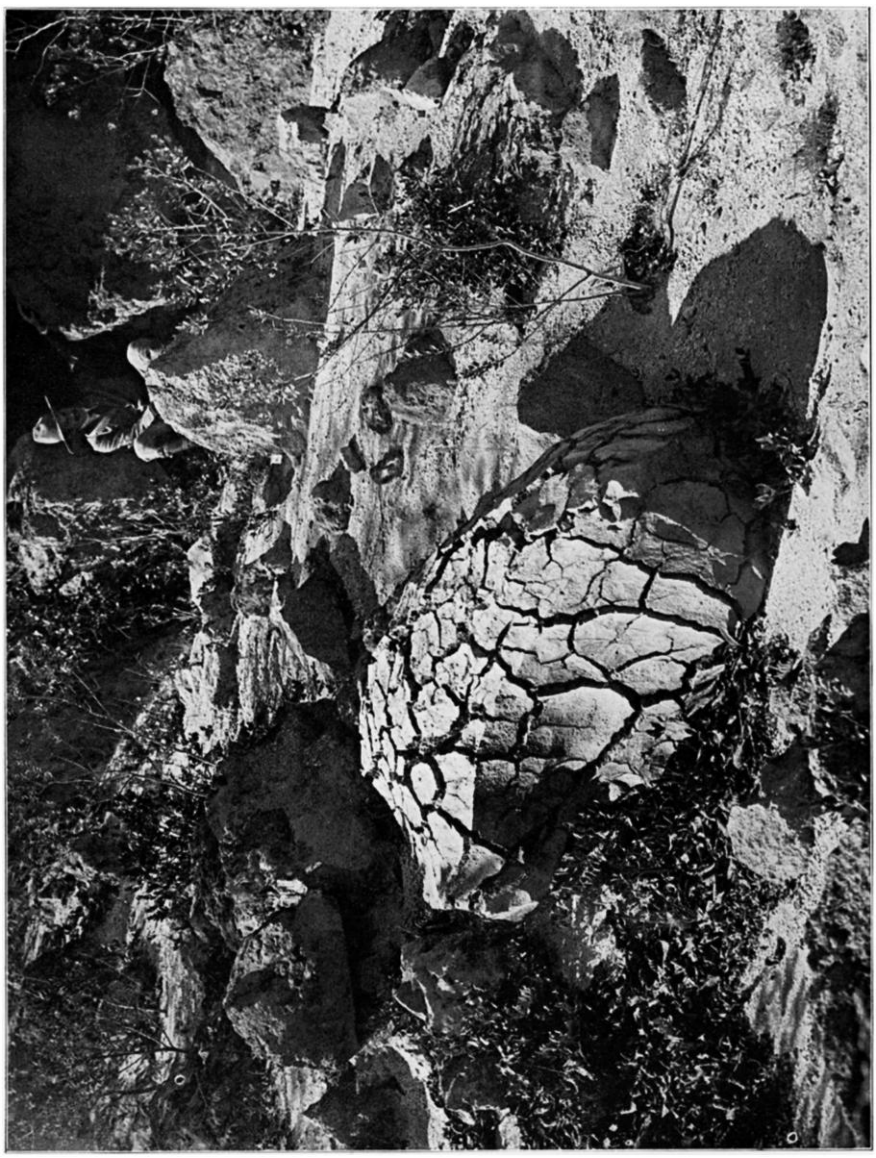
The tidal wave of February 26, 1902, is reported by Aurelio Arias, director of the Meteorological Observatory of San Salvador,† to have extended along the coast of Salvador about 120 kilometres, especially at Barra del Paz, and to have reached as far north as Acajutla. At about 7 p.m. three waves, of which the first was the smallest, swept on the land and caused great damage. Their height is not mentioned, but about 100 persons were killed at the village of Santiago, and 85 at Barra del Paz. Loud "retumbos" (subterranean noises) were heard, and thought to proceed from under the sea.

The Cerro Quemado, also known as the volcano of Quezaltenango, is near the town of that name, and as viewed from the Plaza, seems actually to overhang it. Though it had a small and perhaps doubtful outbreak in 1891, its last eruption of importance was in 1785, and while no accurate records are preserved, it is probable that, at any rate, some of the lava-streams which form such a conspicuous feature of the mountain were formed in that year. As mentioned above, most of the eruptions of these Guatemalan volcanoes have been of the explosive type,

* Report to the Government, quoted by Sapper, p. 49.

† *El Siglo*, San Salvador, **20**, No. 3, 184 (June 20, 1902).

PLATE I.



Swan Electric Engraving Co, Ltd.

Tempest Anderson photo.

BREAD-CRUST BOMB IN THE CRATER OF THE CERRO QUEMADO.

and characterized by the emission of large quantities of fragmentary ejecta, ash, lapilli, and pumice, while often no lava is poured out. The last considerable eruption of Cerro Quemado was an exception, for not only were enormous quantities of lava discharged, but the form of the streams was peculiar. They consolidated on quite deep slopes, and often terminated in almost vertical walls, perhaps 100 feet or more in height. The lava appears to have been quite pasty at the time of its discharge, and to have quickly consolidated into a crust, which, as the lava under it continued to flow, broke up into blocks of varying but generally considerable size, and these have been pushed and rolled forward till they have formed a sort of wall, and have so helped to prevent the further progress of the lava. This, of course, is not unusual, but I have seldom seen the final slopes so steep, though another similar case occurs at Colima, in Mexico. As confirming the theory that the lava must have been pasty and almost consolidated at the time of its emission, I found in the crater of the mountain several well-marked bread-crust bombs, which are considered as characteristic of the Vulcanian type of eruption, *i.e.* where the explosions have taken place from among lava more or less consolidated. The idea is that the mass of lava before its ejection had cooled sufficiently for its surface to have consolidated, while the interior still remained pasty or even liquid, and that when it was thrown suddenly into the air, and the outside pressure relieved, the vapours, which in different degree always exist in the lava, became separated and formed vesicles, and so swelled the mass and caused the crust to crack. One of these bread-crust bombs is shown in Plate I., and is indistinguishable from others I have seen on Vulcano, after the typical Vulcanian eruption of 1888, and also on Colima, where they appeared to be associated with the above-mentioned lava-stream. The crater itself presents confirmatory appearances. It is a large hollow filled chiefly with blocks and slabs of well-consolidated lava with definitely broken edges, showing that they were quite solidified before they took their present position. It contains a few insignificant fumaroles, and some sparse pine trees are striving hard for a precarious existence. At the foot of the volcano are some hot springs at Almolonga, and at Zunil some small geysers.

The volcano of Santa Maria, as viewed from the slopes of the Cerro Quemado, from which it is only a few miles distant on the south, appears as a very regular cone (Plate II.). It is covered to the top on this, its north, side with vegetation, which appears to have been only partially destroyed by the great eruption of 1902. It was ascended in March, 1902, only a few months before this eruption, by Mr. Walter S. Ascoli, who found a small crater on the summit, consisting of an irregular, shallow, rocky depression some 120 feet in diameter. At the bottom the rocks were split up, leaving narrow clefts between them, from which, however, no steam or vapour escaped. The beds forming the mountain

dipped outwards in every direction in the manner usual in volcanic cones. The volcanoes mostly spring from a plateau about 5000 feet above sea-level, and Santa Maria is no exception, standing at the edge of the high land. The country to the north is all an elevated region, while to the south are the foothills, the "costa," which slope gradually down to the coastal plain. They are mostly formed of fragmentary volcanic materials, and are much cut up into steep, narrow ridges separated by deep valleys similar to those on the flanks of the West Indian volcanoes. These ridges were, before the eruption, the seat of coffee plantations, which were then devastated, and have only partially recovered. At the foot of the mountain was a comparatively flat piece of ground overlooking this system of valleys, which was somewhat less sloping than the surrounding parts, and had consequently been selected as a camping-ground by the engineers engaged in making a survey for a railway from the coast round the mountain to the town of Quezaltenango behind it. It was covered with a dense tropical growth like the rest of the mountain, from which it showed no special difference.

It was from this place that the eruption of October 24, 1902, broke out. Slight earthquakes were felt in the neighbourhood during the day, and about 5 p.m. a loud and increasing sound was heard in San Felipe, a neighbouring village. This sound appeared to come from the direction of the mountain. It was compared by some to the noise of a waterfall, by others to a gigantic boiler blowing off. The noise lasted half an hour. About this time dark clouds were noticed from Quezaltenango and elsewhere in the direction of the mountain. They were at first ascribed to a thunderstorm. Towards evening a slight sprinkling of sand occurred at Quezaltenango, which soon covered the landscape with white. The wind changed from south to east, and ashes began to fall at Helvetia, a coffee plantation 6 miles to the south-west. About 7 p.m. a glow began to appear, and lightning was noticed in the neighbourhood of the present crater, and roaring sounds were heard. About 8 p.m. the air had sufficiently cleared for an enormous black cloud to be visible to persons at a distance from the mountain. It was seamed with countless curved lines of red and green electric discharges; violent claps of thunder were noticed (but it is not mentioned at what distance they were best heard). About 1 a.m., October 25, stones began to fall at Sabina, a bathing establishment at the foot of the mountain towards the south-east. At 3 a.m. pumice-stones fell abundantly in Helvetia. They measured 15–25 centimetres, and weighed $\frac{1}{2}$ to $\frac{3}{4}$ lb. They were first cold, then hot, and later were mixed with stones of heavier material as big as the fist. Lapilli the size of peas fell at Quezaltenango, 10 miles north-north-east. The eruption increased in violence, and the whole district was enveloped in darkness. The maximum intensity was reached about 11 a.m. on Sunday the 25th, though it remained severe till nightfall. It was not

Tempest Anderson, photo. *Swan Electric Engraving Co, Ltd.*

SANTA MARIA FROM THE SLOPES OF CERRO QUEMADO.

until midday on the 26th that the air began to clear a little and the light to return. The eruption continued with varying severity for most of the week. Towards the end of the eruption, as is generally the case, outbursts of whitish steam began to preponderate over the dark ash-laden clouds. Don Carlos Moesly, of Helvetia, gave me a graphic description of how a building at Suiza, in which a large number of people had taken refuge, collapsed by the weight of ashes on the roof. With the assistance of a French machinist * and some natives he extricated twenty-two alive, but eighteen were left dead.

When all was clear again, it was seen that an entirely new crater had been formed at the base of the mountain, and that the whole surrounding country was devastated and deeply covered with ashes. This crater is oval in form, with the long diameter parallel to the coast, and as far as my plane-table observations, which were made from the Finca Helvetia at a distance of about 6 miles, can be relied upon, this measures from $\frac{3}{4}$ to $\frac{7}{8}$ of a mile. The shorter diameter is not very much less, probably from $\frac{1}{2}$ to $\frac{5}{8}$ of a mile. The whole side of the mountain was blown away, exposing a section of several thousand feet in height, in which the dip of the strata mentioned above is very evident. Owing to the dip being with the slope, landslides almost constantly take place, and are gradually filling up the crater, though the latter is still apparently from 1000 to 1500 feet in depth. It has a lake at the bottom and two very active fumaroles, or perhaps rather hot springs, from which steam and hot water escape with a violence almost worthy of the name geyser. These fumaroles issue from the foot of the cliff, at a point where traces of a great radial crack in the mountain are visible. Observations on these points are, however, very difficult. Helvetia, my base, was fully 6 miles distant, and direct access was cut off by many impassable ravines. The ascent, as mentioned below, was only possible by making a long *détour* to the south-east *viâ* Palmar, from which side ridges lead more or less in the desired direction. The crater was almost constantly full of a cloud of dust which drifted away before the wind, and looked very suggestive of commencing eruption, but careful examination showed that this was due solely to the falling stones, except an occasional puff of steam from the fumaroles, which now and then rose above the lip of the crater. When a view of the great cliff was occasionally obtained, I could see many beds of tuff and agglomerate, but could never be certain of any compact lava. The mode of origin seems a perfect example of that attributed by Sir Charles Lyell to the Val del Bove on Etna, and in order of magnitude it is enormously greater than that of the eruptions of the Soufrière and Montagne Pelée in the same year.

* The French machinist was the only man who stayed with Mr. Moesly all through the eruption, and he is still employed there at increased wages.

The eruption cloud rose to a great height. It was seen from the sea. The captain of one steamer * measured the height with a sextant, and recorded it as 17 to 18 miles. Another put it as much as 30, but this may be merely an estimate. The sounds accompanying the eruption were loud, and, as has been observed elsewhere, were heard even louder at distant places than close to the mountain. Thus at Guatemala city, the capital, the detonations were at times so strong that they were supposed to proceed from the neighbouring volcanoes.

There is no evidence of the occurrence of any incandescent avalanche or hot blast like those which occurred in St. Vincent and Martinique, but there are unconfirmed rumours of explosions having taken place in the hot ash, like those which occurred in the islands just mentioned, and which were there traced to the action of water on that material. The ashes measured later on were $7\frac{1}{2}$ English feet deep at Suiza, and $4\frac{1}{2}$ to 5 feet at Helvetia, the place to which the works were moved after the catastrophe. At Nil, more to the north-east, and nearer the mountain in the track of the main discharge of ashes, the depth was 10 to 12 feet. Still nearer the mountain the depths were much greater. At San Antonio the top of the chimney was all that remained uncovered, from which it is concluded that the deposit was about 14 metres in thickness. At the Baths of Sabina, near the foot of the mountain, the ashes were at least 30 feet thick, while nearer the crater the depth was not less than 100 feet, and may have been 200 feet in places. The ashes were carried widely over the district to the west and north-west, and even into remote parts of Mexico, such as Acapulco and Colima. Mr. Gehrke, a partner in a firm of coffee merchants, who had large interests in the crops which were destroyed, and who visited the district soon after the eruption and measured the depths of the deposit, estimates the total amount in the district as not less than twenty thousand million tons, without reckoning that carried away to a distance by the wind. Sapper mentions maps showing the distribution in Mexico as having been made by more than one observer, but states they only agree in broad general features. It will be remembered that "Krakatoa" sunsets were observed in Europe in the autumn of 1902 and were attributed to the West Indian eruption in the previous May. There was always a difficulty in understanding this late appearance, and there is now, I believe, no reasonable doubt that they were due to Santa Maria.

The ash deposits immediately after the eruption presented a pretty uniform surface, the old valleys, at any rate near the crater, having been in great measure, if not entirely, filled up. The surface was at first quite soft and incoherent, and difficult to walk on without sinking. Torrents of rain fell either at the time of or directly after the eruption, a large portion of which sank into and consolidated the new deposits,

* Captain Saunders, of the Pacific Mail S.S. *Newport*.

Tempest Anderson, photo. *Swan Electric Engraving Co, Ltd.*

NEW GORGE OF RIVER NIMA AT PALMAR.

reducing the measured thickness at the same time. A large portion of the rain, however, ran off, producing a feather-pattern erosion, shown in some of the earlier photographs, like that noticed in St. Vincent and Martinique.* As in those islands also, the torrents of water and mud flowed in new courses independent of the old ones, which had been filled up, and formed new channels, in many cases cutting deep into the soil and subjacent beds which previously existed. Thus a deep and narrow ravine, about 80 or 100 feet deep and perhaps 100 or 120 feet wide, now exists to the east of, and not many yards from, the Plaza of Palmar. It has been cut out of the old tuff and agglomerate, and now conveys the water from the river Nima, which formerly ran in quite a different direction into the Samalá (see Plate III.). In other cases the floods carried away bridges and deepened the old ravines, and the mud brought down blocked up the river Ocosito near Ocós, and altered the configuration of the coast in that neighbourhood. All these changes strikingly recall similar ones in St. Vincent.†

When the surface of the ash deposits had become more consolidated, and before denudation had had time to produce much effect, access to the mountain was easy, but as the rain and atmospheric agencies did their work, deep gullies were formed, divided by narrow ridges. In the low grounds, where change had been less active, the ridges, at the time of my visit, were generally flat-topped, where the crust had protected the underlying, less-consolidated material. This often weathered into almost vertical walls, till another somewhat harder layer was reached, which formed a new shelf, the whole making a succession of steps, such as to remind one of the tops and keyboards of a succession of pianos placed end to end, along the tops of which it was not difficult to walk (see Plate IV.). Further up the mountain, where the process was further advanced, intermediate blocks had often been entirely washed away, and this necessitated constant ascents and descents, which were decidedly fatiguing. Further up again, as in Plate V., the whole top crust had generally been removed, and the ridges were often reduced to mere knife-edges, which were liable to give way and precipitate the traveller into the deep crevasse on either side. This plate, which is taken on the south-west of the mountain above Palmar and the site of the Baths of Sabina (from which direction the wind was blowing at the time of the eruption), exhibits well the comparative thinness of the ash on that side of the mountain, as shown by the dead tree-trunks, which still project through the ash. Nearer the crater the ash becomes much thicker and the barrancos deeper. This plate also exhibits the structure of the mountain, with the beds of tuff and agglomerate dipping conformably to the slope. This shows that they

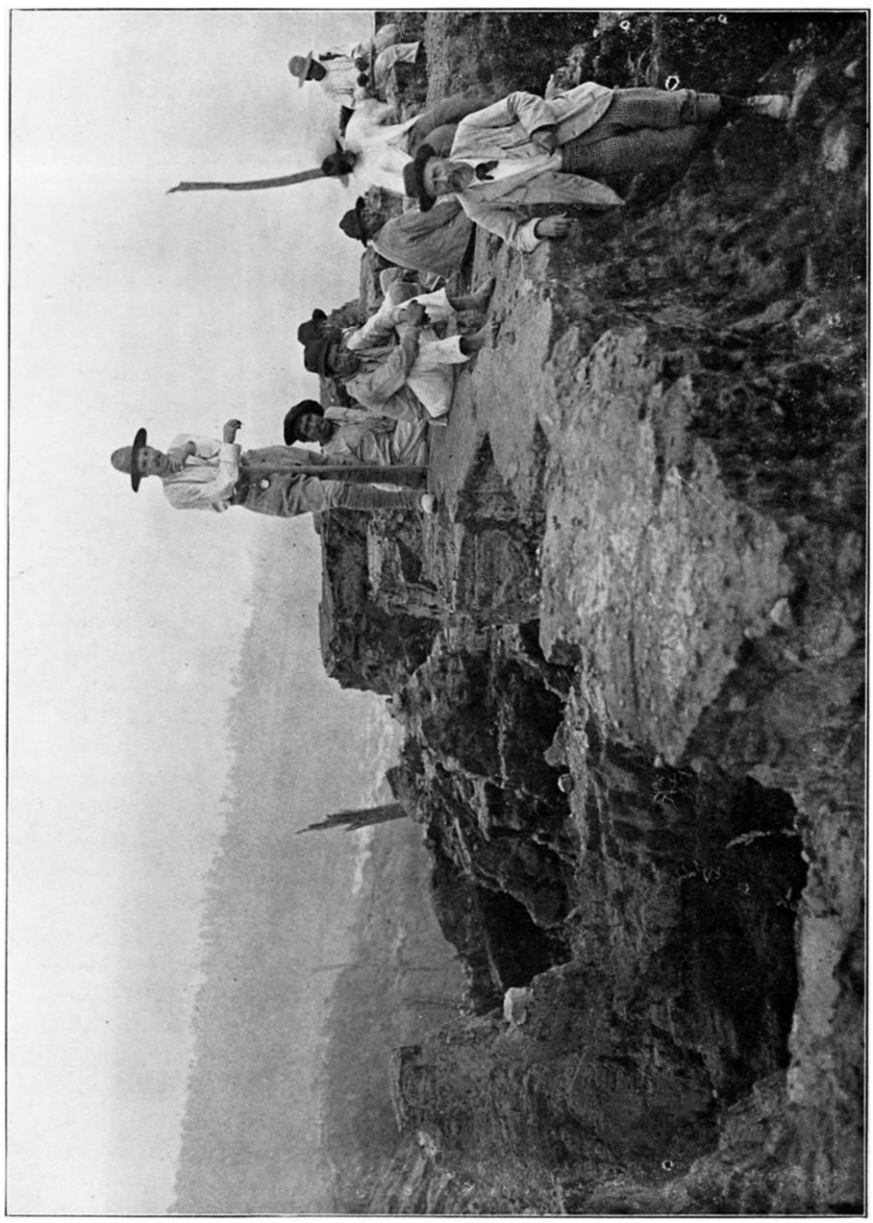
* Anderson and Flett, part i. plate 28 ; Sapper, ' Ereignisse,' Taf. vii.

† Anderson and Flett, *loc. cit.* ; Anderson, *Geographical Journal*, March, 1903.

were deposited as ejecta from the old crater on the summit, and not from one in the position of the new crater. The thick beds of ash with their deep barrancos extended far beyond the left of the plate. All this presents a striking resemblance to the corresponding localities on the slopes of the Soufrière. On some of the ridges in the lower ground, as, for instance, in the coffee plantations, the resemblance is still more striking. Plate VI. is practically indistinguishable from a plate to appear in the Soufrière Report, Part II., and may be compared with Part I., Plate 35, which shows a similar place directly after the eruption. In each the ridge and slopes had been covered with a thin layer of ash. On the ridge this only received the rain which actually fell on it. This mostly sank in, and a firm crust was produced which offered considerable resistance to further change. On the slopes on each side the ash was exposed not only to the rain which fell directly on it, but also to the wash from the higher parts, and in many places had been carried away, and thus exposed the soil, on which vegetation is returning in many cases from the old roots.

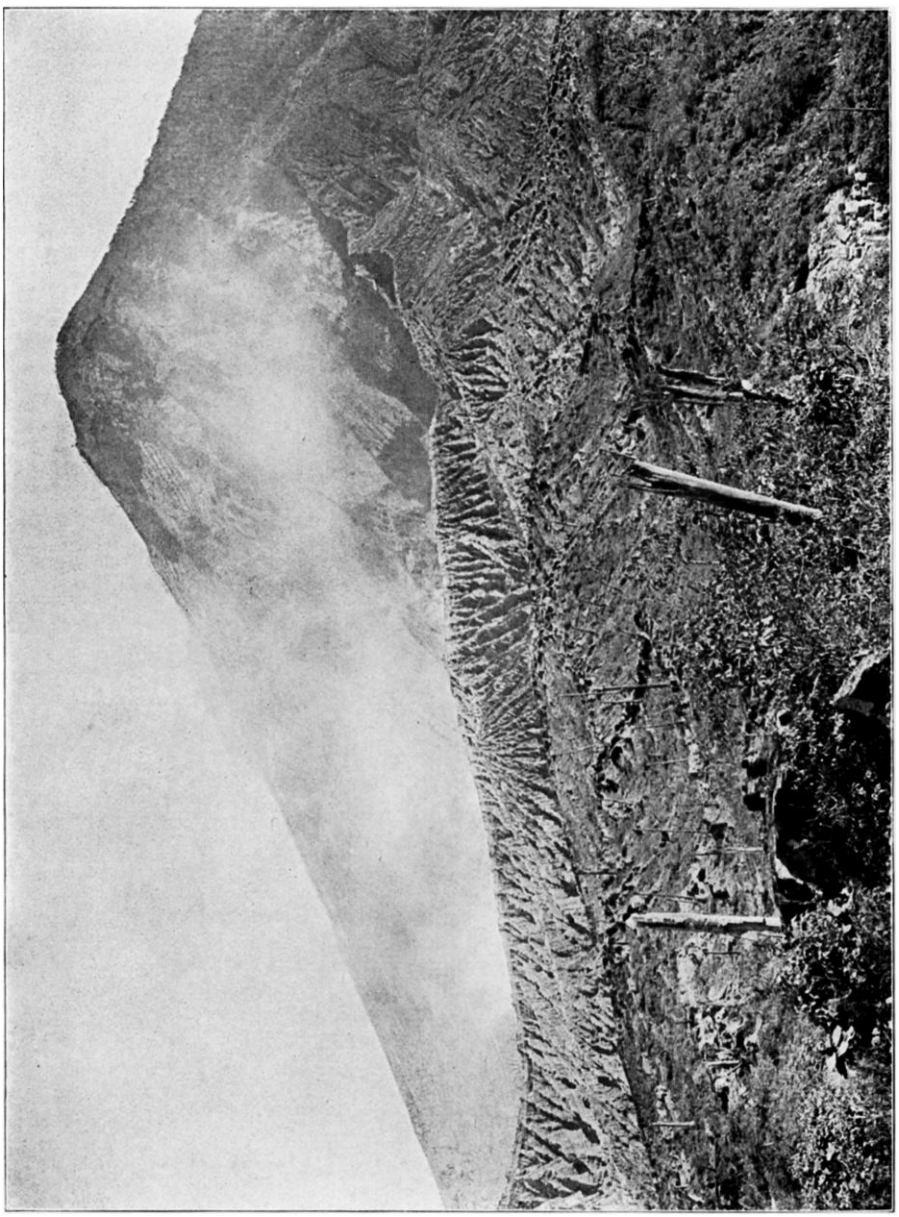
The loss of life is supposed to have been very great, but, unfortunately, no accurate statistics are available, as the victims were chiefly Indians who had come down from their villages in the mountains into the coffee zone to assist at the harvest. Still the opinion of those on the spot puts it at possibly two or three thousand.

The lake of Atitlan is not only one of the most interesting, but also one of the most beautiful places in the world, and its interest is much increased by the survival of several villages of Indians who retain many of their primitive customs, and still wear curious costumes. The lake is, roughly speaking, nearly circular, or would be so if it were not for several big volcanoes on its south bank, beyond which the plateau slopes rapidly down to the coastal plain. Its longest diameter is about 20 miles. On the east, north, and west, where there are no volcanoes, the slopes are usually very steep, though in a sufficiently advanced state of denudation to be a good deal cut up by valleys of rivers and brooks which flow into the lake. It has generally been supposed that the basin of this is only a continuation and union of these valleys, and that after they had been excavated, the volcanoes broke out on their beds and formed the lakes by blocking the exit for the water. This supposition is certainly plausible. The north shore is formed of volcanic tuffs and conglomerates of recent geological age, and sufficiently denuded to agree with either this or with the hypothesis that the lake itself is a crater, while the dip of their beds is so complicated that its evidence is not conclusive either way. I noticed, however, that the west shore of the lake extended in a well-marked, almost precipitous bank right round to the south of the volcanoes of San Pedro and Atitlan, and was perfectly separate from the slopes of the former, and to a large extent from those of the latter. I visited it, and found it composed of beds of tuff all dipping to the south



Tempest Anderson, photo. *Swan Electric Engraving Co, Ltd.*

A RIDGE IN THE NEW ASH ON SANTA MARIA.



Tempest Anderson photo. *Swan Electric Engraving Co, Ltd.*

THE CRATER OF SANTA MARIA, FROM ABOVE THE BATHS OF SABINA.

Tempest Anderson, photo. *Swan Electric Engraving Co, Ltd.*

A RIDGE COVERED WITH CONSOLIDATED ASH, HELVETIA.

PLATE VII.

Swan Electric Engraving Co, Ltd.

TROPICAL FOREST ON THE SLOPES OF ATITLAN.

Tempest Anderson photo.

towards the Pacific and away from the lake. Thus both the naked-eye form of the ridge, and the geological structure, suggest that it is the lip of an enormous crater, and that the volcanoes of San Pedro, Atitlan, and Toliman, giants as they are, are merely secondary cones thrown up on its floor. If that is so, this crater lake must certainly be one of the largest, if not the largest, in the world.

I made the ascent of Atitlan along with the proprietor of the steamer on the lake, with whom I was boarding, and a party of his friends. We started from San Lucas, at the east end of the lake, and rode first through cultivated fields, then through a woodland track, crossing one or two lava-beds exposed in the bed of a stream, till at a clearing we left the horses, which could be got no further, and we entered on foot the virgin forest which clothed the slopes of the mountain. We soon had to have a path cut, which rendered progress slow, but we pushed on as far as possible till nearly nightfall, when we camped under a sailcloth brought for the purpose. Plate VII. shows the view from our camp, which was naturally the most open spot we could find. The trees are covered with mosses and lichens, which in places depend in festoons, and with hanging roots which grow down from the branches till they reach the ground and take root on their own account. The Mozo has a machete in his hand, such as is used for cutting a path. The foliage overhead is so dense that the place is quite gloomy, even in broad daylight. The night was not particularly cold, but the ground was damp and disagreeable. We heard the cries of various animals in the night, but they did not come near us. Next morning we were up before daylight, and, without any special adventure, reached the top. The way for the last few hundred feet was over large, rather loose scoriæ, and the actual top was a sort of plain with a slight depression in it, which might be supposed to be the remains of a crater. The surface was a mass of small blocks of compact lava, with cracks from which vapours escaped here and there. The view was very striking. The whole Lake of Atitlan was at our feet, except where hidden by the volcanoes of Toliman and San Pedro. The crater ring surrounding the lake could be distinctly traced, while the whole volcanic range from Santa Maria or beyond, on the west, to Fuego, Acatenango and Agua on the east, was distinctly visible. The coastal plain lay below us, and we got occasional glimpses of the ocean beyond, but soon the moisture condensed, as usual before midday, and instead of the Pacific we looked down on an ocean of clouds. I have seen this wonderful spectacle from many other heights, but never more grandly than on this occasion. On our descent, as we got to the level of the sea of clouds we had an opportunity of watching their formation. The warm moist air from the Pacific met the cold dry air from the plateau above the rim of the old crater of the lake, and the rolling, seething mass of cumulus clouds formed a mass never to be forgotten.

The volcanoes of Fuego, 13,120 feet, and Agua, 12,286 feet, are other members of the chain more to the east, and are near to the city of Antigua Guatemala, once the capital of Spanish America. Fuego has been repeatedly in eruption in historic times, the last date being 1880, but its outbreaks, which are of the explosive type, present no special features beyond their violence. It has a large and very deep crater open towards the Pacific, and this has such a characteristic aspect that it is of great value as a landmark, for even a glimpse of it, through a break in the clouds, cannot be mistaken, and gives the navigator a sure bearing. Agua presents a well-marked crater breached to a certain extent in the direction of a valley leading down to Antigua. It has not had an ordinary volcanic eruption during the historic period, but in 1541 a great flood of water descended the mountain and destroyed a still older capital, Ciudad Vieja, situated at its base. It has been supposed that the flood proceeded from the bursting of a lake in the crater. This, however, extends to a depth at least 50 feet below the old breach, and I could not see either a raised beach, or any other evidence of the crater having held a lake. On the whole, therefore, I am inclined to believe that the flood was really the result of a cloud-burst on the mountain and not a volcanic phenomenon at all. After this catastrophe the city of Antigua was built, and in its turn was destroyed by a violent earthquake in 1773, in consequence of which the present capital was built, and the seat of government was removed to it. The ruins of Antigua, including many churches overgrown with vegetation, are very picturesque and interesting.

Guatemala appears to have a great future before it. Up to the present time access to it has been almost entirely by steamer on the Pacific *viâ* Panama or San Francisco, in either case a most circuitous and expensive route; but now two new ways are in process of being opened—one through Mexico *viâ* the Tehuantepec railway across the isthmus of that name, at either end of which magnificent new harbours have been constructed at Coatzacoalcos and Salina Cruz; and the other by a new railway direct to the capital from Puerto Barrios, also a new port on the Atlantic seaboard, to which steamers already run from New Orleans direct.

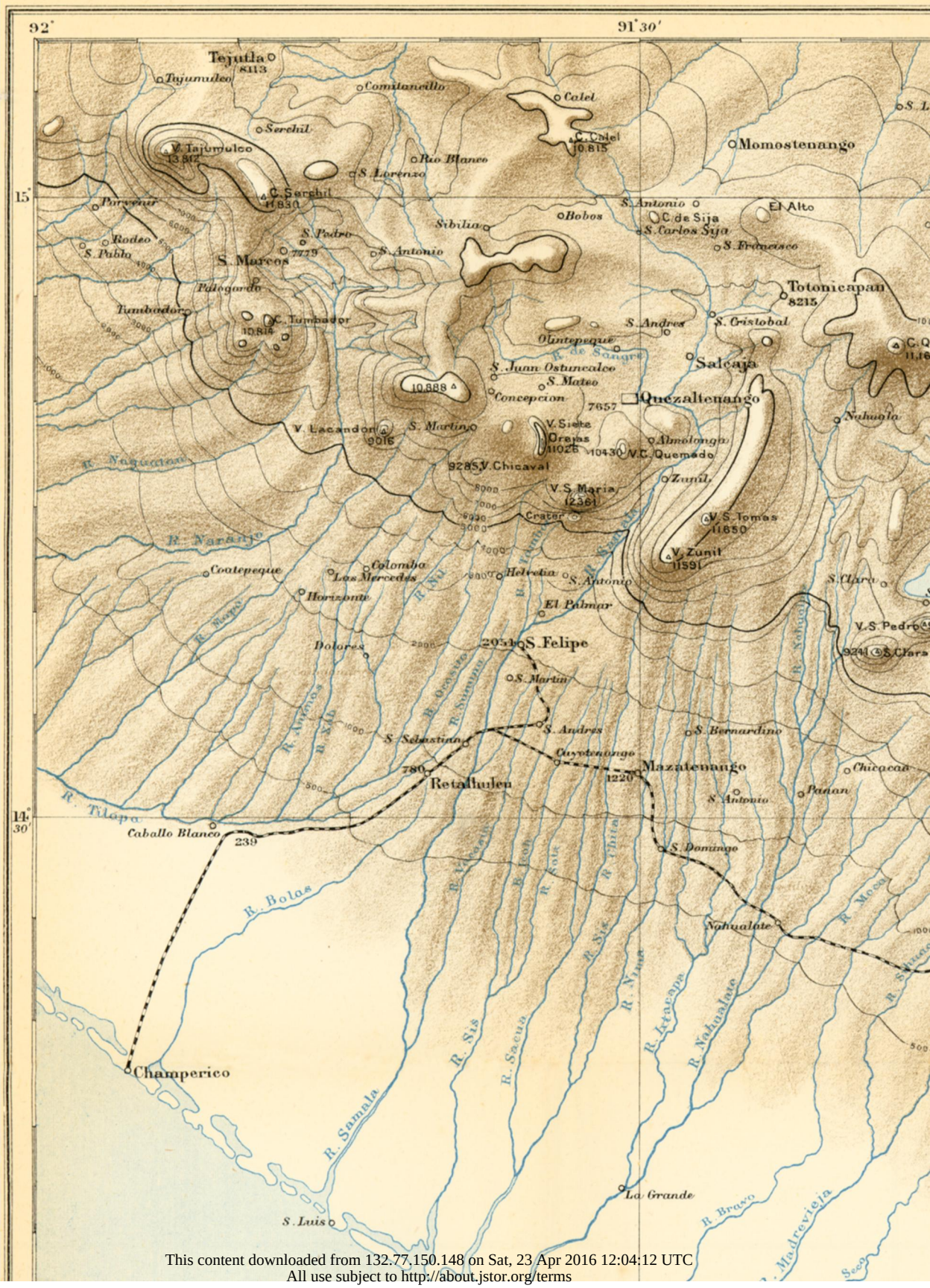
My cordial thanks are due to Sir Edward Grey, of the Foreign Office, and Mr. Carden, the British Minister at Guatemala, for their good offices with the Guatemala Government, and to Señor Juan Barrios, Foreign Minister of Guatemala, who exerted himself most effectively on my behalf with various local authorities. I found these gentlemen uniformly courteous and obliging, and to their kind assistance in obtaining trustworthy guides, porters, and other facilities too numerous to mention, much of the success of my expedition was due. I wish also particularly to thank Mr. Walter G. Ascoli, F.R.G.S., of Manchester, Guatemala, and Quezaltenango, Mr. Gehrke, F.R.G.S., and Mr. Moesly,

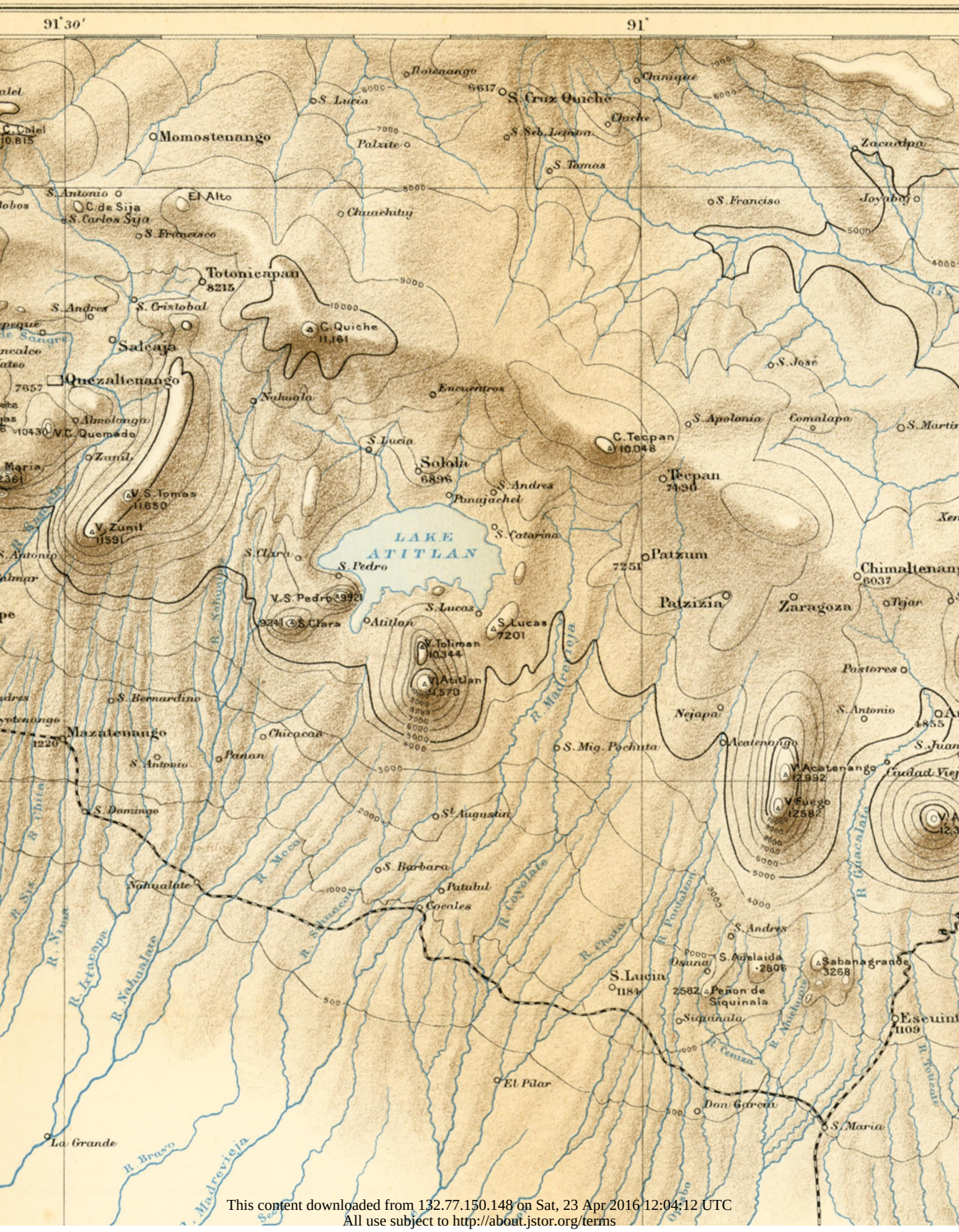
of Finca Helvetia, as well as other planters too numerous to mention, for their kind assistance and hospitality. Their local knowledge in a country like this was simply invaluable.

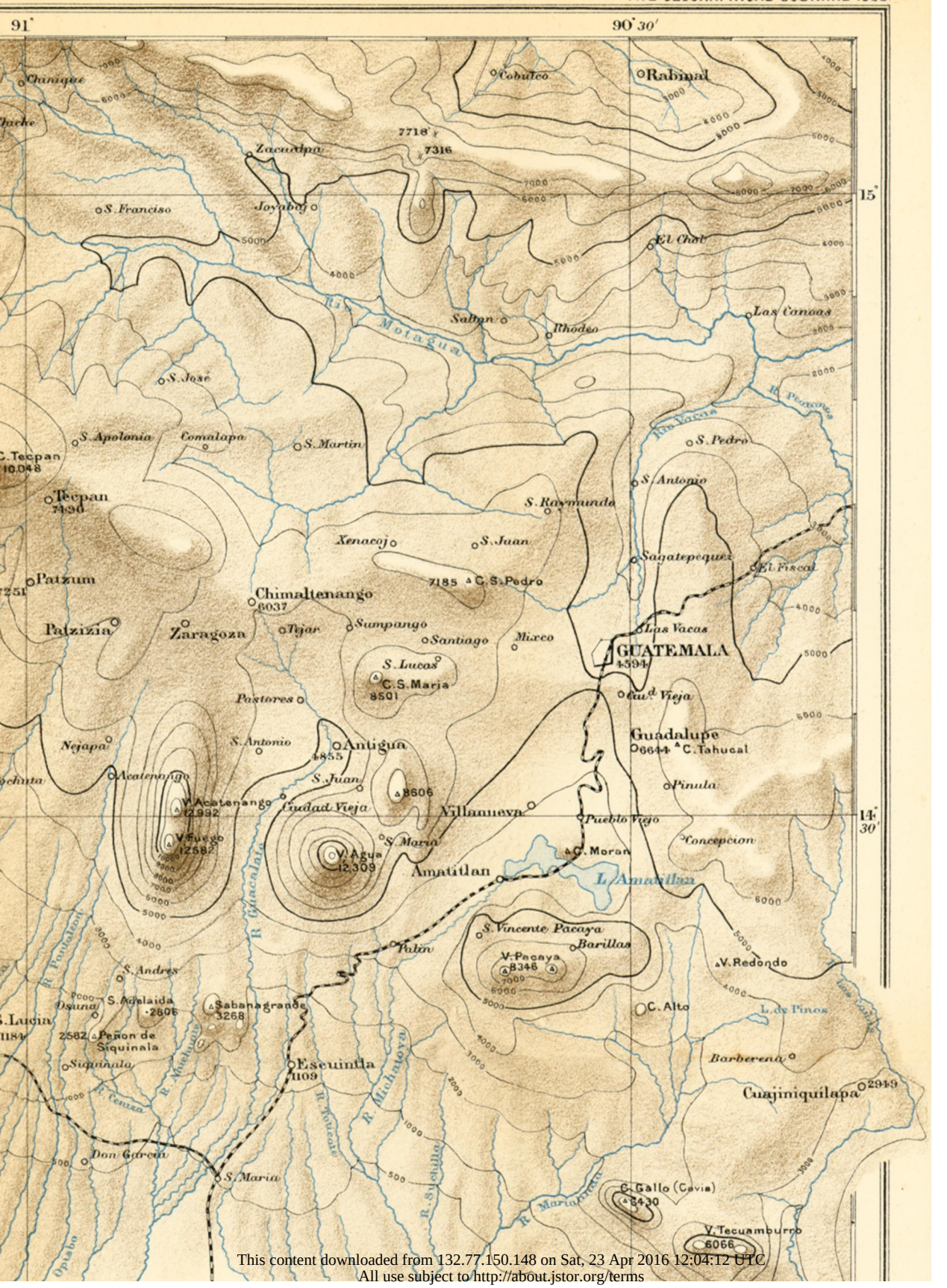
Before the paper, the Chairman, Colonel CHURCH: It is with much regret that I have to announce that our President is unable to be present this evening owing to a slight illness. Our lecturer this evening is already known to you, and about four years ago he entertained us with his experiences, his studies, and his wonderful photographic plates of the volcanic eruptions in Martinique and Mont Pelée. I may mention that not only did he greatly distinguish himself by his analysis of those eruptions, but that he is also familiar with many parts of the world where he has done good work in the same direction, work always characterized by a thoroughness which is worthy of admiration. He has taken care to possess himself of everything in the shape of mechanical appliances known to photography, and consequently what he does is perfectly reliable. He was accompanied in his examination of Mont Pelée and Martinique by Dr. Flett, of the Geological Survey. The country from which he now returns with so much valuable information is one of the great volcanic centres of the world. I will now call upon Dr. Tempest Anderson to read his paper.

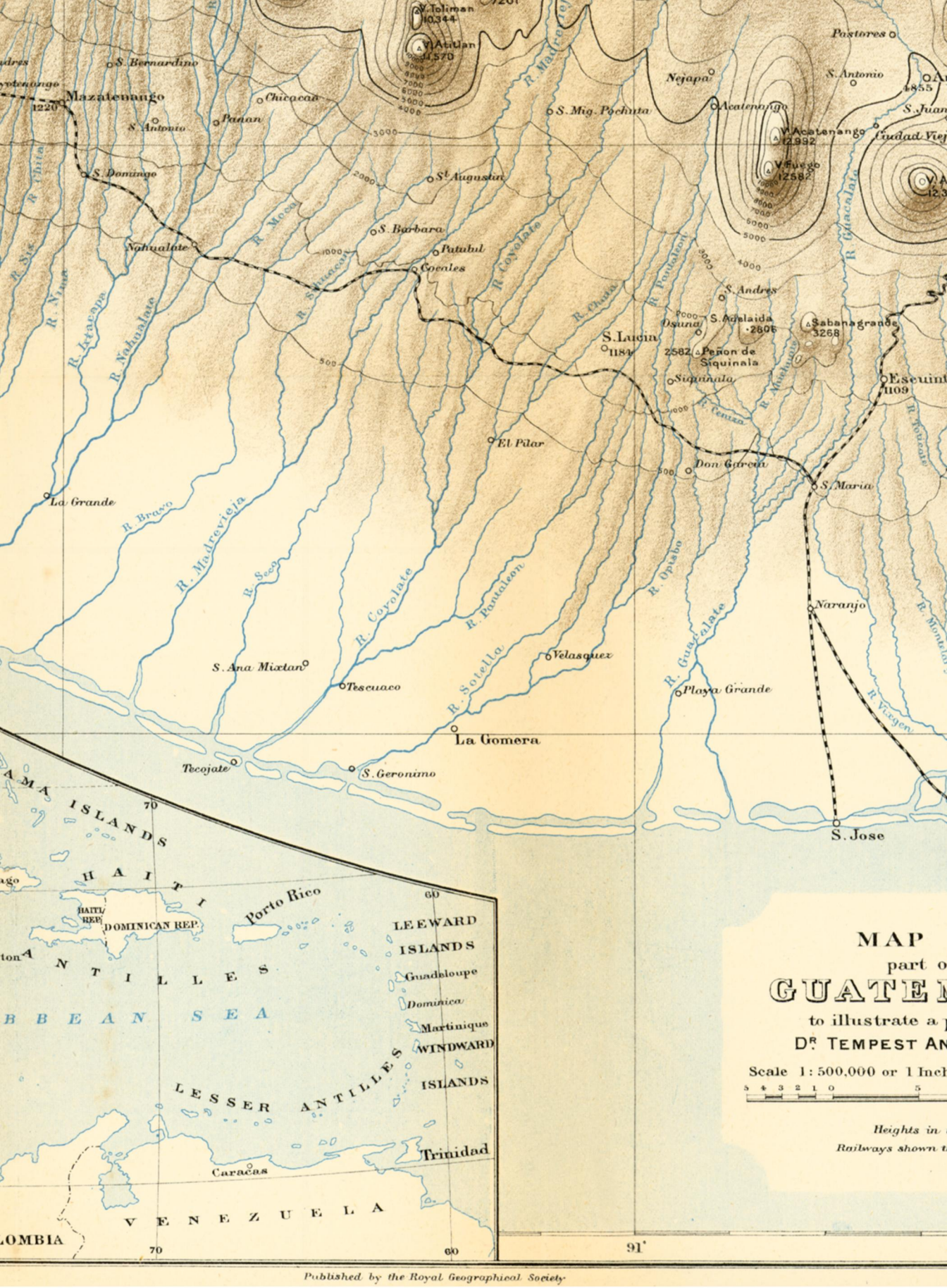
After the paper, Dr. FLETT: Listening to Dr. Anderson's descriptions to-night, and seeing on the screen the beautiful series of photographs of Guatemalan scenery and volcanoes, I could not help being struck very greatly with the similarity which exists between the volcanic phenomena in Guatemala and those with which Dr. Anderson and I became acquainted in the year 1902, when we had the opportunity of visiting together the volcanoes of the West Indies. There is some connection between the volcanoes of St. Vincent, Martinique, and those of Guatemala, because in May, 1902, when Montagne Pelée in Martinique and the Soufrière in St. Vincent burst into eruption, there were earthquakes in Guatemala; and six months later, while the volcanic activity was still going on in the West Indies, this great eruption took place of which Dr. Anderson has shown photographs to-night. One feature of the outbursts in both these districts was that the products were principally ashes, sand, and dust, so that the scenery of the Guatemalan volcano is very like that of the volcanoes in Martinique, where the whole surface of the ground was covered over with thick layers of ashes and sand.

Equally striking to us, perhaps, who are accustomed to temperate climates is the extraordinary rapidity with which these great masses of ashes are swept away from the bare surface of the ground in tropical climates. The photographs, for example, shown us to-night, when compared with the photographs taken in 1902 and 1903 by Prof. Karl Sapper, show that, vast as was the quantity of material ejected, the greater part of it has been swept away from the higher ground by the rivers, and transported to the sea. In the same way, in the West Indies, the larger part of the material which wrought devastation there was very soon removed, and with it part of the underlying soil, which had been, of course, left bare and unprotected by the destruction of the vegetation. I think you will agree with me that the year 1902 is one which will be marked with a red letter in the history of volcanic activity. In that year we had three volcanic outbursts of great magnitude: these were, the eruptions at Montagne Pelée, at the Soufrière in St. Vincent, and at Santa Maria in Guatemala. It is a curious fact that the greatest of these three in physical magnitude, namely, the Guatemalan eruption, is one which has been least known hitherto to English and American geologists, whereas the one which was least in point of mere magnitude has, on account of its fatal action on the town of









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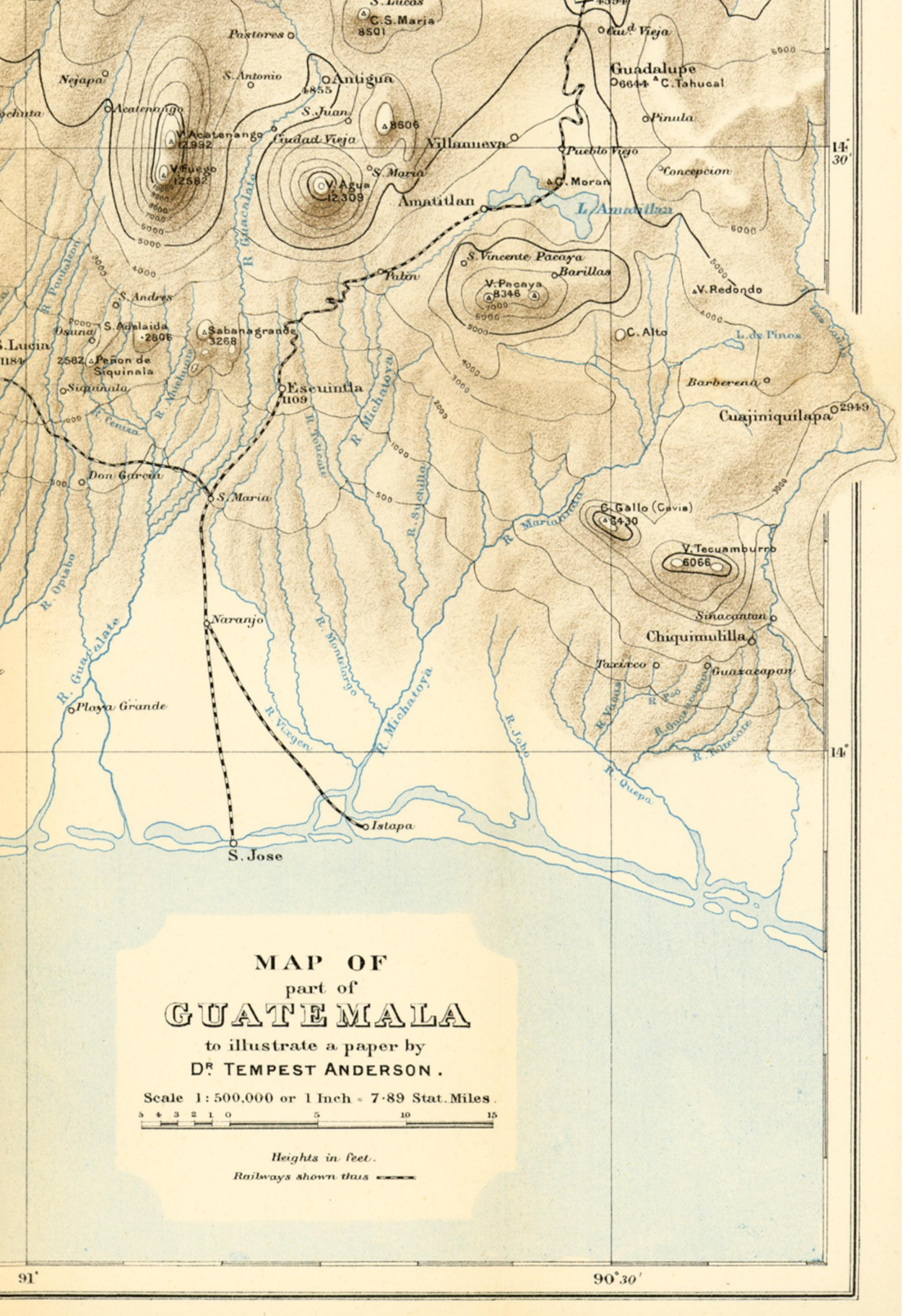

MAP OF
part of
GUATEMALA
to illustrate a paper by
Dr TEMPEST ANDERSON.

Scale 1:500,000 or 1 Inch = 7·89 Stat. Miles.

5 4 3 2 1 0 5 10 15

Heights in feet.

Railways shown thus ———