ever, it would seem to be a blacker and compacter rock than any that I have seen, more like some of those from Antisana.

"Guaguapichincha aus 14,238 Fuss Höhe." Black, pitchstone-like, small albite, green augite, magnetite (glassy andesite).

SiO_2	67·07	Sp. gr. 2·579
Al_2O_3	13·19	
Fe_2O_3	4·74	
Mn_2O_3	0·32	
CaO	3·69	
MgO	3·46	
K_2O	2·18	
Na_2O	4·90	
Ignition	0·30	
TiO_2	trace	
	99·85	

From the above descriptions, it may be, I think, fairly inferred that the main peak or cone of Pichincha consists chiefly of hornblende-andesites, and the second summit (Rucu-Pichincha) of hypersthen-iferous augite-andesites; and that there is considerable uniformity in the character of the rocks of this volcanic mountain.* Those from Antisana, which it is intended to describe in the next communication, are of a rather more varied nature.

III. "Report on the Tidal Disturbances caused by the Volcanic Eruptions at Java, August 27 and 28, 1883, and the Propagations of the 'Supertidal' Waves." By Major A. W. Baird, R.E. Communicated by Lieutenant-General J. T. Walker, R.E., F.R.S., with a letter from the Communicator containing an Abstract of the contents of the Paper. Received January 24, 1884.

(Abstract.)

At the request of Major A. W. Baird, R.E., I herewith forward for presentation to the Royal Society, a report which he has prepared on the Tidal Disturbances caused by the now famous volcanic eruptions which occurred on the 27th and 28th August last year, in the Island of Krakatoa and the Straits of Sunda, between Sumatra and Java. For

* I have seen, in collections of rocks from Hungary, specimens bearing considerable resemblance to those from Pichincha: for instance, an "amphibol-andesite" from Altsohl is like those of Guagua-Pichincha, and one from Blanfuss, Kremnitz, like specimens from Nina-urcu and Rucu-Pichincha.

some years past it has been Major Baird's special duty, as an officer of the Great Trigonometrical Survey of India, to supervise the operations for the investigation of tidal phenomena which have been carried on under the orders of the Government at a number of points on the Indian coast lines from Kurrachee round to Moulmein, and also at Aden. A tidal observatory, containing a self-registering tide-gauge, and all the necessary meteorological instruments, has been established at each of these points; every observatory has a man in charge who tends the instruments, sets the diagrams to true time as received telegraphically from Madras, and submits daily reports to Major Baird.

After the occurrence of the eruptions at Krakatoa, Major Baird made a careful examination of the diagrams at the whole of his tidal stations, seventeen in number, and at twelve of them he found more or less distinct evidence of tidal disturbance. In the accompanying report he sets forth this evidence, and gives such further facts as he has been able to collect from information supplied by eye-witnesses of the disturbances on the coasts of Ceylon and at other localities where as yet tidal stations have not been established. He also gives the magnitudes of the "supertidal" waves and the intervals between them; shows by calculation the probable time of the great eruption at Krakatoa; and then deduces the velocities of the waves which reached each station. He furnishes copies, on a much reduced scale, of the original diagrams of the tidal registrations of the 27th and 28th August which were made at each of his own stations; and he also gives a chart of a portion of the Indian Ocean which he has prepared to illustrate the course of the first great supertidal wave.

The testimony of the diagrams of self-registering tide-gauges must ordinarily be expected to be much more precise and reliable than that of eye-witnesses. This may be more particularly claimed in the present instance; for the clocks of the gauges were carefully supervised, and their times checked daily, at every station but Port Blair, by Madras time signals, and the diagrams are on so large a scale, 60 inches in length by 24 in breadth, that any sensible variation of sea-level is measurable on them; for it is depicted on the full natural scale wherever the tide range does not exceed 5 feet, and on half that scale where the range exceeds 5 but does not exceed 10 feet, the corresponding time scale being in all cases 1 inch to an hour; and as the stations at which the range of tide is less than 10 feet happen to be those at which the disturbances were greatest, very exact measures of the times and amplitudes of all the supertidal waves, whether small or great, are forthcoming for all the more important stations. The diagrams accompanying Major Baird's report were intended for illustration rather than for measurement; thus they have all been drawn on a much smaller scale than any of the originals,

viz., the uniform scale of 1 inch=3 feet for height and=6 hours for time. The original diagrams are too bulky to be reproduced to full scale for publication; but Major Baird presents in his report all the details which they furnish by giving the numerical elements of the time and height of every appreciable supertidal wave, remarking, with characteristic modesty, that thus the whole of the facts will be available for the further treatment of the subject by more competent hands.

The principal facts set forth by Major Baird are the following:—

1st. The primary effect of the great eruption at Krakatoa was a marked fall in the sea level—or in other words, the formation of a negative supertidal wave—at each of his stations.

2ndly. This negative wave was succeeded by a great positive wave at an interval ranging from seventy-five minutes at Negapatam, the station nearest Krakatoa, to twenty-four minutes at Aden, the most distant station.

3rd. Supertidal wavelets of greater or less magnitude were registered at the whole of the Indian stations some hours, more or less, before the effects of the great eruption; they are evidences of antecedent minor eruptions, the occurrence of which they would establish even in the absence of all other information on the subject. The intervals between these warnings and the great eruption which they heralded range from about three hours at Aden, the most distant station, to eighteen hours at Negapatam, the nearest station. This shows that the explosions were at first comparatively faint and feeble, being felt only at the nearest stations, but afterwards they increased in intensity, becoming sensible even at the most distant station three hours before the effects of the great eruption.

4th. Great supertidal waves of amplitudes ranging from a maximum of 22 inches at Negapatam to a maximum of 9 inches at Aden, were registered at all the stations which were in a position to receive the full force of the eruptions at Krakatoa, unobstructed by the configuration of the foreshore. Other waves of less magnitude, ranging down to half the maxima values, occurred at these stations at intervals of one to two hours for about twelve hours after the first great wave.

5th. The secondary great waves were succeeded by wavelets gradually diminishing in size, but continuing for some time; they are traceable on the diagrams for the 29th and 30th August, the second and third days after the great eruption; they cease first at Port Blair about 8 P.M. of the 29th, at Negapatam at 4 A.M. of the 30th, and, lastly, at Aden at 5 P.M. of the 30th.

6th. Loud reports resembling the firing of distant guns were heard at Port Blair and on the Nicobar Islands on the 26th and 27th August, and being supposed to be signals from a vessel in distress a steamer was sent out in search of the vessel; similar reports were

heard at two places on the coast of Ceylon on the 26th, first at 6 P.M. and afterwards at midnight.*

These facts show clearly that the terrible eruption at Krakatoa, which carried desolation over the surrounding regions and was attended with such an appalling loss of life, was preceded for some hours by minor eruptions which were insignificant only by comparison, for they produced effects which were sensible even at Aden, a distance of upwards of 4000 miles. It is possible, therefore, that some at least of the subsequent supertidal waves may be due to eruptions occurring subsequently to the great eruption.

It is a singular fact that we are still without any precise and definite information of the time at which the great eruption took place. In a very interesting and suggestive note on the Barometrical Disturbances which passed over Europe between the 27th and 31st August—communicated to the Royal Society on the 12th December—General Strachey gives an investigation of the speed of barometric waves travelling from Krakatoa round the earth, some from east to west, others from west to east, and he estimates that the great disturbance which caused the initial barometric rise probably occurred at 9 h. 24 m. local time on the morning of the 27th August. Now Major Baird shows that the primary effect of the great eruption was to produce a recession or fall of the sea-level at each of his tidal stations, and this was also noticed at the Mauritius. It seems probable that the initial barometric rise occurred at the same time as the initial oceanic fall or great negative wave, which is shown to have preceded the first great positive wave by an interval ranging from 75 minutes at the nearest Indian station to "about a quarter of an hour" at the Mauritius. Major Baird has ascertained from Her Majesty's Consul at Batavia that the first great positive wave reached Batavia at 12 h. 10 m. mean local time on the afternoon of the 27th August; he infers from the table of the velocities of free tide waves in Sir George Airy's article on Tides and Waves in the "Encyclopedia Metropolitana," that as the distance from Krakatoa to Batavia is about 105 miles, and the average depth of the sea between them 186 feet, the wave must have taken about two hours to travel that distance. Thus, allowing five minutes for difference of longitude, the local time of the occurrence of the first great positive wave at Krakatoa would be 10 h. 5 m. A.M., or about 1 h. 40 m. later than General Strachey's estimated time of the initial barometric rise. If, however, we assume this time to have been identical with that of the initial oceanic fall, and to have preceded the first great positive wave by an interval somewhat greater at

* The times throughout Major Baird's report are referred to the meridian of Port Blair, in lat. 11° 41′ N., and long. 92° 45′ E. of Greenwich, the easternmost tidal station at which the tides were disturbed.

Krakatoa than at the nearest Indian station—an inference to be drawn from the fact that all the recorded intervals between the negative and positive waves increase as the distances from the centre of disturbance diminish—the difference between General Strachey and Major Baird will practically disappear. When we consider the absolute independence of the two methods of deduction which they have respectively employed, the facts of the one being derived from the atmosphere, while those of the other are derived from the ocean, the coincidence between the two results appears very striking.

The Admiralty chart of the Eastern Archipelago shows that Krakatoa is situated at the focus of what may be regarded as a parabolic figure formed by the configuration of the contiguous portions of the coasts of Java and Sumatra; the axis of the figure is directed westwards towards the Indian Ocean, and nearly at the apex there is an opening to the north-east formed by the Straits of Sunda. Thus the waves generated by an eruption at Krakatoa would be mostly propelled towards the Indian Ocean, both directly and, though in a minor degree, by reflection from the coasts; the rush of waters towards the coasts would only have one outlet, namely, the Straits of Sunda, through which, as is well known, a great wave passed, carrying widespread destruction for some distance beyond, along the contiguous coasts of Java and Sumatra. This wave may possibly have impinged with great force on the south-west coast of the island of Borneo, which is on the prolongation of a straight line drawn from Krakatoa through the Straits of Sunda. But to the north-west, at Singapore, no trace of tidal disturbance appears to have been met with; a self-registering tide-gauge is established there, and the distance from Krakatoa is less than one-third of that of the nearest Indian station; but the Master Attendant reports that the gauge records "no difference whatever in the tide." This may be due to the fact that the wave through the Straits of Sunda, when it bent round to the north-west towards Singapore, had but a shallow sea to advance over, and its course must have been greatly impeded by the numerous islands and shoals and the narrow straits and passages between them; thus it may have well broken up and disappeared at some distance short of Singapore.

In an appendix to his report, Major Baird gives the respective velocities with which the great primary positive wave travelled to Galle, the Mauritius, the coast of Africa, and three of his own stations. He necessarily assumes that the as yet unknown time at which this wave issued from Krakatoa is to be fixed from the known time of its advent at Batavia, by deducting two hours from the latter in accordance with the velocity table in Airy's Tides and Waves already referred to. He obtains for the maximum velocity 467 statute miles per hour, both for Port Louis, in the Mauritius, distant

3400 miles, and for Port Elizabeth, in South Africa, distant 5450 miles; that the same value should be obtained for two places, one of which is 2050 miles further from the origin than the other, shows that there is not likely to be any gross error in the time adopted for the starting of the wave from Krakatoa; the value is, moreover, interesting in that it is practically identical with Airy's velocity of a free tide-wave over an ocean 15,000 feet deep, which is approximately the depth of the ocean on this line; in other directions the velocities are less, namely, towards Galle, 397; Negapatam, 355; and Aden 371 miles. In the calculations the velocity has been assumed uniform in each instance, as a matter of convenience, but it must in reality have been greatest wherever the ocean depth was greatest. The greatest depth is known to occur on the lines to Ports Louis and Elizabeth, for which we have the greatest velocities; but the wave which impinged on the Indian stations, and eventually reached Aden must for a considerable portion of its course have been identical with the wave which impinged on Ports Louis and Elizabeth, and then it must have travelled with the same high velocity; afterwards, on passing over shallower oceans, its velocity must have been materially retarded, and may have fallen much below the averages, 355 to 397 miles, for the whole course. This appears probable, moreover, from the evidence of the earthquake in the Bay of Bengal on the 31st December, 1881, of which an account—communicated by myself—was published in the "Proceedings of the Asiatic Society of Bengal" for March, 1883. The position of the centre of impulse has been fairly well fixed at a point nearly on the line between Port Blair and Negapatam, and the time is known within a few minutes. The supertidal waves caused by this earthquake at the contiguous tidal stations much exceeded in magnitude the waves caused at the same places by the eruption at Krakatoa, but their velocity was found to range between 240 and 120 miles an hour, varying with the general depth of the water traversed and the configuration of the foreshore at the respective stations. It is probable, therefore, that for the latter portion of its course the wave from Krakatoa to the same stations travelled with no greater velocity than on the occasion of the earthquake in the Bay of Bengal.

Presents, December 6, 1883.

Transactions.

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