P818

GREAT EARTHQUAKE AT LISBON, NOV. 1, 1755.

J C Branner

THEIR HISTORY, PHENOMENA, AND PROBABLE CAUSES.

BY

MUNGO PONTON, F.R.S.E.,

AUTHOR OF "THE GREAT ARCHITECT, AS MANIFESTED IN THE MATERIAL UNIVERSE," ETC.

"He looketh on the earth, and it trembleth: he toucheth the hills, and they smoke."—Ps. civ. 32.

LONDON:

T. NELSON AND SONS, PATERNOSTER ROW;

EDINBURGH; AND NEW YORK.

1868.

PREFACE

TO rank as a scientific treatise on Earthquakes and Volcanoes, this little Work has no pretensions whatever. Its aim is simply to convey a general notion of the awful grandeur of these phenomena, of their amazing frequency, their wide distribution, and the terrible energy of the forces brought into play, as measured by their stupendous effects.

Those who wish to dive more deeply into the subject, will address themselves to the study of Mr. Mallet's elaborate Reports on Earthquakes to the British Association for the Advancement of Science, to Dr. Daubeny's volume on Volcanoes, to Sir Charles Lyell's "Principles of Geology," to Mr. Poulett Scrope's "Treatise on Volcanoes," and to the works of which mention is made in those publications. But to that greater number who can devote to this interesting topic only a small reserve of time and thought, the following pages will perhaps supply, in a condensed form, as much information as they may care to acquire.

CLIFTON, 1867.

CONTENTS

—o—

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

CHAPTER VI.

CHAPTER VII.

CHAPTER VIII.

CHAPTER IX.

CHAPTER X.

CHAPTER XVII.

CHAPTER XVIII.

CHAPTER XIX.

CHAPTER XX.

CHAPTER XXI.

CHAPTER XXII.

EARTHQUAKES AND VOLCANOES.

CHAPTER I.

THE COMPARATIVE FREQUENCY OF EARTHQUAKES IN ANCIENT AND MODERN TIMES.

EARTHQUAKES and Volcanoes are among the most interesting of natural phenomena. Few are more wonderful, none more terrific. They have accordingly in all ages aroused the fears of the multitude, and allured the study of the philosopher. Both phenomena are due to one and the same cause—namely underground heat. Whence this heat, and how it operates, are subjects of inquiry which will be more advantageously approached after an examination of the phenomena illustrating its effects.

In the history of earthquakes, nothing is more remarkable than the extreme fewness of those recorded before the beginning of the Christian era, in comparison with those which have been registered since that time. So striking is the contrast, as almost to justify our giving a physical interpretation to the prophecy of our Saviour, that one of the signs of the establishment of his religion in the world should be the occurrence of earthquakes in divers places. Doubtless the Greek word used by the Evangelist, who records this utterance, means simply commotions, and may refer to political disturbances as well as to natural movements in the earth. Nevertheless the fact is remarkable that, in so far as the knowledge of the civilized world is concerned, earthquakes began to be more frequent from the beginning of the progress of Christianity.

It may be that the mention of earthquakes as among the signs of the approaching establishment of their religion, may have directed the attention of the early Christians more particularly to those phenomena, and so have multiplied the number of recorded instances. Yet, even making due allowance for the extreme negligence of the ancients in registering natural events, it seems hard to believe that, had there been as many *great* earthquakes before the Christian era as there have been since its commencement, so few of them should have been recorded, or even been transmitted by tradition.

It is to be borne in mind, however, that, before the birth of Christ, there was but a small portion of the habitable surface of the globe known to those who were capable of handing down a record of natural events. The vast increase in the number of earthquakes in recent times is mainly owing to the enlargement of our knowledge of the earth's surface, and to the greater freedom of communication now subsisting among mankind. Earthquakes might have been as frequent throughout the entire globe in ancient times as now; but the writers of the Bible, and the historians of Greece and Rome, might have known nothing of their occurrence. Even at the present time, many an earthquake might happen in central Africa, or in central Asia, of which we might never hear, and the recollection of which might die out among the natives in a few generations. In countries, too, which are thinly inhabited, and where there are no large cities to be overthrown, even great earthquakes might happen almost unheeded. The few inhabitants might be awe-struck at the time; but should they sustain no personal harm, the violence of the commotion and the intensity of their terror would soon fade from their memories.

Dr. Daubeny, in his work on volcanoes, cites an example of this complete oblivion, even where the event must have occurred not far from the ancient centre of civilization. The town of Lessa, between Rome and Naples, and not far from Gaeta, stands on an eminence composed of volcanic rocks. In digging the foundations for a house at this place some years ago, there were discovered, many feet beneath the present surface, a chamber with antique frescoes and the remains of an amphitheatre. Yet there is not only no existing account of the destruction of a town on this site, but not even a tradition of any volcanic eruption in the neighbourhood.

It has been observed that earthquakes are apparently somewhat capricious in their distribution. Large districts of country may enjoy an immunity from them for long periods of time, and then become more than usually subject to agitation. It is therefore quite possible that, before the Christian era, the countries embraced in the Roman world were in reality seldom convulsed by earthquakes. Egypt, in particular, has been noted for its immunity. The frequency and violence of the earthquakes in Italy may have, in truth, greatly increased since the foundation of Christianity. It is well known that Vesuvius had for ages remained in absolute repose before the great eruption in A.D. 79, while it has continued to be in action from time to time ever since.

The total number of earthquakes registered up to the end of the year 1850, is stated by Mr. Mallet, in his Report to the British Association, as 6831, and of these only 58 happened before the Christian era. A large proportion, however, of the grand total were slight, and this may be more especially affirmed of those of recent date. Of destructive earthquakes, such as have overthrown cities and destroyed many lives, the total number registered up to 1850 is 216, and other 15 have happened up to the end of 1865 —making in all 231, and of these only 4 occurred before the birth of Christ.

But to make the comparison more exact— in the sixty-five years which have elapsed of the present century, there have happened, within the limits of the old Roman world, no less than 35 earthquakes so disastrous as to have arrested the attention of the historian. Of these there have occurred 11 in Italy, 8 in Asia Minor, 5 in Greece, 3 in Persia, 2 in Syria, 2 in Candia, 2 in Sicily, 1 in Egypt and 1 in Spain. On the other hand, in the sixty-five years that preceded the utterance of our Lord's prediction, there were, within the same regions, only 9 recorded altogether, 3 in Asia Minor, 1 in Palestine, 1 in Upper Egypt, 1 in Cyprus, 1 in the Greek Islands, and 1 in Italy. Of these only four are noted as having been very destructive.

Now, it is scarcely credible that had there been so many as 35 *destructive* earthquakes in the earlier of these two periods, only four of them should have arrested the attention of the historians of the time, while they registered other five of minor importance. There is thus established a strong probability that the number was in reality much smaller in the earlier than in the later interval. This probability will be strengthened, when it is borne in mind that the ancient Greeks and Romans viewed earthquakes with superstitious dread—regarding them not only as evidences of the present anger of their gods, but also in the more important aspect of prognostics of calamities that were to follow.

Thus Herodotus, in reference to the earthquake that happened at Delos, after the visit of the Persian fleet, says: "But after he (the Persian leader) had put to sea from thence, Delos was shaken by an earthquake, as the Delians say, the first and last time that it was so affected to my time. And the Deity assuredly by this portent intimated to men the evils that were about to befall them. For during the reigns of Darius son of Hystaspes, of Xerxes son of Darius, and of Artaxerxes son of Xerxes—during these three successive generations, more disasters befell Greece than during the twenty generations that preceded the time of Darius—partly brought upon it by the Persians, and partly by the chief men among them contending for power. So that it is nothing improbable that Delos should be moved at that time, having been until then unmoved. And in an oracle respecting it had thus been written: 'I will move even Delos, although hitherto unmoved.'"—*Herod.* vi. 98, Cary's Trans.

Such a view as this was more likely to attract the attention of mankind to earthquakes than had they been regarded simply as natural phenomena. The idea of a portent was dear to the heathen mind, and this circumstance tends to establish the greater likelihood, that all the really important earthquakes of the period in question were registered, than that only so small a proportion of them attracted the attention of any contemporaneous or later historian.

The comparative fewness of the earthquakes recorded during the sixty-five years that preceded our Lord's prediction, may have therefore had quite as much a foundation in fact as in historical negligence. It may be really true that the number of earthquakes within the limits of the old Roman empire may have greatly increased since that time, and that our Saviour may have foreseen this increase when He said that, among the signs of the establishment of His religion there should be earthquakes in divers places.

Earthquakes may be distinguished into those which are in immediate connection with volcanic eruptions, and those which have apparently no such relation. The former sort, though often violent, are for the most part limited in their range, and will be best considered along with the eruptions with which they are connected.

Another distinction that may be drawn is between those earthquakes in which the centre of disturbance is under the land, and those in which it is under the sea. The latter are always accompanied by a great sea-wave, which is absent in the former. Some earthquakes are also characterized by peculiar atmospherical phenomena, chiefly electrical; while others exhibit nothing of the sort. As respects their violence, earthquakes present every degree, from tremors barely perceptible, to shocks so violent as not only to overthrow houses, but to toss men and animals into the air. For convenience, however, they may be arranged under three categories: 1st, The disastrous, comprehending all those capable of overthrowing buildings; 2nd, The severe, being those capable of forming rents in houses and fissures in the ground; and, 3rd, The harmless, which are too feeble to damage buildings or rend the ground. This last kind are by much the most numerous; while the first sort are comparatively rare.

Earthquakes also differ as respects their frequency in any given place, although, as a general rule, wherever there has been an earthquake once, especially if it be severe, others may be expected. There are some places in which there have been a continuous succession of harmless shocks almost daily, for years together, as at Comrie in Perthshire, especially from 1839 to 1847, at Ragusa from 1843 to 1850, at Pignerol in 1808, and at Maurienne in 1839. There are other places in which disastrous shocks are frequent, but with considerable intervals of repose, as in Southern Italy, Syria, Chili, Mexico, the Indian Archipelago, Japan, &c. In most other places the shocks are transient and of rare occurrence.

Regarding them chronologically Mr. Mallet distinguishes the registered earthquakes into five periods, thus :—

	Total.	Disastrous.	No. of Years.
Those recorded before A.D.,............	58	4	1700
Thence to end of 9th century,...... ..	197	15	900
Thence to end of 15th century,..	532	44	600
Thence to end of 18th century,..	2804	100	300
Thence to 1850,...........................	3204	53	50
	8631	216	

It will thus be perceived how very great has been the increase since the beginning of the Christian era ; and although much of this increase is due partly to more perfect registration, and partly to there being a larger portion of the earth's surface comprehended in the records, still there are good reasons, as already indicated, for suspecting that there has been a gradual augmentation in the number of earthquakes themselves, more especially of the more disastrous kinds.

Some philosophers, and among them Mr. Mallet, object to this view, on the ground of its appearing to involve the idea of a gradual increase in the intensity of the internal heat of the earth, and of the forces by which earthquakes are caused. But the increase in the number of earthquakes does not of necessity involve any such idea; consequently there is no force in this objection. A large proportion of earthquakes, as will be afterwards explained, have their origin in the efforts of the strata to readjust themselves to alterations in the distribution of the pressure exerted on their surfaces. Such alterations are continually in progress, through the action of great rivers, the waves of the sea, landslips, volcanoes and other causes; and they must go on increasing as the world grows older. It is therefore no wonder that the positions of repose, occupied by the strata, should be continually becoming more and more unstable, and their endeavours to regain a stable equilibrium more and more frequent. There is no need to imagine any increase in the internal heat of the earth. All that is requisite is to suppose the opportunities for its being brought into action to be on the increase—such opportunities being afforded by dislocations of the strata, having their origin in causes altogether distinct from the internal heat, and independent of its intensity.

Such is the frequency of earthquakes now-a-days, that Baron Humboldt in his "Cosmos" says—"If we could obtain daily intelligence of the condition of the whole surface of the earth, we should very probably arrive at the conviction, that this surface is almost always shaking at some one point; and that it is incessantly affected by the re-action of the interior against the exterior."—*Cosmos*, i. 199.

Looking to the immense number of recorded earthquakes, it will be perceived to be impossible, in a work like this, to notice more than a few of the most remarkable. So great is the similarity in the attendant phenomena, that to cite too many examples would involve tiresome repetitions. Reserving for separate consideration the three greatest earthquakes on record—that of Lisbon in 1755, the succession of shocks in Calabria in 1783, and the tremendous catastrophe at Riobamba in 1797—a brief outline shall first be given of some of the other disastrous earthquakes, in their chronological order. This course seems necessary with a view to convey to the reader an idea of the nature of these phenomena, of their frequency, and of their wide distribution over the surface of the globe.

CHAPTER II.

EARTHQUAKE ANNALS PRIOR TO THE DISCOVERY OF AMERICA.

OF the early disastrous earthquakes, one of the most notable occurred about the year B.C. 285 or 284, in the island of Niphon, one of the Japanese group. On that occasion, in one of the provinces named Oomi, a large tract of country was ingulfed in a single night, and there was formed, in its place, a lake 72½ miles long by 12½ wide. In an adjoining province named Sourouga there was at the same time upheaved a volcanic mountain, which still continues active, and will be noticed in the sequel. Of the formation of a lake in the place of ground ingulfed during an earthquake, the Lacus Cimini, in central Italy, is another example. It is said to occupy the position of a city which was ingulfed about the year B.C. 1450.

The famous Colossus of Rhodes was thrown down by an earthquake in the year B.C. 224. This celebrated statue was of bronze, 105 feet in height, and of similar gigantic proportions throughout. The legs were filled with large masses of stone to give it stability, and there was in the interior of the body a winding staircase, which led to the top of the head, whence a splendid view could be obtained. Its feet were strongly fastened to the two moles, which formed the entrance to the harbour, and ships in full sail passed between its legs. Notwithstanding its great weight, and the strength of its fastenings, it was laid prostrate by the violent undulation of the ground during the earthquake.

About three years after this event, central Italy was much agitated by earthquakes—between fifty and sixty shocks having occurred in one year. Hills were thrown down, the courses of rivers blocked up or turned aside, and many towns were overthrown. About the same time, Libya, on the northern coast of Africa, was greatly shaken, and nearly a hundred towns and villages destroyed.

About the years 85 or 82 B.C., the lake before mentioned, which was formed in the province of Oomi in Japan, was the scene of another convulsion, during which there was thrown up in the middle of it an island, which is now called Tsikou-bo-sima. About twenty-five years after this there was a succession of earthquakes in China, during which whole mountains are said to have fallen down and filled up the valleys.

These occurrences were probably landslips on a great scale. From A.D. 107 to 115, parts of China were again much convulsed. In A.D. 262 there were extensive shocks felt over central and southern Italy, Libya, and Asia Minor. In several places, the earth opened and poured forth salt water. These shocks were attended with much noise. A similar discharge of water from fissures opened in the earth occurred during an earthquake in Hungary in A.D. 518, several of the rents were twelve feet wide, and the water which issued from them was boiling hot.

The city of Antioch was, not for the first time, visited with this terrible scourge about the year A.D. 525, on which occasion however the shocks continued at intervals for a whole year, accompanied by excessive heat. Much of the city was destroyed. During the two succeeding years, the citizens rebuilt a considerable portion of the ruined edifices; but they were again overthrown in A.D. 528 by a violent shock, repeated many times in the course of an hour. About thirteen years after this, there was a shock felt throughout nearly the whole of the then known world, during which a large portion of the city of Cyzicus, situated on an island in the Bosphorus, was overthrown. A succession of shocks, which lasted forty days, and were in like manner felt over a large area, including Constantinople and part of Egypt, occurred about ten or twelve years afterwards. These shocks laid in ruins the ancient city Berytus, on the Syrian coast, where Beyrout now stands.

In 557 Antioch was again the centre of a succession of shocks, which extended to several other neighbouring cities. They continued for ten days, and were accompanied not only by loud underground rumblings, but by extraordinary atmospherical phenomena—thunder, lightning, and luminous meteors. Five or six years after this, there was a remarkable occurrence on the banks of the Rhone. A mountain, said to be Dent du Midi in the Valais, began groaning and grumbling dreadfully for some days, and then a large portion of it, with the houses upon it and their inhabitants, fell into the stream below. This was evidently a landslip, but probably caused by volcanic forces.

The whole empire of Japan was much disturbed by earthquakes in A.D. 600; and eighty-four or eighty-five years thereafter, in the province of Tosa, in the island of Sikokf, one of the Japanese group, there was another dreadful convulsion, during which a tract of land, estimated at half a million of acres, was ingulfed in the sea. Constantinople and its neighbourhood, together with the greater part of Asia Minor, was in 740 again agitated by intermittent shocks, which lasted for about eleven months, causing much damage in the cities, and destroying many of the inhabitants. The coast was in several places elevated, and the sea driven back. Two years afterwards, Egypt and Arabia were similarly agitated, and several landslips of mountains occurred. The turn of Palestine, Syria, and Mesopotamia came next. Between the years 746 and 775 these countries experienced several shocks, attended with much damage to buildings and considerable loss of life. There were several landslips of mountains, and a chasm opened in the earth about 1000 paces in length.

In 794 the celebrated Pharos, the lighthouse of Alexandria in Egypt, was thrown down by a violent shock; and about seven years afterwards the Basilica of St. Paul's at Rome shared a similar fate, along with many other buildings in Italy, during an earthquake which was felt not only in that country, but in France and Germany.

Unfortunate Antioch was again convulsed in 859, when upwards of 1500 houses were reduced to ruins. This same earthquake was accompanied by a great landslip—a part of the mountain Askræos having fallen into the sea. The years 893 and 894 were distinguished by earthquakes very destructive to human life. In the former, 180,000 persons perished in India under the ruins of their dwellings; and in the latter year, 20,000 were in like manner destroyed in Georgia, in the neighbourhood of Lake Erivan.

The Basilica of the Lateran in Rome was overthrown by a shock in 896, and the monastery of Monte Cassino, in the Campania, in 1005. About two years after this, 10,000 persons perished in the district of Irak, in Arabia—partly buried in the ruins of their dwellings, partly ingulfed in fissures of the earth.

In 1021 there was felt, in Germany and Switzerland, a shock attended in the latter country by curious effects. The wells were all troubled, and the water in many of them became red. Great inundations followed the earthquake, and it was accompanied by luminous meteors. Eight years thereafter half the city of Damascus was overthrown by a violent shock, and in 1035 Jerusalem suffered severely. A few years afterwards there was a very fatal shock at Tabriz, in Persia, during which 50,000 persons were buried under the ruins of their houses. In 1052 a violent shock visited Khusestan, also in Persia, during which a large mountain near the city of Ardschan was cleft in twain. Eleven years thereafter the walls of the city of Tripoli, in Syria, were overthrown by a powerful shock. The coast of Syria was in 1069 again violently convulsed, and the sea, after retiring for a considerable distance from the shore, returned with a mighty wave which swept everything before it, with great destruction to life and property.

In 1110 the counties of Salop and Nottingham, in England, experienced a smart shock, and the river Trent was stopped in its course; about a mile in length of its bed was laid dry, and so continued from morning till three in the afternoon.

Persia was again severely visited in 1139. The town of Gausana was destroyed, and black water issued from fissures in the earth. It is computed that 100,000 lives were lost. About nineteen years subsequently there was great loss of life at Antioch, Tripoli, Damascus, Aleppo, and other towns in Syria, through the overthrow of houses, 20,000 persons having perished. In the same year, but whether at precisely the same time is uncertain, a considerable portion of the bed of the Thames was laid dry, as that of the Trent had been before.

Calabria and Sicily were severely agitated in 1169 or 1170; the city of Catania was destroyed, and 15,000 people perished. This earthquake appears to have been connected with an eruption of Mount Etna, which took place about the same time. The whole of England was shaken in 1185. The shock was particularly severe at Lincoln, where the cathedral and several houses were overthrown. The following year there was a severe shock felt nearly all over Europe. It was most powerful in Calabria and Sicily, where many towns were injured or destroyed; while even in England several houses were shaken down.

In 1188 a remarkable convulsion was experienced in the islands of the Indian Archipelago. It is said that on this occasion the islands of Java and Sumatra, which had previously been united, were severed from each other, and the Straits of Sunda formed between them. Sir Stamford Raffles, who found this catastrophe recorded in the Javanese annals, under date of the Javan year 1114, hesitates about accepting the truth of the statement, by reason of the great difference between the geological formations of the two islands. He nevertheless admits that the vast scale of the volcanic convulsions which have occurred in this quarter in modern times tends strongly to corroborate the historical statement. The native annals record other occurrences of the same kind, that took place subsequently. They state that Sumatra, Java, Bali, and Sumbáwa were all at one time connected together; that the detachment of Bali from Java took place about ninety years after the separation between Java and Sumatra, and that seventy-six years later Sumbáwa became a distinct island.

The Chinese Empire began to be much disturbed about 1333, and the convulsions continued for nearly ten years. The capital, Kiang-si, was swallowed up in a great chasm, and the loss of life was immense. Several mountains were either ingulfed in underground cavities, or fell down upon the plains and valleys, blocking up the courses of rivers, and causing great inundations, which proved most destructive to life and property.

In Tuscany, during an earthquake in 1335, a large mass was separated from Monte Falterona, near Florence, and fell down, putting the earth in motion to a distance of four miles. A few years after this event Iceland and Norway were violently shaken, and in the latter country much damage was done. A river was ingulfed, and several days afterwards it reappeared above ground, bringing up with it such quantities of loose materials as to choke up the valley through which its course lay, so producing an inundation. Central Europe was much agitated in 1348—great fissures opening in many places, and discharging pestilential vapours. Two years afterwards a mountain in Switzerland was cleft in twain.

The coast of Syria was in 1402 visited by another disastrous shock, accompanied by a great sea-wave, similar to that which occurred in 1069. It did immense damage. There were also several great landslips among the mountains. In 1456 the kingdom of Naples experienced several violent and destructive shocks, during which 60,000 persons perished. The Grecian Archipelago was greatly agitated in 1491, and in the island of Cos 5000 lives were lost.

CHAPTER III.

EARTHQUAKE ANNALS OF THE SIXTEENTH, SEVENTEENTH, AND EIGHTEENTH CENTURIES.

THE earthquakes hitherto noticed all occurred in the Old World; but the discovery of America in 1492 soon brought a great accession to the number of recorded instances.

The high land in the neighbourhood of Cabul, in Afghanistan, was violently convulsed in 1505. The earth undulated like a sea—portions being raised from twelve to fourteen feet above their former level, and then depressed as far below it. There were also opened great fissures, whence water issued and flooded the land. Four or five years afterwards, Constantinople and the towns in its neighbourhood experienced a succession of shocks during three weeks. In Constantinople 1700 houses were overthrown, and the sea rose so high as to wash over its walls.

In 1530 occurred the first of the many recorded earthquakes of America. The Gulf of Paria, with the adjacent coast of Cumana, in

Venezuela, was the scene of the catastrophe. It was accompanied by a great sea-wave, the tide suddenly rising twenty-four feet, and then retiring. There were also opened in the earth several large fissures, which discharged black fetid salt water and petroleum. A mountain near the neighbouring Gulf of Caracas was split in twain, and has since remained in its cloven condition.

Next year the Spanish peninsula, the opposite coast of Africa, and parts of Switzerland and Flanders, were simultaneously shaken. The shocks were most severe at Lisbon, and they continued for eight days, at the rate of seven or eight in a day. All the churches and 1500 houses were overthrown. This earthquake was also accompanied by a great sea-wave, which rushed up the Tagus and caused it to overflow its banks.

Palestine was convulsed in 1546. The bed of the Jordan was dried, and is said to have so continued for two days. The sea-wave accompanying this earthquake was very large, and much damage was done in several of the towns.

About ten years afterwards there was an earthquake of extreme violence in the province of Chan-si, in China, the shocks having continued in succession for two hours. A large tract of country sixty leagues in circumference sank down, and was replaced by a lake. This catastrophe was attended with great loss of life.

The year 1586 was distinguished by three great earthquakes. The first, on the coast of Peru, was accompanied by a great sea-wave eighty-four feet high, which inundated the country for two leagues inland. The second overthrew the city of Guatemala, in Central America. The third occurred in Japan, where also it was accompanied by a great sea-wave, which did immense damage. The town of Nangasuma was destroyed, several hills were thrown down, and there were opened in the earth vast fissures, whence suffocating sulphurous vapours arose.

The Azores were fearfully convulsed in 1591. The shocks were most severe in St. Michael's, so famed for its oranges. They continued in quick succession for nearly a fortnight, and inflicted much injury. In many parts of the islands the surface of the ground was altered by great changes of level, hills being converted into hollows, and plains into hills. In one place a stream of clear water sprung from the earth, and after continuing to flow for four days disappeared. Many buildings were overthrown. The sea in the neighbourhood of the islands was greatly agitated, and much damage was done to shipping. There was a recurrence of earthquakes in the Azores thirty-three years afterwards, during which a new island arose out of the sea near St. Michael's, and this event was followed by another similar twelve years later. From 1595 to 1598 severe shocks occurred in Japan, destroying many towns, either by the oscillations of the ground, or by the high sea-waves which accompanied them.

The kingdom of Naples was again violently shaken in 1626, and thirty towns and villages were destroyed, with much loss of life. From one part of the coast the sea first retired about two miles, and then returned in a vast wave, inundating the land. The Pyrenees were agitated in 1660, and in the province of Bigorre a mountain sank and was replaced by a lake, while a hot spring became suddenly cold. A similar occurrence took place, two years afterwards, in the province of Oomi, in Japan, where a mountain was wholly ingulfed. A lake of great depth was, in the following year, entirely swallowed up during an earthquake in Iceland. In 1665, after a severe shock in Naples, there was found to have been formed in the ground, about three miles from that city, a fissure 350 feet long and 100 feet wide, whence arose fire and smoke. Two years afterwards the coasts of the Adriatic were agitated, and the city of Ragusa, in Dalmatia, was overthrown, with much loss of life. The earthquake was at that place accompanied by a fearful gale; the sea retired and returned four times in quick succession, and loud submarine explosions were heard. In 1672 violent shocks were felt in the Greek islands, and one of them was ingulfed in the sea with all its inhabitants.

The coast of Peru was again severely convulsed in 1687, and the great sea-wave which accompanied the earthquake destroyed the town and harbour of Callao. The following year the island of Jamaica was shaken, and the earth appeared to rise in waves like those of the sea, the movement advancing from south to north. Great injury was done to the shipping in Port Royal, through the violent agitation of the sea. The same year the city of Smyrna was reduced to ruins, and a peninsula was detached from the mainland, by the formation of a channel one hundred paces wide. The ground in the neighbourhood of the city was at the same time much rent.

The island of Jamaica was again convulsed in 1692, and more violently than it had been four years previously. The same appearance was presented of the ground rising in waves like those of the sea. The city of Port Royal was nearly destroyed, and a piece of land of one thousand acres sank into the sea. A man named Louis Gelday is said to have been caught in one of the fissures formed in the ground, and tossed out again by a succeeding shock without injury. Great masses of earth and rock were detached from the Blue Mountains, carrying with them forests of timber. These were hurled into the sea, where they covered a large extent of surface like floating islands. The land at the side of the harbour sank, carrying down the store-houses and other buildings upon it. The ships in the harbour were wrecked, so that, after the earthquake, the chimney-tops of the buildings and the masts of the ships were seen together above water. In the northern parts of the island several plantations, with their inhabitants, were ingulfed in the chasms that opened in the ground, and were replaced by lakes, which afterwards dried up. Several others were overwhelmed by landslips; and one in particular was moved bodily to a distance of half a mile, with all its growing crops, which sustained no injury.

The following year the eastern coast of Sicily was the centre of a great convulsion, which was felt over a large portion of Europe. The city of Catania was reduced to ruins, and many churches and convents in Sicily and Calabria were overthrown. The loss of life was dreadful, 93,000 persons having perished. An eruption of Mount Etna accompanied this earthquake, and it resulted in an extensive subsidence along the coast. There were also formed in the ground numerous long fissures, emitting sulphurous water; and from one, at the distance of four miles from the sea, the water ejected was salt. In the town of Noto, in Sicily, one half of a street half a mile in length sank down, leaving the remaining half overhanging.

The district of Quito, in South America, was violently shaken in 1698, and during the shock a great part of the cone and crater of the volcano of Carguairazo fell in, a stream of water and mud issuing at the same time from the broken sides of the mountain. In the following year the island of Java was severely convulsed in connection with a volcanic eruption of Mount Salek. Many houses in Batavia, although at a distance of six days' journey from the mountain, were overthrown. Great landslips accompanied this convulsion, seven hills having, it is said, fallen into the river that flows through the city.

A far more disastrous earthquake, at least as respects the destruction of human life, occurred in Japan towards the end of 1703. It resulted in the total destruction of the city of Yeddo, and 200,000 persons are said to have perished. At Palermo, in 1726, during a violent earthquake which shook down 1600 houses, the earth opened in one of the streets of the city, and threw out burning sulphur, with red-hot stones, while the atmosphere appeared as if on fire. The flames issuing from the earth kindled the wood-work of the houses in the street, and they were all consumed. About five years afterwards, a large portion of the city of Pekin, the capital of China, was overthrown in less than a minute, burying about 100,000 persons in the ruins.

There was another dreadful convulsion on the coast of Peru, in 1746, when the sea twice retreated and dashed in again with a tremendous wave about eighty feet high, overwhelming Lima and four other sea-ports. A portion of the coast sank down, producing a new bay at Callao; and in several mountains in the neighbourhood there were formed large fissures whence water and mud gushed forth. On the 24th of May 1751, the city of Concepcion in Chili was entirely swallowed up during an earthquake, and the sea rolled over its site. The ancient port was destroyed, and a new town was afterwards erected ten miles inland. The great sea-wave, which accompanied this earthquake, rolled in upon the shores of the island of Juan Fernandez, and overwhelmed a colony which had been recently established there. The coast near the ancient port of Concepcion was considerably raised on this occasion, and the high water-mark now stands twenty-four feet below its former level, as proved by beds of recent shells being found at that height above it. Beds of similar shells have been discovered in the neighbouring hills at a height of several hundred feet, thus showing how great has been the elevation of this coast, since the present races of mollusks inhabited those shores. St. Domingo was severely shaken in 1751, and a large portion of its capital, Port-au-Prince, overthrown. A tract of the coast, twenty leagues in length, subsided, and has ever since formed an extensive bay.

The year 1755 was one of the most calamitous in the history of earthquakes. In the month of October several strange meteorological phenomena occurred in the Spanish peninsula, such as frequent halos round the sun and moon, numerous luminous meteors, and terrific thunder-storms with much rain. The waters, both of wells and rivers, became turbid and fetid; rats and reptiles came forth as if frightened, and domestic animals showed much uneasiness. On the first of the following month of November occurred the great earthquake of Lisbon, of which a separate account will be afterwards given. On the 8th, 16th, and 18th of the same month, the shocks at Lisbon were repeated, though with less violence. Nevertheless, at sea, sixty leagues from the coast of Portugal, the shock on the 8th is said to have been felt as severely as that on the 1st; while on the 16th the sea rose to a great height, and the undulation of the earth was so great as to resemble that of the sea in a tempest. On the 18th, the New England states of North America were violently shaken, probably about the same time as the Portuguese coast. The shocks were accompanied by loud underground explosions. The sea was much agitated in the harbours along the North American coast, and many dead fishes were thrown up. This agitation of the sea extended as far as the West Indies. The shocks were felt by the crew of a ship in the Atlantic, at the distance of seventy leagues from Cape Ann, on the coast of Massachusetts. On the same day shocks were felt not only at Lisbon, but at Gibraltar, at Fez and Mequinez in Morocco, at Tangier and Tetuan on the north African coast, in the neighbourhood of Rome, in Savoy, on the banks of the Rhine, and partially in England. During the remainder of the month shocks continued to be felt in various places, chiefly those already named. On the 9th of December there was another violent shock at Lisbon; and on the same day, Switzerland, Northern Italy, the Tyrol, with parts of France and Southern Germany, were shaken, the shocks being accompanied by underground noises, and the opening of fissures with discharges of water. On the two following days there were repetitions of the shocks; but they were more partial in their distribution, nor did they cease to be felt at intervals, with more or less violence, for several months. On the 10th of July 1756, there were two sharp shocks at Lisbon, during which there rose from the ground a cloud of smoke that obscured the sun, and filled the air with a sulphurous smell.

The convulsions in the Azores were renewed in 1757, with very destructive effects to life and property. There were eighteen new islets thrown up to the north of the island of St. George; and Monte Formoso in this island was split in twain, one half falling into the sea, and leaving an interval of six hundred feet between the two portions. In the island of Topo the earth was rent, and a large extent of land slid into the sea. Several hills sank down, and others shifted their places. A fissure was formed in the middle of the village of Norte Grande, and the one half of it was carried into the sea to the distance of nine hundred feet from the other half, so forming a new islet. Three years afterwards, Syria was much agitated, with great destruction to life and buildings. There was a large sea-wave at Acre. In 1761 the coast of Portugal was again convulsed, and the shocks were felt over a vast area, extending as far as Madeira towards the south, and the British Islands and Holland towards the north. Nearly about the same time shocks were felt at Thessalonica.

On the 2nd of April 1762, the coast of Chittagong, in the north-east of the Bay of

Bengal, was violently shaken. There were formed in many places large openings in the ground, whence water and mud, smelling strongly of sulphur, were ejected. A large river was dried up at a place called Bardavan, while at Bar Charra, near the sea, a tract of land sank down and was submerged, drowning two hundred people and all their cattle. Sixty square miles of the coast permanently subsided. One mountain sank down till only its summit remained visible; while another disappeared altogether. Several other hills were rent asunder, and chasms from thirty to sixty feet wide were formed. The towns upon the tract which subsided were overflowed, and one was submerged upwards of ten feet. This great subsidence was accompanied by a corresponding elevation of the ground in the islands of Ramree and Cheduba, lying to the southward.

Hungary was the scene of a succession of shocks in 1763, when many houses were overthrown in Comorn. There were formed in the earth large openings, from which sulphurous vapours arose. Jets of water, the thickness of a man's arm, ascended from the Danube to a height of five feet, the water being mixed with sand, and having a sulphurous smell. The same year there was a disastrous shock in the Moluccas, during which the tide suddenly fell thirty feet, and then rolled in with a great wave.

The coast of Caracas in South America, and the adjacent island of Trinidad, were violently convulsed in 1766, and the whole city of Cumana was reduced to ruins. The shocks were continued for upwards of a year, and were at first repeated almost hourly. There were frequent eruptions of sulphurous water from fissures in the ground, and an island in the Orinoco disappeared. Four years thereafter the western coast of St. Domingo was similarly agitated, and its chief city, Port-au-Prince, nearly destroyed. There were formed in the earth great clefts, whence arose poisonous vapours that caused an epidemic. Hot springs also rose in several places, but they proved temporary. This earthquake was accompanied by a great sea-wave, which swept over the country to a distance of a league and a half from the shore.

The district of Guatemala in Central America was visited by successive shocks in 1773 and 1775. The city of St. Iago, with all its inhabitants, was ingulfed in huge chasms which opened in the earth. These earthquakes were connected with volcanic eruptions in the neighbourhood. A catastrophe similar to that of St. Iago occurred in 1780 in the island of Candia, where, during a violent earthquake, the castle of Eropeter, with its garrison of three hundred Turkish soldiers, and also thirteen small villages in the neighbourhood, with their inhabitants, were swallowed up in chasms.

In 1783 occurred the great Calabrian earthquakes, of which a separate account will be afterwards given. The island of Java was, in 1786, visited by a succession of shocks which lasted four months. Great fissures and chasms were formed, in one of which an entire village, with its inhabitants, was swallowed up. Into another a rivulet plunged, and flowed thenceforward in a subterranean channel. Sulphurous vapours were emitted from the fissures. In the district of Caracas, near the junction of the Caura with the Orinoco, an earthquake, in 1790, caused a large subsidence of a portion of the forest of Aripao, and the formation, in its place, of a lake eight hundred yards in diameter, and from eighty to one hundred feet in depth.

The year 1797 was distinguished by the great earthquake of Riobamba, of which also a separate account will be given. The Lesser Antilles were likewise agitated by a succession of shocks, commencing in February of this year, and continuing till September, when an eruption of a volcano in Guadaloupe caused them to cease. Towards the end of this year, the coast of Caracas was again convulsed, and those portions of Cumana which had been rebuilt during the last thirty years were once more laid in ruins. On the shores of the bay of Cariaco, immediately before the shocks, flames issued from the earth, followed by a noise like the bubbling of gas in water. During the summer of the following year, Tuscany was visited by a succession of shocks, and the town of Siena was reduced to a heap of rubbish, deep chasms having been formed in the principal square.

CHAPTER IV.

EARTHQUAKES OF THE NINETEENTH CENTURY.

THERE were two severe shocks of earthquake in 1806 at Krasnojarsk in Siberia, during which a mountain in the neighbourhood of that place was ingulfed, and a lake, 300 feet in circumference and 180 feet deep in some parts, occupied its place. The water of this lake was sulphurous. As the country around was covered with ashes, it is probable that this event was connected with some volcanic eruption. A few weeks afterwards, a similar lake of sulphurous water was formed near the mountain of La Fajola, in the neighbourhood of Rome, where several severe shocks were felt at the time.

In April 1808 began a remarkable series of shocks in Piedmont and the neighbouring districts of country. They were very frequent during the months of April and May, but gradually diminished both in frequency and force till the beginning of July. Some of them were accompanied by underground rumblings, others not. A few were sufficiently severe to do considerable damage to buildings.

St. Michael's, in the Azores, was visited by two severe earthquakes in 1811, and on both occasions they were accompanied by the eruptions of a submarine volcano, which threw up dust, ashes, and fragments of lava into the air. The points of eruption on the two occasions were about two and a half miles asunder; but neither of the craters ever appeared above water. These eruptions were attended with loud explosions.

In December of this year commenced a long series of disturbances in the valleys of the Mississippi, Ohio, and Arkansas. These shocks continued at intervals till 1813, and were more distinguished by their frequency than their violence, which was, nevertheless, on several occasions very considerable. These long continued earthquakes are the more remarkable, from the circumstance that the countries affected by them are situated far from any volcano. The surface of the valley of the Mississippi was a good deal altered by these convulsions—several new lakes having been formed, while others were drained. There were also several new islands raised in the river, and during one of the shocks the ground a little below New Madrid was for a short time uplifted so high as to stop the current of the

Mississippi, and cause it to flow backwards. The ground on which this town is built, and the bank of the river for fifteen miles above it, subsided permanently about eight feet, and the cemetery of the town fell into the river. In the neighbouring forest the trees were thrown into inclined positions in every direction, and many of their trunks and branches were broken. It is affirmed that in some places the ground swelled into great waves, which burst at their summits and poured forth jets of water, along with sand and pieces of coal, which were tossed to the height of trees. On the subsidence of these waves, there were left several hundreds of hollow depressions from ten to thirty yards in diameter, and about twenty feet in depth, which remained visible for many years after. Some of the shocks were vertical, and others horizontal, the latter being the most mischievous. These earthquakes resulted in the general subsidence of a large tract of country, between seventy and eighty miles in length from north to south, and about thirty miles in breadth from east to west.

The Bay of Caracas was the scene of a dreadful earthquake in 1812. The city of Caracas was totally destroyed, and ten thousand of its inhabitants were buried beneath its ruins. The earth undulated like a boiling liquid. Large masses of rock were riven from the mountains, and hurled into the valleys, the shocks having agitated the mountains fully more than the plains. At Valentia and Puerto Cabello, immense torrents of water issued from clefts in the ground, and the level of the lake of Maracaibo was simultaneously lowered. The shocks were accompanied by loud and prolonged underground rumblings, and were repeated on successive days for about a month, when they were brought to an end by a very violent eruption of the volcano in the island of St. Vincent. The shocks were also felt by the crews of vessels at sea for a considerable distance from the coast, and appeared as if the ships had struck on a rock.

On the night of the 13th of August 1816, the counties of Inverness, Perth, and Aberdeen, in Scotland, were smartly shaken, and the shock produced a singular effect. In the town of Inverness there is a handsome octagonal spire, the upper portion of which, to the extent of five or six feet from the top, was disengaged by the shock, and twisted round about a sixteenth part of a circle, so that the angles of the upper portion came to rest over the middle of the faces of the lower portion. Unfortunately for science, this spire was, a few years after, restored to its original state.

In April 1817 there was a calamitous shock at a place called Chang Ruh on the western frontier of China, during which 11,000 houses were overthrown, with a loss of between 2000 and 3000 lives. In August of the same year, portions of the Morea were violently shaken by a succession of shocks, which continued for about eight days with much subterranean noise and terrific whirlwinds, which destroyed the town of Vostitza in seventeen minutes. The sea in the neighbourhood of that place became scalding hot, thus indicating that a submarine volcano was the probable cause of the disturbance.

In the month of June 1819, the districts of Cutch and Gujerat, in the western parts of the Indian peninsula, were much agitated by successive shocks. The undulations of the ground were quite visible, and it was with difficulty that people could keep their feet. The earthquake was accompanied by a violent tempest, and a loud rushing noise. Bhooj, the capital of Cutch, was overthrown, and 2000 of the inhabitants were crushed in the ruins. Several other smaller towns and villages shared a similar fate. At Anjar, to the eastward of Bhooj, the fort with its tower fell to the ground in a mass of ruins; and even at Ahmedabad, much further to the east, on the other side of the Gulf of Cutch, the great mosque, built by Sultan Ahmed nearly 450 years before, was overthrown. From the hills in the neighbourhood of Bhooj, several large masses of rock and earth were detached and hurled into the valleys; but the appearance of the landscape around was otherwise little altered. The eastern channel of the Indus, however, which flows through the Runn of Cutch, sank to a depth of seventeen feet near the fort of Luckput, lying to the north-west of Bhooj, and from three to eight feet in the other parts of the channel. The fort and village of Sindree, north of Luckput, were at the same time overflowed, having sunk down so much, that only the tops of the houses and walls remained visible above water after the shock, which, however, had not overthrown any of the buildings. A tract of land, 2000 square miles in area, was at the same time so much depressed, that the sea from the Gulf of Cutch rushed in, and converted it into a lagoon. This inundation overwhelmed the village, and a great part of the fort of Sindree. There remained above water little more than the upper part of the north-west tower, which, having sustained no injury, afforded temporary shelter to the inhabitants, who escaped in boats the following day.

Simultaneously with this great depression, a remarkable elevation was produced at no great distance. Between five and six miles to the northward, there was raised a long mound or bank, which the inhabitants named Ullah-Bund, or God's Bank. The extent of country thus elevated is nearly fifty miles in length from east to west, and its breadth in some parts is about sixteen miles. The height is nearly uniform, and its greatest amount is about ten feet.

This occurrence is the more remarkable from its having happened so far from any known focus of volcanic action. The nearest site of subterranean disturbance is at the distance of upwards of two hundred miles from Bhooj, in the south-eastern corner of Beloochistan, where are numerous mud volcanoes. The phenomena which resulted from this earthquake are highly instructive. They illustrate the manner in which similar interchanges of land and sea may have been produced in other parts of the world, but of which no record has been preserved. There are manifest traces of successive similar elevations and depressions on the shores of the Bay of Baiæ near Naples; while the raised beaches of our own island testify to like occurrences that must have happened long before the period at which the annals of our nation begin, if not before the existence of the human race itself.

In 1821, Kamtschatka was convulsed by a succession of severe shocks, which terminated in a violent eruption of a volcano with an unpronounceable name. About two-thirds of the cone of Alaid, a small conical island of the Kurile group, fell in during this eruption. The following year Syria was severely shaken, and a large portion of the city of Aleppo was destroyed, with many thousands of its citizens. These earthquakes were accompanied by the elevation of a rock in the Mediterranean, between Alexandria and Cyprus.

In November 1822, the coast of Chili began to be violently convulsed by a succession of shocks, the first of which was of great severity. The heavings of the earth were quite perceptible to the eye. The sea rose and fell to a great extent in the harbour of Valparaiso, and the ships appeared as if they were first rapidly forced through the water, and then struck on the ground. The town of Valparaiso and several others were completely overthrown. In some parts the earth opened, and discharged water mixed with sand, which gathered in heaps three or four feet high. At the promontory of Quintero, fissures were formed in the solid granite parallel to each other and to former similar rents. Sounds like those produced by the escape of steam accompanied this earthquake, and it was felt throughout a distance of 1200 miles along the coast, a portion of which—extending to about 100 miles—was permanently raised to a height varying from two to four feet. At Quintero the elevation was four feet, and at Valparaiso three feet; but about a mile inland from the latter place the elevation was as much as six or seven feet; while the whole surface raised is estimated at nearly 100,000 square miles.

The city of Schiraz in Persia suffered severely in June 1824, a considerable portion of it having been ingulfed in a chasm. A large part of the town of Kazroun was destroyed, and some mountains in its neighbourhood were thrown down. This district was again shaken in October of the following year. Lancerota, one of the Canary group of islands, was, during the month of July 1824, violently convulsed, in connection with a volcanic eruption, during which masses of lava, vapour, and salt water were ejected. In September following, Manilla, in the Philippine Islands, was so severely shaken, that several of the churches, the barracks, one of the bridges, and many private houses, were overthrown. The ground was rent at a place about four miles from the city, and the fishes were killed in a neighbouring river.

The island of St. Maura in the Ionian Islands, which had previously experienced a succession of smart shocks, was in January 1825 visited by an earthquake of such severity as to overthrow nearly the whole of the town of St. Maura, and to injure greatly the town of Prevesa, where there were also formed rents in the earth. Many of the inhabitants perished under the ruins of their dwellings. In the following month of April, the islands of Sumbáwa, Java, Borneo, and Celebes, were violently convulsed by a succession of shocks, which in the first-named island lasted eleven days. These earthquakes accompanied an eruption of the volcano of Tomboro, and proved very destructive to human life.

Santa Fé de Bogota, in New Grenada, South America, was visited in May 1826 by two very severe shocks. Several dwellings were so injured, that they fell the following day. At a distance of a mile from the town, there was opened in the ground a fissure 200 feet wide, whence sulphurous vapours rose. The undulations of the ground produced a motion like that of a boat in a stormy sea. In November of the following year, a still more destructive earthquake visited the same region. In Bogota and the neighbouring towns immense damage was done. The shocks were of unusual duration, so that the houses were crumbled into ruins ; and there were violent underground detonations at intervals of half a minute. Much injury was caused by the overflowing of the neighbouring rivers, owing to their beds becoming obstructed by landslips; and their waters carried down masses of mud impregnated with sulphur. Great rents were formed in the ground, whence noxious gases emanated. This earthquake is remarkable from the circumstance of its having been nearly simultaneous with severe shocks felt at Ochozk, on the eastern coast of Siberia. The distance, however, is too great to render it probable that these two earthquakes had their origin in the same internal disturbance—more especially as it was not felt in the intervening places. This improbability is heightened by the circumstance, that the earthquakes in New Grenada were repeated on the two following days, whereas those at Ochozk occurred only once, continuing from five to seven minutes.

In August 1827, fort Kolitaran, near Lahore, was shaken down, and about 1000 persons buried beneath its ruins. A hill in the neighbourhood fell bodily into an adjacent river, causing a considerable inundation of the country round. In November following, several of the West Indian Islands were sharply convulsed—particularly Martinique, where a number of buildings were overthrown. In Guadaloupe the earthquake was accompanied by a violent gale. The shock was felt at sea at a distance of 100 leagues from Martinique, and all the vessels in the several harbours of the islands were affected by it. The earthquake was repeated in Martinique on the following day, and again at the distance of a week.

On the 2nd of February 1828, the island of

Ischia, off the coast of Naples, was shaken with great violence. This earthquake was remarkable for the extreme loudness of three successive underground explosions, which were heard along the coasts of the islands. Several buildings were overthrown, with loss of life. The hot spring of Rica, in this island, had its temperature permanently increased after the earthquake. Two days after this event, the city of Tabasco in Mexico experienced a severe shock. The bank of the river on which it is situated sank thirty feet, and a small town higher up the river was overthrown.

On the 30th of March following, there was a destructive earthquake at Callao and Lima, which reduced a great portion of them to ruins. It was attended by a singular circumstance. There were several ships in the harbour, all of which were affected by the shock, but its force seemed to be concentrated on a French vessel of war. The crew first heard a noise like distant thunder; then the ship began to jolt, like a cart driven over a rough road, and it swung about fourteen inches on either side; the water all round commenced to hiss and boil, and to throw up bubbles of gas having a strong sulphurous smell, with quantities of dead fish. The water, which was twenty-five fathoms deep, and previously clear, became quite turbid. When the ship's anchors were weighed, the chain cable of one of them was found to have been half melted in a considerable part of its length, the links having been also stretched lengthwise. The chain cable of the other anchor had not sustained any injury, nor had those of any of the other ships in the bay at the time. This curious incident may have been due to one of two causes: The chain cable, which was half fused, may have come into contact with a small quantity of very hot lava, ejected from a fissure at the bottom of the sea where it lay; or a very powerful electrical discharge may have passed through the cable. But whatever the cause, the effect was most remarkable.

In the month of August of the same year, the southern parts of Georgia experienced a succession of shocks, during which great damage was done; partly by the overthrow of towns and villages, partly by the opening of chasms in which some were ingulfed. One village was buried by a great landslip from a neighbouring mountain, and three large springs of water issued from the cleft whence the earth had fallen. The ground was also rent in several other places, and water issued from the fissures. In the following month of September, Murcia and Valentia in Spain began to be agitated by a succession of shocks, which continued at intervals till 21st March 1829, when a severe and calamitous earthquake shook these provinces. Numerous towns and villages were overthrown, with great destruction of life. The most violent shock took place about half-past six in the evening, and was succeeded by nearly a hundred others during the night. The underground explosions resembled discharges of cannon. The ground was rent in many places — black mud, sand, and water being thrown out. From some of the fissures the sand came forth dry. The river Segura had its course changed, and it formed a new mouth. The water suddenly disappeared from a lake in Estremadura, and the vibrations were felt as far as Madrid. The shocks were repeated with less severity for some time afterwards.

The coasts of Thrace and Macedonia, with the adjacent island of Thaso, were, in the spring of 1829, twice violently shaken—on the 13th of April and 15th of May. The shocks were felt as far as Adrianople on the one side, and Salonica on the other. Much damage was done in both cities, and several small towns and villages were overthrown. Quantities of reddish water were suddenly poured forth from a mountain in the neighbourhood of the small town of Drama, which was totally destroyed. In the month of August the same year, there was a violent earthquake in New South Wales, accompanied by a dreadful tempest. The earth was raised up in distinct waves, and the ground was much rent in many places. In October following, Chili was again severely shaken, and many houses in Valparaiso and Santiago were thrown down, with much loss of life. On the 26th of November thereafter, Transylvania and the neighbouring countries experienced several smart shocks.

At Kisliar, in Circassia, there was a severe shock in March 1830, attended by a violent gust of wind. A mountain in the neighbourhood was cleft in twain, and one of the halves sank down considerably. Many houses were overthrown in the town and neighbouring villages, and several hundred lives were lost. In the following month of June, the province of Honan, in China, was so violently convulsed, that twelve towns were either overthrown or ingulfed in chasms, together with their inhabitants. Upwards of 6000 are said to have perished. This earthquake was accompanied by violent atmospherical disturbances—much thunder, wind, and hail-storms.

Several of the West Indian Islands had a severe visitation in August 1831—a calamitous earthquake, accompanied by a terrific hurricane and a volcanic eruption. The island of Barbadoes suffered most severely. The damage done to property was immense, and nearly 3000 persons perished. In October following, the coast of Peru, about Arica, was violently shaken, and many houses were overthrown in the town and neighbouring villages. This earthquake was attended by loud underground rumblings, and was felt at sea at a distance of 100 miles from the coast. The principal shocks were followed by a succession of others, of less intensity, till February, or during four months.

A large portion of the peninsula of Hindustan was violently shaken in August 1833. Three severe shocks were felt at Calcutta, and four at Lucknow. The centre of disturbance seems to have been at Katmandu, where the shocks were accompanied by very loud subterranean explosions. Many houses were overthrown there and at other places; while at Chupra a chasm of considerable length and depth was opened in the earth. The succession of shocks continued with more or less violence for twenty-four hours. In October of the following year, a portion of the country round Batavia was convulsed, and part of a mountain sank into the earth, causing the destruction of a village at its base.

The town of Acapulco, in Mexico, was totally destroyed in January 1835, and in the following month of February the coast of Chili was violently convulsed. Three shocks succeeded each other in quick succession—the first being less severe than the two by which it was followed. The shocks were repeated with less violence for about twelve days. The effects of the strong shocks were calamitous; the towns of Concepcion, Talcahuana, and Chillan having been wholly overthrown. The land along a considerable extent of the coast was elevated about four or five feet; but in the following month of April it partially subsided to within two or three feet of its former level. The permanent elevation was still more conspicuous in the island of Santa Maura, about twenty-five miles south-west from Concepcion. This island, which is about seven miles long by two broad, had its northern end raised no less than ten feet, and its southern about eight feet—the elevation being intermediate in the intervening space. The bed of the sea all round the island was also raised, and a similar elevation of the land was observed in some small islands near. The ground in many places along the coast of the mainland was rent, and from the fissures there came forth gases, mud, and salt water. The sea, after retreating from the coast, flowed in and again retired, but only to return with an enormous wave, which rushed up twenty-eight feet above high water-mark. This surge was succeeded by another still larger, followed by two smaller. A dense smoke was seen to issue from the sea in two places; and in one of them there was formed a whirlpool, resembling an inverted cone, as if the water were rushing into some cavity which had been opened underneath. The shocks were felt on board vessels at the distance of one hundred miles from the coast.

Mr. Darwin, in his "Voyage of the Beagle," gives an interesting account of this earthquake. On examining the ruins of Concepcion, he discovered some square ornaments on the coping of some walls, which had been moved by the earthquake into a diagonal position—much in the same manner as the upper part of the spire at Inverness was twisted round. A similar phenomenon has been observed at other places. During this earthquake, the island of Juan Fernandez, 360 miles north-east of Concepcion, was violently convulsed, and a submarine volcano near the shore burst into eruption. At Chiloe also, 340 miles to the southward of Concepcion, the earthquake was felt more strongly than in the intervening space; and two volcanoes in the neighbourhood of Chiloe burst into violent action. The surface agitated is estimated by Mr. Darwin at 720 miles in length, and 400 in breadth. In November of the same year, Concepcion was again shaken; and on the same day the volcano of Osorno, 400 miles distant, renewed its activity.

During the month of August 1835, the central parts of Asia Minor were severely shaken, particularly in and around Kaisarieh. A succession of shocks continued for six hours, the earth undulating like a tempestuous sea, with much underground noise resembling thunder. Mount Ardscheh, in the neighbourhood, emitted dense smoke and flames with loud noise, but without any eruption of lava. Many houses were overthrown in Kaisarieh and the neighbouring villages, for a circuit of more than thirty miles. One village was ingulfed, and a lake was formed in its place. The loss of life was considerable. In October following, Castiglione in Calabria was reduced to ruins, burying about one hundred of its inhabitants under the rubbish. On the 1st of the succeeding month of November, the southern Moluccas were convulsed in connection with a volcanic eruption in the island of Banda. The neighbouring island of Amboyna was severely shaken, with much destruction of buildings and loss of life. One of the shocks is said to have lasted for more than half a minute; but it is more probable that it was a rapid succession of several shocks that occurred in this interval of time. This earthquake was distinguished by the peculiarity of its having been preceded for three weeks by a dense sulphureous fog, probably an emanation from the volcano in Banda.

Unfortunate Calabria was again convulsed on the night of the 24th of February 1836, when the towns of Rossano and Croscia were reduced to ruins, and long deep fissures were formed in the earth. The sea retired forty paces at one part of the shore, and advanced to an equal extent at another. Volcanic substances and several strange species of fish were thrown up on the beach. An igneous meteor was observed during this earthquake.

On the 1st of January 1837, the central parts of Syria, between Beyrout and Damascus, were violently shaken. Many houses were overthrown, and between 3000 and 4000 of the inhabitants perished. Great rents were formed in the ground, and even in the solid rocks, while several new hot springs appeared. The water in the lake of Tiberias was much agitated during this earthquake, and the shocks were repeated with diminishing severity for about a fortnight. The extent of country affected was about five hundred miles in length by about ninety in breadth. In November of the same year, the coast of Chili was again convulsed, and the town of Valdivia reduced to ruins. The sea off the coast was greatly agitated, and a portion of the bed of the sea in the Archipelago of Chonos, off the coast of Patagonia, was permanently raised about eight feet.

The West Indian Islands of Martinique and Guadaloupe were again violently shaken in

January 1839, with overthrow of houses and loss of life. In the following March, San Salvador and Guatemala experienced severe shocks, during which a mountain fell, and buried an entire village with all its inhabitants. Rents in the ground were formed within the city, and many houses were ruined. The shocks were accompanied by horrible subterranean noises. Much about the same time the Burmese Empire was convulsed, specially about Amarapoora, by two severe shocks, attended with much underground rumbling. The shocks in San Salvador di Guatemala were renewed with great violence in October of the same year, and those in Burmah in March 1840 with destructive effects.

During the summer and autumn of 1840, Mount Ararat and its neighbourhood were greatly convulsed. The undulations of the ground were quite perceptible, and large fissures were seen to open and close again in sympathy with the wavy motion of the earth. There were also several vertical explosions accompanied by jets of water mixed with sand and gravel. Great landslips took place from the mountain and did immense damage—3000 houses having been overthrown, with great loss of life. In October following, the island of Zante, which is liable to numerous slight shocks, experienced one of unusual severity, which overthrew several villages. In May 1841 the island of Terceira, in the Azores, experienced a succession of severe shocks, attended by loud underground noises. Much damage was done by the overthrow of buildings, and a fissure a mile in length was formed along the shore. In the month of September following, an unusually violent and sudden shock was felt at Cartago, in Costa Rica, Central America, which was very destructive in its effects, both in the city and neighbouring villages—the whole country being strown with ruins. This shock was also felt in a modified degree in the United States.

Loodianah, Peshawur, and other parts of Western and Northern India were severely shaken in February 1842. The greatest damage was done at Jellalabad, whose defences, which had recently been repaired with great labour and care, were nearly all destroyed.

The foregoing annals bring down the history of the more disastrous, or otherwise remarkable earthquakes, to the end of the period embraced in Mr. Mallet's Reports to the British Association. The following chapter contains a brief account of those which have happened since that time.

CHAPTER V.

RECENT EARTHQUAKES.

THE Lesser Antilles were visited by a severe earthquake in February 1843. It was most calamitous in Antigua and Guadaloupe, especially in the latter. In Antigua the undulations of the ground were perceptible to the eye. The hills rocked to and fro, while huge masses were detached from them and hurled into the valleys beneath. The ground opened in large fissures, which immediately closed again. The town of Antigua was laid in ruins; but the black population being in the fields at the time, the loss of life was small. The water in the harbour was observed to whirl round and round in an extraordinary manner, and the islands in it were so enveloped in clouds of dust, as to be obscured from view. The town of Point à Pitre, in Guadaloupe, was so completely overthrown as to resemble a stone quarry, and 4000 persons perished either among the ruins or in the fires which were kindled in the woodwork of the ruined houses. There were numerous landslips in the neighbourhood of the town, and all the springs near it were immediately rendered dry. This earthquake was felt as far to the northward as Washington and Bermuda; and as far to the southward as Demerara. In the following month of March there were slight shocks in some parts of England and the Channel Islands. In these latter there was another slight shock in December.

On the 19th of February 1845, there was in New Grenada, South America, an earthquake attended by peculiar circumstances. The shock was felt chiefly in the plain traversed by the Lagunilla, a small tributary of the river Magdalena, and was accompanied by much noise. Immediately after the shock there was seen to issue from the ravine, in which the stream rises, a great flood of liquid mud, which flowed rapidly over the whole plain, carrying everything before it. Tall trees were swept down as if they had been straws, while houses and cottages were overwhelmed along with their inhabitants. Only a few of them escaped to the mountains, unfortunately to meet a worse death by perishing with hunger, the mountains being unapproachable through the sea of mud. A smaller number, who were near the edge of the torrent, escaped over branches of trees. The surface of land covered by this muddy inundation was about forty square miles.

In the month of April following, the city of Mexico was much shaken. A good deal of damage was done to buildings, especially to churches and other edifices of large size, several of which were reduced to ruins. The loss of life was moderate.

The East Indian peninsula was considerably disturbed by earthquakes during this year. There were repeated shocks felt at Calcutta, and one on the 7th of September was severe. During the month of July, there were several smart shocks in Assam. They were accompanied by much underground rumbling. Smyrna and its neighbourhood were severely shaken in September, when a good many houses were overthrown. Much rain accompanied the shocks, and some mineral springs, which for several years previously had run dry, began to flow afresh and exhale sulphurous odours. Demerara also experienced a smart shock this year.

The north of Italy was convulsed in March 1846. The shocks were felt at Genoa and Leghorn, where many houses were injured and some overthrown. Several villages throughout Tuscany were nearly destroyed; and at Volterra a government prison fell, and some of the prisoners were buried in the ruins. There was considerable loss of life throughout Tuscany, and Pisa was severely shaken. The Leaning Tower is said to have rocked in a wonderful manner, but it was not injured. The vaulted roof, however, of an old church fell. The chief peculiarity in this earthquake was that, in several places, jets of muddy boiling water sprang from the earth. The town of Catania in Sicily experienced several severe shocks during the following month of April. A good many houses and other buildings were rent, but none appear to have been overthrown. Towards the end of summer, a smart shock, accompanied by loud underground rumbling, traversed the Duchy of Nassau in Germany.* Smyrna was more severely visited in August, several minarets and houses having been overthrown, and a few people killed. The sea was greatly agitated, but the atmosphere was serene. The shock extended to Mytelene. In November following, a smart but harmless shock traversed the county of Perth, accompanied by underground rumbling.

In 1847 there were only two harmless shocks —one at Catania in Sicily, and one at Fécamp on the coast of Normandy. New Zealand was visited by a long succession of smart shocks in 1849. That part of Asia Minor lying between Brusa and Kutahya was smartly shaken in 1850. Valparaiso and its neighbourhood experienced a severe shock in April 1851, and at Casa Blanca, about thirty miles distant, it was

* Personally experienced.

so violent as to overthrow several houses. The kingdom of Naples, however, was visited by a more disastrous shock in the month of August following. Many of the smaller towns had most of their houses overthrown, and some were completely reduced to ruins. Nearly one thousand persons lost their lives, and a great many were severely injured. The province of Basilicata, bordering on Calabria the tremulous, suffered most.

During the year 1852 there were shocks felt in Jamaica, in Cuba, at Acapulco in South America, in Scotland, and in Wales. Those in the three first-named places, though severe, were harmless; the other two were slight. The shock at Caernarvon in Wales was preceded by a peculiar electrical condition of the air, which was hot and oppressive. The bells in the town were thrown into a vibratory condition, and emitted a humming noise like what they give forth for some time after being tolled. The shock itself was of a very tremulous character, and accompanied by loud underground rumbling. In November of the same year there was also a severe earthquake in Java, which overthrew many houses, but fortunately without loss of life. It was accompanied by a great sea-wave, which thrice rolled in with terrific violence.

The year 1853 proved very calamitous. On the 1st of January smart shocks were felt in

Jersey, and—at the Antipodes—Cape Egmont in New Zealand. Upper Canada experienced a rather severe shock on the 13th of March, and there was one at Brighton on 1st April, which was felt on the opposite French coast. On the 21st of the same month, Schiraz in Persia was visited by a most disastrous earthquake, during which the city was almost entirely overthrown, and nearly 12,000 persons perished. The shocks continued at intervals during five days. Cumana in Venezuela, on the 15th of July following, experienced a tremendous shock, which overthrew all the public buildings, and nearly the whole of the private houses; 4000 persons perishing in the ruins, while many others sustained grievous injuries. The bridge across the river Manzanares, connecting the two sides of the town, was also thrown down. During this earthquake there were opened several clefts in the ground, whence boiling water gushed forth. On the 18th of the following month of August, the northern parts of Greece were much shaken, and many houses in Thebes were overthrown with considerable loss of life. The shocks continued at intervals for eight days. On the 20th of September shocks were felt at Hobart Town in Tasmania.

The city of San Salvador in Guatemala was reduced to a heap of ruins on the night of the 16th of April 1854; only a single public building and a very few private houses having been left standing. Nearly 5000 of the inhabitants were buried in the rubbish. There was a premonitory shock before the great one, otherwise the loss of life would have been even more terrible. Slight shocks were felt in the south of France on 20th July, at Nice on 28th December, and at Alessandria and Turin on the following day. On the 23rd of this month there was a dreadful shock in the island of Niphon, one of the Japanese group. It was accompanied by a succession of great sea-waves, which caused the total wreck of the Russian frigate *Diana*, lying at the time in the bay of Simoda. At 9·45 A.M. the crew observed the ship to be violently shaken for about a minute, and at ten o'clock an immense wave came rolling into the bay, and, running up the beach, immersed the village of Simoda, driving a large Japanese junk ashore. The frigate held to her anchors; but the rise of the wave on the shore gave to those on board the impression that their ship was sinking. The water, in about five minutes, rushed out of the bay, but only to return with greater violence, causing the frigate to drag her anchors. This wave washed ashore all the boats, and on its retreat swept both them and the ruins of the village in an indiscriminate mass of confusion into the bay. A third still more powerful wave followed, and on its retirement the bay became agitated with many whirlpools. The frigate had sustained so much damage that she eventually became a total wreck. On shore the destruction was complete. The Japanese village was wholly swept away, and three hundred of its inhabitants perished. A column of smoke was seen on a distant hill, and a strong smell of sulphur pervaded the air. On the following day the tide rose to a great height on the opposite coast of China.

New Zealand was visited by a succession of shocks in January 1855. The first and most severe happened on the 23rd. The ground was much riven in many places. Some of the fissures opened and closed again, while others threw out water. Several houses were thrown down, and a few people killed. The sea-coast in the neighbourhood of Wellington, on the northern shore of Cook's Straits, was permanently elevated two feet by this earthquake. A shock was felt much about the same time at Truro, South Australia. A terrible earthquake shook the opposite coasts of the Sea of Marmora on the 28th of February 1855. Several minarets were thrown down in Constantinople, and several chimney-stalks, among others those of the British embassy. But it was in Brusa, on the southern coast, that this earthquake proved so calamitous. Here the shocks were repeated at intervals for five days. Nearly the whole town was overthrown by the shock of 28th February, and many of the inhabitants were killed. A storm of thunder, lightning, and rain preceded this shock, and the air was pervaded by a strong smell of sulphur. Large masses of rock were detached from Mount Olympus, and some houses were crushed by their fall. Several new hot springs made their appearance in the neighbourhood after this earthquake. On the 25th of July a smart shock traversed parts of Switzerland, Lombardy, and the south of France.

The next year, 1856, proved specially prolific in earthquake shocks. They were felt in California, the Punjab, in parts of China, in Egypt, in the Caucasus, in Malta, at Rhodes, in Candia, at Palermo, and in Wiltshire. The shock in China reduced to ruins the town of Yoo-Tching, with much loss of life. In Cairo two mosques and one hundred and twenty houses were thrown down, and a few people were killed. At Schemcka in the Caucasus many houses were overthrown, yet with small loss of life. But Canea, the chief port in the island of Crete, was the greatest sufferer. On the 11th of October nearly the whole town was overthrown, only eighteen remaining out of 3620 houses. Upwards of seven hundred people lost their lives. The other shocks of this year were harmless—those in California numerous.

On 9th October 1857, in Illinois, United States, there was a smart shock preceded by a remarkable electrical condition of the atmosphere, during which there was observed a luminous appearance, described by some as a meteor, by others as vivid flashes of lightning; the sky at the same time wearing a tempestuous aspect. In December following, the kingdom of Naples was severely convulsed. On the 7th there was a smart shock, which threw down the cone of Mount Vesuvius; but on the 16th the city of Naples was much more sharply shaken; several houses were ruined, but no lives were lost. At other places in the kingdom, however, the shock proved greatly more calamitous. Potenza, Polla, and other towns and villages were completely overthrown. In the territory of Bela there were several great landslips from the mountains, which did immense damage. Part of the road between Pertosa and Polla was carried away bodily to the distance of two hundred feet, and the mountain above it was cleft in twain. By this earthquake 30,000 persons are said to have lost their lives, and 250,000 to have been rendered houseless. A luminous meteor preceded the shock, and the air was pervaded by a strong sulphureous smell. Vesuvius was quiet during these convulsions, but became active soon after they ceased. During the shock of the 16th, the magnetic needles in the Observatory at Brussels were violently agitated.

The shocks throughout the kingdom of Naples were renewed in the months of March and April 1858; but fortunately they passed over without doing much damage. The kingdom of Mexico was severely convulsed on the 19th of June following, with great destruction both to property and life. In the city of Mexico itself there were several fissures opened in the streets. In September there was a slight shock in Dorsetshire, and on the 11th of November a severe one in Lisbon. In the city itself some of the houses were rent; but in a small town about twenty-five miles higher up the Tagus, some houses were overthrown and several lives were lost.

On the 22nd of March 1859, the beautiful city of Quito, in point of situation the highest in the world, was visited by a tremendous shock. In little more than a minute, the entire city was nearly reduced to ruins. Almost all the private houses were overthrown, and the public buildings sustained immense damage—some of the fine churches having been partially ruined. Fortunately the loss of life does not appear to have been great. Several other towns in the neighbourhood were destroyed. Quito, though situated in a plain, on the flank of the volcano of Pichinca, had previously enjoyed a comparative immunity from earthquakes so remarkable, as to have excited surprise in the mind of Baron Humboldt. There was a slight shock felt in Cornwall on the 18th of September of the same year, and it was renewed on the 13th of January following. In December 1859, the State of San Salvador in Central America was sharply convulsed, and many houses in different towns and villages were overthrown. The distance traversed by the shock appears to have been about 150 miles. During this earthquake, several large holes and fissures were opened in the earth—some of them 100 yards wide. On the 3rd of September 1860 there was a slight shock felt in the county of Kent.

The island of Sumatra was, in February 1861, visited by a violent shock, accompanied by a great sea-wave, and considerable subsidences of the dry land. A small island, with a fort and magazines on it, called Singkel, was almost wholly ingulfed in the sea. At Polo Nyas, the great wave, dashing upon the shore, overthrew the fort, and on retiring swept away forty-nine soldiers and Malays. On other parts of the coast much damage was done in a similar manner—the sea rushing in, destroying houses and sweeping away the inhabitants. Several villages were overthrown by the earthquake itself, and some hundreds of persons were buried in the ruins. The earth rose and fell visibly in different parts; and there were opened several fissures whence boiling water gushed forth, while other clefts simply opened and closed again. The centre of disturbance was probably at the bottom of the sea near the coast.

The western portions of La Plata were severely convulsed on the 20th of March 1861. The city of Mendoza was entirely overthrown, and a large part of San Juan, on the eastern slope of the Andes. The number of persons who perished was, in the former place, between 6000 and 7000, and in the latter about 3000. As far to the eastward as Cordova, the shock was so severe as to throw down part of the church, and even at Buenos Ayres the tremor was sensibly felt. This earthquake was preceded by a remarkable storm and the fall of a hot rain, which drove the people into their houses for shelter—thus greatly contributing to augment the loss of life. There appears to have been a connection between this earthquake and a volcanic eruption in the Andes—showers of ashes and broken masses of rock having fallen in one of the passes.

The island of Rhodes experienced a severe shock on the 22nd of April 1863. Many of the public buildings and private houses in the city were overthrown, as were also those in the various villages scattered throughout the island. Several hundred persons were buried under the ruins. A succession of slighter shocks continued for several days, after the first and disastrous convulsion. The city of Manilla had a similar calamitous visitation on the 3rd of July. There was much destruction of buildings, and nearly 1000 of the inhabitants perished. The captains of ships lying in the harbour observed a curious luminous appearance over the city at the time of the earthquake, and the shocks produced the same effect on board as if the ships had struck on a rock. There were two distinct shocks; one running from north to south, the other from east to west, and both happened within a minute. The central and western parts of England experienced, on the 6th of October, a somewhat smart shock, accompanied in some parts by subterranean noises. On the 18th of the following month of November, there was felt, in the neighbourhood of the lake of Como, a shock attended by a great landslip from the mountain of Molina. The masses of earth and stone fell upon four houses and buried them with their inmates, fifty-five in number. Both the lakes of Como and Lugano were much agitated by the convulsion.

There were three slight shocks felt in England during the year 1864—on the 2nd of January at Beeston near Nottingham; on 21st August at Lewes in Sussex; and on 20th September in parts of Hampshire. There was a rather sharp shock in the island of St. Helena on the 15th of July. One of greater severity traversed part of Mexico on the 3rd of October. It was less severe in the capital than at Puebla, where several public buildings and a large number of houses were overthrown, with considerable loss of life. The earthquake was felt along the whole line between the cities of Mexico and Vera Cruz.

In 1865 there were four earthquakes, but none of them disastrous. One was on the 7th of May, at Comrie in Scotland; the second was in Styria on the 13th of July; the third, on the 18th of the same month, was felt by the crews of two vessels in the Mediterranean, a little to the northward of Oran, on the northern coast of Africa. On the 11th and 12th December, there were several smart shocks in Tuscany. The centre of disturbance appears to have been at Fierenzuola, about twenty-eight miles north of Florence. Happily this, the last year of our annals, passed over without loss of life from this dreadful scourge.

The foregoing sketch of earthquake history conveys only a somewhat vague idea of the nature of these tremendous phenomena—of their extreme frequency, their wide distribution, and their calamitous consequences. To enable the mind to acquire a more lively impression, and realize to itself the horrors of such a catastrophe and its attendant circumstances, it is needful to go into more minute details in a few selected cases. None appear so well adapted to this purpose, as the great earthquakes of Lisbon, Calabria, and Riobamba. The three following chapters shall, accordingly, be devoted to a condensed account of the particular incidents of those three events.

CHAPTER VI.

THE GREAT EARTHQUAKE OF LISBON.

ON the night of the 31st of October 1755, the citizens of the fair city of Lisbon lay down to sleep, in merciful ignorance of what was awaiting them on the morrow. The morning of the 1st of November dawned, and gave no sign of approaching calamity. The sun rose in his brightness, the warmth was genial, the breezes gentle, the sky serene. It was All Saints' Day—a high festival of the church of Rome. The sacred edifices were thronged with eager crowds, keen to enjoy the gorgeous ceremonial with which the priests of that communion fascinate the imaginations, and inthral the intellects of their people—dazzling their eyes with splendid spectacles, ravishing their ears with grand and solemn music.

The ceremonies being now in full progress, the assembled throngs are suddenly startled from their devotions. The ground beneath them begins to "grate harsh thunder." The horrible sounds drown the peal of the organs and the voices of the choirs. These underground thunders having rolled away, an awful silence ensues. The panic-stricken multitudes are paralysed with terror. Forthwith the ground begins to heave with a long and gentle swell, producing giddiness and faintness among the people. The tall piles sway to and fro, like willows in the wind. Shrieks of horror rise from the terrified assemblies. Some invoke the Virgin Mary—but she hears them not; others their patron-saint — but he is deaf. Many rush in crowds to escape from the buildings, they are prevented by others rushing in, as to a place of safety. Again the earth heaves, and this time with a longer and higher wave. Crash! Down come the ponderous arches, the stately columns, the massive walls, the lofty spires, tumbling upon the heads of priests and people. The graven images, the deified wafers, and they who had knelt in adoration before them—the worshipped and the worshippers—are, in a moment, buried in one undistinguishable mass of horrible ruins. Only a few, who were nigh the doors, escaped to tell the tale.

Nor fares it better with those who had remained in their dwellings. The terrible earth-wave has overthrown the larger number of the private houses in the city, burying their inhabitants under the crumbling ruins. Those who were in the streets have more generally escaped. The foot-passengers indeed have been killed or severely injured by the falling materials; but those who were in carriages have for the most part remained unhurt, as have also the inhabitants of the few houses that have not been thrown down.

The simultaneous sudden overthrow of so many buildings raises vast volumes of fine dust, which fill the atmosphere and obscure the sun, producing a palpable darkness. Meanwhile the air trembles with the most doleful sounds—the groans of agony from the wounded and the dying; the screams of despair from the horrified survivors; the wails of lamentation from the suddenly bereaved; the dismal howlings of the dogs, and the terrified cries of the other animals.

In two or three minutes the clouds of dust fall to the ground, and disclose the scene of desolation which a few seconds have wrought. The ruin, though general, is not universal. There are still a considerable number of houses left standing—fortunately tenantless; for a third great earth-wave traverses the devoted city, and most of the buildings which had withstood the previous shocks, already severely shaken, are entirely overthrown. Lisbon is reduced to chaos.

A sudden impulse now seizes the surviving citizens to escape from the scene of devastation. They stay not to succour those only half buried in the ruins. The instinct of self-preservation wings their flight. The more fortunate of the fugitives run in the direction of the open country, and succeed in saving their lives; but a great multitude rush down to the harbour, thinking to escape by sea. Here, however, they are met by a new and unexpected foe. The tide, after first retreating for a little, comes rolling in with an immense wave, about fifty feet in height, carrying with it ships, barges, and boats, and dashing them in dire confusion upon the crowded shore. Overwhelmed by this huge wave, great numbers are, on its retreat, swept away into the seething waters and drowned. A vast throng, however, have taken refuge on the fine new marble quay, which has been but recently completed, having cost much labour and expense. These the great sea-wave has spared, sweeping harmlessly by them. But, alas! it is only for a moment. The vast structure itself, with the whole of its living burthen, sinks instantaneously into some awful chasm, which had opened underneath. The mole and all who were on it, the boats and barges moored to its sides, all of them filled with people, are in a moment utterly ingulfed. Not a single corpse, not a shred of raiment, not a plank nor a splinter float to the surface, and a hundred fathoms of water have covered the spot.* To the first great sea-wave several others succeed, and the bay continues for a long time in a state of tumultuous agitation.

About two hours after the first overthrow of the buildings, a new element of destruction came into play. The domestic fires of the ruined houses, having been scattered in all directions, inflamed the timbers, and a vast conflagration, urged by a violent wind, soon raged among the ruins, consuming everything combustible, and completing the wreck of the city. This fire, however, which lasted four days, was not altogether a misfortune. It consumed the thousands of corpses which would otherwise have tainted the air, adding pestilence to the other misfortunes of the survivors. They were threatened, nevertheless, with an enemy not less appalling; for famine stared them in the face. Almost everything eatable, within the precincts of the city, had been consumed. A set of wretches, moreover, who had escaped from the ruins of the prisons, prowled among the rubbish of the houses in search of plunder, so that whatever remained in the shape of provisions, fell into their hands and was speedily devoured. They also broke into the houses that remained standing, and

* This cavity appears to have been subsequently filled up; as there are not more than five fathoms of depth at the present time, 1866.

rifled them of their contents. It is said that many of those who had been only half crushed by the ruins, and might have escaped by being extricated, were ruthlessly murdered by those merciless villains.

The total loss of life by this terrible catastrophe is estimated at 60,000 persons, of whom about 40,000 perished at once, and the remainder died afterwards of the injuries and privations they sustained. Twelve hundred were buried in the ruins of the general hospital, eight hundred in those of the civil prison, and several thousands in those of the convents. The loss of property amounted to many millions sterling—even that of the English merchants alone amounting to several millions.

Although the earth-wave traversed the whole city, the shock was felt more severely in some quarters than in others. All the older part of the town, called the Moorish quarter, was entirely overthrown; and of the newer part, about seventy of the principal streets were ruined. Some buildings that withstood the shocks were destroyed by the fire. The cathedral, eighteen parish churches, almost all the convents, the halls of the inquisition, the royal residence, and several other fine palaces of the nobility and mansions of the wealthy, the custom-houses, the warehouses filled with merchandise, the public granaries filled with corn, and large timber yards with their stores of timber, were all either overthrown by the earthquake, or consumed by the flames.

RUINS OF THE CATHEDRAL—LISBON.

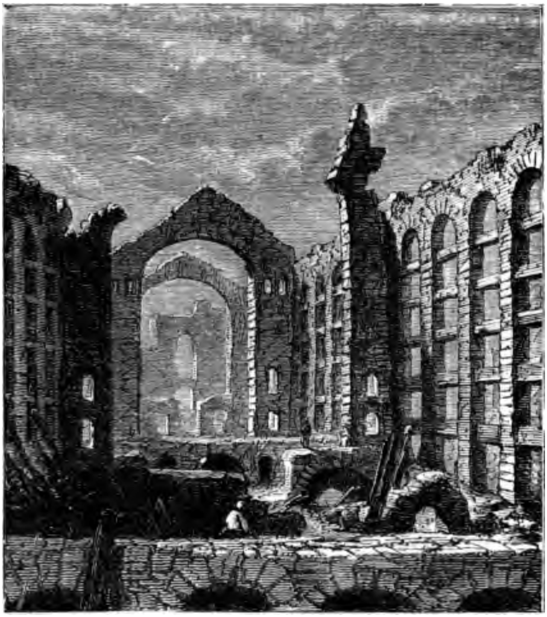
The woodcuts, on this and the following pages, show the appearance presented by the ruins of the Cathedral, the churches of St. Paul and St. Nicolas, and of the Opera-house, shortly after the catastrophe, as represented in engravings taken at the time.

RUINS OF THE CHURCH OF ST. PAUL—LISBON.

The almost total destruction of Lisbon did not terminate the miseries of her citizens. Nearly all the corn and other provisions stored in the city had been destroyed. A few sacks of grain had been rescued from the ruins; but no means remained of converting them into bread, so that starvation seemed imminent.

RUINS OF THE CHURCH OF ST. NICOLAS—LISBON.

The king and court were fortunately not in Lisbon at the time of this great disaster, but were living in the neighbourhood at the castle of Belem, which happily sustained no injury. The royal family, however, were so alarmed by the shocks, that they passed the following night



RUINS OF THE OPERA-HOUSE--LISBON.

in carriages out of doors. None of the officers of state were with them at the time.

On the following morning the king hastened to the ruined city, to see what could be done towards restoring order, and administering to the care of the wounded, and supplying the hungry multitudes with food. The people were fortunate in having, on this trying occasion, a monarch so able and energetic as Joseph I., and at the head of affairs a minister of such administrative talent as the Marquis Pombal.

The king and queen, with the members of their family and court, exerted themselves to the uttermost—the ladies devoting themselves to the preparation of lint and bandages, and to nursing the wounded, the sick, and the dying, of whom the numbers were overwhelming. Among the sufferers were men of quality and once opulent citizens, who had been reduced in a moment to absolute penury. The kitchens of the royal palace, which fortunately remained standing, were used for the purpose of preparing food for the starving multitudes. During the first two or three days, it is said that a pound of bread was worth an ounce of gold. One of the first measures of the government was to buy up all the corn that could be obtained in the neighbourhood of Lisbon, and to sell it again at a moderate price to those who could afford to buy, distributing it gratis to those who had nothing to pay.

It was needful also to provide shelter for the houseless thousands whose homes lay in ruins. Not many were so bold as to seek a retreat in the few houses left standing; for most of them were rent and tottering to their fall. A large encampment was formed with the military tents that could be procured from the neighbouring arsenals, and wooden barracks were erected with the utmost possible despatch. Into these, as well as into the tents, were brought quantities of hay and straw, on which the people might lie. The king also organized parties to examine the ruins, and endeavour to extract any persons who might be found entangled among them, but still alive. Not a few were, even after the lapse of several days, found yet breathing, and on being rescued from their perilous position, were restored to life.

This great earthquake was followed by a succession of shocks for about a month, during which nearly thirty were reckoned, some of them severe. It was several months before any of the citizens could summon courage to begin rebuilding the city, which, meanwhile, presented little else than great mounds of ruins, with passages between them, marking the positions of the former streets. At first they began erecting houses built of wood, which were imported from Holland, all ready to be put together. But by degrees their confidence returned. The earth had relapsed into repose, and they set about the task of rebuilding with so much energy, that in ten years Lisbon again became one of the most beautiful capitals of Europe.

The most distinguishing peculiarities of this earthquake were the swallowing up of the mole, and the vast extent of the earth's surface over which the shocks were felt. Several of the highest mountains in Portugal were violently shaken, and rent at their summits; huge masses falling from them into the neighbouring valleys. These great fractures gave rise to immense volumes of dust, which at a distance were mistaken for smoke by those who beheld them. Flames were also said to have been observed: but if there were any such, they were probably electrical flashes produced by the sudden rupture of the rocks.

The portion of the earth's surface convulsed by this earthquake is estimated by Humboldt to have been four times greater than the whole extent of Europe. The shocks were felt not only over the Spanish peninsula, but in Morocco and Algeria they were nearly as violent. At a place about twenty-four miles from the city of Morocco, there is said to have happened a catastrophe much resembling what occurred at the Lisbon mole. A great fissure opened in the earth, and an entire village, with all its inhabitants, upwards of 8000 in number, were precipitated into the gulf, which immediately closed over its prey. The earthquake was also felt as far to the westward as the West Indian Islands of Antigua, Barbadoes, and Martinique, where the tide, which usually rises but two feet, was suddenly elevated above twenty feet; the water being at the same time as black as ink. Towards the north-west, the shock was perceptible as far as Canada, whose great lakes were all disturbed. Towards the east, it extended to the Alps, to Thuringia, and to Töplitz, where the hot springs were first dried up, and soon after overflowed with ochreous water. Northward, it reached the British Islands. In Scotland the waters both of Loch Lomond and of Loch Ness rose and fell repeatedly. Towards the north-east, the shock was sensibly felt throughout the flat country of Northern Germany, in Sweden, and along the shores of the Baltic.

At sea, 2° 18′ to the southward of Lisbon, the ship *Denia* was strained as if she had struck on a rock; the seams of the deck opened, and the compass was upset. On board another ship, forty leagues to the westward of Cape St. Vincent, the shock was so violent as to toss the men up perpendicularly from the deck. The great sea-wave rose along the whole southern and western coasts of Portugal and Spain; and at Cadiz is said to have risen to a height of sixty feet. At Tangier, on the northern coast of Africa, the tide rose and fell eighteen times in rapid succession. At Funchal in Madeira, where the usual ebb and flow of the tide is seven feet, it being half tide at the time, the great wave rolled in, and at once raised the level of the water fifteen feet above high water-mark. This immense tide, rushing into the city, caused great damage, and several other parts of the island were similarly flooded. The tide was also suddenly raised on the southern coast of Ireland; the shock was sensibly felt at Cork, and a sudden rise of the tide followed soon after. At Kinsale, a large wave rushed into the harbour, whirling round the vessels lying there, and then dashed into the market-place.

All these facts tend to show that the convulsion which produced the great Lisbon earthquake, must have had its origin at a great depth under the bed of the Atlantic, somewhere off the coast of Portugal, and that the disturbance must have been of a very violent kind. It is said that the convulsion affected only the tertiary strata, and that buildings erected on the secondary strata escaped injury. If so, it would follow that the seat of the disturbance was near the junction of those two formations, under the bed of the ocean.

CHAPTER VII.

THE GREAT CALABRIAN EARTHQUAKES.

WHILE affecting a far less extensive area, consequently having their origin at a more moderate depth, the Calabrian earthquakes of 1783 were in their continuance longer than those of Lisbon, and in their local intensity more severe. The first violent shock took place on the 5th of February, and a second equally severe on the 28th of March following; but the country continued to be agitated by shocks of more or less severity, and separated by longer or shorter intervals, until the end of 1786, or during nearly four years. Although the shocks were perceptible over a great part of Sicily, and as far north as Naples, the area, which was severely convulsed, did not exceed five hundred square miles, comprehending the south-eastern parts of the nearer, the whole of the further Calabria, and the neighbourhood of Messina on the opposite coast of Sicily. Nevertheless, in the month of March 1783, the Ionian islands of Zante, Cephalonia, and Sta. Maura were sympathetically convulsed, and in the latter island in particular much damage was done both to life and property.

The centre of disturbance seems to have been under the town of Oppido in the further Calabria, and it extended in every direction from that spot to a distance of about twenty-two miles, with such violence as to overthrow every city, town, and village, lying within that circle. This ruin was accomplished by the first shock on the 5th of February. The second, of equal violence, on 28th March, was less destructive, only because little or nothing had been left for it to overthrow.

At Oppido, the motion was in the nature of a vertical upheaval of the ground, which was accompanied by the opening of numerous large chasms, into some of which many houses were ingulfed—the chasms closing over them again almost immediately. The town itself was situated on the summit of a hill, flanked by five steep and difficult slopes. The whole town was so completely overthrown by the first shock, that scarcely a fragment of wall was left standing. The hill itself was not thrown down; but a fort, which commanded the approach to the place, was hurled into the gorge below. It was on the flats immediately surrounding the site of the town, and on the rising grounds beyond them, that the great fissures and chasms were opened. On the slope of one of the hills opposite the town, there was opened a vast chasm, in which a large quantity of soil covered with vines and olive trees was ingulfed. This chasm remained open after the shock, and

CHASM NEAR OPPIDO, CALABRIA.

exhibited the appearance represented in the above woodcut. It was somewhat in the form of an amphitheatre, and notwithstanding all it had swallowed, it retained a depth of 200 feet, and was about 500 feet in length.

At Canna-Maria, in the adjacent district, another chasm opened and swallowed up four farm houses, several oil-stores, and some large dwelling-houses. This voracious gulf immediately closed again, so that not a vestige of the buildings remained visible. Similar occurrences took place at Sinopoli, Sta. Christina, and Terranuova. This last town stood at the end of a plain immediately above three deep gorges. At the first shock, part of the ground on which the town was built was riven away, and glided down the slope of one of the three gorges, dragging along with it the houses which it sustained. The whole fell, in a confused mass of timber, stones, and earth, into the valley beneath, which it partially filled. In another quarter of the town the ground was rent perpendicularly throughout its entire height above the valley; and one portion of the land thus severed, with all the houses upon it, tumbled in one mass, by a perpendicular fall of upwards of 300 feet, into the gulf below. Out of the 2000 inhabitants of the town, 1400 were precipitated with their dwellings, and many were crushed or buried under the ruins. A few, however, marvellously escaped, by being thrown upon the top of the rubbish, instead of under it. Some even landed on their feet, and were able to scramble over the heaps of ruins; while others, being only half buried, were extricated without having sustained much injury. Terranuova was thus turned topsy-turvy; the three valleys, above which it had stood, were half filled with the masses of earth and rubbish. Among other strange appearances which the ruins presented, the masonry of the well of a convent remained standing like a tower about eight or nine feet in height, and slightly inclined.

These great landslips stopped the course of a small river, and the outlets of an abundant spring,—so producing two small lakes, whose stagnant waters, rendered putrid by the numerous corpses and other organic matters, exhaled pestiferous miasms, which cut off by fever the remaining inhabitants. Landslips also occurred in several of the neighbouring valleys, and the level ground all round was much rent by fissures.

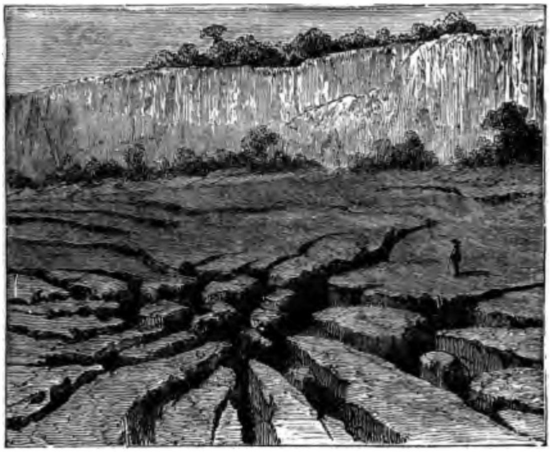
The village of Moluquello, opposite Terranuova, shared a similar fate. One half of it fell into a valley on its right, and the other into a valley on its left; so that scarcely a cart-load of masonry remained on the original site. When, after the lapse of several years, excavations were made among the ruins of Terranuova, the walls of the buildings and their contents were found to have been crushed into one compact mass.

In some of the valleys where the landslips had occurred, oaks, olives, vines, and corn were seen growing at the bottom of the ravines, having apparently sustained as little injury as the vegetation remaining on the ground 500 feet higher and three quarters of a mile distant, whence the travelled earth had been launched. In one ravine, a huge mass, 200 feet high and

CLEFT IN HILL OF ST. ANGELO, NEAR SORIANO.

with a base of 400 feet, which had been detached by a former earthquake, travelled bodily down the slope of the valley to a distance of four miles.

Among the many curious fissures formed by the great shock, there was one which remained open by the side of a small pass over the hill of St. Angelo, near Soriano, and not far from the little river Messima. Though not of large dimensions, it is remarkable for its crescent form, as shown in the prefixed woodcut.



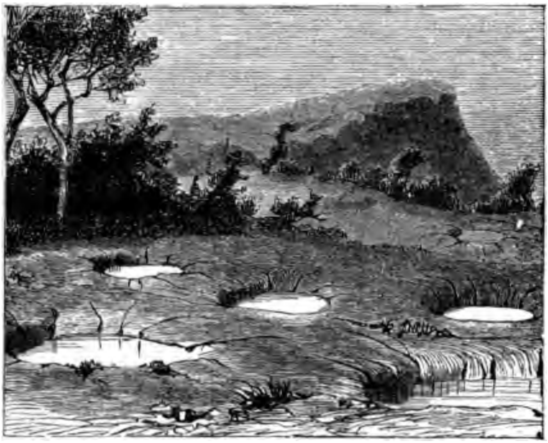
FISSURES NEAR JEROCARNE.

On a level piece of ground at another place, named Jerocarne, there were formed numerous fissures which remained open. They ran in all directions, giving the ground the appearance of having been shivered like glass. These remarkable rents are shown in the above woodcut.

Some of the fissures found in other places were of very large dimensions, and may have been partially enlarged by the successive shocks —particularly that of the 28th March. A calcareous mountain named Zefirio, at the southern extremity of the further Calabria, was cleft in twain, leaving a rent nearly half a mile long, and with an irregular breadth of many feet. In the district of Plaisano, there was formed a ravine nearly a mile long, 105 feet wide, and 30 feet deep. In this same district there were opened two large gulfs—one at a place called Cezulle, three quarters of a mile long, 150 feet broad, and above 100 feet deep; another at La Fortuna, nearly a quarter of a mile long, 30 feet wide, and 225 feet in depth. In the district of Fosolano there were opened three similar gulfs —one measuring about 300 feet square by 30 feet deep; a second about 750 feet square; and a third nearly half a mile long, 15 feet broad, and 30 feet deep. In the territory of San Fili there was formed a cleft half a mile long, 2½ feet wide, and 25 feet in depth.

A similar cleft was formed in the district of Rosarno. The town of that name, built on a sandy hill near the river Metramo, was almost entirely overthrown—the castle of the prince, the churches, and the houses, forming one great heap of ruins. The river ceased to flow for a short time. In the neighbourhood of this town was exhibited in a marked manner the curious phenomenon which presented itself in several other parts of Calabria—namely, the formation of numerous circular openings in the ground, as shown in the subjoined woodcut.

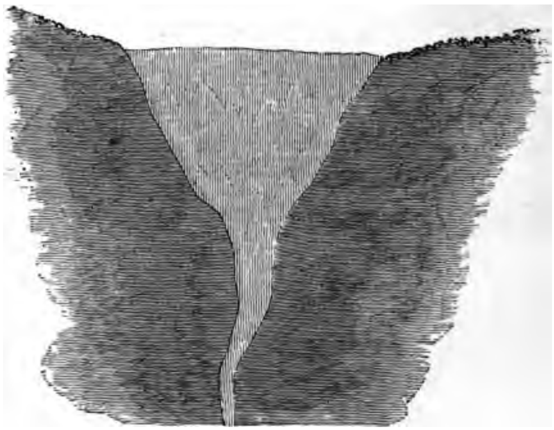
These holes were in general about the size of



CIRCULAR OPENINGS NEAR ROSARNO.

a carriage-wheel, some larger, some smaller. Many of them were filled with water to within a foot or two of the surface, and presented the appearance of wells. But a larger number were filled with dry sand, having in some cases a convex, in others a concave surface. On being laid open, these cavities were found to be funnel-shaped; a portion of moist sand in the centre showing the tube, through which the water had risen. The following woodcut represents a section of one of those conical openings.

A small circular pond of a like character was formed in the neighbourhood of Polistena,



SECTION OF CONICAL OPENING.

a rich and populous town separated into two parts by a river. This town was completely overthrown, not a house having been left standing. A part of the bank of the river gave way, dragging down the houses with it. One half of the inhabitants perished, and the other half found refuge in wooden barracks beyond the walls. There were numerous large fissures formed near the town, one of which is represented in the subjoined woodcut.

Besides the small circular openings above mentioned, there were formed several larger

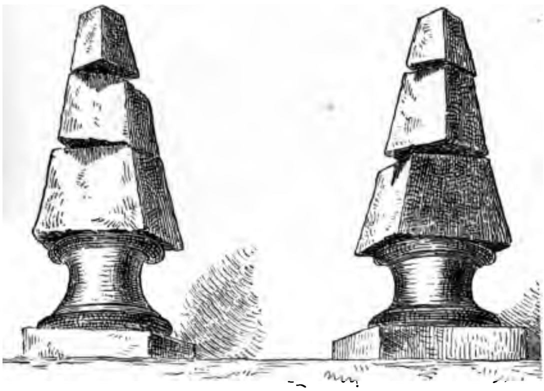
FISSURE NEAR POLISTENA.

hollows filled with water. Near Seminara, there was opened a large chasm, whence water issued and formed a lake 1785 feet in length, 937 in breadth, and 52 in depth. It was named Lago del Tolfilo, and all attempts to drain it have proved unsuccessful, owing to its being fed by springs rising from the bottom. Another lake of still greater dimensions was formed near Sitizzano, but in a different way. A valley was filled up, nearly to the level of the high grounds on either side, by great landslips from the bounding hills. A barrier was thus formed athwart the course of two streams, whose waters erelong accumulated into a lake of great depth, nearly two miles in length and a mile in breadth. No less than fifty other lakes of smaller size were formed, either by the opening of chasms or the filling up of valleys, besides numerous small ponds.

Instead of the circular holes before mentioned, there were in several places formed conical mounds of sand, supposed to have been thrown up by jets of water, similar to those which had formed the funnel-shaped hollows.

Among the many curious effects produced by this earthquake, there were observed several instances of the peculiar twisting of pieces of masonry, similar to that which occurred in the case of the spire at Inverness, and to those noticed by Mr. Darwin at Concepcion. One of the most remarkable was at a small town named Stefano del Bosco. At the ends of the façade of the convent of St. Bruno there stood two obelisks, the stones of which were displaced in this peculiar manner, as shown in the annexed figure; the angles of the upper stones being brought to coincide with the faces of the stones below them.

Another still more curious effect was produced in some of the towns and other places where loose masses happened to be lying on the ground at the time. These were, by the force of the shock, tossed high into the air, and



OBELISKS AT ST. BRUNO.

several paving stones, thus projected, landed with their faces downwards.

Of the fissures formed in the ground a good many closed again by slow degrees, after sundry extraneous substances, and even animals, had fallen into them; so that, if the rocks ever happen to be exposed to view, future geologists will find in them veins filled with organic remains, perhaps mingled here and there with stray works of art.

A rather remarkable phenomenon occurred at St. Lucido, similar, however, to what has occurred during earthquakes elsewhere. This was a great eruption of mud. About two miles from Laureana are two ravines which had a swampy soil. Immediately before the first great shock there oozed out from this soil quantities of calcareous mud, which, rapidly accumulating, rolled down the ravine in two great streams. These, afterwards uniting, flowed onwards with increased force from east to west. The mass attained a breadth of 225 feet, and a depth of nearly 15. It advanced for nearly a mile before it stopped, sweeping everything before it in its course, overwhelming animals and trees. It contained fragments of reddish earth, having a sulphurous smell, and by degrees hardened into a solid mass, losing half its height in drying.

The effects produced by the great landslips were in some cases of a very striking kind. The annexed woodcut shows the appearance presented by those which resulted at Casalnuovo.

The town of this name was situated in a pleasant plain at the foot of a mountain. It had previously suffered from an earthquake, and, in rebuilding it, the inhabitants had adopted extraordinary precautions, to guard against the consequences of a similar visitation. The houses were low, the walls well braced, the streets were wide and adorned with trees, while

LANDSLIP NEAR CASALNUOVO.

vines climbed upon the fronts of the houses, so that the place had a most agreeable appearance. All these precautions, however, proved futile and vain. The whole town was levelled with the ground. Among others the Marquis Gerace, a highly respectable nobleman, was, with all his family and servants, crushed to death under the ruins of his villa. The entire plain sank. The sloping grounds resting upon the sides of the mountain slid down, leaving large gaps in their place, and covering with great masses of rock and earth the plains below. Throughout the entire distance between Casalnuovo and Sta. Christina, a space of eighteen miles, the whole ground was rent in an extraordinary way with fissures, chasms, and small ravines. By another landslip an extensive olive ground and orchard near Seminara slid through a distance of 200 feet into a valley beneath, 60 feet deep, carrying with it a small inhabited house, which remained entire, preserving its inmates without injury. The olive trees growing on the land likewise sustained no damage, and bore an abundant crop of fruit the same year. In another part of the high ground from which this orchard was detached, there was formed a deep chasm, into which a neighbouring river immediately flowed, entirely abandoning its former channel. A still more extraordinary journey was performed by another piece of ground, composing two farms near Mileto. This tract, a mile and a half long, and half a mile broad, travelled bodily down the valley to the distance of a mile, carrying with it, uninjured, a cottage and several large olive and mulberry trees, most of which remained erect and sustained no harm. A similar immunity to houses occurred at Catanzaro. In the quarter of that town called San Giuseppe, the ground sank to various depths from two to four feet, but the houses built upon it, for the most part, remained standing upon it without injury.

DISASTER AT SCILLA.

The most calamitous of the landslips occurred on the sea-coast of the Straits of Messina, near the celebrated rock of Scilla, where huge masses fell from the tall cliffs, overwhelming many villas and gardens. At Gian Greco a continuous line of precipitous rocks, nearly a mile in length, tumbled down. The aged Prince of Scilla, after the first great shock on 5th February, persuaded many of his vassals to quit the dangerous shore, and take refuge in their fishing boats—he himself showing the example. That same night, however, while many of the people were asleep in the boats, and others on a flat plain a little above the sea-level, another powerful shock threw down a great mass from the neighbouring Mount Jaci, which fell with a dreadful crash, partly into the sea, and partly upon the plain beneath. Immediately the sea rose to a height of twenty feet above the level ground on which the people were stationed, and, rolling over it, swept away the whole multitude. This immense wave then retired, but returned with still greater violence, bringing with it the bodies of the men and animals it had previously swept away, dashing to pieces the whole of the boats, drowning all that were in them, and wafting the fragments far inland. The prince with 1430 of his people perished by this disaster.—See the prefixed woodcut.

It is doubtful whether these great sea-waves were caused by the fall of the huge mass of rock into the sea, or by some upheaval beneath its bed. The sea in the straits, and all along the coast of Calabria, was much agitated during the convulsion, and great numbers of fish were cast ashore. On the Sicilian coast, near Messina, the sea is said to have appeared, at the time of the great shock, as if it had been boiling—probably owing to the discharge of vapours from beneath.

It was on the north-eastern shores of Sicily, however, that the greatest amount of damage was done. The first severe shock, on the 5th of February, overthrew nearly the whole of the beautiful city of Messina, with great loss of life. The shore for a considerable distance along the coast was rent, and the ground along the port, which was before quite level, became afterwards inclined towards the sea, the depth of the water having, at the same time, increased in several parts, through the displacement of portions of the bottom. The quay also subsided about fourteen inches below the level of the sea, and the houses near it were much rent.

But it was in the city itself that the most terrible desolation was wrought—a complication of disasters having followed the shock, more especially a fierce conflagration, whose intensity was augmented by the large stores of oil kept in the place. An authentic account of this calamity has been preserved in a report sent by the Senate of the city of Messina to the King of Naples, bearing date the 8th of February. It runs as follows:—

"Sire,—Messina's frightful situation from the effects of the earthquake, which began on the 5th of the month at half an hour after noon, and which still continues, leads the Senate to believe that you will forgive their communicating to you directly an account of this disaster, instead of transmitting it to your Majesty, according to custom, through the hands of His Excellency the Viceroy.

"Your Majesty's feeling heart will, we doubt not, be touched by the deepest sorrow at the harrowing spectacle of a splendid city instantaneously changed, by a terrible and unexampled event, into a heap of ruins. The concussions of the earth, coming in succession every quarter of an hour, with inconceivable violence, have overthrown, from top to bottom, every building whatever. The royal palace, that of the archbishop, the whole of the maritime theatre, the pawn-repositories, the great hospital, the cathedral, the monasteries and nunneries—nothing has escaped destruction. The religious recluses are seen running through the streets in dismay, to seek, if possible, some place of refuge and safety, with the small number of persons escaped like themselves, almost by a miracle, from this overthrow. The sight is doubtless fearful; but there is one yet more terrible,—that of the largest proportion of the citizens, dead and dying, buried beneath the ruins of their dwellings, without its being possible, from the want of labourers, to render assistance under such circumstances, to withdraw from beneath the rubbish those still breathing. Shrieks and cries, groans and sighs—all the accents of grief are everywhere heard; while the impossibility of redeeming from death those wretched victims, renders still more harrowing the voice of despair that appeals in vain for help and compassion.

"A new scourge has been added to all these calamities, and augments their horror. From amid the ruins of the overthrown buildings there is seen all at once to arise a raging fire. Unhappily—the first shocks having begun about dinner-time—the fires, then lighted in the kitchens, had kindled various combustible substances found among the remains of the crumbling houses. The king's lieutenant instantly hastened to the spot with his troops; but the absolute want of labourers and needful appliances rendered all efforts unavailing, and it was impossible, not only to extinguish the fire, but even to stop the progress of the flames, which continued to devour the sad remains of a city, once the glory of her sovereigns, and the most flourishing in the kingdom.

"To so many simultaneous disasters have to be added a thousand others beyond description horrible. The corn magazines having been overthrown, bread, that most needful of aliments, fails. The Senate have been obliged immediately to remedy this evil, by detaining in harbour the vessels laden with this commodity. But

EARTHQUAKE AT MESSINA. 1783.

how make bread when the shops and utensils adapted to this trade are buried under the ruins, while the bakers have either perished or fled? The water-courses having been turned aside, the public fountains are drained, and the mills can no longer grind corn. This aggravation of disasters has reduced almost to despair the remaining inhabitants, who demand with loud cries bread for their sustenance. Some bemoan their goods and chattels, others their parents. In spite of the zeal and activity shown by the magistrates in restraining robbers, there are yet found wretches, without either humanity or religion, who, regardless of this divine wrath displayed before their eyes, have pillaged not only private houses but also the public edifices and the pawn-repositories. Naught then, save the powerful protection of your Majesty, can redress such manifold misfortunes, so rapid in their succession, and give new existence to this city, which requires to be wholly restored. The Senate beseech your Majesty instantly to transmit the needful succours of men and money, to clear the roads covered by ruins and corpses. The Senate equally entreat your Majesty to send to this city provisions of all sorts, for the subsistence of the inhabitants dispersed in the plains, and who, destitute of food, will be obliged to take flight, to the great detriment of your royal treasury." This last touch is inimitable.

The foregoing woodcut shows the appearance presented by a part of the city after this dreadful occurrence.

According to official reports made soon after the events, the destruction caused by the earthquakes of 5th February and 28th March throughout the two Calabrias was immense. About 320 towns and villages were entirely reduced to ruins, and about 50 others seriously damaged. The loss of life was appalling—40,000 having perished by the earthquakes, and 20,000 more having subsequently died from privation and exposure, or from epidemic diseases bred by the stagnant pools and the decaying carcasses of men and animals. The greater number were buried amid the ruins of the houses, and not a few perished in the fires that were kindled in most of the towns, particularly in Oppido, where the flames were fed by great magazines of oil. Not a few, especially among the peasantry dwelling in the country, were suddenly ingulfed in fissures. Many who were only half buried in the ruins, and who might have been saved had there been help at hand, were left to die a lingering death from cold and hunger. Four Augustine monks at Terranuova perished thus miserably. Having taken refuge in a vaulted sacristy, they were entombed in it alive by the masses of rubbish, and lingered for four days, during which their cries for help could be heard, till death put an end to their sufferings.

Of still more thrilling interest was the case of the Marchioness Spadara. Having fainted at the moment of the first great shock, she was lifted by her husband, who, bearing her in his arms, hurried with her to the harbour. Here, on recovering her senses, she observed that her infant boy had been left behind. Taking advantage of a moment when her husband was too much occupied to notice her, she darted off, and, running back to her house, which was still standing, she snatched her babe from his cradle. Rushing with him in her arms towards the staircase, she found the stair had fallen—so barring all further progress in that direction. She fled from room to room, chased by the falling materials, and at length reached a balcony as her last refuge. Holding up her infant, she implored the few passers by for help; but they all, intent on securing their own safety, turned a deaf ear to her cries. Meanwhile her mansion had caught fire, and ere long the balcony, with the devoted lady still grasping her darling, was hurled into the devouring flames.

A few cases are recorded of devotion similar to that of this heroic woman, but happily attended by more fortunate results. In the great majority of instances, however, the instinct of self-preservation triumphed over every other feeling, rendering the wretched people callous to the dangers and sufferings of others. Still worse was the conduct of the half-savage peasantry of Calabria. They hastened into the towns like vultures to their prey. Instead of helping the sufferers, they ransacked the smoking ruins for plunder, robbed the persons of the dead, and of those entangled alive among the rubbish, perpetrating still more atrocious crimes. Several cases occurred of persons being rescued alive from the ruins after the lapse of many days. Some were delivered at the end of three, four, or five days, and one even on the seventh day after interment. Those who were thus rescued all declared that their direst sufferings were from thirst.

During these great Calabrian earthquakes the volcano of Stromboli was unusually quiet, and did not regain its wonted activity until they had ceased. Mount Etna threw out a considerable quantity of vapour at the beginning of the commotions, but there was no other sign of activity in that volcano.

The annals of earthquakes have brought to light a remarkable relation between those of Syria and those of Southern Italy and Sicily, namely, that a period of convulsion in the one country corresponds to a period of repose in the other.

CHAPTER VIII.

THE GREAT EARTHQUAKE OF RIOBAMBA.

RIOBAMBA must have stood, it would appear, almost immediately over the focus of the dreadful earthquake of 4th February 1797. This unfortunate city was situated in the district of Quito in South America, and not far from the base of the great volcano of Tunguragua. That mountain was probably the centre of disturbance, and the shock was experienced with disastrous effects over a district of country extending about 120 miles from north to south, and about 60 miles from east to west. Every town and village comprehended within this district was reduced to ruins. The shocks, however, were felt, though in a milder form, over a much larger area, extending upwards of 500 miles from north to south, and upwards of 400 miles from east to west. The northern limit was about Popayan in New Grenada, the southern about the river Piura in the north-western angle of Peru. The eastern limit was about the river Napo in

Ecuador, and the shock extended thence westward to the sea.

That the cause of the disturbance was deep-seated, and had widely extended volcanic relations, is proved by what occurred at Pasto, about 225 miles to the northward of Tunguragua. For about three months before the convulsion occurred, the volcano of Pasto had been continuously throwing out an immense column of black volcanic smoke, probably composed of fine dust and ashes. But at the moment of the earthquake this great column suddenly disappeared.

One strange peculiarity of this convulsion was, that the first great shock was neither immediately preceded nor accompanied by any underground noises near the centre of disturbance.* This is all the more remarkable when the extreme violence of the commotion is considered. But a still more singular circumstance was that, about eighteen or twenty minutes *after* the shock, subterraneous noises of the most appalling kind were heard at Quito, about 200 miles to the north of Riobamba, and at Ibarra, still further to the north. At Tacunga and Hambato, again, lying about midway between

* Some time before the earthquake, however, about the beginning of the year 1797, there were frequently heard, proceeding from the interior of Tunguragua, underground noises, so loud and alarming as to have led Antonio Pineda the naturalist, who was there at the time, to foretell the approach of some great convulsion.

Riobamba and Quito, these underground noises were not heard, although at both of those places the earthquake itself produced calamitous effects.

The most striking feature in this great catastrophe was the peculiar effect produced by the underground disturbance on the volcano of Tunguragua. The usual volcanic phenomena of the mountain were suspended; there were no ejections from its crater, which gave forth less vapour than usual; but in the ground at its base there were opened enormous fissures, whence there issued immense volumes of water, and of a sort of fetid mud called by the natives *Moya*. These streams overflowed and devastated the country to a wide extent all round. So great was the flood poured forth, that in some of the neighbouring valleys, 1000 feet in breadth, the water rose to the height of 600 feet. The mud accumulated in vast masses in the hollows, and in several places barred the river-courses, so forming large lakes, which remained for upwards of eighty days, owing to the inability of the waters to remove the obstructing barriers. These floods of water and mud were discharged from the interior of the mountain, the mud being probably composed of the sulphureous dust and ashes of the volcano blended with water. What was strangest of all, these floods contained immense quantities of dead fishes of a peculiar species. There can be no doubt that these fishes must have been bred in subterranean lakes, in the lower parts of the interior of the mountain, at some distance from the focus of its volcanic fires. The species is named from its peculiar abode *Pymelodes Cyclopum.* It is small, and has rather a singular appearance, as shown in the following woodcut.

At Riobamba the shocks, which began about a quarter before 8 o'clock A.M., are said to have been quite vertical; and, as they continued for the extraordinary time of four minutes, there

PYMELODES CYCLOPUM.

must have been a rapid succession of them during that interval. The effects are described as having resembled those produced by the explosion of a deep-seated mine, though unaccompanied by noise; but it is evident that no single upheaval of the ground vertically could endure for four minutes; so that the ground must have been uplifted and let down again many times successively during that period. Some faint idea may be formed of the extreme violence of the vertical motion from the fact mentioned by Humboldt, that the dead bodies of some of the inhabitants who perished were tossed over a small river to the height of several hundred feet, and landed on an adjacent hill.

Vertical movements, so powerful and so long continued, could not fail to produce an enormous displacement of the ground, and to be very destructive to all buildings which it sustained. The soil was rent, and, as it were, torn asunder and twisted, in an extraordinary manner. Several of the fissures opened and closed again; many persons were ingulfed in them; but a few saved themselves by simply stretching out their arms, so that, when the fissure closed, the upper parts of their bodies were left above ground, thus admitting of their being easily extricated. In some instances whole cavalcades of horsemen and troops of laden mules disappeared in those chasms; while some few escaped by throwing themselves back from the edge of the cleft.

The amount of simultaneous elevation and depression of the ground was in some cases as much as twelve feet, and several persons who were in the choir of one of the churches escaped by simply stepping on the pavement of the street, which was brought to a level with the spot where they stood. The amount of lateral displacement was also extraordinary. Humboldt states that he was shown a place where the whole furniture of one house had been found under the remains of another; and he was led to infer that the earth had moved almost like a fluid, in streams or currents, the direction of which was first downwards, then horizontal, and, lastly again, upwards. The intermingling of different parts of the soil was such as to have raised disputes about the ownership of objects, which had been carried through several hundred yards of distance, from one man's ground to another's.

Instances occurred of whole houses sinking bodily into the earth, till their roofs were fairly underground; but so little were the buildings thus ingulfed injured, that their inhabitants were able still to live in them, and by the light of flambeaux to pass from room to room, the doors opening and shutting as easily as before. The people remained in them, subsisting on the provisions they had in store, for the space of two days, until they were extricated safe and sound.

With the bulk of the inhabitants, however, it fared far otherwise. The loss of life in the city, and throughout the district most convulsed, was enormous, 40,000 persons altogether having perished.

Of Riobamba itself the ruin was complete. When Humboldt took a plan of the place after the catastrophe, he could find nothing but heaps of stones eight or ten feet high; although the city had contained churches and convents, with many private houses several stories in height. The town of Quero was likewise entirely overthrown.

At Tacunga the ruin was nearly as thorough, not a building having been left standing save an arch in the great square, and part of a neighbouring house. The churches of St. Augustin, St. Domingo, and La Merced, were at the moment thronged with people hearing mass. Not one escaped alive. All were buried, along with the objects of their worship, under the ruins of their consecrated buildings. In several parts of the town and its neighbourhood there were opened large fissures in the ground, whence quantities of water were poured forth. The village of St. Philip near Tacunga, containing a school in which upwards of forty children were assembled at the time, disappeared bodily in a chasm. A great many other villages with their inhabitants were destroyed, by being either overthrown or ingulfed.

Even at Quito, although so distant from the centre of disturbance, a great deal of damage was done to the churches and other public buildings by the shock, several being wholly ruined. The private houses and other buildings of moderate height, however, were spared. The superstitious inhabitants of this fair city, both priests and people, having been greatly alarmed by an unwonted display of luminous meteors, had devoted the previous day to carrying in procession through their streets the graven images and relics of their saints, in the vain hope of appeasing the Divine wrath. They were doomed to learn by experience that these their idols were powerless to protect even the consecrated edifices dedicated to their honour, and in which they were enshrined. It is to be hoped that the shock itself, and the awful underground thunderings by which it was followed about twenty minutes afterwards, while filling their minds with terror, may have led some of them, at least, to seek the favour of their Creator otherwise than by parading before him the objects of their senseless idolatry.

A remarkable concomitant of this disastrous earthquake was that from the lake of Quilotoa, in the district of Llactagunga, there issued flames and volumes of stifling vapours, which suffocated numerous herds of cattle that were feeding on its shores.

The first great shock, on the morning of the 4th of February, was succeeded the same day by two others less severe, at 10 A.M. and at 4 P.M. Unlike the first, these two were accompanied by underground noises. The shocks were repeated at intervals during the rest of February and the following March. Even so late as the 5th of April, at half past 2 A.M., there was felt a shock not much short of the first in its severity.

It will be observed that in their phenomena these earthquakes strongly resembled those of Calabria, only they were of far greater intensity. The vertical character of the motion at Riobamba corresponded with that of the upheaval at Oppido, and even the great eruption of mud from Tunguragua had its counterpart, on a small scale, in the similar eruption at St. Lucido. The same remarkable displacements of the ground were observable in both instances, only those at Riobamba had less of the character of mere landslips than had those in Calabria. The amount of underground disturbance was obviously much greater in the case of the American catastrophe.

The details which have thus been given of the three great earthquakes of Lisbon, Calabria, and Riobamba, may serve to convey a tolerably clear notion of the awful nature of such a visitation, and to inspire a feeling of thankfulness that our beloved country has been hitherto exempt from this terrible scourge, save in a very mitigated form.

CHAPTER IX.

EARTHQUAKE PHENOMENA.

EVERY earthquake results from the passage of an earth-wave through the place where the shock is felt. This wave is essentially of the same nature as that which would be raised in the sea by a great submarine explosion. In that case, the water is first lifted perpendicularly into a dome-shaped mass immediately over the site of the explosion, and, on the subsidence of this dome, a system of circular waves is propagated outwards from it in all directions. In like manner, in the case of a great earthquake caused by some subterranean explosion, the ground is uplifted vertically right over the site of the disturbance, and on its subsidence a system of earth-waves is propagated outwards from this centre—the waves travelling in the direction of the rays of the circle, consequently in straight lines. Owing, however, to the want of perfect sameness in the nature of the substances through which the earth-waves travel, they do not retain that symmetry of form and uniformity of direction which are exhibited in the waves formed on the surface of water. In traversing rock formations much rent by fissures, or strata composed of loose materials or clayey substances, the waves will experience considerable retardation. They will pass with the greatest rapidity through solid masses of granite, and similar compact rocks; but such are seldom to be found in long continuous tracts of country.

It hence arises that the shock travels with different degrees of speed through different sorts of strata, and where the waves in one direction greatly outrun those in another, they may give rise to transverse vibrations on either side. Thus, if the shock pass through a dike of compact granite or greenstone running through diverse loosely compacted strata, it will traverse the dike more rapidly than the looser strata; so that it will, after a while, propagate lateral vibrations through those strata before the principal wave has had time to reach them. It may also happen that, from faults in the strata, the shock may be arrested in its course in one particular direction and restricted to another. The tract agitated by the shock may thus come to be in the form of a long, but comparatively narrow, belt of country.

When the earthquake begins with the direct

CHAPTER IX.

EARTHQUAKE PHENOMENA.

EVERY earthquake results from the passage of an earth-wave through the place where the shock is felt. This wave is essentially of the same nature as that which would be raised in the sea by a great submarine explosion. In that case, the water is first lifted perpendicularly into a dome-shaped mass immediately over the site of the explosion, and, on the subsidence of this dome, a system of circular waves is propagated outwards from it in all directions. In like manner, in the case of a great earthquake caused by some subterranean explosion, the ground is uplifted vertically right over the site of the disturbance, and on its subsidence a system of earth-waves is propagated outwards from this centre—the waves travelling in the direction of the rays of the circle, consequently in straight lines. Owing, however, to the want of perfect sameness in the nature of the substances through which the earth-waves travel, they do not retain that symmetry of form and uniformity of direction which are exhibited in the waves formed on the surface of water. In traversing rock formations much rent by fissures, or strata composed of loose materials or clayey substances, the waves will experience considerable retardation. They will pass with the greatest rapidity through solid masses of granite, and similar compact rocks; but such are seldom to be found in long continuous tracts of country.

It hence arises that the shock travels with different degrees of speed through different sorts of strata, and where the waves in one direction greatly outrun those in another, they may give rise to transverse vibrations on either side. Thus, if the shock pass through a dike of compact granite or greenstone running through diverse loosely compacted strata, it will traverse the dike more rapidly than the looser strata; so that it will, after a while, propagate lateral vibrations through those strata before the principal wave has had time to reach them. It may also happen that, from faults in the strata, the shock may be arrested in its course in one particular direction and restricted to another. The tract agitated by the shock may thus come to be in the form of a long, but comparatively narrow, belt of country.

When the earthquake begins with the direct upheaval of a dome-shaped tract, the direction of the resulting shocks propagated from it will be inclined to the vertical at all possible angles until it becomes quite horizontal. It is most destructive to buildings after it has become considerably inclined to the perpendicular, and before its strength has become much diminished by diffusion over a greater space. But shocks nearly horizontal, if sufficiently powerful, are exceedingly effective in overthrowing buildings.

Besides the vertical and horizontal shocks, Baron Humboldt and some other authorities recognize a sort of whirling shock, to which they attribute the twisting of buildings and the displacement of portions of the surface; but other authorities demur to this mode of explaining these phenomena. It is quite conceivable, however, that if there be a certain lapse of time occupied in the underground explosion, one portion of the dome-shaped mass may be raised before another, so that its edge may be as it were slightly tilted, and that, on subsiding, it may come down somewhat in the manner of an inverted saucer which is allowed to drop on a table with one of its edges slightly inclined. In this case, the system of waves propagated would take something of a spiral direction, the radii from the centre being all considerably bent. Indeed, it is only on the supposition of the upheaved dome's coming down perpendicularly—every part of its edge descending to the level at the same instant of time—that the system of waves would be quite circular, and the radii of the circle quite straight. The bending of the lines in which the waves are propagated might also be produced by variations in the nature of the strata through which the shocks pass, much in the same manner as luminous waves are diverted from their straight course by refraction through different media.

On the other hand, it is conceivable that the phenomena of twisting may be produced by lateral waves acting on the moved masses before they can regain their original position, after they have been disturbed by the great wave; or that they may be urged by two shocks rapidly succeeding each other, but differing slightly in their direction, so as to give to every object put in motion a certain tendency to turn round horizontally. In the particular case of the top of the spire at Inverness, the twisting may possibly have been accomplished by the action of the wind on the vane, at the moment of the oscillation. But the twisting of the Calabrian obelisks must have been due to one of the other causes before assigned.

In some cases, the undulatory motion of the earth is quite perceptible to the eye, and the formation of rents is doubtless due to the extent of this motion, and the inability of the strata to accommodate themselves to the waves. But in less violent commotions, the character of the movement is more akin to that which would be communicated to a large expanse of iron floor by giving it a severe blow with a mallet from beneath. Nine-pins set on the floor under such circumstances, would illustrate the action of such an earthquake on buildings.

Diverse estimates have been formed of the speed with which the earth-wave travels. Mr. Mallet made some experiments with a view to determine this point, by exploding gunpowder in compact granite, in dislocated granite, and in sand. According to his experiments, the rate in compact granite is nearly 19 miles in a minute; in the dislocated granite, nearly 15; and in loose sand, only between 9 and 10. These results, however, are below the rates of advance of some actual earthquake shocks, as estimated by the times of their occurrence at different places. Thus in the case of the great Lisbon earthquake, if estimated from the time it reached Corunna, the rate of transit was about 23 miles in a minute; if estimated from the time it reached Cork, the rate would be 30 miles; if from the time it reached Santa Cruz, on the coast of Barbary, 37 miles;—the mean being 30 miles in a minute, which, making allowance for errors of observation, is probably near the truth. In the case of the great Indian earthquake in 1819, the estimated rate of the speed of the wave was only between 13 and 14 miles in a minute, which is nearer the rate given by Mr. Mallet's experiments. From the Indian earthquake of 1834 again, it appears that the rate was very diverse in different directions—showing that the wave must have passed through certain strata much more rapidly than through others. These various rates were estimated at 11, 14, 26, and 40 miles in a minute, so that the differences would seem to have been very great. Observations on the time of transit, between two ships, of a shock felt at sea, gave a rate of about 17 miles per minute.

From all these observations it follows that the rate of transmission of the wave is greatly affected by the nature of the strata through which the shock passes, and that something may also be due to the power of the shock itself. For a strong shock will be better able to overcome obstacles, such as faults in the strata, or the intervention of loose or soft materials, than would a weak shock, which might be greatly retarded by obstacles of this nature. It is, therefore, not surprising that the great Lisbon earthquake should have travelled so rapidly. The extremely rapid rate of 40 miles a minute, assigned to the Indian earthquake of 1834, in one direction, while it was only 11 in another, gives ground to suspect errors of observation or calculation.

One of the most interesting of earthquake phenomena is the great sea-wave which rolls in upon the land with such destructive effects. This wave is observed only when the origin of the shock is at the bottom of the sea. When the shock has its origin on land, and the earth-wave approaches the sea, it first causes the water to retreat for a short way, and then to return with considerable force, but seldom beyond the point at which it had previously stood. The first retreat in this case is caused by the rising of the beach with the swell of the earth-wave; and its immediate subsidence, while the edge of the water is in its turn elevated, causes the return-wave, which then flows back upon the shore.

When the impulse acts from the bottom of the sea again, the order of the phenomena is the same, but their extent is greatly exaggerated. The sea first retires a long way from the beach, and then returns in a mighty wave of great height, which runs up far beyond the highest tide-mark — sweeping every thing before it. Sometimes the first great wave is succeeded by several others, owing to a repetition of the primary impulse at the bottom of the sea. The retreat of the water, in this case, before the arrival of the principal wave, is due, in great measure, to the formation of the large dome-shaped wave immediately over the seat of disturbance. The water is drawn away from the beach to supply the place of that which goes to form the liquid dome; and it is by the subsequent fall of this dome that the great rolling wave, which comes towards the shore, is raised. The first retreat, however, is probably in part also due to the circumstance that the earth-wave propagated along the bottom of the sea, outruns the wave propagated along its surface; so that, simultaneously with the water's being drawn away from the shore, the beach itself is temporarily elevated, and helps to force back the tide. The greatest sea-waves are produced when the centre of disturbance is near the shore. When it is very far removed from it, only one or more large rollers rush towards the beach, and in this case the previous retreat is imperceptible.

Owing to the enormous speed with which the earth-wave travels, it is evident that any single shock can never be of long duration at any one point. The actual duration, however, will depend as much on the length of the wave as on its velocity. If the rate of propagation, for example, be 20 miles in a minute, and the wave be at the same time a mile in length, the duration of the shock at any one place will be three seconds. Some waves may be longer than a mile, and may travel at a slower rate, so as to increase the duration of the shock considerably; but when shocks are said to last as long as half a minute, there is reason to suspect either a rapid succession of impulses, or an error of observation. Where the earth-waves are so short and abrupt as to be visible to the eye, a rapid succession of impulses seems to be the only probable explanation of the endurance of the shock.

The formation of fissures in the ground is the natural consequence of the passage of the earth-wave; for owing to their rigidity the strata are unable to accommodate themselves readily to the undulatory motion, and so become rent in the effort. The sudden opening and closing again of such fissures is the most obvious result of the passage of the wave-motion; but in certain cases the disturbance may be so great, and the materials so unyielding, that large, wide, and permanent fissures may be formed. From some of these clefts, what appears like smoke and flame has been observed to issue. In most instances, these phenomena are probably owing to the formation of the fissure itself; for when large solid masses of rock are suddenly rent, there always results a strong electrical discharge, which may exhibit itself in a sudden flash from the cleft. In such a case, the appearance of smoke would in all likelihood be due to a cloud of dust rising from the fracture. There may be other cases, however, in which true smoke and flame may rise from a rent. In several places there are known to be large underground reservoirs of petroleum, or rock oil. Should a fissure penetrate down to such a reservoir, and the petroleum take fire from the electrical discharge produced by the rupture, then true smoke and flame might arise through the cleft.

Some of these fissures pour forth noxious gases, others sulphurous vapours. These make their appearance chiefly in volcanic countries, and are doubtless due to the rent's reaching down to such a depth as to promote the escape of steam and other vapours arising from the heated materials lying underneath. The most common discharge from the clefts made by earthquakes, however, is water, sometimes pure, sometimes salt; at one time mixed with sand, at another mixed with mud—the water being either hot or cold. Such discharges are obviously owing to the rent's having penetrated down to underground collections of water in cavernous strata.

In close connection with the opening of fissures are the rending of mountains and the formation of landslips. In some cases these phenomena take place on a great scale, and with very marked secondary effects; such as the filling up of river-beds and the opening of new channels for their waters, the formation of new lakes and new springs, some cold, some hot. There is reason to believe that, in a few cases, where large portions of mountains fall down, or other great landslips take place, these occurrences may be rather the causes than the consequences of the earthquake felt in the neighbourhood. But any earthquakes arising from such a cause must be very superficial and partial, and can never assume the peculiar features of a true earthquake, due to disturbances taking place at great depths in the earth.

Instances are recorded of the entire swallowing up of large tracts of country, sometimes with towns upon them, while lakes have been formed in their place. Even mountains have thus been ingulfed and replaced by lakes. Doubtless in all such cases, the ground must have been extensively cavernous; containing large subterranean reservoirs of water. When the strata over such cavities are violently shaken, they will be very liable to be riven. The whole superincumbent mass will then sink down into the hollow beneath, and the water which it contained will rise to the surface. Such occurrences are most likely to take place in districts which have once been the seat of volcanic action; for all the materials thrown up from beneath, in the form of ashes or lava, must be replaced by underground spaces which will eventually become filled with water. The ground above is thus, in such localities, a mere crust, over large cavernous spaces, from which the solid materials have been transferred to the surface by the volcanic action. It is accordingly not at all wonderful, that, on their being violently shaken, such surfaces should sink down into those hollow depths.

There is good reason to believe that subsidence on a great scale is continually taking place in the bed of the ocean itself, more especially in that of the Pacific. This sort of subsidence is due mainly to alterations in the distribution of pressure, caused by the vast quantity of solid substances carried down by the great rivers, and spread over the bottom of the sea. For supposing that there exist under the ocean's bed extensive reservoirs of liquid lava, the additional weight given to the superincumbent strata over this flexible surface will cause them to break and sink down. Such great subsidences cannot occur without giving rise to earth-waves, which will be propagated towards the shore.

In some earthquakes the land, instead of sinking down, is elevated, and that over large tracts. In general where this occurs, there is a subsequent partial subsidence. This phenomenon is most easily explicable on the supposition of the injection of lava into horizontal or inclined rents, or seams in the strata. By this injection the superincumbent solid mass is forced upwards, sometimes to the extent of several feet. The partial subsidence which ensues may be due either to the shrinking of the materials as they cool, or to the subsequent escape of portions of the fluid lava. Injections of lava of this description would be very likely to flow from any extensive subsidence of the bed of the ocean, such as those above mentioned.

The violent effects of earthquakes on buildings is easily comprehensible, when the nature of the motion and the speed with which it travels are borne in mind. It is no great wonder that whole cities should be laid in ruins in a few seconds of time, and that the destruction of human life should be so dreadful as it has proved to be, in some of the more disastrous earthquakes. The marvel is rather how any of the inhabitants of a city thus visited can escape. Much depends on the character of the shocks. When they are vertical or nearly so, the effects on buildings are seldom so severe as when they are more nearly horizontal, unless indeed the vertical shocks be of great violence, such as those at Oppido and Riobamba.

The effect on trees is to make them sway to and fro; and this oscillation is sometimes so violent as to cause the tops to touch the ground. In some instances the tree works a conical hole in the soil all round the trunk. This conical form is owing to the circumstance of the tree's performing its successive oscillations in different planes, like the swaying of a top when it is about to fall. This effect arises from the tree's being a sort of inverted pendulum, and the shock's having acted upon it not so directly as to make it oscillate in a fixed plane.

The extent of surface over which an earthquake may be felt is very variable. It depends on three things—1st, The absolute force of the impulse; 2nd, The depth of the seat of disturbance; and, 3rd, On the nature of the strata through which it passes. When the shock is both powerful and deep-seated, the area affected is enormous. The space disturbed by the great Lisbon earthquake, for example, was 3300 miles in length and 2700 in breadth, or not far short of nine millions of square miles. The Syrian earthquake of 1759 is computed to have extended over 90,000 square miles; the Calabrian earthquakes over 16,000; the Chilian earthquake of 1822 over 100,000; that of 1835 over 288,000. Sometimes the length of the area convulsed greatly exceeds the breadth. Thus, in this last case, the length was nearly double the breadth, and in the Syrian earthquake of 1837 the length was between five and six times the breadth. This circumstance is doubtless owing to the disposition of the strata. Sometimes the shock, although locally very violent, does not extend itself to any great distance. This happened in the case of the earthquake which destroyed nearly the whole of the city of Coquimbo, in Chili, in the year 1820. In such a case the shock is nearly vertical, and not deep-seated.

Even in those districts of country which are liable to be much agitated by shocks, there are sometimes observed to be spots which escape from the earth-wave. On this point, Humboldt in his "Cosmos" says—"Where such a wave proceeds in a regular course along a coast, or at the foot of and parallel to the direction of a mountain-chain, interruptions at certain points have sometimes been remarked, and continue for centuries. The undulation passes onward in the depth below, but it is never felt at those points on the surface. The Peruvians say of these upper strata, that they form a bridge." In a note to this passage he adds—"These local interruptions to the transmission of the shock, through the upper strata, seem analogous to the remarkable phenomenon which took place in the deep silver mines of Marienberg in Saxony, at the beginning of the present century, when earthquake shocks drove the miners in alarm to the surface, where meanwhile nothing of the kind had been experienced. The converse phenomenon was observed in November 1823, when the workmen in the mines of Falun and Persberg felt no movement whatever, whilst above their heads a violent shock of earthquake spread terror among the inhabitants at the surface" (*Cosmos*, i. 199). Sometimes such favoured spots lose their immunity in consequence of some great convulsion.

The larger number of shocks are accompanied by underground noises, but in some even of the most violent shocks these are altogether absent. For example, in the great earthquake of Riobamba, there was at that place no subterranean noise of any kind. These underground sounds vary exceedingly. The most common resemble the rumbling of a train of waggons along a road, or through a tunnel. Sometimes they are like thunder, at other times like the explosion of a mine. They occasionally are harsh and grating, like what might be produced by the edges of rocks grinding against each other. More rarely they are like the clanking of chains, or clear and ringing like the breaking of glass. At other times the sound resembles that of a mighty wind rushing underground. It has also been compared to the noise of steam discharged under water. In point of intensity, the sound varies from a low murmur, or rumbling, to reports compared to what would be produced by the simultaneous discharge of a hundred pieces of artillery. In such cases there is reason to suspect that an actual explosion of some kind takes place at a great depth in the earth. But in most instances the noise is probably due to the cracking of the strata displaced by the earth-wave.

It has occasionally happened that loud and long-continued subterranean noises have been heard, without their having been accompanied either by earthquake shocks or any other outward indications of internal disturbance. One of the most remarkable examples of this kind occurred at Guanaxuato, in Mexico, and is described by Humboldt in his "Cosmos." This city is situated in a mountain district, but far from any active volcano. The sounds were first heard at midnight, on the 9th of January 1784, and they continued more than a month. The loudest reports occurred from the 13th to the 16th of January, when they seemed like slow rolling thunder, with intervening short thunderclaps. Both before and after this period the sounds were neither so loud nor so frequent, and after the 16th they gradually died away. The phenomenon was confined to a limited space under the city and its immediate neighbourhood. Great alarm was excited among the inhabitants; but no shocks of earthquake were felt, nor did any other consequences follow. What is still more remarkable, in the neighbouring mines, which are 1598 feet deep, not the slightest trembling of the ground was perceived. Something similar happened in the island of Meleda, off the Dalmatian coast, where subterranean noises were heard from March 1822 to September 1824; but these were occasionally attended by slight shocks.*

Some earthquakes are accompanied by remarkable atmospherical phenomena—such as great hurricanes, storms of thunder and lightning, rain, hail, &c.; but during others the weather is perfectly calm and the sky serene. In certain cases the magnetic needle is strongly affected, and permanent magnets drop their keepers; but in other cases these effects are absent. There is a class of earthquakes, indeed, during which the electrical state of the air is such as to indicate great tension; in so much that some observers have been led to attribute the shock itself to a strong electrical discharge passing through the strata, between the outer air and some surface underneath, highly charged with electricity of an opposite kind. The aurora borealis is also a not unfrequent concomitant of earthquakes. The connection between electricity and earthquakes, however, is yet very obscure; and the electrical tension is quite as likely to be the result of the

* At Nakous, near the shore of the Red Sea, there are heard at intervals underground sounds resembling the tinkling of a bell. This phenomenon is probably due to some sort of suppressed volcanic agency.

underground disturbance which causes the shock, as to be in any case the cause of the shock itself.

The peculiar effects produced on animals during earthquakes are in part, perhaps, due to the electrical condition of the air, though doubtless the more marked phenomena are produced by the passage of the earth-wave itself. Where the physiological effect precedes the arrival of the shock, the electrical state of the air is the more probable exciting cause. For example, some people have complained of headache, giddiness, and squeamishness, before feeling the shock. Birds are particularly sensible of its approach, especially ducks and geese. Dogs howl, horses neigh, swine grunt, and asses bray, all showing at the same time great restlessness and uneasiness. During the shock horses and oxen stretch out their legs to avoid being overthrown.

The times at which earthquakes happen have been made the subject of laborious research by M. Perrey of Dijon. The general result is, that earthquakes are usually more frequent in winter and autumn than in spring or summer. But this law varies considerably in different localities. M. Perrey has also investigated with great care the relation between the frequency of earthquakes and the motions of the moon. He has arrived at the following conclusions:

The number of earthquakes when the moon is nearest to the earth is greater than when she is farthest away. They are also more frequent when the action of the sun and moon on the earth is in the same direction; and shocks are likewise more frequent when the moon is near the meridian than when she is near the horizon. From these results it has been concluded that there is something of the nature of a tidal action exerted on the reservoirs of liquid lava in the interior of the earth, which may have a certain connection with the production of earthquakes.*

As regards the local distribution of earthquakes, it may in general terms be affirmed that few parts of the earth's surface can be regarded as exempt from this dreadful scourge. Never-

* The idea that the subterranean lakes of molten lava, which throw up jets through the vents of volcanoes, are subject to a tidal action, and are affected by the moon's motion, has been confirmed by the phenomena presented during the great eruption of Mount Vesuvius now in progress. In a letter dated Naples, 1st March 1868, from the correspondent of *The Times* newspaper, there occurs the following passage:—

"I have alluded to the periodicity of the eruptions. It seems now to be confirmed that the volcano acts under lunar influence. In truth, the periods of its greatest eruptions get every day about half an hour later, coinciding with the evolutions of the planet. Palmieri says:—

"'The eruption of Vesuvius maintains the periodic character already described by us, hence there are no novelties. All that is to be noted are the hours of return, with their duration and intensity, which are of interest to the scientific rather than to the curious observer. Hamilton was the first who marked a diurnal period in a long-continued eruption, and from his limited number of observations he believed that the recurrences were at fixed hours. In 1855, however, we had an opportunity of studying this phenomenon better, and we observed the daily "retard" of each increase of the lava; now we have had the opportunity of confirming what we then observed. Were there a good path, we could tell travellers and guides at what hour they should be near the summit without any risk from the projectiles or burning lava.'"

theless there are certain districts which are much more liable than others to be visited by them, while some particular spots seem to be specially exposed to shocks of great severity. There is appended to Mr. Mallet's reports to the British Association, and published in their volume of Reports for 1858, an elaborate map, which shows at a glance the distribution of the lines of greatest earthquake intensity over the globe. These lines, for the most part, follow the sea-coast. Africa *appears* to be comparatively free from earthquake action, and also Australia; but in both cases the apparent exemption may be due merely to the absence of records. It is remarkable, however, that while the western portions of South America, especially between the Andes and the sea, are frequently and violently convulsed, the eastern portions of that continent enjoy a wonderful immunity. On the other hand, Iceland, Portugal, Italy, Asia Minor, Syria, the Indian Archipelago, parts of China, Japan, Kamtschatka, Hawaii, Mexico, Peru, Chili, the Antilles, the Azores, the Canaries, are all countries of great disturbance, and nearly all of them are closely connected with active volcanoes. It is thus evident that between the earthquake and the volcano there is some intimate relation, which will be better understood after we shall have given some separate attention to the subject of volcanic phenomena.

CHAPTER X.

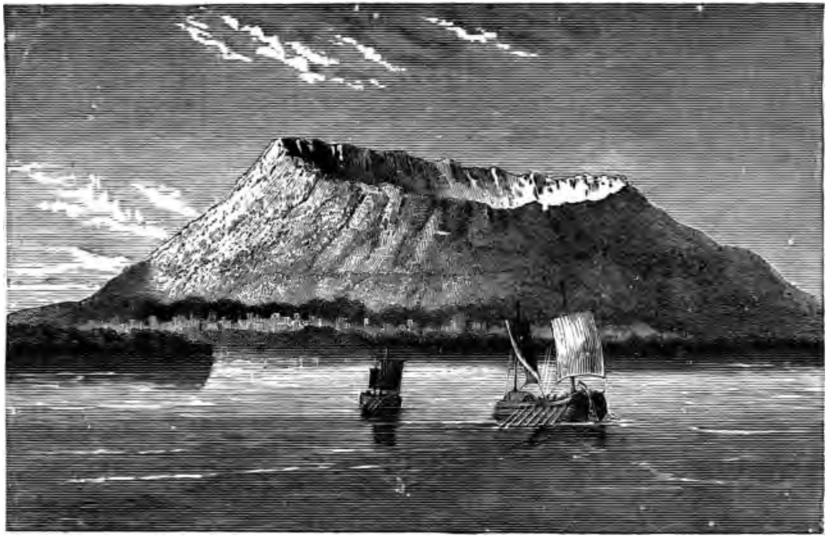
THE MEDITERRANEAN GROUP OF VOLCANOES—VESUVIUS, MONTE NUOVO, ISCHIA.

OF the two hundred active volcanoes, or thereabout, which are scattered over the face of the globe, the most interesting are those constituting the Mediterranean group—Vesuvius, Etna, and the Lipari Islands. The first named, by reason of its remarkable associations, and its being the only active volcano on the European continent, invites priority of attention.

For many long ages prior to A.D. 79, Mount Vesuvius had existed as an extinct volcano, retaining, however, some traces of its having been once in a state of activity. It was a mountain of large dimensions, but of moderate height. Its sides were clothed with gardens and vineyards, presenting a most luxuriant vegetation. Strabo describes it as surrounded by beautiful farms of great fruitfulness, and richly wooded except at the top, where it was flat and barren, and where the slaggy appearance of the stones led him to suspect there had once been a burning crater. The same impression seems to have been entertained by Diodorus Siculus. The dangerous character of the mountain, however, was generally so little suspected, that, besides many villas, the cities of Stabiæ, Herculaneum, and Pompeii, had been erected at its base, and their inhabitants had dwelt for many generations in undisturbed security. The appearance presented by the mountain at this period is shown in the annexed woodcut.

It was not until the year A.D. 63 that any alarm was excited in the minds of those dwelling in the neighbourhood of the mountain. In that year, however, both the mountain itself and all the country around it were shaken by a violent earthquake, which overthrew a considerable number of houses in the cities. This convulsion was succeeded by about sixteen years of profound repose, during which the houses that had been thrown down were in the course of being rebuilt.

On the 24th of August, A.D. 79, occurred the first great recorded eruption of Mount Vesuvius. A vivid description of it has been fortunately handed down to us, in a letter addressed to Tacitus by the younger Pliny. His uncle, the elder Pliny, was at the time in command of the Roman fleet at Misenum, where he had with him several members of his family, including his nephew. It was from this point that the



MOUNT VESUVIUS BEFORE ERUPTION OF A.D. 79.

eruption was first descried. They saw rising from the top of the mountain what seemed to them like a column of dense black smoke, but which was in reality a great volume of dust, ashes, and stones, thrown up by the force of vapours rushing from the vent, which had been opened in the volcano. Pliny likens it to a tall pine-tree throwing out great branches at its top.

Struck with wonder at this phenomenon, the elder Pliny, a man of philosophical spirit and inquiring mind, hastened with a party towards the shore, that he might land and examine more narrowly this remarkable convulsion of nature. He first steered for Retina, the modern Resina, but was prevented from landing there by tremendous showers of ashes and hot stones, and by the sudden retreat of the sea. He then made for Stabiæ, where he disembarked, and hastened to the house of his friend Pomponianus. Here he remained till the evening, occasionally gazing at the mountain, and exerting himself to allay the fears of those around him. As night drew on, streaks of fire were seen here and there on the mountain side, which he attributed to the burning of the woods and villages; but to show how little he was personally apprehensive of danger, he retired to his chamber, and erelong dropped asleep.

Meanwhile the fall of stones and ashes in

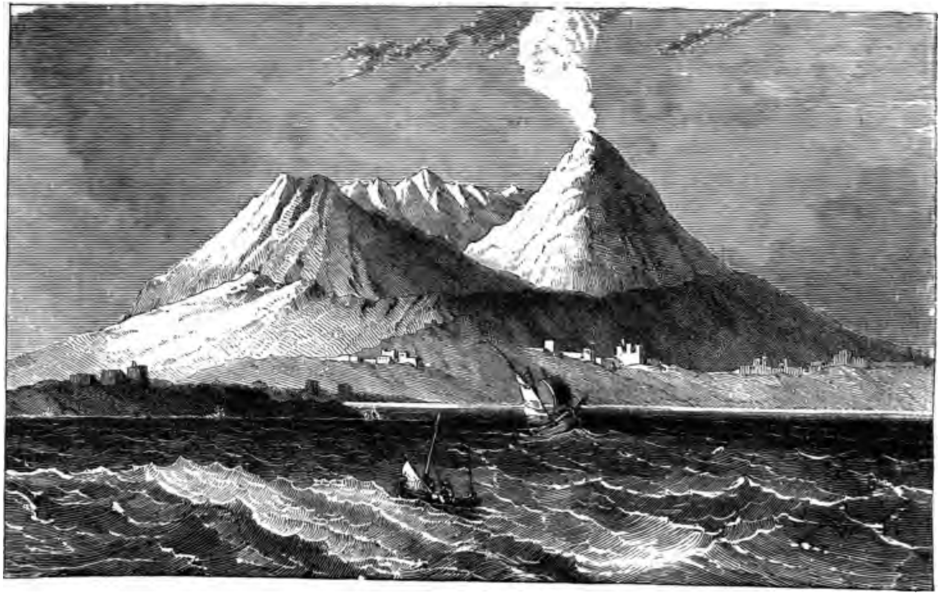
Stabiæ itself, waxed fast and furious. The inner court of the villa was becoming rapidly filled, and Pliny's servants, now fully alive to the imminence of the danger, roused their master, who immediately joined his friend Pomponianus, whom he found with his family and household already assembled around him. The party now consulted together as to the best course to be pursued; and perceiving the probability of the villa's being buried erelong in the stones and ashes, they resolved on endeavouring to effect their escape. Tying pillows on their heads with napkins, to shield them from the falling stones, they sallied forth. Although it was morning, the darkness was deeper than that of midnight, and they had to grope their way through the laden atmosphere by the light of torches. They succeeded in gaining the beach, with the intention of escaping by water; but the sea was so tempestuous, as to render embarkation impossible. His servants spread a sail-cloth for Pliny, who lay down to rest. But presently flames and sulphurous vapours rose from the ground and dispersed the party. By the help of two of his servants who remained with him, Pliny succeeded in rising; but he had scarcely attained his feet, when he fell down dead, being overpowered by the suffocating vapours.

The cities of Stabiæ, Herculaneum, and Pompeii, were entirely buried under the immense mass of ashes, stones, &c., thrown out by the mountain during this dreadful eruption. So suddenly did the fatal shower come upon them, that many of the inhabitants perished in their dwellings or in their streets. No lava was ejected from the mountain on this occasion; but it is suspected that, along with the ashes and other loose materials, there was a considerable eruption of fluid mud. For, while Pompeii was buried only in ashes and loose stones, Herculaneum is entombed in a much more consistent substance, which has evidently been once in a plastic condition, and which appears to be composed of volcanic ashes cemented by mud. This former plasticity is proved by the casts of statues and masks which have been found here. The showers of volcanic ashes, dust, pumice, and stones, continued to fall on those devoted cities for eight successive days, accompanied by torrents of rain, which would doubtless tend to unite together the loose materials.

It is a remarkable fact that the volcanic ashes from Pompeii, on being examined under the microscope by Ehrenberg, were found to contain a large proportion of the siliceous shells of diatomaceæ partially fused. This curious circumstance raises a probability that the mountain, previous to the eruption, had been very extensively cavernous, and had contained large collections of water, in which the diatoms had been profusely propagated. These siliceous shells form the cases of the frustules of this order of plants; and the amazing rapidity with which they multiply will readily account for there having been accumulated in the interior of the mountain enormous beds of them, which were thrown out from the summit as fine dust by the force of the elastic vapours acting from beneath. Possibly, however, the deposits of these siliceous shells may have been formed at the bottom of the sea, in the neighbourhood of the mountain, and been forced into the volcanic focus along with the sea-water, whose sudden conversion into explosive steam, through contact with highly heated materials, may have caused the eruption.

The appearance which Mount Vesuvius presented after the great convulsion of A.D. 79 is shown in the annexed woodcut. In a portion of the ancient crater, there had been upheaved a large cone, composed of the loose materials ejected by the mountain, and on the summit of this cone had been formed the new crater of the volcano. This part of the mountain, with the cone and crater, retained the old name of Vesuvius; while to the former crater, and that portion of the mountain which it crowns, was subsequently given the new name of Monte Somma

Herculaneum, having been situated several



MOUNT VESUVIUS AFTER ERUPTION OF A.D. 79.

miles nearer to the crater than Pompeii, has had heaped over its site a greater accumulation of materials, produced by the successive eruptions of the volcano which have happened since the cities were first destroyed. Hence, while Pompeii is buried only in ashes and loose stones, there have been formed over the substance in which Herculaneum was first entombed several layers both of lava and alluvial deposits, to a depth of from 70 to 112 feet.

It was not until the year 1713 that any traces were obtained of the buried cities; and notwithstanding the greater thickness of the overlying masses, it was Herculaneum that was first discovered. In the course of that year a well was being sunk, and the workmen, to their surprise, came right down upon the theatre, where they soon after found the statues of Hercules and Cleopatra. Owing to the difficulty of cutting through the superincumbent materials, and the stiffness of the substance in which the buildings are embedded, but little progress has been made in the disinterment of this city, in comparison with what has been done at Pompeii, whose site was not discovered till forty years afterwards. Of the latter city a large proportion has been laid open, and the entire circuit of the walls ascertained to be three miles, so that its population must have been considerable. Many of the public buildings and private houses have been exposed, and their valuable contents removed to a museum in Naples devoted to the purpose. Some whole streets have been cleared; and among other places of interest the cemetery of Pompeii, of which a representation is given in the annexed woodcut.

It would be foreign to the purpose of this work to enter into further details respecting the discoveries of works of ancient art, MSS., and other remarkable objects found in these two cities; while so much has already been written on the subject, as to render it unnecessary to say more. Little of interest has been found in the remains of Stabiæ, which was a place of minor importance compared with the other two cities, whose melancholy fate it shared.

Since the disastrous eruption of A.D. 79, Vesuvius has been in activity a great many times; nor does its energy appear to have been at all diminished during the present century. The second eruption occurred in A.D. 203; and the third, which was much more violent, in 472. So immense was the volume of ashes discharged on this occasion, that they fell over nearly the whole of Europe, exciting much alarm even as far as Constantinople. This eruption was followed by three others, during which nothing was yet thrown out but the same sort of loose materials—ashes, stones,

CEMETERY OF POMPEII.

pumice, &c. In 1036, however, there occurred a violent eruption, during which lava was for the first time ejected. To this succeeded other five eruptions at irregular intervals—the series terminating in 1500 with one of no great energy. After this the crater sank into a state of perfect quiet, in so much that the whole mountain became again covered with luxuriant vegetation; and even the interior of the crater had, in 1611, become covered with shrubbery—thus indicating an absence of deleterious exhalations.

In 1631 the activity of the volcano was suddenly renewed by an eruption of terrible violence. All the vegetation which had overspread the interior of the crater was immediately ignited and tossed high into the air. Great streams of lava came forth on this occasion, and overwhelmed the villages at the foot of the mountain, on the side of the bay of Naples. There were also thrown out immense torrents of hot water, which wrought great desolation. Other four eruptions happened during the same century, and since that time they have been gradually becoming more frequent, though perhaps less violent. During an eruption in 1737 there issued a stream of lava which, passing through the village of Torre del Greco, flowed onwards till it was stopped by the sea.

A still more formidable stream was thrown out in 1794, which not only again destroyed Torre del Greco, but, with a front of 1127 feet, advanced into the sea to the distance of 362 feet. During a prior eruption in 1779, the stones and ashes, and even the jets of liquid lava, were thrown up to a prodigious height. Sir William Hamilton affirms, that they shot up in a great column of fire as high as 10,000 feet above the sea. A portion of the ashes and stones was drifted away to some distance; but the greater proportion of these, and nearly all the lava, still red hot and liquid, fell upon the cone, on part of Monte Somma, and into the valley between them. The whole mass which thus fell, still vividly glowing, formed a continuous fiery expanse about two and a half miles in breadth, which, with the lofty column of fire issuing from the top, presented a magnificent but very terrific spectacle. The heat, radiating from this vast glowing surface, is said to have been perceptible at a distance of six miles all round.

The lava, as it issues from the crater of Vesuvius, is perfectly liquid, and glows with an intense white brilliancy, like that of molten silver; but, as it descends, it begins to cool at the top, and a quantity of broken slag is formed on the surface of the stream, becoming erelong a continuous coating. The speed of the current, very rapid at first, gradually slackens until, on the level at some distance from the mountain, its progress is scarcely perceptible.

Since the commencement of the present century the eruptions of Vesuvius have been frequent, and sometimes of long continuance, so that to enter into their details would be tedious. During an eruption in 1820 there was observed a peculiar phenomenon—the vapours issuing from the crater presenting three distinct colours green, white, and black. The next eruption, which occurred in 1822, was ushered in by the tumbling down of the principal cone, which had attained a height of upwards of 600 feet. It fell with a dreadful crash on the night of the 22nd October; and on the following evening there commenced an eruption which lasted continuously for twelve days. The internal detonations of the mountain were terrific; while the quantity of ashes and other matters thrown out was so great as to produce at noon a darkness deeper than that of midnight in the neighbouring villages, whose inhabitants had to grope their way by torch-light. The quantity of aqueous vapour thrown into the higher atmosphere on this occasion produced a magnificent volcanic storm of thunder and lightning, followed by torrents of rain.

A phenomenon similar to that which occurred in 1820, but on a still greater scale, was remarked during an eruption in February 1848.

There rose from the mountain a column of vapour 40 feet in height, which is said to have presented all the colours of the rainbow. This may have been owing to the glare of the lava falling upon it in some peculiar direction, so as to produce a true rainbow on the vapour, after it had assumed the vesicular form. A few hours afterwards there rose ten circles of vapour, which presented the same colours as in 1820—green, white, and black. These circles gradually assumed the form of a cone of considerable height, and from under it two streams of lava came pouring forth.

The eruption of 1855 presented a far more imposing spectacle. Between Monte Somma and Vesuvius there is a vast ravine of great depth, the first descent to which, on the side of Vesuvius, is a sheer precipice. A great stream of lava, about 200 feet in width, issuing from the crater, took the direction of this ravine, and on arriving at the edge of the precipice plunged heavily over it, forming a magnificent fiery cascade about 1000 feet in height. On reaching the valley beneath, it wended its way through the woods, consuming the trees in its course, and destroying several villages through which it flowed. A grander sight than this cascade of fire must have presented, it would be difficult for the human mind to imagine.

The mountain continued active from 1855

almost continuously up to 1858. Towards the end of May and the beginning of June of the latter year, its activity increased in violence, there having been opened in the course of two days on the sides of the cone five new fissures, all pouring forth great torrents of lava at the same time.

Of the many accounts of ascents made to the crater of this volcano, one of the most interesting is that given by Mr. Babbage in his "Passages from the Life of a Philosopher." The ingenious inventor of the calculating machine reached the summit of the cone before sunrise, and he thus describes what he saw and what he did:—

"It was still almost dark; we stood upon the irregular edge of a vast gulf, spread out below, at the depth of about 500 feet. The plain at the bottom would have been invisible but for an irregular network of bright red cracks spread over the whole of its surface. Now and then the silence was broken by a rush upwards of a flight of red-hot scoria, from the diminutive crater within the large one. These missiles, however, although projected high over the summit of the cone, never extended themselves much beyond the small cavity from which they issued.

"Those who have seen the blood-vessels of their own eye, by the aid of reflected light, will have seen, on a small scale, a perfect resemblance of the plain which at that time formed the bottom of the great crater of Vesuvius.*

"As the morning advanced, the light increased; and, some time before sunrise, we had completed the tour of the top of the great crater. Then followed that glorious sight—the sun when seen rising from the top of some lofty mountain.

"I now began to speculate upon the means of getting a nearer view of the little miniature volcano in action at one corner of the gulf beneath us. We had brought ropes with us, and I had observed, on our tour round the crater, every dike of congealed lava by which the massive cone was split. These presented but-

* Mr. Babbage is here slightly inaccurate. To be satisfied on this point, the observer must seat himself before a mirror, and place a lighted candle on a table immediately behind his right ear—all other light being excluded from the room. He must then hold a piece of transparent plate-glass at an angle of 45° in front of his right eye, so as to throw the reflected light from the candle into its pupil. On now looking at the mirror with his left eye, he will see the image of the interior of his right, which will appear glowing like a carbuncle or a topaz. To see the far more curious phenomenon to which Mr. Babbage alludes, the observer must enter a pretty large room with a single lighted taper—all other light being excluded. Seating himself at one corner of the room with a table at his right hand, he will place the taper on it in such a position that the flame shall be a few inches from his right temple, and a little in front of it. He will then take in his right hand a small lens of short focus, and having concentrated the light obliquely on the pupil of his right eye, he will give the lens a rapid but slight vibratory motion, so as to flicker the light—keeping his eye meanwhile steadily fixed on the opposite corner of the room. After having continued this motion for some little time, the observer will lose sight of all external objects, and will see a highly magnified image of the interior of his eye, with the bright red blood-vessels branching out upon it in every direction. It is to this latter appearance that Mr. Babbage compares the bottom of the crater of Vesuvius.

tresses, with frequent ledges, or huge steps, by which I hoped, with the aid of ropes, to descend into the Tartarus below.

"Having consulted with our chief guide Salvatori, I found that he was unwilling to accompany us, and proposed remaining with the other guides on the upper edge of the crater. Upon the whole, I was not discontented with the arrangement; because I left a responsible person to keep the other guides in order, and also sufficient force to lift us up bodily by the ropes, if that should become necessary.

"The abruptness of the rocky buttresses compelled us to use ropes; but the attempt to traverse the steep inclines of light ashes and of fine sand would have been more dangerous, from the risk of being ingulfed in them.

"Having well examined the several disadvantages of these rough-hewn, irregular, titanic stairs, I selected one, which séemed the most promising for facilitating the descent into the crater. I was encumbered with one of Troughton's heavy barometers strapped to my back—looking much like Cupid's quiver, though probably rather heavier. In my pocket I had an excellent box sextant; and in a rough kind of basket two or three thermometers, a measuring tape, and a glass bottle enclosed in a leather case, commonly called a pocket-pistol, accompanied by a few biscuits.

"We began our descent by the aid of two ropes, each supported above by two guides. I proceeded, trusting to my rope, to step wherever I could; and then, cautiously holding on by the rope, to spring down to the next ledge. In this manner we descended until we arrived at the last projecting ledge of the dike. Nothing then remained for us but to slide down the steep and lengthened incline of fine sand. Fortunately the sand itself was not very deep, and was supported by some solid material beneath it. I soon found that it was impossible to stand; so I sat down upon this moving mass, which evidently intended to accompany us in our journey. At first, to my great dismay, I was relieved from the care of my barometer, of which the runaway sand immediately took charge. I then found myself getting deeper and deeper in the sand, and still accelerating my downward velocity.

"Gravity had at last done its work, and become powerless. I soon dug myself out of my sandy couch, and rushed to my faithful barometer, lying at some distance from me, with its head just unburied; fortunately it was uninjured. My companion, with more skill or good fortune, or with less encumbrances, had speedily alighted on the burning plain we now stood upon.

"The area of this plain, for it was perfectly flat, was in shape somewhat elliptical. The surface consisted of a black scoriaceous rock, reticulated with ditches from one to three feet wide, intersecting each other in every direction. From some of these, fumes, not of the most agreeable odour, were issuing. All those above two feet showed that, at that depth below us, everything was of a dull red heat. It was these ditches with red hot bottoms, which, in the darkness of the night, had presented the singular spectacle I described as having witnessed on the evening before.

"At one extremity of this oval plain, there was a small cone, from which the eruptions before described appeared to issue."

The enterprising philosopher then measured trigonometrically the height of the edge of the crater, and found its lowest points to be 570 feet above the plain on which he stood. His walking-stick, which he had thrust only a few inches into the soil as a mark during his measurement, was kindled into flames. He then began to watch the eruptions from the small cone above mentioned, and he goes on to say:—

"These periodical eruptions interested me very much. I proceeded to observe and register them, and found they occurred at tolerably regular intervals. At first, I performed this at a respectful distance, and out of the reach of the projected red-hot scoria. But as I acquired confidence in their general regularity, I approached from time to time more nearly to the little cone of scoria, produced by its own eruptions.

"I now perceived an opening in this little cone, close to the perpendicular rock of the interior of the great crater. I was very anxious to see real liquid lava; so immediately after an eruption, I rushed to the opening, and thus got within the subsidiary crater. But my curiosity was not gratified; for I observed, about forty or fifty feet below me, a huge projecting rock, which, being somewhat in advance, effectively prevented me from seeing the lava lake, if any such existed. I then retreated to a respectful distance from this infant volcano, to wait for the next explosion.

"I continued to note the intervals of time between these jets of red-hot matter, and found that from ten to fifteen minutes was the range of the intervals of repose. Having once more reconnoitred the descent into the little volcano, I seized the opportunity of the termination of one of the most considerable of its eruptions, to run towards the gap, and cautiously to pick my way down to the rock, which hid from me, as I supposed, the liquid lava. I was armed with two phials—one of common smelling-salts, and the other containing a solution of ammonia. On reaching the rock, I found it projected over the lake, which was really filled by liquid fiery lava. I immediately laid myself down, and, looking over its edge, saw, with great delight, lava actually in a state of fusion.

"Presently I observed a small bubble swelling up on the surface of the liquid lava; it became gradually larger and larger, but did not burst. I had some vague suspicion that this indicated a coming eruption; but on looking at my watch, I was assured that only one minute had elapsed since the termination of the last. I therefore watched its progress: after a time the bubble slowly subsided without breaking.

"I now found the heat of the rock on which I was reposing, and the radiation from the fluid lava, almost insupportable; whilst the sulphureous effluvium painfully affected my lungs. On looking round, I fortunately observed a spot a few feet above me, from which I could, in a standing position, get a better view of the lake, and perhaps suffer less inconvenience from its vapours. Having reached this spot, I continued to observe the slow formation and absorption of these vesicles of lava. One of them soon appeared. Another soon followed at a different part of the fiery lake, but, like its predecessor, it disappeared as quietly.

"Another swelling now rose about half way distant from the centre of the caldron, which enlarged much beyond its predecessor in point of size. It attained a diameter of about three feet and then burst, but not with any explosion.

The waves it propagated in the fiery fluid passed on to the sides, and were thence reflected back, just as would have happened in a lake of water of the same dimensions.

"This phenomenon re-appeared several times, some of the bubbles being considerably larger in size, and making proportionally greater disturbance in the liquid of this miniature crater. I would gladly have remained a longer time, but the excessive heat, the noxious vapours, and the warning of my chronometer, forbade it. I climbed back through the gap by which I descended, and rushed as fast as I could to a safe distance from the coming eruption.

"I was much exhausted by the heat, although I suffered still greater inconvenience from the vapours. From my observations of the eruptions before my descent into this little crater, I had estimated that I might safely allow myself six minutes, but not more than eight, if I descended into the crater immediately after an eruption.

"If my memory does not fail me, I passed about six minutes in examining it, and the next explosion occurred ten minutes after the former one. On my return to Naples, I found that a pair of thick boots I had worn on this expedition were entirely destroyed by the heat, and fell to pieces on my attempt to take them off." —*Passages in the Life of a Philosopher*, pp. 216–222.

On the northern side of the bay, and to the westward of Vesuvius, but on the other side of

THE PHLEGRÆAN FIELDS.

1. Monte Nuovo.
2. Monte Barbaro.
3. Lake Avernus.
4. Lucrine Lake.
5. The Solfatara.
6. Puzzuoli.
7. Bay of Baiæ.

the city of Naples, lies a very volcanic district, forming the northern shore of the Bay of Baiæ.

Here are the Phlegræan Fields of classic times. This tract contains several volcanic craters, and its general appearance will be easily understood from an inspection of the prefixed woodcut, copied from Lyell's "Principles of Geology."

Of the craters which this district contains, that of the Solfatara is the only one retaining any degree of activity, and it is of a very subdued kind—consisting of exhalations of aqueous vapour mixed with sulphurous and muriatic acid gases. This crater is said to have been in active eruption in A.D. 1198; but it has remained in its present state ever since. To the westward lies Lake Avernus, supposed also to be an ancient crater. In classic times it emitted noxious exhalations, but these have long ceased. Nearer to the Bay of Baiæ is Monte Barbaro, on whose summit is a deep circular crater about a mile in diameter, and now covered with vineyards. Immediately to the southward of this mountain, and close upon the Bay of Baiæ, stands Monte Nuovo—occupying the site partly of a former level plain, and partly of a portion of the Lucrine Lake, which lies at its base, divided from the sea by a narrow belt of shingle.

Monte Nuovo was the result of an eruption which began on the 29th of September 1538. The neighbourhood, and particularly the town of Puzzuoli, lying a little to the eastward, had for two years before this date been much disturbed by earthquakes, and on the day and night previous to the eruption there had been felt about twenty shocks, more or less severe. During this time, the plain intervening between Monte Barbaro and the sea was slightly raised and much cracked—water issuing from some of the fissures. The sea rapidly dried up for about 200 paces adjoining the plain, leaving many fishes on the deserted beach. On the morning of the 29th, the ground of the plain first sank about fourteen feet, and there issued forth a stream of water, first cold and then tepid. A short time afterwards, the ground that had sunk began to swell up again, till it formed a mound; and then in its centre there was opened a crater, whence issued fire, stones, ashes, vapours, and mud. Some of the stones thrown up are described as being larger than an ox, and many of them were tossed to a great height. They fell all round the orifice, and together with the ejected mud formed a constantly increasing mass. The eruptions continued for a week—those on the fourth and seventh days being the most violent, after that of the first day. The materials accumulated by these eruptions at length formed a hill 440 feet in height above the level of the sea, and having a circumference of about a mile and a half. The crater on its summit descends in the interior to a depth of 421 feet, so that the bottom is only nineteen feet above the sea-level.

Such was the origin of Monte Nuovo, which is now covered with a most luxuriant vegetation, composed chiefly of arbutus, myrtle, and other evergreens. It presents in this respect a striking contrast to the older extinct volcano of Monte Barbaro, whose aspect is comparatively sterile.

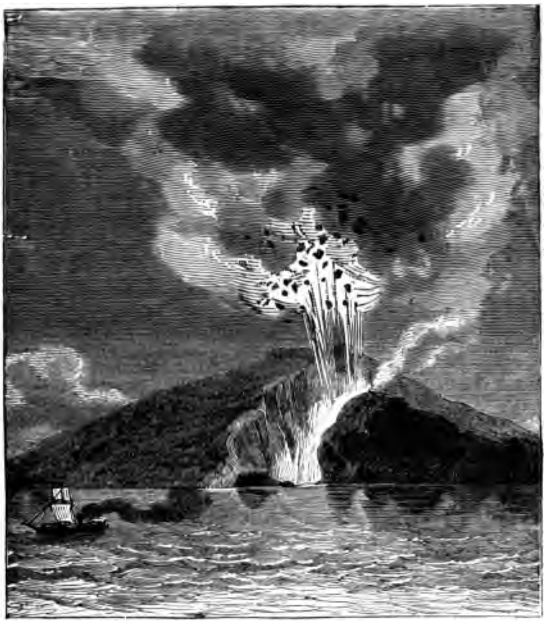
Immediately adjacent to this part of the Italian coast lie the islands of Procida and Ischia, both of volcanic origin. Ischia, although only eighteen miles in circumference, contains no less than twelve considerable volcanic cones, which have been formed in succession. Some of these craters were very active for a length of time before the beginning of the Christian era; but after the breaking out of Vesuvius the eruptions in Ischia ceased for a long while. This repose, however, was interrupted in the years 1301 and 1302, after Vesuvius had been long and was still inactive. In 1301 Ischia was much disturbed by a very rapid succession of earthquakes of great violence; and they were terminated in 1302 by an eruption of lava from the Campo del Arso, not far from the town of Ischia. This eruption was succeeded by another period of rest, which remained unbroken till 1828, when the whole island was convulsed by the violent earthquake which has been previously mentioned.

CHAPTER XI.

THE MEDITERRANEAN GROUP OF VOLCANOES, CONTINUED—THE LIPARI ISLANDS, THE CYCLOPEAN ISLES.

SOUTH-EASTWARD of Ischia, between Calabria and Sicily, the Lipari Islands arrest attention for the volcanic phenomena they present. Of these, the most remarkable and best known is Stromboli, which consists of a single mountain, having a very obtuse conical form. It has on one side of it several small craters, of which only one is at present in a state of activity. The general appearance of the island is shown in the annexed woodcut.

The total height of the mountain is about 2000 feet, and the principal crater is situated at about two-thirds of the height. Stromboli is one of the most active volcanoes in the world. It is mentioned as being in a state of activity by several writers before the Christian era, and the commencement of its operations extends into the past beyond the limits of tradition. Since history began, its action has never wholly ceased, although it may have varied in intensity from time to time. It has already been mentioned that, during the great Calabrian earthquakes, it was more quiescent than usual. It has also been observed, that the violence of its eruptive



STROMBOLI.

force has a certain dependence on the weather —being always most intense when the barometer is lowest.

From the peculiar position of the crater, it is possible to ascend the mountain and look down upon it from above. Even when viewed in this manner, it presents a very striking appearance. While there is an uninterrupted continuance of small explosions, there is a constant succession of more violent eruptions, at intervals varying in length from seven to fifteen minutes. Several eminent observers have approached quite close to the crater, and examined it narrowly. One of the latest who has achieved this somewhat hazardous adventure is M. Quatrefages, who has given a vivid description of his experience. He and his party first climbed to the summit of the old cone—more than 600 feet above the present crater, which opens on its crumbled sides.

"As if to celebrate our arrival," says this eminent naturalist, "the volcano saluted us by an eruption. We saw the abyss kindling at our feet, whilst a magnificent jet of fire rose towards us with a noise resembling the rapid discharge of artillery.

"Standing immediately above the crater, and unable to advance far over this moving soil, we were impeded in our observations by the mountain itself; whilst we were, moreover, almost constantly surrounded by clouds impregnated with stifling gases. To avoid these inconveniences we descended a lateral ridge, where we were able at our leisure to contemplate the desolate scene displayed before our eyes. Three concentric ridges, of which the outer ones are partially destroyed, encompass the volcanic crater. Behind us, steep declivities stretched down to the cultivated regions, which we had found it so arduous to traverse; but which appeared, when seen from our elevated position, to be a mere plain. To our left, our eyes rested on the highest peak of the island, which was once a portion of the most ancient, and the outermost, of the three concentric ridges, and which was separated from us by a deep ravine. To the right was the small elevation from which we had just descended; whilst in front of us, the ridge, on which we were standing, curved in a semicircle towards a mass of lava suspended over a precipice, and at the same time enclosed a steeply-inclined mass of the cinders and scoria, abruptly cut by the edges of the abyss, into which the existing crater opens.

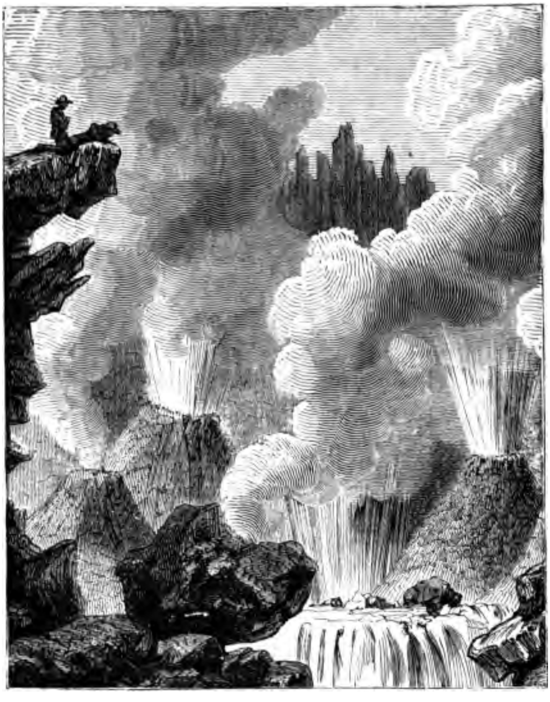
"This crater encloses within its walls six distinct mouths. Two of these secondary craters eject that smoke impregnated with hydrochloric and sulphurous acid gases, which is at all times being emitted from the summit of the mountain. The third mouth, which is situated to the right, also throws out a thick and whitish smoke, in the midst of which red fiery stones flash like sparks, as they incessantly rise and fall, in the midst of a strange noise resembling the heavy surf driven on a storm-beaten coast, and making one involuntarily think of the mythical caves of the demons. To the left lie the three mouths, which exhibit only intermittent eruptions; two of these evidently belong to the same focus, for they always kindled and became extinguished simultaneously. The third, whose eruptions are much less frequent than the others, is nearest to the spectator. The most formidable detonations proceed from this crater, which, moreover, throws up the highest jets of burning cinders and rocks.

"As we had arrived in broad daylight, we had been enabled thoroughly to examine all those rocks of lava, and at our leisure to contemplate the steep ridges, the declivities of ashes, and all that singular scene, whose uniform blackness was broken only in a few places by masses of sombre red scoria; but the sun had now set, and the short twilight of those southern latitudes was rapidly giving place to night. In proportion as the light became extinguished in the sky, it seemed to revive within the depths of the abyss. The smoke assumed a redder tint—becoming gradually more and more fiery. The showers of sparks increased; while the concentrated light within the crater itself enabled us better to follow each varying phase of the eruption. The explosions of the two smaller mouths recurred every seven or eight minutes; whilst ten or twelve minutes intervened between the eruptions of the large crater. The phenomenon was always affected in the same manner; thus, for instance, at the moment when the volcano began to exhibit signs of activity, the smoke, which issued from the openings to the right, assumed a bright and vivid red colour; while more and more quickly recurring detonations preceded every jet of burning matter. These jets were thrown up in diverging directions, and almost without any smoke, from one of the two sister craters; whilst from the other they darted upwards, as if impelled by the current of violet-coloured vapour, that escaped from the mountain with a loud whistling sound. The principal crater ejected a broad and expanded jet of incandescent rocks and lava, which nearly reached the platform on which we were standing, and fell with a loud noise—one portion being carried into the sea, and the remainder thrown back into the abyss from whence it had been ejected, whilst the wind blew over us clouds of the black and fine sand and ashes.

"The night had long since closed around us, and our guides were urgent that we should make the descent, we were therefore compelled to yield to their request and prepare for our return; but before we made a final retreat, we waited to see another eruption, and this, fortunately, proved to be most magnificent. The three mouths were playing simultaneously, and reflecting the reddish brightness of the lava; whilst the triple enclosure of the crater revealed itself once more to our eyes."—*Rambles of a Naturalist*, ii. 24.

The following woodcut shows the appearance presented by the crater of Stromboli, when visited by M. Hoffman in 1828.

This eminent geologist, while having his legs held by his companions, stretched his head over the precipice, and, looking right down into the mouth of one of the vents of the crater immediately under him, watched the play of the liquid lava within it. Its surface resembled molten silver, and was constantly rising and falling at regular intervals. A bubble of white vapour rose and escaped, with a decrepitating noise, at each ascent of the lava—tossing up red-hot fragments of scoria, which continued dancing up and down with a sort of rhythmic play upon the surface. At intervals of fifteen minutes or so, there was a pause in these movements. Then followed a loud report, while the ground trembled, and there rose to the surface of the lava an immense bubble of vapour, which, bursting with a crackling noise, threw out to the height of about 1200 feet large quantities of red-hot stones and scoria, which, describing parabolic curves, fell in a fiery shower all round. After another brief repose, the more moderate action was resumed as before.



CRATER OF STROMBOLI.

A little to the southward of Stromboli lies Lipari, the principal island of the group. This island appears to be almost entirely of volcanic origin, and before the Christian era was even more violent in its activity than Stromboli. It has for many centuries, however, remained in a state of absolute repose—showing no other signs of igneous action than its hot springs, and its great beds of pumice, obsidian, and other volcanic productions.

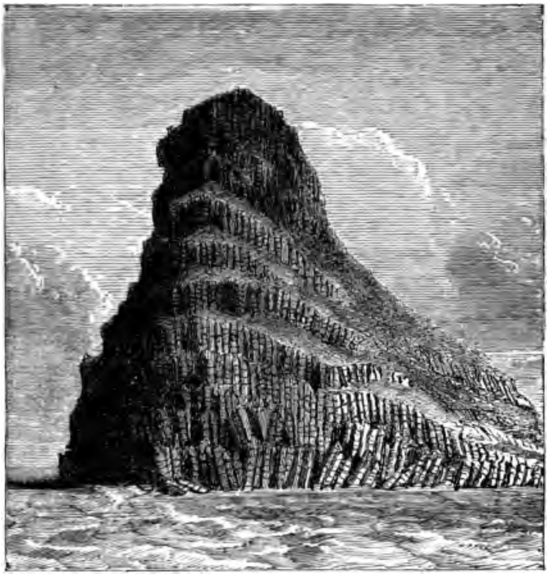
Immediately to the south of Lipari lies the island of Volcano, which was in a state of activity before the Christian era, and still retains on its summit a crater, whence steam and other vapours are exhaled. Among its emanations are boracic acid, ammonia, and silenium—the most prevalent, however, being sulphurous acid. This crater was among those visited by Dr. Daubeny, who, after remarking on the solemn grandeur of the scene, and its tendency to inspire superstitious awe, says:—"To me, I confess, the united effect of the silence and solitude of the place, the depth of the internal cavity, its precipitous and overhanging sides, and the dense sulphurous smoke, which, issuing from all the crevices, throws a gloom over every object, proved more impressive than the view of the reiterated explosions of Stromboli, contemplated from a distance and in open day." *

There is close to this island a volcanic rock, still emitting sulphurous vapours from its cre-

* Daubeny on Volcanoes, p. 193.

vices, and which is called Volcanello. It is said to have been thrown up from the sea in the year 182 B.C.

Still further to the south, and close to the



THE CYCLOPEAN ISLES.

eastern coast of Sicily, lie the Cyclopean Isles, whose very curious columnar structure clearly indicates their volcanic origin. The above woodcut shows the remarkable appearance presented by one of these islands.

Dr. Daubeny, in reference to them, makes the following remark: "These, though now detached, must at one period have formed a continued stratum; for they are covered with a bed of marl, which seems evidently to have been continuous from the one to the other of these islands. This circumstance, and their general compactness, prove that these formations took place under the surface of the water." *

* Daubeny on Volcanoes, p. 202.

CHAPTER XII.

MEDITERRANEAN GROUP OF VOLCANOES, CONTINUED—MOUNT ETNA.

ON the eastern coast of Sicily, and not far from the sea, rises in solitary grandeur Mount Etna—the largest and highest of European volcanoes. Its height above the level of the sea is a little over 10,870 feet—considerably above the limit of perpetual snow. It accordingly presents the striking phenomenon of volcanic vapours ascending from a snow-clad summit. The base of the mountain is eighty-seven miles in circumference, and nearly circular; but there is a wide additional extent all round overspread by its lava. The lower portions of the mountain are exceedingly fertile, and richly adorned with corn-fields, vineyards, olive-groves, and orchards. Above this region are extensive forests, chiefly of oak, chestnut, and pine, with here and there clumps of cork-trees and beech. In this forest region are grassy glades, which afford rich pasture to numerous flocks. Above the forests lies a volcanic desert, covered with black

MOUNT ETNA.

lava and slags. Out of this region, which is comparatively flat, rises the principal cone, about 1100 feet in height, having on its summit the crater, whence sulphurous vapours are continually evolved.

The great height of Etna has exerted a remarkable influence on its general conformation: for the volcanic forces have rarely been of sufficient energy to throw the lava quite up to the crater at the summit. The consequence has been, that numerous subsidiary craters and cones have been formed all round the flanks of the mountain; so that it has become rather a cluster of volcanoes than a single volcanic cone. The prefixed woodcut will convey an idea of its general appearance.

The subsidiary elevations occur chiefly in the woody region. Without taking into account numerous mounds of ashes and cinders, there are about 80 of these secondary cones—52 on the west and north, 27 on the east side of the mountain. Mount Minardo, one of the largest of these cones, is more than 700 feet high; and a pair close together, called Monti Rossi, are 450 feet in height. They unite at the base, and have a circuit of nearly two miles. As many of these subsidiary hills are wooded, they give the mountain an exceedingly curious and picturesque aspect.

The earliest record of the eruptions of Etna is found in Thucydides, who states that three had occurred before the beginning of the Peloponnesian war, which was in 431 B.C.; but there may have been many earlier of which no tradition has been preserved. There was an eruption in 396 B.C., during which there was thrown out an immense stream of lava, extending a distance of twenty-four miles from the summit to the sea, where it ends. Its breadth, in its lower parts, exceeds two miles, and there are under it layers of lava of older date. It is now covered in many parts with large trees.

To this eruption succeeded four others previous to the year 100 B.C.; after which the mountain became very restless, and its eruptions were frequent. After the beginning of the Christian era, and more especially after the breaking forth of Vesuvius in 79 A.D., Etna enjoyed longer intervals of repose. Its eruptions since that time have nevertheless been numerous—more especially during the intervals when Vesuvius was least active—there being a sort of alternation between the periods of great activity of the two mountains; although there are not a few instances of their having been both in action at the same time.

The most memorable of the eruptions of Etna was that which elevated the double cone of Monti Rossi, before mentioned, and destroyed a large part of the city of Catania. It happened in the year 1669, and was preceded by an earthquake, which overthrew the town of Nicolosi, situated ten miles inland from Catania, and about twenty miles from the top of Etna. The eruption began with the sudden opening of an enormous fissure extending from a little way above Nicolosi to within about a mile of the top of the principal cone, its length being twelve miles, its average breadth six feet, but its depth is unknown. It opened with a loud crash, and emitted a vivid light. Five other parallel fissures of similar size opened afterwards, sending forth great clouds of volcanic vapours, accompanied by thundering noises, so loud as to be heard at a distance of forty miles. Immediately above Nicolosi there were opened two large gulfs, from which great quantities of ashes, stones, sand, and slags were thrown up. These continued to be ejected for nearly four months, and it was by their accumulation that the Monti Rossi were formed.

From the great fissure above-mentioned, there issued an immense stream of glowing lava. In the earlier part of its course, it encountered one of the smaller cones, named Mompiliere, which was much penetrated by subterranean cavities. Into these the lava flowed, and the entire cone subsided to a considerable extent—probably by the fusion of part of its base. After passing this point, the lava flowed onwards with resistless force — overwhelming fourteen towns and villages in its course. At length it reached the walls of Catania, which were sixty feet in height and of great strength. The citizens hoped that these would suffice to resist the fiery torrent; but they were doomed to disappointment. The lava gradually accumulated till it overtopped the rampart, and then fell over it in a glowing cascade. There being now no further obstacle to its progress, it flowed through the city, of which it destroyed a considerable portion on its way towards the sea, where it finally stopped. At its termination it was 600 yards wide and 40 feet deep. Strange to say, the rampart of Catania was not overthrown by the lava, but simply buried in it; and parts of it may still be seen with the solidified lava curving over its top.

The speed with which this great lava-stream travelled varied greatly in different parts of its course. The first 13 miles of its journey were accomplished in 20 days; while 23 days were required for its passage over the last two miles. Its velocity near its source was estimated at 1500 feet an hour; whereas towards the end it took several days to advance a few yards. As usually happens with lava-streams, its surface became speedily encrusted with slag, which was continually broken and cemented again, as the under-current of the fluid portion slowly advanced. An attempt was made to divert its course from Catania, by breaking through the sides of the crust; and a small lateral stream was formed in this way. But the inhabitants of Paterno, a village which would have been overwhelmed had the main stream followed this lateral direction, forcibly resisted the attempt. The citizens of Catania were thus obliged to await the gradual advance of the stream, and trust to the solidity of their rampart; which, however, proved of no avail.

Among the towns overflowed by this great eruption was Mompiliere. Thirty-five years afterwards, in 1704, an excavation was made on the site of the principal church of this place, and at the depth of thirty-five feet the workmen came upon the gate, which was adorned with three statues. From under an arch which had been formed by the lava, one of these statues, with a bell and some coins, were extracted in good preservation. This is the more remarkable, for in a subsequent eruption, which happened in 1766, a hill about fifty feet in height, being surrounded on either side by two streams of lava, was in a quarter of an hour swept along by the current. This event may be explained by supposing that the hill in question had been cavernous in its structure, and that the lava, penetrating into the cavities, had forced asunder their walls, and so detached the superincumbent mass from its supports.

The cavernous structure of many parts of Mount Etna is one of its most striking peculiarities. Near Monti Rossi there is a remarkable succession of these underground cavities. The outermost, called Fossa della Palomba, is 625 feet in circumference. At its entrance its depth is 78 feet; but beyond this point is the descent into another dark cavern, the first in a succession of others smaller, which lead down to a large gallery, 90 feet long, and with a varying breadth of 15 to 50 feet. At the end of this gallery is a passage leading to other caverns which have never been explored.

Many of these caverns are employed as ice-houses—a strange purpose, one would suppose, to which to apply cavities so near the magazines of volcanic fire. But a discovery was made in 1828 of a still more extraordinary character. During the summer of that year the heat was so great that the stores of ice preserved in the caverns became exhausted. In this strait, the magistrates of Catania applied to Signor Gemmelaro, to ascertain if he, who was well acquainted with every part of the mountain, knew of any crevices in which hardened snow might be found. That gentleman called to his remembrance a small mass of perennial ice at the foot of the cone; and impressed with the idea that it might be the out-cropping of a much greater mass, he procured a large body of workmen to examine the spot. On quarrying forward, it was found that the margin of ice was truly what he had suspected—the out-cropping of a great glacier; but it proved to be composed of ice so hard and compact as to render all attempts to remove it impracticable, by reason of the great expense. This glacier owed its preservation to its having been first covered with a layer of ashes, and then overflowed by a current of lava, which had quickly solidified over it; while the non-conducting power of the layer of ashes had prevented the ice from melting. This lava had accumulated to the thickness of several hundred yards, and had thus effectually protected the ice from the action of the sun and external air.

One of the most striking features of Mount Etna is the Val del Bove—a deep valley lying on the eastern side of the great cone, which is otherwise rather symmetrical. It is a large and almost circular depression, stretching from near the summit to within the upper limit of the woody region. It is prolonged downwards on one side by two other narrow ravines, reaching to the margin of the cultivated parts of the mountain. Viewed from above, the Val del Bove has much the form of an amphitheatre. It is surrounded by a wall of highly inclined rocks, varying from 1000 to more than 3000 feet in height—the highest being at the upper end, and the diminution being gradual on either side of the descent. These walls are traversed by ridges of hard lava, which project from them in high relief, and are supposed to have been formed by injection from beneath, into fissures rent in the previously existing rock.

The valley is of large dimensions, being between four and five miles in diameter, and it has much the aspect of an extinct crater. Sir Charles Lyell, however, who examined it with great care, thinks that this is not its true character, but that it has been formed either by the falling in of a large portion of the mountain, or that it has been scooped out by the action of water. He seems to regard the former as the more probable cause.

When seen from a great distance, the bottom of this remarkable valley appears flat; but a nearer view shows its floor to be exceedingly uneven. It has been traversed by numerous streams of lava, the upper surfaces of which resemble the waves of a tempestuous ocean, which have been suddenly petrified. Its uniformity of surface is also interrupted by two prominent masses of rock, standing like islands in this solidified sea. These peculiar features are best seen when the valley is viewed from beneath. The desolation of the scene is much heightened by the perfect silence which prevails.

It is not by its streams of fire alone that Etna ravages the valleys and plains at its base. It sometimes also deluges them with great floods of water. On the 2nd of March 1755, two streams of lava, issuing from the highest crater, were at once precipitated on an enormous mass of very deep snow, which then clothed the summit. These fiery currents ran through the snow to a distance of three miles, melting it as it flowed. The consequence was, that a tremendous torrent of water rushed down the sides of the mountain, carrying with it vast quantities of sand, volcanic cinders, and blocks of lava, with which it overspread the flanks of the mountain, and the plains beneath, which it devastated in its course.

Since the beginning of the present century, Etna, although less restless than Vesuvius, has had a good many fits of activity. In 1811 there was an eruption from the great crater, accompanied by loud detonations and much shaking of the mountain. A stream of lava burst from the side of the cone a little below the summit. Erelong it ceased to flow, and immediately a second mouth was opened lower down. A third followed, and then a succession of others, till no less than seven had been opened—all lying in the same line downwards, thus indicating that a vast perpendicular rent had been gradually formed in the side of the cone.

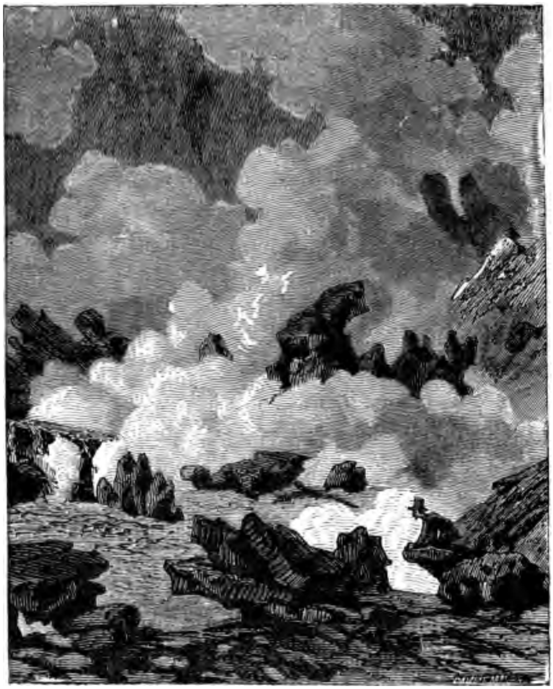
Another great eruption from the principal crater took place in 1819, presenting some peculiarities. Near the point whence the highest stream of lava issued in 1811, there were opened three large mouths, which, with loud explosions, threw up hot cinders and sand, illuminated by a strong glare from beneath. Shortly afterwards there was opened a little lower down another mouth, from which a similar eruption took place; and erelong still further down there appeared a fifth, whence there flowed a torrent of lava, which rapidly spread itself over the Val del Bove. During the first forty-eight hours it flowed nearly four miles, when it received a great accession. The three original mouths became united into one large crater, from which, as well as from the other two mouths below, there poured forth a vastly augmented torrent of lava, which rushed with great impetuosity down the same valley. During its progress over this gentle slope, it acquired the usual crust of hardened slag. It directed its course towards that point at which the Val del Bove opens into the narrow ravine beneath it—there being between the two a deep and almost perpendicular precipice. Arrived at this point, the lava-torrent leaped over the precipice in a vast cascade, and with a thundering noise, arising chiefly from the crashing and breaking up of the solid crust, which was in a great measure pounded to atoms by the fall—throwing up such vast clouds of dust as to awaken an alarm that a fresh eruption had begun at this place, which is within the wooded region.

The great cone of Etna was ascended in 1834 by Messrs Elie de Beaumont and Leopold von Buch. The former has given a minute description of a circular opening which then existed on the margin of the great crater, with a sketch, of which the annexed woodcut is a copy.

This gulf had a diameter varying from 260 to 330 feet; but its depth could not be discerned. It contained numerous vents, from which continually ascended clouds of sulphurous vapours, that crept lazily along its sides, amid the most profound silence.

An ascent to the great crater was also made in 1844 by M. Quatrefages, who gives the following graphic description of what he saw:—

"At our feet yawned the great crater. It was not here a simple inverted cone or funnel, as we had observed in all the secondary cones, and which is the case even on the summit of Vesuvius itself. Nor did we see before us that uniform blackness of the rocks and ashes which characterizes Stromboli. The effects of the eruption of the preceding year were still apparent; and the crater of Etna, at the period of our visit, had the appearance of a deep and



SUBSIDIARY CRATER OF ETNA, 1834.

irregular valley, beset with points and capes, and formed by abrupt slopes bristling with enormous scoria and blocks of lava, heaped up in masses, or rolled and twisted in a thousand different ways, by the force of the volcanic action, or the accidental influences to which they had been subjected in the act of falling. The blue, green, and white lava, stained here and there with broad black patches, or streaks of dull red, made the livid colour of the surrounding rocks still more striking. A death-like silence reigned over this chaos; long lines of white vapour were noiselessly escaping from a thousand different fumarolles (vents), and, trailing slowly along the sides of the crater, carried to the spot where we were standing suffocating emanations of sulphurous and hydrochloric acids. The pale light of the moon, joined to the rising dawn, was a fit accompaniment to this wild scene, whose grand and supernatural character no language can adequately express.

"The soil on which we were treading was entirely composed of cinders and scoria, and was humid and warm, and covered with a white coating that looked like hoar-frost. This humidity, however, was an effect of the acid emitted from the crater, which moistened and corroded everything that came into contact with it; while the silvery film, on which a few crystals were sparkling, was a deposit of sulphur sublimated by the volcano, and of salts formed by the chemical re-actions which were incessantly occurring in this formidable laboratory. By following the narrow ridge which borders the crater to the south, we reached the highest point, which is situated on its eastern extremity. Here an indescribable spectacle presented itself to our gaze. The sky was perfectly pure, the air was exquisitely transparent; while the horizon, which, from the shortness of the twilight, was now brightly illumined, appeared to have no other limits than that which resulted from the curvature of the earth's surface. From our lofty pedestal we looked down a depth of four or five thousand feet upon the highest summits of the Pelorian and Madonian Mountains; while the whole of Sicily lay spread before us as on a map."

Having given a glowing description of the landscape lighted by the rising sun, M. Quatrefages goes on to say:—"After throwing one last look at the valley of the crater, we left our place of observation, and descended towards the foot of a mamelon (mound) which lay to the east. Our guide soon stopped us near a narrow and steep declivity, which was entirely detached from the rounded margin of the cone, and abutted upon a precipice which descended to a depth of several hundred feet. There we saw him roll up the sleeve of his jacket, and apply it to his mouth—a proceeding which he signified by signs that we must imitate, rushing forward across the slope as he exclaimed, 'Fate presto!' Without hesitation we followed him, and speedily reached the margin of the mouth, which, in 1842, had thrown its lava into the Val del Bove, and which, being re-opened by the eruption of 1843, appeared still to threaten the neighbouring district. It was from thence that the smoke issued that we had seen from Giardini, and it was from the depths of its abysses that we had from time to time heard rolling peals of subterranean thunder.

"Here all description becomes absolutely impossible. A vast irregularly circular enclosure, formed by perpendicular walls, encircled the chasm. To the left, at the foot of the escarpment, a large blow-hole had been opened, from which darted forth clouds of fiery red smoke. In the centre, to the right, everywhere lay enormous blocks of lava that had been shivered, cracked, and torn—some black, others of a dark red, but all exhibiting in their crevices the vivid tints of the lava from which they had been formed. A thousand streams of white or gray smoke were crossing and re-crossing each other in all directions with a deafening noise, and with a whistling sound similar to that of a locomotive from which the steam is escaping. Unfortunately we could do no more than throw a hasty glance at this strange and terrific scene. The hydrochloric acid entered our throats, and penetrated to the last ramifications of the bronchial tubes; and with haste, and almost intoxicated, as it were, we regained the protecting slope, where we might breathe more at ease; and then, resting on our staffs, sprang to the edge of the declivity, which was solely composed of movable *débris;* and in five minutes we had reached the base of the cone, which it had cost us more than an hour to ascend."—*Rambles of a Naturalist*, ii. 92, *et seq.*

After the eruption of 1843, mentioned in the above account, Etna rested for about nine years; but in the autumn of 1852 there was a great eruption, of which full details were given in the journals of the day. Two new mouths were opened in the Val de Leone, which, after throwing out immense quantities of ashes, stones, and ammoniacal vapours, poured forth two large streams of lava. After these had continued to flow for a considerable time, the pressure of the glowing liquid became so great that it burst the barrier between the two mouths, and they were thrown into one—thus forming a great chasm, from which the lava rushed forth in larger quantity and with increased violence. The mass of rock which had divided the two mouths was shivered into fragments, and tossed into the air to a great height. Some of these pieces were as large as a cottage, and they were glowing at a white heat. In the great cloud of ashes and vapour which was formed over the burning chasm, forked lightnings played incessantly, and there were thunders in the air as well as in the bowels of the mountain. There also arose every now and then fierce hurricanes, which drifted the ashes hither and thither with great fury. The lava-current attained an extreme breadth of about two miles, and an extreme depth of 160 feet; but in some parts of its course its depth was only about 12 feet. Owing to its having flowed over a highly cultivated district of country, the damage it inflicted was immense; but, happily, no lives appear to have been lost. This eruption continued, with some short intervals of rest, from the beginning of August till about the middle of December.

In the beginning of 1865, Etna was again in violent activity, when there was a repetition of the same phenomenon observed in 1811—namely, the opening of seven new craters, all in a right line of descent from the summit—the highest being at the height of 5578 feet above the level of the sea. There was no other remarkable feature attending this eruption.

penetrated to the last ramifications of the bronchial tubes; and with haste, and almost intoxicated, as it were, we regained the protecting slope, where we might breathe more at ease; and then, resting on our staffs, sprang to the edge of the declivity, which was solely composed of movable *débris;* and in five minutes we had reached the base of the cone, which it had cost us more than an hour to ascend."—*Rambles of a Naturalist,* ii. 92, *et seq.*

After the eruption of 1843, mentioned in the above account, Etna rested for about nine years; but in the autumn of 1852 there was a great eruption, of which full details were given in the journals of the day. Two new mouths were opened in the Val de Leone, which, after throwing out immense quantities of ashes, stones, and ammoniacal vapours, poured forth two large streams of lava. After these had continued to flow for a considerable time, the pressure of the glowing liquid became so great that it burst the barrier between the two mouths, and they were thrown into one—thus forming a great chasm, from which the lava rushed forth in larger quantity and with increased violence. The mass of rock which had divided the two mouths was shivered into fragments, and tossed into the air to a great height. Some of these pieces were as large as a cottage, and they were glowing at a white heat. In the great cloud of ashes and vapour which was formed over the burning chasm, forked lightnings played incessantly, and there were thunders in the air as well as in the bowels of the mountain. There also arose every now and then fierce hurricanes, which drifted the ashes hither and thither with great fury. The lava-current attained an extreme breadth of about two miles, and an extreme depth of 160 feet; but in some parts of its course its depth was only about 12 feet. Owing to its having flowed over a highly cultivated district of country, the damage it inflicted was immense; but, happily, no lives appear to have been lost. This eruption continued, with some short intervals of rest, from the beginning of August till about the middle of December.

In the beginning of 1865, Etna was again in violent activity, when there was a repetition of the same phenomenon observed in 1811—namely, the opening of seven new craters, all in a right line of descent from the summit—the highest being at the height of 5578 feet above the level of the sea. There was no other remarkable feature attending this eruption.

CHAPTER XIII.

NORTH ATLANTIC VOLCANOES.

THE most northern of this group ot volcanoes is that on the Island of Jan Mayen off the coast of Greenland, the snow-covered cone of which may be occasionally seen peering above the mists and clouds that usually envelop its lower parts. Very little is known of this mountain. It was visited in 1817 by Captain Scoresby, who found on its summit a magnificent crater about 2000 feet in diameter, and about 500 in depth. It exhibited traces of recent activity.

The island of Iceland is one of the most volcanic countries in the world—whether we regard the number of volcanoes concentrated in so small a space, or the extraordinary violence of their eruptions. In the northern part of the island there are four—Krabla, Leirhnukur, Trolladyngur, and Skaptár; three in the south—Hecla, Eyafiall, and Katlagia; and one in the east, named Orœfa. Of these the best known are Skaptár and Hecla.

One of the most remarkable of the recorded eruptions of these volcanoes was that of Skaptár-Jokul, which began on the 11th of June 1783. It was preceded by a long series of earthquakes, which had become exceedingly violent immediately before the eruption. On the 8th, volcanic vapours were emitted from the summit of the mountain, and on the 11th immense torrents of lava began to be poured forth from numerous mouths. These torrents united to form a large stream, which, flowing down into the River Skaptâ, not only dried it up, but completely filled the vast gorge through which the river had held its course. This gorge, 200 feet in breadth, and from 400 to 600 feet in depth, the lava filled so entirely, as to overflow to a considerable extent the fields on either side. On issuing from this ravine, the lava flowed into a deep lake which lay in the course of the river. Here it was arrested for a while; but it ultimately filled the bed of the lake altogether—either drying up its waters, or chasing them before it into the lower part of the river's course. Still forced onwards by the accumulation of molten lava from behind, the stream resumed its advance, till it reached some ancient volcanic rocks which were full of caverns. Into these it entered, and where it could not eat its way by melting the old rock, it forced a passage by shivering the solid mass, and throwing its broken fragments into the air, to a height of 150 feet.

On the 18th of June, there was opened above the first mouth a second of large dimensions, whence there poured another immense torrent of lava, which flowed with great rapidity over the solidified surface of the first stream, and ultimately combined with it to form a more formidable main current. When this fresh stream reached the fiery lake, which had filled the lower portion of the valley of the Skaptâ, a portion of it was forced up the channel of that river, towards the foot of the hills whence it takes its rise. After pursuing its course for several days, the main body of this stream reached the edge of a great waterfall called Stapafoss, which plunged into a deep abyss. Displacing the water, the lava here leaped over the precipice, and formed a great cataract of fire. After this, it filled the channel of the river, but extending itself in breadth far beyond it, until it reached the sea.

The 3rd of August brought fresh accessions to the flood of lava still pouring from the mountain. There being no room in the channel, now filled by the former stream, which had pursued a north-westerly course, the fresh lava was forced to take a new direction towards the south-east, where it entered the bed of another river with a barbaric name. Here it pursued a course similar to that which flowed through the channel of the Skaptâ—filling up the deep gorges, and then spreading itself in great fiery lakes over the plains.

The eruptions of lava from the mountain continued, with some short intervals, for two years, and so enormous was the quantity poured forth during this period, that, according to a careful estimate which has been made, the whole together would form a mass equal to that of Mont Blanc. Of the two streams, the greater was 50, the less 40 miles in length. The Skaptâ branch attained on the plains a breadth varying from 12 to 15 miles—that of the other was only about half as much. Both currents had an average depth of about 100 feet; but in the deep gorges it was no less than 600 feet. Even as late as 1794, vapours continued to rise from these great streams, and the water contained in the numerous fissures formed in their crust was hot.

The devastation directly wrought by the lava-currents themselves was not the whole of the evils they brought upon unfortunate Iceland and its inhabitants. Partly owing to the sudden melting of the snows and glaciers of the mountain, partly owing to the stoppage of the river-courses, immense floods of water deluged the country in the neighbourhood—destroying many villages and a large amount of agricultural and other property. Twenty villages were overwhelmed by the lava-currents; while the ashes thrown out during the eruption covered the whole island, and the surface of the sea for miles around its shores. On several occasions the ashes were drifted by the winds over considerable parts of the European Continent—obscuring the sun and giving the sky a gray and gloomy aspect. Out of the 50,000 persons who then inhabited Iceland, 9336 perished, together with 11,460 head of cattle, 190,480 sheep, and 28,000 horses. This dreadful destruction of life was caused partly by the direct action of the lava-currents, partly by the noxious vapours they emitted, partly by the floods of water, partly also by the destruction of the herbage produced by the ashes, and lastly in consequence of the desertion of the coasts by the fish, which formed a large portion of the food of the people.

Mount Hecla has been the most frequent in its eruptions of any of the Icelandic volcanoes. Previous to 1845, there had been twenty-two recorded eruptions of this mountain, since the discovery of Iceland in the ninth century; while from all the other volcanoes in the island there had been only twenty during the same period. Hecla has more than once remained in activity for six years at a time—a circumstance that has rendered it the best known of the volcanoes

MOUNT HECLA—ICELAND.

of this region. The prefixed woodcut will convey an idea of its appearance.

After enjoying a long rest of seventy-nine years, this volcano burst again into violent activity in the beginning of September 1845. The first inkling of this eruption was conveyed to the British Islands by a fall of volcanic ashes in the Orkneys, which occurred on the night of 2nd September during a violent storm. This palpable hint was soon confirmed by direct intelligence from Copenhagen. On the 1st of September a severe earthquake, followed the same night by fearful subterranean noises, alarmed the inhabitants and gave warning of what was to come. About noon the next day, with a dreadful crash, there were opened in the sides of the volcano two new mouths, whence two great streams of glowing lava were poured forth. They fortunately flowed down the northern and north-western sides of the mountain, where the low grounds are mere barren heaths, affording a scanty pasture for a few sheep. These were driven before the fiery stream; but several of them were burnt ere they could escape. The whole mountain was enveloped in clouds of volcanic ashes and vapours. The rivers near the lava-currents became so hot as to kill the fish, and to be impassable even on horseback.

About a fortnight later there was a fresh eruption of greater violence, which lasted twenty-two hours, and was accompanied by detonations so loud as to be heard over the whole island. Two new craters were formed, one on the southern, the other on the eastern slope of the cone. The lava issuing from these craters flowed to a distance of more than twenty-two miles. At about two miles from its source, the fiery stream was a mile wide, and from 40 to 50 feet deep. It destroyed a large extent of fine pasturage and much cattle. Nearly a month later, on the 12th of October, a fresh flood of lava burst from the southern crater, and soon heaped up a mass at the foot of the mountain from 40 to 60 feet in height, three great columns, of vapour, dust, and ashes, rising at the same time from the three new craters of the volcano. The mountain continued in a state of greater or less activity during most of the next year; and even as late as the month of October, after a brief pause, it began again with renewed vehemence. The volumes of dust, ashes, and vapour, thrown up from the craters, and brightly illuminated by the glowing lava beneath, assumed the appearance of flames, and ascended to an immense height.

Among the stones tossed out of the craters, was one large mass of pumice weighing nearly half a ton, which was carried to a distance of between four and five miles. The rivers were flooded by the melting of the ice and snows, which had accumulated on the mountain. The greatest mischief wrought by these successive eruptions was the destruction of the pasturages, which were for the most part covered with volcanic ashes. Even where left exposed, the herbage had acquired a poisonous taint, which proved fatal to the cattle, inducing among them a peculiar murrain. Fortunately, owing to the nature of the district through which the lava passed, there was on this occasion no loss of human life.

The Icelandic volcanoes are remarkable for the electrical phenomena which they produce in the atmosphere. Violent thunder-storms, with showers of rain and hail, are frequent accompaniments of volcanic eruptions everywhere; but owing to the coldness and dryness of the air into which the vapours from the Icelandic volcanoes ascend, their condensation is so sudden and violent, that great quantities of electricity are developed. Thunder-storms accompanied by the most vivid lightnings are the result. Humboldt mentions in his "Cosmos," that, during an eruption of Katlagia, one of the southern Icelandic volcanoes, the lightning from the cloud of volcanic vapour killed eleven horses and two men (*Cosmos*, i. 223). Great displays of the aurora borealis usually accompany the volcanic eruptions of this island—doubtless resulting from the quantity of electricity imparted to the higher atmosphere by the condensation of the ascending vapours. On the 18th of August 1783, while the great eruptions before mentioned were in progress, an immense fire-ball passed over England and the European Continent, as far as Rome. This ball, which was estimated to have had a diameter exceeding half a mile, is supposed to have been of electrical origin, and due to the high state of electric tension in the atmosphere over Iceland at that time.

CHAPTER XIV.

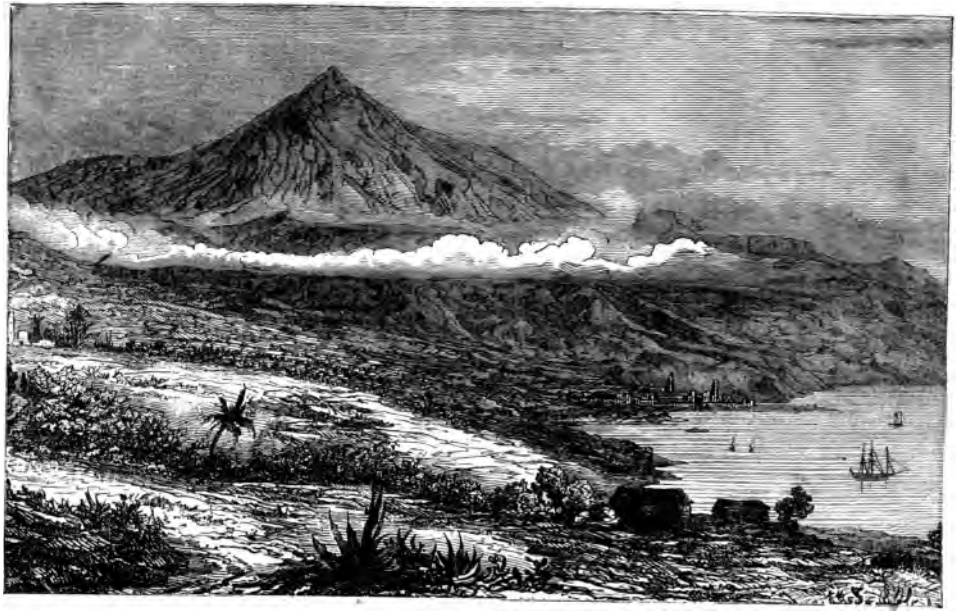
VOLCANOES OF THE AZORES, THE CANARY ISLANDS, AND AFRICA.

ALTHOUGH the Azores are mostly of volcanic origin, and have been much troubled with earthquakes, as mentioned in our annals, there is at present only one active volcano in the group—that of El Pico, which is continually emitting volcanic vapours.

The volcanoes of the Canary Islands are of greater interest; for among them is the famous Peak of Teneriffe, whose snow-clad summit is a conspicuous land-mark to the mariner. The annexed woodcut exhibits the graceful outline of its very pointed cone. The total height of the mountain is 12,090 feet; but that of the cone is only about 550 feet. Nothing has been emitted from the crater on the summit, ever since it was known to Europeans, but columns of sulphurous vapour. There were, however, lateral eruptions in 1704 and 1706, resulting in the destruction of the best harbour in the island. This mountain contains a subsidiary elevation, named Chahorra, and there was an eruption from a crater formed upon it in 1798, which continued for more than three months. Both streams of lava and quantities of ashes and stones were thrown out on this occasion; and it is affirmed by Humboldt that some of the stones were projected to a height so great, that they occupied from twelve to fifteen seconds in their descent—thus showing that some of them must have been tossed to a height of about 3000 feet. This eminent traveller visited the principal crater on the summit of the Peak, and found it to be oval in its form and of small dimensions—300 feet in its longer and 200 feet in its shorter diameter, with a depth of about 100 feet.

The neighbouring island of Palma contains a vast volcanic crater, called the Great Caldera, which is no less than 5000 feet in depth. In the mountain forming the walls of this crater are numerous deep ravines called baraccos, which are regarded as fissures that have been rent by volcanic action.

The volcanoes in the island of Lancerota are those which have been most recently in action, a crater having opened in August 1824 near the port of Rescif in this island. The eruption was preceded by violent earthquakes, and the quantity of matter ejected was so great as to form a considerable hill in twenty-four hours.



THE PEAK OF TENERIFFE.

The phenomena appear to have resembled those attending the formation of Monte Nuovo near Naples.

But Lancerota was, during the last century, the scene of a far grander series of eruptions, which lasted for no less than six years. They began on the 1st of September 1730, by the sudden opening of a great fissure in the earth, whence there was thrown up a quantity of volcanic materials so immense as to form in one night a considerable hill. A few days later there was opened another crater, whence flowed a stream of lava which overwhelmed several villages. On the 7th of September there was thrust up with a thundering noise, from the bottom of the lava-stream, a huge solid rock, which, dividing the current, so changed its direction as to cause it to overflow the large and flourishing town of St. Catalina, and several more villages in its new course. Four days after this, the lava receiving a great accession, advanced into the sea with a terrific roar. Vast quantities of fish were killed, and thrown up to the surface, or stranded on the beach. After a short rest, there were opened on the very site of St. Catalina, which had been overflowed by the lava, three new craters, whence were vomited large quantities of sand, stones, and ashes. On the 28th of October a remarkable occurrence took place—all the cattle in the island dropped down dead. They had been choked by noxious vapours which rose from the ground, and being condensed on ascending into the air, fell in showers. To add to the terror of the inhabitants inspired by the fiery streams, there arose a furious tempest, exceeding in violence any that had ever been experienced in the island before. On the 10th of January 1731, there was thrown up a hill of considerable height; which on the same day fell down again into the crater whence it arose, giving place to several currents of lava, which made their way to the sea. In the following months of February and March, there were raised several new cones, which poured forth lava; and fresh additions were subsequently made to their number, till it amounted to about thirty. In the following June the western shores were covered with dying fish of different species—some of them quite new to the inhabitants. Smoke and flames were seen to rise from the sea, at a short distance from the coast. This condition of volcanic activity in the island did not cease till 1736, and the eruptions compelled a large portion of the inhabitants to emigrate to the neighbouring islands.

Lancerota was in 1815 visited by the celebrated geologist, L. von Buch, who examined the scenes of these convulsions with great care. He found the cones of eruption to be all situated in a right line nearly due east and west—the highest rising 600 feet above its base, and 1378 feet above the sea-level, while several of the others were nearly as high. On the top of the loftiest, called Montagna di Fuego, is a large crater with precipitous rocky walls, broken at one side, whence the lava had flowed. It contained two other minor craters, which were then still emitting sulphurous vapours. To the westward of this elevation lies a surface of three square miles, wholly covered with black lava—its uniformity of aspect being interrupted only by a few scattered cones. The line of large cones is about two miles in length, and the ejected lava has covered nearly a third of the entire island, the streams in many cases extending themselves in large broad sheets but slightly inclined towards the sea, and several square leagues in extent.

To the southward of the Canaries lie the Cape de Verde Islands, which are also volcanic. In one of them is a volcano named Fuego, which, after a repose of fifty years, burst out afresh in 1847. There were opened no less than seven mouths, whence issued great streams of lava, that desolated the highly cultivated parts of the island, destroying much cattle, and inflicting grievous losses on the inhabitants.

On the eastern coast of Africa the islands of Mauritius and Bourbon are both of volcanic origin, but only the latter contains an active volcano. It is named Salazes, and is very energetic in its activity, having on an average about two eruptions in a year. This volcano is chiefly distinguished by the peculiarity of one of the substances which it ejects. It is a variety of pumice so fibrous as to resemble spun glass. Bory St. Vincent, who gives an account of this mountain, says that on one occasion the quantity of these films was so great as to form a cloud enveloping the entire summit of the mountain. He and his party, who witnessed this eruption, found themselves covered with fine shining threads as flexible as silk. A similar substance has been occasionally found among the ejections from the volcanoes of Hawaii and Guadaloupe.

There is also a group of volcanic islands in the Red Sea, lying in the track of the Indian steamers. They are named the Zebayer Islands. One of them, Djebel Seer, was found to be smoking when visited by the officers of the *Benares* during the survey of the Red Sea; but it soon after ceased to show any signs of activity. In the autumn of 1846, however, another of them, named Saddle Island, threw out a column of volcanic vapours. On the African coast of the Red Sea, about mid-way between the Straits of Babelmandeb and Massouah, there is a volcano named Djebel Dubbeh, from which an eruption took place in May 1861. It was preceded by severe earthquakes, and the ashes thrown out spread as far as the coasts of Yemen. The explosions, too, were heard at a great distance. The column of vapour and ashes, issuing from the mountain, appeared at night to be illuminated by the glare of lava, producing the appearance of flames.

There are said to be, between the Red Sea and Egypt, one or two other mountains from which volcanic smoke has been seen to ascend. Besides these, no other volcanoes have yet been discovered on the African continent.

CHAPTER XV.

ASIATIC VOLCANOES.

THERE are a few volcanoes on the continent of Asia, and many more in its adjacent islands. In the Elburz range of mountains, which skirts the Caspian Sea on the south, there is a lofty volcano named Demavend, which has been in activity within historic times. There are also, it is said, some volcanoes in central Asia; but very little is known about them, except that a few of them are represented as being still active. In Kamtschatka there are several, which have been in eruption at no distant period. One of them, named Klutscheu, which is 15,000 feet in height, consequently covered with snow and glaciers, had a great eruption in 1829. Within 700 feet of the summit, there was formed a crater which poured forth an immense torrent of lava. Its progress was for a time arrested by the snow and glaciers; but the glowing mass at length became so great that it burst through this barrier with a horrible roar, and came thundering down the steep declivity of the mountain. The noise was heard at a distance of fifty miles.

But it is in the Asiatic Islands that volcanoes are both most numerous and most active. Among the nearest to the mainland is Barren Island, in the Bay of Bengal, to the southward of the coast of Pegu. The whole of this island seems to be nothing else than a large volcanic crater. The walls, on their outer sides, rise from the sea with a moderate ascent; but on the inner side they are nearly perpendicular, and enclose a circular basin into which the sea finds access by a breach. In the centre of this basin rises a volcanic cone, about 500 feet in height, which is frequently in action. There was an eruption from it in 1792.

Further to the south lie the islands of the Malayan Archipelago, which are very volcanic in their character. They form a curved and closely connected chain, whose principal links are Sumatra, Java, Sumbáwa, and Timor. Of these Java is the most remarkable for the number of its active volcanoes, distinguished by the great quantity of sulphur and sulphurous vapours which they discharge. There are in Java no less than thirty-eight volcanoes which have been known to be in activity, and one of them attains a height of 10,000 feet.

In 1772 there was a great eruption of the volcano named Papandáyang, during which a large portion of that mountain, formerly one of the highest in Java, was swallowed up. The following is the narrative of this event, given by Dr. Horsfield in the "Batavian Transactions," vol. ix.:—

"The account which has remained of this event asserts that, near midnight between the 11th and 12th of August, there was observed about the mountain an uncommonly luminous cloud, by which it appeared to be completely enveloped. The inhabitants, as well about the foot as on the declivities of the mountain, alarmed by this appearance, betook themselves to flight; but before they could all save themselves, the mountain began to give way, and the greatest part of it actually fell in and disappeared in the earth. At the same time a tremendous noise was heard, resembling the discharge of the heaviest cannon. Immense quantities of volcanic substances, which were thrown out at the same time and spread in every direction, propagated the effects of the explosion through the space of many miles.

"It is estimated that an extent of ground, of the mountain itself and its immediate environs, fifteen miles long and full six broad, was by this commotion swallowed up in the bowels of the earth. Several persons, sent to examine the condition of the neighbourhood, made report that they found it impossible to approach the mountain on account of the heat of the substances which covered its circumference, and which were piled on each other to the height of three feet; although this was the 24th of September, and thus full six weeks after the catastrophe. It is also mentioned that forty villages, partly swallowed up by the ground, and partly covered by the substances thrown out, were destroyed on this occasion, and that 2957 of the inhabitants perished. A proportionate number of cattle was also destroyed; and most of the plantations of cotton, indigo, and coffee, in the adjacent districts, were buried under the volcanic matter."

Among the volcanoes of Java, the most remarkable for the size of its crater is Tengger. This crater is of a circular form, and nearly four miles in diameter. Its depth is about 1800 feet, and from the plain which forms its floor there rise four cones of eruption, one of which, called Bromo, has but recently ceased throwing out lava. Between the years 1838 and 1842, there was formed at the bottom of this crater, near the cones, a lake of hot and acid water.

Another of the volcanoes of this island, named Guntur, had an eruption in 1800, during which great quantities of lava were ejected; but black mud is more frequently thrown out by the

Javan volcanoes than lava. The crater of Guntur is of an oval form—its greatest diameter being about 100 yards, and its depth inconsiderable. It emits volumes of hot sulphurous vapour.

On 8th October 1822 there was an eruption from another mountain, named Galon-goon. Previous to the explosion, the mountain was covered with dense forest; while the country all around it was highly cultivated and thickly peopled. It exhibited no trace of former activity, save a small circular hollow on its summit. A warning of the approaching event was given by the river Kunir, which flows from its flank; for in July its waters became for a while turbid and hot. The eruption began with a loud detonation, which was followed by the ejection of an immense flood of boiling water, mixed with mud and burning sulphur, and accompanied by great quantities of ashes and small stones, which were thrown out with such violence that some of them were carried to a distance of forty miles. All the valleys in the neighbourhood, and all the river beds, became filled with the hot mud and burning sulphur. The streams overflowed their banks, and carried away many people who were endeavouring to escape, besides cattle and wild beasts. A space extending to a distance of twenty-four miles from the mountain was overspread with bluish mud to such a depth that the people were buried in their houses, and all the villages and plantations in this tract were completely covered up by the fetid mass. It was a remarkable circumstance that, owing to the violence with which the mud and other matters were thrown out from the volcano, several villages near the mountain were less injured than others lying at some distance beyond them.

The first eruption, which lasted about five hours, was followed by immense torrents of rain, which, owing to the obstructed state of the river-courses, flooded the country, spreading the mud in all directions. But on the 12th of October there was a second and still more violent eruption, when, along with the hot water and mud, huge masses of basalt were tossed to a great height—some of them falling at a distance of seven miles. A severe earthquake accompanied this second eruption, and a large semicircular gulf is said to have been formed on one side of the mountain. These two eruptions proved very destructive to human life—114 villages having been destroyed, and 4000 persons having perished.

Mount Merapia, situated in the district of Kadoc, had, in September 1849, an eruption which lasted three days. The mountain is said to have emitted gigantic flames, and ejected large quantities of stones and ashes; but there does not appear to have been any current either of lava or mud. The stones and ashes covered a vast extent of country, involving much destruction of crops; but the inhabitants had time to save themselves by flight.

Several of the half-extinct craters in Java are of great interest. One of them in particular, named Guevo-Upas, or the valley of poison, seems to have given origin to the celebrated fable of the Upas tree. It is about half a mile in circumference, and the gas evolved from its soil appears to be carbonic acid, which proves deadly to every living thing that comes nigh. The valley is consequently strewn with numerous carcasses of the victims to this invisible subtle poison. Another crater, named Taschem, at the eastern end of the island, contains a lake about a quarter of a mile long, from which a small river flows. The waters, both of the lake and river, are so strongly impregnated with sulphuric acid, that nothing can live in them; and they even prove destructive to sea-fish approaching too near the mouth of the stream.* A more singular phenomenon is exhibited by a crater near the volcano of Talaga-Bodas, which continually emits volcanic vapours. These,

* Humboldt discovered another similar river impregnated with sulphuric acid. the source of which is a hot spring, taking its rise, at the height of about 10,000 feet, in a volcano near the city of Popayan in New Grenada.

while they prove fatal to the life of any animal approaching them, have the singular property of corroding the bones, but preserving the soft parts, such as the flesh, nails, hair, and skin. This circumstance raises a probability that the vapours are those of muriatic acid.

Another highly interesting crater is that of the volcano of Tangkuban Prahu, so named from its resemblance to an inverted boat. This crater is nearly a mile and a half in circumference, funnel-shaped, but with very irregular sides—its margin having also various degrees of elevation. It was visited by the officers of the *Novara,* during their exploring expedition. They describe it as appearing at a little distance to be a vast gulf, filled with great volumes of vapour, which are continually rushing up from beneath with a loud noise, resembling that of many steam-engines letting off steam from their safety-valves. On a nearer approach, this immense fuming chasm is found to be divided, by a narrow ledge of rock, into two nearly equal elliptical basins, surrounded by steep walls. Those of the basin on the eastern side of the partition are between 500 and 600 feet in perpendicular depth. They are perfectly bare from top to bottom, and their surfaces are bleached of a grayish-white by the action of the vapours continually ascending from beneath. In 1846 there was an eruption from this part of the crater, when great quantities of stones and sand were thrown out, along with a stream of boiling mud much impregnated with sulphur. The bottom of the basin still retains traces of this eruption; for all round the edge, at the base of its rocky walls, there is an accumulation of the sand, stones, and other hard masses which were ejected; while the centre is occupied by liquid mud mingled with much sulphur. The western basin has nearly double the depth of the other, and its sides are less abrupt in their descent. Their whole surface is densely covered with brushwood almost to the bottom, thus presenting a marked contrast to the bare bleached walls of the eastern cavity. The bottom of the western basin is nearly quite flat, and in its centre is a pool of water of a pale sulphur yellow colour, due to its sulphurous impregnations. The flat floor which surrounds this pool is simply a crust of sulphur, covering the surface of boiling bitter waters underneath. From these arise the sulphurous vapours, which force their way noisily through numerous fissures in the crust. On being broken, this crust displays beautiful crystals of sulphur on its lower surface. The eastern basin is named by the natives, "The King's Crater;" the western, "The Poison Crater."

The island of Sumbáwa, to the eastward of Java, contains the most formidable of all the volcanoes in this group—perhaps in the whole world. It is named Tomboro, and one of its most memorable eruptions took place in 1815. Sir Stamford Raffles has fortunately preserved accurate accounts of this tremendous convulsion, which he describes as far exceeding in duration and force any of those recorded of Etna or Vesuvius. It extended its evidences, by tremulous motions and the sound of explosions, over the whole of the Moluccas, Java, and a considerable part of Celebes, Sumatra, and Borneo—throughout a circuit having a radius of 1000 miles, reckoned from the volcano as a centre. Within a radius of 300 miles the effects were astounding. In Java, which is just within that range of distance, the sky at noon was overclouded with ashes, through which the sun's rays could not penetrate. These fell in showers on the houses, streets, and fields, covering them to the depth of several inches; and the explosions so much resembled the reports of artillery, as to be mistaken for them by the military. These signs were attributed to an eruption of some of the volcanoes in the island of Java itself; but none thought of referring them to so great a distance as Sumbáwa. The following is the account given by the Rajah of Sang'ir, who was an eye-witness of the event:—

"About 7 P.M. on the 10th of April, three distinct columns of flame burst forth near the top of the Tomboro Mountain (all of them apparently within the verge of the crater), and after ascending separately to a very great height, their tops united in the air in a troubled, confused manner. In a short time the whole mountain next Sang'ir appeared like a body of liquid fire, extending itself in every direction. The fire and columns of flame continued to rage with unabated fury, until the darkness caused by the quantity of falling matter obscured it, at about 8 P.M. Stones at this time fell very thick at Sang'ir—some of them as large as two fists, but generally not larger than walnuts. Between 9 and 10 P.M. ashes began to fall, and soon after a violent whirlwind ensued, which blew down nearly every house in the village of Sang'ir—carrying the roofs and light parts away with it. In the port of Sang'ir, adjoining Tomboro, its effects were much more violent—tearing up by the roots the largest trees, and carrying them into the air, together with men, horses, cattle, and whatever else came within its influence. This will account for the immense number of floating trees seen at sea. The sea rose nearly twelve feet higher than it had ever been known to do before, and completely spoiled the only spots of rice-land in Sang'ir—sweeping away houses and everything within its reach. The whirlwind lasted about an hour. No explosions were heard till the whirlwind had ceased, at about 11 P.M. From midnight till the evening of the 11th, they continued without intermission. After that time their violence moderated, and they were heard only at intervals; but the explosions did not cease entirely until the 15th of July. Of the whole villages of Tomboro, Tempo, containing about forty inhabitants, is the only one remaining. In Pekâté no vestige of a house is left; twenty-six of the people, who were at Sumbáwa at the time, are the whole of the population who have escaped. From the most particular inquiries I have been able to make, there were certainly not fewer than 12,000 individuals in Tomboro and Pekâté at the time of the eruption, of whom only five or six survive. The trees and herbage of every description, along the whole of the north and west sides of the peninsula, have been completely destroyed, with the exception of a high point of land, near the spot where the village of Tomboro stood."

The town of Tomboro was not only invaded by the sea on this occasion, but its site permanently subsided; so that there is now eighteen feet of water where there was formerly dry land.

In the island of Bali, lying immediately to the east of Java, there is a volcano named Karang Asam, from which there was a violent eruption about seven years before the event above distinct columns of flame burst forth near the top of the Tomboro Mountain (all of them apparently within the verge of the crater), and after ascending separately to a very great height, their tops united in the air in a troubled, confused manner. In a short time the whole mountain next Sang'ir appeared like a body of liquid fire, extending itself in every direction. The fire and columns of flame continued to rage with unabated fury, until the darkness caused by the quantity of falling matter obscured it, at about 8 P.M. Stones at this time fell very thick at Sang'ir—some of them as large as two fists, but generally not larger than walnuts. Between 9 and 10 P.M. ashes began to fall, and soon after a violent whirlwind ensued, which blew down nearly every house in the village of Sang'ir—carrying the roofs and light parts away with it. In the port of Sang'ir, adjoining Tomboro, its effects were much more violent—tearing up by the roots the largest trees, and carrying them into the air, together with men, horses, cattle, and whatever else came within its influence. This will account for the immense number of floating trees seen at sea. The sea rose nearly twelve feet higher than it had ever been known to do before, and completely spoiled the only spots of rice-land in Sang'ir—sweeping away houses and everything within its reach. The whirlwind lasted about an hour. No explosions were heard till the whirlwind had ceased, at about 11 P.M. From midnight till the evening of the 11th, they continued without intermission. After that time their violence moderated, and they were heard only at intervals; but the explosions did not cease entirely until the 15th of July. Of the whole villages of Tomboro, Tempo, containing about forty inhabitants, is the only one remaining. In Pekâté no vestige of a house is left; twenty-six of the people, who were at Sumbáwa at the time, are the whole of the population who have escaped. From the most particular inquiries I have been able to make, there were certainly not fewer than 12,000 individuals in Tomboro and Pekâté at the time of the eruption, of whom only five or six survive. The trees and herbage of every description, along the whole of the north and west sides of the peninsula, have been completely destroyed, with the exception of a high point of land, near the spot where the village of Tomboro stood."

The town of Tomboro was not only invaded by the sea on this occasion, but its site permanently subsided; so that there is now eighteen feet of water where there was formerly dry land.

In the island of Bali, lying immediately to the east of Java, there is a volcano named Karang Asam, from which there was a violent eruption about seven years before the event above described. In Sumatra, the largest of this chain of islands, there is a range of volcanoes extending in a linear direction. One of them, called Berapi, is 12,000 feet in height, and is continually smoking; but no records have been preserved of any eruptions from this range of volcanoes. In Timor, the most easterly of these islands, there was once a mountain named the Peak, which used to be a volcano in constant activity, like Stromboli. It served as a lighthouse to mariners in those seas, being visible at a distance of 300 miles. During a great eruption in 1637, however, the mountain disappeared bodily, leaving a lake in its place.

Several of the Moluccas, or Spice Islands, are volcanic. In one of them, named Machian, a mountain was, during a violent eruption in 1646, rent from top to bottom, and has remained two distinct mountains ever since. In another of them named Sorea, which consists of little else than a large volcanic mountain, there was an eruption in 1693, during which the cone crumbled bit by bit into a vast crater, that was converted into a fiery lake, and occupied nearly half of the whole island. Successive portions of the mountain continued to fall into this glowing abyss, which was thus continually increased in its dimensions, and the whole population of the island were ultimately compelled to fly.

The earthquake which shook the islands of

Amboyna and Banda in November 1835 was connected with an eruption from a volcano in the latter.

In Sangir, an island immediately to the north of Celebes, there is also an active volcano, from which there was a great eruption in March 1856. It caused immense destruction of property and loss of life—upwards of 2800 persons having perished. Besides great quantities of stones, ashes, and other loose substances, the volcano threw out vast streams of lava; while from the sides of the mountain there burst forth great torrents of water, so that the fertile country around was desolated. A large portion from the side of the mountain fell into the sea, leaving, in place of the former gentle slope, a sheer precipice 300 feet in height.

The whole of the chain of islands running along the eastern coast of Asia is very volcanic. This chain comprehends the Philippine, the Japanese, the Kurile, and the Aleutian groups. Very little, however, is known of the individual volcanoes or of their eruptions, although several of them have been casually mentioned by navigators. In the Japanese group, the most conspicuous volcano is that of Fousi Yama—having a height of upwards of 10,000 feet. Its cone is of a remarkably regular form, and it has on its summit a large oval crater.

According to the Japanese annals, this cone was raised about B.C. 285 or 284, at the same time that the large tract of country in the province of Oomi was ingulfed, as mentioned in our earthquake annals. Another Japanese volcano, named Wunzen, is said to have had its cone thrown down with loud explosions in 1793. A third, named Asama Yama, had a great eruption in 1783, and is still in a subdued state of activity.

In one of the Aleutian group of islands, a volcano was observed, by the crew of the Russian frigate *Dwina*, to be in violent action during the month of June 1856, insomuch that a large extent of the surface of the sea was covered with pumice.

CHAPTER XVI.

VOLCANOES IN THE SANDWICH ISLANDS AND ANTARCTIC OCEAN.

HAWAII, or Owhyhee, the principal island of the Sandwich group, contains some of the most stupendous volcanoes in the world. Indeed, the whole island, which is 4000 square miles in extent, may be regarded as of volcanic origin. It contains four volcanic mountains—Kohola, Haialalai, Mouna Kea, and Mouna Loa. The two last named are the chief, the former being about 18,000 feet, the latter about 16,000 feet, above the sea-level. Although their height is so vast, the ascent to their summits is so gradual, that their circumference at the base is enormous. The bulk of each of them is reckoned to be equal to two and a half times that of Etna. Some of the streams of lava which have emanated from them, are twenty-six miles in length by two miles in breadth.

Mouna Loa presents the curious feature of having two distinct and seemingly unconnected craters—one on the summit of the mountain, and another on its flanks, at a much lower level. This last is named Kirauea, or Kilauea, and is perhaps the most remarkable volcanic crater in the world. It was visited by Mr. Ellis, a missionary to those parts, who has given an account of it in his missionary tour. The approach to it lies over a vast tract completely covered with old lava; and Mr. Ellis describes his visit to it in the following terms:—

"The tract of lava resembles in appearance an inland sea, bounded by distant mountains. Once it had certainly been in a fluid state, but appeared as if it had become suddenly petrified, or turned into a glassy stone, while its agitated billows were rolling to and fro. Not only were the large swells and hollows distinctly marked, but in many places the surface of those billows was covered by a smaller ripple, like that observed on the surface of the sea at the springing up of a breeze, or the passing currents of air, which produce what the sailors call a cat's paw.

"About 2 P.M. the crater of Kirauea suddenly burst upon our view. We expected to have seen a mountain with a broad base and rough indented sides, composed of loose slags or hardened streams of lava, and whose summit would have presented a rugged wall of scoria, forming the rim of a mighty caldron. But, instead of this, we found ourselves on the edge of a steep precipice, with a vast plain before us, 15 or 16 miles in circumference, and sunk from 200 to 400 feet below its original level. The surface of this plain was uneven, and strewed with huge stones and volcanic rocks, and in the centre of it was the great crater, at the distance of a mile and a half from the place where we were standing. We walked on to the north end of the ridge, where, the precipice being less steep, a descent to the plain below seemed practicable. With all our care, we did not reach the bottom without several falls and slight bruises. After walking some distance over the sunken plain, which in several places sounded hollow under our feet, we at length came to the edge of the great crater, where a spectacle sublime, and even appalling, presented itself before us.

"Immediately before us yawned an immense gulf, in the form of a crescent, about two miles in length, from north-east to south-west; nearly a mile in width, and apparently 800 feet deep. The bottom was covered with lava, and the south-western and northern parts of it were one vast flood of burning matter, in a state of terrific ebullition, rolling to and fro its 'fiery surges' and flaming billows. Fifty-one conical islands, of varied form and size, containing as many craters, rise either round the edge or from the surface of the burning lake; twenty-two constantly emitted columns of gray smoke, or pyramids of brilliant flame; and several of these at the same time vomited from their ignited mouths streams of lava, which rolled in blazing torrents down their black indented sides into the boiling mass below.

"The existence of these conical craters led us to conclude that the boiling caldron of lava before us did not form the focus of the volcano; that this mass of melted lava was comparatively shallow; and that the basin in which it was contained was separated by a stratum of solid matter from the great volcanic abyss, which constantly poured out its melted contents through these numerous craters into this upper reservoir. The sides of the gulf before us, although composed of different strata of ancient lava, were perpendicular for about 400 feet, and rose from a wide horizontal ledge of solid black lava of irregular breadth, but extending completely round. Beneath this ledge the sides sloped gradually towards the burning lake, which was, as nearly as we could judge, 300 or 400 feet lower. It was evident that the large crater had been recently filled with liquid lava up to this black ledge, and had, by some subterraneous canal, emptied itself into the sea, or under the low land on the shore. The gray, and in some places apparently calcined sides of the great crater before us—the fissures

CRATER OF KILAUEA HAWAII.

which intersected the surface of the plain on which we were standing—the long banks of sulphur on the opposite side of the abyss—the vigorous action of the numerous small craters on its borders—the dense columns of vapour and smoke that rose at the north and west end of the plain, together with the ridge of steep rocks by which it was surrounded, rising probably in some places 300 or 400 feet in perpendicular height, presented an immense volcanic panorama, the effect of which was greatly augmented by the constant roaring of the vast furnaces below."

This great crater was also visited by Messrs. Dana and Wilkes of the United States' exploring expedition, from whose drawing the prefixed woodcut is copied. They describe the light from the glowing lava to be so intense as to form rainbows on the passing rain-clouds. The lava appears almost as liquid as water, and its surface is agitated by waves resembling those of the sea, and breaking, like them, upon the shore formed by the bordering terraces of solid lava. Sometimes they rise to the height of the second terrace, and then fall back again in small cascades. Occasionally isolated jets of lava rise to the height of between sixty and seventy feet. The lava, thus tossed into the air, cools in its descent, and falls solidified on the surface of the molten lake, like pieces of broken ice.

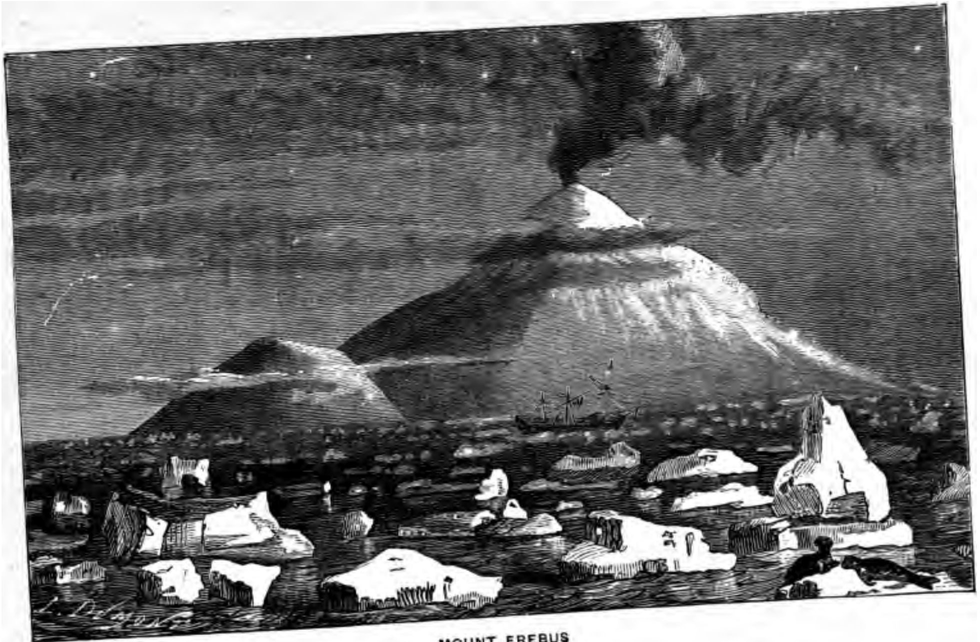
Of the mountain Mouna Loa itself there was a tremendous eruption in 1840, and since then it has been frequently in action. There was, in January 1843, an eruption from a crater at the height of 14,000 feet, not far below the summit. The lava-stream, after descending with great rapidity the slope of the mountain, spread itself over the elevated plain between Mouna Loa and Mouna Kea, traversing it to a distance of between twenty and thirty miles. The current which flowed down the mountain-side soon acquired the usual solid crust. But, even after it had attained a thickness varying from fifty to one hundred feet, the liquid lava could, through the fissures in the crust, be seen rushing down like a torrent at a very rapid rate through this natural tunnel.

One peculiarity of this volcano is its tendency to throw out its lava in jets to an enormous height. The lava seems to be first forced up in the interior of the mountain nearly to the top of the great crater; but instead of overflowing its brim, it opens a passage through the sides of the cone at a considerably lower elevation, so that the pressure of the liquid in the interior forces it from the orifice in a jet, whose height is in proportion to that of the inner column.

This circumstance proves the absence of any internal communication between the crater proper to Mouna Loa and the lower crater of Kilauea, although the latter is situated on the flank of the same mountain — the distance between the two craters being about sixteen miles. For, were there any such communication, the rise of the lava in the vent of the higher crater would inevitably produce a jet in the lower. There is thus established a strong probability that the crater of Kilauea is on the summit of what was once an independent mountain, entirely separated from Mouna Loa; but that the intervening space has now been filled up by the lava and other ejections from the latter, so that the whole appears to be a continuous slope, and to form a single mountain.

The lava-jets thrown up from Mouna Loa during a great eruption in 1852, are estimated to have reached a height of 500 feet—those of some later eruptions double that height. The lava, as it ascends, is described as being white hot; but in its descent it acquires a blood-red tint, and it comes down with a fearful noise. The quantity of lava ejected during some of the recent eruptions has been enormous. One stream is described as having travelled fifty miles, with an average breadth of three miles. A great stream, which burst forth from the side of the mountain in August 1855, had in the beginning of July 1856 reached a distance of sixty miles from its source—burning its way through the forests, and at that date still advancing at the rate of about a mile in a fortnight. In January 1859 this volcano was again in vigorous action, throwing up intermitting jets of lava to the estimated height of 800 or 1000 feet. From this great fiery fountain the lava flowed down in numerous streams, spreading over a width of five or six miles. One stream, probably formed by the junction of several smaller, attained a height of from twenty to twenty-five feet, and a breadth of about an eighth of a mile. Great stones were also thrown up along with the jet of lava, and the volume of smoke, composed probably of fine volcanic dust, is said to have risen to the height of 10,000 feet.

An eruption described as having been of still greater violence took place in 1865, characterized by similar phenomena, particularly the throwing up of jets of lava. This fiery fountain is said to have continued to play without intermission for twenty days and nights, varying only as respects the height to which the jet arose, which is said to have ranged between 100 and 1000 feet, the mean diameter of the jet being about 100 feet. This eruption was accompanied by explosions so loud as to have been heard at a distance of forty miles. A cone of about 300 feet in height, and about a mile



MOUNT EREBUS

in circumference, was accumulated round the orifice whence the jet ascended. It was composed of solid matters ejected with the lava, and it continued to glow like a furnace, notwithstanding its exposure to the air. The current of lava on this occasion flowed to a distance of thirty-five miles, burning its way through the forests, and filling the air with smoke and flames from the ignited timber. The glare from the glowing lava and the burning trees together was discernible by night at a distance of 200 miles from the island.

Several of the other islands in the Pacific, particularly the groups of the Friendly Islands and New Hebrides, contain active volcanoes; but little is known of them, except that they have been occasionally seen in a state of eruption by passing mariners.

Much further south, on the frozen shores of Victoria Land in the Antarctic regions, Sir James Ross, in 1841, sailing in his discovery ships, the *Erebus* and *Terror*, discovered two great volcanic mountains, which he named after those two vessels. The prefixed woodcut, taken from his sketch, shows the appearance of Mount Erebus, which is continually covered, from top to bottom, with snow and glaciers.

This mountain is about 12,000 feet high, and although the snow reaches to the very edge of the crater, there rise continually from the summit immense volumes of volcanic fumes, illuminated by the glare of glowing lava beneath them. These vapours ascend to an estimated height of 2200 feet above the top of the mountain.

Founding on the phenomenon of the glacier imprisoned under lava on the sides of the cone of Mount Etna, Sir Charles Lyell has thrown out a conjecture that the cones of these two Antarctic volcanoes may possibly be composed of successive layers of ice, divided from each other by intervening layers of volcanic ashes and hardened lava. Considering that, in such a climate, each new layer of ashes and lava ejected by the mountain must of necessity become speedily covered with snow and ice, this conjecture appears to be far from improbable.

CHAPTER XVII.

AMERICAN AND WEST INDIAN VOLCANOES.

THERE are no volcanoes known to exist in any part of North America, except in the promontory of Aliaska, in the Russian territories. Several of the West Indian Islands, however, are partly, if not wholly, of volcanic origin; and some of them contain active volcanoes. The most remarkable of these is Le Souffrier, in the island of St. Vincent. Its first recorded eruption was in 1718; but the most violent was in 1812, when nearly the whole island was desolated by the great streams of lava and vast quantities of ashes and stones which it threw out. These ashes were projected to so great a height into the atmosphere, that, notwithstanding the trade-winds were blowing violently from Barbadoes to St. Vincent, they were carried to the former island, and fell there. The distance to which they were wafted in this direction was about 200 miles. This eruption was preceded by a succession of disastrous earthquakes on the coasts of the mainland, about Caracas; but these ended when the activity of the volcano began.

Guadaloupe also contains an active volcano, from which there was an eruption in 1797. In Martinique there is a mountain named Pelée, which was in activity in August 1851. It threw out no lava, but great quantities of ashes and mud strongly impregnated with sulphur.

South America is famed for the great number and vast size of its volcanoes. These are found chiefly in the range of the Andes. The most remarkable among them are, Cotopaxi, Tungur-agua, Pichinca, Antisana, and Sangay. The first-named is the highest volcano in the world, being upwards of 19,000 feet above the level of the sea. Its cone is remarkable for the regularity of its form; and, being covered with a uniform coating of perpetual snow, it has the appearance of having been turned in a lathe. The snow-line is sharply defined, and the regions underneath it are wooded. Its aspect at a distance is shown in the annexed wood-cut.

The eruptions from this mountain are rare; but there are columns of vapour continually rising from the crater on the summit. The last great eruption of this volcano was in 1741, when the column of ashes and vapour from the crater is said to have risen to a height of about 5000 feet above the cone. The mountain con-

COTOPAXI.

tinued in a state of brisk activity for three years, during which immense streams of lava were thrown out, and spread over the adjacent plains.

The explosions from this volcano when in action are tremendous, and large stones have been ejected from it to vast distances. One huge mass, estimated to weigh 200 tons, is said to have been projected in 1533 to a distance of about ten miles from the crater.

Although now the highest volcano in the world, Cotopaxi could not always boast of this pre-eminence—at least, if any trust can be placed in native traditions. These relate that the mountain called Capac Urcu was once higher even than Chimborazo, but that, not long before the discovery of America by the Spaniards, there took place a series of dreadful eruptions, which lasted eight years, during which its cone was broken down, and the fragments now lie scattered over the adjacent plains. Similar occurrences elsewhere, render this tradition by no means improbable.

The most picturesque of the volcanoes of the Andes is Pichinca, of which a view is given in the annexed woodcut. It consists of several cones, of which four are conspicuous—the most southerly, named Ruas, being that which contains the active crater.

It is on a plain formed on the flanks of this mountain that Quito is situated; and to this dangerous neighbourhood that beautiful city doubtless owes its recent overthrow by a destructive earthquake. Baron Humboldt ascended to the crater of Pichinca, and nearly lost his life in the adventure. Having approached the edge, in order to obtain a view of the lava boiling at the bottom of the abyss, he became enveloped in a dense fog, and nearly stepped upon the steep incline, which descends so rapidly, that had he once planted his foot on it, he would have slid into the glowing lake of fire beneath.

The eruptions from the South American volcanoes are quite as frequently of sulphurous mud as of lava. An eruption of this kind from Tunguragua has already been mentioned, in connection with the disastrous earthquake of Riobamba. Another similar took place from the volcano of Imbaburu, in 1691. So great was the quantity of the small fish, previously described, which was on this occasion thrown out along with the mud, that a fever which ensued was attributed to their pestilential effluvia. In like manner, on the 19th of June 1698, the cone of Carguairazo fell in, and a great eruption of mud containing dead fishes followed.

Antisana, however, is remarkable for the large streams of lava which it has poured forth.

PICHINCA

It had frequent fits of activity between 1590 and 1718, since which time it has been quiet. At the height of about 13,600 feet above the sea-level is a plain, formerly the bed of a considerable lake, now reduced to very narrow limits. From the centre of this plain rises the snow-clad summit, containing a dome-like portion, connected by a group of jagged peaks with a truncated cone of eruption situated on the north side. The ejected lavas have formed numerous walls of basalt at the foot of the mountain, and there are also great beds of very spongy pumice.

It has been observed that small volcanoes are usually the most active; and those of the Andes being generally of great height, their fits of activity are correspondingly rare. To this rule, however, Sangay is an exception. Although towering to the height of upwards of 18,000 feet, its activity has ever since 1728 been almost incessant. Its eruptions are accompanied by loud detonations, which are heard at great distances. In 1842 and 1845 its thunderings were heard at Payta, on the Peruvian coast. These explosions sometimes succeed each other with amazing rapidity; but so loose and incoherent are the materials composing the cone, that no concussion is felt. The fumes from the crater are very dense—sometimes gray, sometimes orange, in colour. The solid substances thrown out along with these fumes are cinders and dross, occasionally accompanied by round stones of about two feet in diameter. These either fall back again into the crater, or alight on the edge of the cone, to which they impart an incandescent glow. On cooling, the ejected matters become quite black, so that they give the general surface of the cone a most dismal aspect. They are accumulated on the slope and all round the base of the cone in beds, which in some parts attain a thickness of between 300 and 400 feet.

Another exception to the general infrequency of paroxysms of activity among the South American volcanoes, is presented by Rancagua, in Chili, which is in a state of perpetual restlessness similar to that of Stromboli. Chillan, another of the volcanoes of Chili, burst into action in November 1864, when there was formed a new crater, whence immense quantities of ashes and other loose matters were ejected, along with streams of lava. The whole summit of the cone, which is usually snow-clad, became covered with volcanic ashes in a layer of considerable depth. This fact illustrates the manner in which layers of ice and snow may alternate with layers of lava; for such thick coatings of ashes will prevent the lava from melting the snow to any considerable extent, and will rather facilitate its conversion into ice. For the snow, being first reduced to a half-melted state, and then subjected to the strong pressure of the lava, when regelation ensues, very hard and compact ice will be formed underneath.

The volcanoes of Mexico are remarkable in this respect, that they are all ranged in a right line, running nearly due east and west—some of them being at a great distance from the sea. The principal active cones are those of Tuxtla, Orizaba, Popocatepetl, Colima, and Jorullo. Of these the last-named is the most interesting, because of its recent origin. No further back than the middle of last century, the site of this remarkable volcano was a level plain, comprehending several highly-cultivated fields, which formed the farm of Don Pedro di Jorullo. The plain was watered by two small rivers, called Cuitimba and San Pedro, and was bounded by mountains composed of basalt—the only indications of volcanic action. These fields were well irrigated, and among the most fertile in the country — producing abundant crops of sugar-cane and indigo.

In the month of June 1759, the cultivators of the farm began to be disturbed by strange subterranean noises of an alarming kind, accompanied by frequent shocks of earthquake, which continued for nearly a couple of months; but they afterwards entirely ceased, so that the inhabitants of the place were lulled into security.

On the night between the 28th and 29th of September, however, the subterranean noises were renewed with greater loudness than before, and the ground shook awfully. The Indian servants living on the place started from their beds in terror, and fled to the neighbouring mountains. Thence gazing upon their master's farm, they beheld it, along with a tract of ground measuring between three and four square miles, in the midst of which it stood, raised up bodily, as if it had been inflated from beneath like a bladder. At the edges this tract was uplifted only about 39 feet above the original surface; but so great was its convexity, that toward the middle it attained a height of no less than 524 feet.

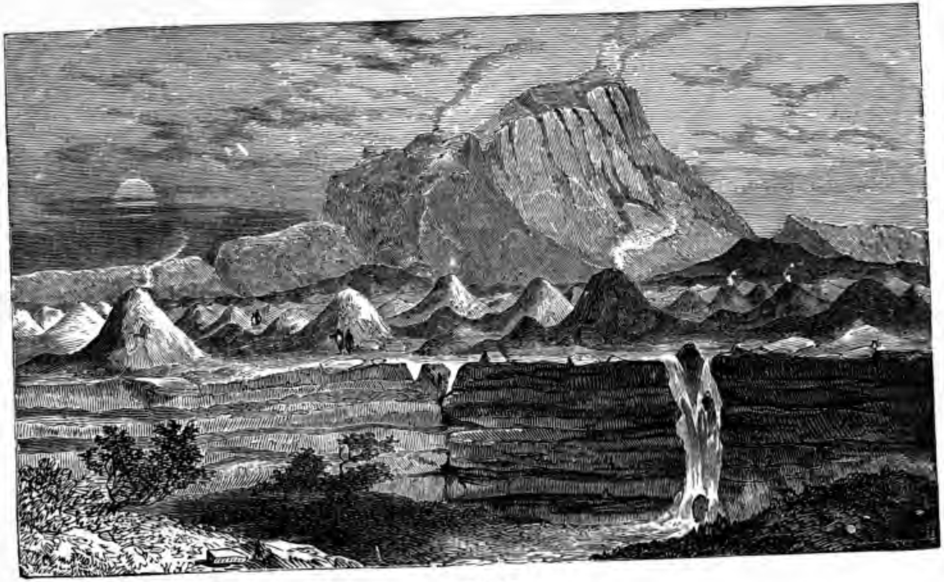
The Indians who beheld this strange phenomenon, declared that they saw flames issuing from several parts of this elevated tract—that the entire surface became agitated like a stormy sea—that great clouds of ashes, illuminated by volcanic fires glowing beneath them, rose at several points, and that white hot stones were thrown to an immense height. Vast chasms were at the same time opened in the ground, and into these the two small rivers above-mentioned plunged. Their waters, instead of extinguishing the subterranean conflagration, seemed only to add to its intensity. Quantities of mud, enveloping balls of basalt, were now thrown up; and the surface of the elevated ground became studded with small cones, from which volumes of dense vapour, chiefly steam, were emitted—some of the jets rising from 20 to 30 feet in height. These cones the Indians called ovens; and in many of them there is heard a subterranean noise resembling that of water briskly boiling. Out of a great chasm in the midst of those ovens, there were thrown up six larger elevations—the highest being 1600 feet above the level of the plain, and now constituting the principal volcano of Jorullo. The smallest of the six was 300 feet in height; the others of intermediate elevation. The highest of these hills has on its summit a regular volcanic crater, whence there have been thrown up great quantities of dross and lava, containing fragments of older rocks. The ashes were transported to immense distances—some of them having fallen on the houses at Queretaro, more than forty-eight leagues from Jorullo. The volcano continued in this energetic state of activity for about four months; in the following years its eruptions became less frequent; but it still continues to emit volumes of vapour from the principal crater, as well as from many of the ovens in the upheaved ground. The remarkable appearance presented by this volcano, with its surrounding ovens, is shown in the annexed woodcut, taken from Humboldt's sketch.

The two rivers, which disappeared on the first night of this great eruption, now pursue an underground course for about a mile and a quarter and then re-appear as hot springs, with a temperature of 126° F.

This wonderful volcanic upheaval is all the more remarkable from the inland situation of the plain on which it occurred—it being no less than 120 miles distant from the nearest ocean; while there is no other volcano nearer to it than 80 miles.

The activity of the ovens has now almost ceased; and portions of the upheaved plain on which they are situated have again been brought under cultivation. The crater of the volcano at present gives forth only sulphurous vapours, like those of others in a subdued state of activity.

Of the other Mexican volcanoes, one of the grandest is Popocatepetl, which towers to the height of 17,850 feet above the level of the sea. This mountain, although active at the time of the Spanish conquest, has since enjoyed a long rest, and now shows but little indication of internal heat. Its crater is a vast circular basin, whose nearly perpendicular walls are in some parts of a pale rose tint, in others quite black. The bottom contains several small fuming cones, whence arise vapours of changeable colour—being successively red, yellow, and white. All round them are large deposits of



JORULLO.

sulphur, which are worked for mercantile purposes.

Orizaba has a not less lofty snow-clad peak. This mountain was in brisk volcanic activity from 1545 to 1560, but has since then relapsed into a prolonged repose. It was climbed, in 1856, by Baron Müller, to whose mind the crater appeared like the entrance to a lower world of horrible darkness. He was struck with astonishment on contemplating the tremendous forces required to elevate and rend such enormous masses—to melt them, and then pile them up like towers, until by cooling they became consolidated into their present forms. The internal walls of the crater are in many places coated with sulphur, and at the bottom are several small volcanic craters. At the time of his visit, the summit was wholly covered with snow; but the Indians affirmed that hot vapours occasionally ascend from fissures in the rocks.

There are some volcanoes in the peninsula of Lower California, and one of them, named Mount St. Elia, is said to be of great height—between 17,000 and 18,000 feet above the sea-level. Nothing, however, is known of their history or their eruptions.

CHAPTER XVIII.

SUBMARINE VOLCANOES.

THE upheaval of Monte Nuova and Jorullo raises an expectation that similar occurrences may take place at the bottom of the sea, resulting in the formation of new islands. There are accordingly not a few instances of the kind on record—some of the islands thus upheaved having remained permanently above water, while others have continued visible for only a limited time.

The Bay of Santorin, in the island of that name, which lies immediately to the north of Crete, has long been noted for its submarine volcanoes. According to one account, indeed, the whole island was at a remote period raised from the bottom of the sea; but the fact is rather questionable. It is, with more reason, supposed that the bay is the site of an ancient crater, which had been situated on the summit of a volcanic cone that had subsequently fallen in. Certain it is that islands have from time to time been thrown up by volcanic forces from the bottom of the sea within this bay, and that some of them have remained, while others have sunk down again.

Of the existing islands, some were thrown up shortly before the beginning of the Christian era; in particular, one called the Great Cammeni, which, however, received a considerable accession to its size by a fresh eruption in A.D. 726. The islet nearest Santorin was raised in 1573, and was named the Little Cammeni; and in 1707 there was added, between the other two, a third, which is now called the Black Island. The upheaval of this last was witnessed by Father Goree. It made its appearance above water on the 23rd of May 1707, and was first mistaken for a wreck; but some sailors, who landed on it, found it to be a mass of rock, consisting of a very white soft stone, to which were adhering quantities of fresh oysters. While they were collecting these, a violent shaking of the ground scared the sailors away. During several weeks the island gradually increased in volume; but in July, at a distance of about sixty paces from the new islet, there was thrown up a chain of black calcined rocks, followed by volumes of thick black smoke, having a sulphurous smell. A few days thereafter, the water all round the spot became hot, and many dead fishes were thrown up. Then, with loud subterraneous noises, flames arose, and fresh quantities of stones and other loose substances were ejected, until the chain of black rocks became united to the first islet that appeared. This eruption continued for a long time, there being thrown out quantities of ashes and pumice, which covered the island of Santorin and the surface of the sea—some being drifted to the coasts of Asia Minor and the Dardanelles. The activity of this miniature volcano was prolonged, with greater or less energy, for about ten years.

The Bay of Santorin has been the scene of similar phenomena during the past year, 1866. On the 30th of January, at the southern extremity of the Little Cammeni, there were heard loud underground sounds, accompanied by slight shocks of earthquake. On the following day bubbles of gas began to be disengaged from the water in the harbour called Voulcano, while the sounds became much louder. Early in the morning of the 1st of February, a fissure appeared in the central cone of this islet, running from the top down the side. About the same time flames arose from the surface of the sea, which assumed a reddish appearance. Next day the ground on the east side of the harbour began to sink so much, that houses which before stood from six to nine feet above the sea-level could now be entered by boats. There soon after rose in the harbour itself, out of the midst of a dense smoke, a small islet, which gradually increased in size during the succeeding days. The people of Santorin named it "George," after the King of Greece. By the 5th of February it had attained a height of upwards of 60 feet. Its length exceeded 200, and its breadth 90 feet. The masses of which it was composed were all thrown out towards the circumference from the centre, where there was evidently a crater of eruption. The first ejected of those masses were black and cold; but erelong they were succeeded by others in a state of bright incandescence.

These volcanic phenomena increased up to the 13th of February, by which time not only was the whole harbour filled up, and the new islet thus rendered continuous with the Little Cammeni, but the elevation extended to a distance of upward of sixty yards all round what was the entrance to the port. The detonations increased in loudness, and large quantities of incandescent stones were thrown up from the crater. About the same time, at the distance of nearly 150 feet from the coast, to the westward of a point called Cape Phlego, there rose from the sea another island, to which was given the name Aphroëssa. It sank and reappeared several times before it established itself above water.

The detonations and ejection of incandescent lava and stones continued at intervals during three weeks. From the crater of the islet George, which attained a height of 150 feet, some stones several cubic yards in bulk were projected to a great distance. One of them falling on board of a merchant vessel, killed the captain and set fire to the ship.

By the 10th of March the eruptions had partially subsided, but were then renewed, and a third island, which was named Reka, rose alongside of Aphroëssa. They were at first separated by a channel sixty feet deep; but in three days it was filled up, and the two islets became united.

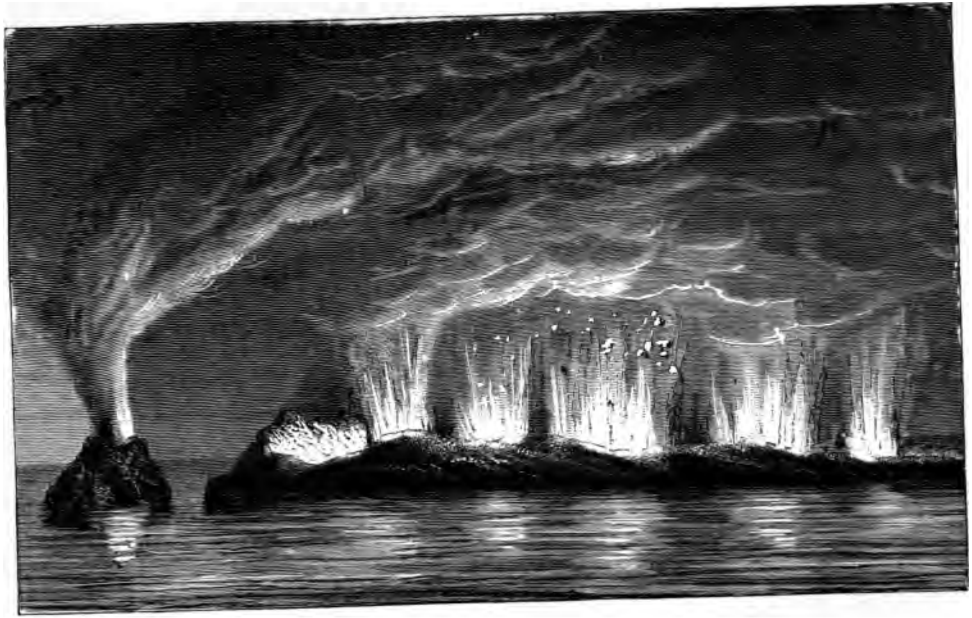
These three new islands were formed partly by upheaval, but to a greater extent by the ejection from the open craters of streams of lava, which became quickly consolidated. The stones and other loose matters thrown out also contributed by their accumulation to the formation of the islets.

In another part of the Mediterranean, near Sciacca, on the south-west coast of Sicily, there occurred, in July 1831, a submarine eruption of a very interesting kind. From the 28th of June to the 2nd of July in that year, the inhabitants of Sciacca had experienced several slight shocks of earthquake. On the 8th of July, John Corrao, the captain of a Sicilian vessel perceived rising out of the sea, at a spot distant about 30 miles south-west of Sciacca, an immense jet of water, which was thrown up with a thundering noise to a great height, at intervals of about a quarter of an hour. This jet produced a thick mist, that soon spread itself over the sea, which was very rough at the time. The surface of the water erelong became covered with a reddish scum, and many dead fishes were seen floating about. On passing near the spot two days afterwards, Corrao found the jet still playing, and he estimated its height to be about 60, its diameter upwards of 800 feet. The cloud of vapour from the jet rose, according to his estimate, to between 20 and 30 times the height to which the water ascended.

All this while a thick mist veiled the horizon from the inhabitants of Sciacca; but on the 12th of July they perceived the air to be pervaded by a strong sulphureous smell, and they saw drifting towards the shore great quantities of black dross, which accumulated on the beach. Multitudes of dead fishes were also seen floating on the water. On the following day they beheld, rising out of the sea, at the spot before indicated, a great column of what seemed by day like black smoke, but which by night became illuminated by the glare of fire glowing from beneath. Bright scintillations were also perceived to be thrown up amid the smoke, and loud reports, as if from heavy ordnance, were occasionally heard.

On the 18th of July, while sailing nigh the spot where these phenomena had been seen, Corrao discovered that there had been thrown up an island, from 9 to 12 feet high, having in its centre a crater whence jets of vapour and clouds of volcanic ashes were being thrown out. Towards evening, the same day, a small English boat despatched by Admiral Hotham approached the place, and found the height of the island increased to upwards of 70 feet, and its circumference to nearly three-quarters of a mile. The sea all round was covered with dross of a chocolate-brown colour, and in the interior of the crater there was a small lagune, communicating with the sea by a narrow channel. The water in the lagune was reddish. Only a few years before this event, soundings had been taken close to this spot, and the depth was found to be 100 fathoms.

The scene of these extraordinary phenomena was visited on the 24th of July by Captain Swinburne, R.N., and M. Hoffmann, the Prussian geologist. They could not approach nearer the island than three-quarters of a league, so great was the agitation of the sea, and such the quantity of dross being thrown out by the volcano. Even at that distance some of the glowing stones fell into their boat. According



GRAHAM'S ISLAND, AUGUST 1831.

to their observations, the diameter of the crater appeared to be about 600 feet, and the island was augmenting from moment to moment by the accumulation of ejected matters, which for the most part fell near to the place whence they were thrown up. There rose from the crater a column of aqueous vapour mixed with volcanic substances to the height of 1800 feet. Occasionally quantities of black dross were thrown up in the midst of this column; but, what was more striking, there rose during their observations a vast column of thick black smoke, which was shot up with great violence to the height of about 600 feet, and then spread itself into a form resembling a huge pine-tree. In the midst of this dark column, glowing stones were frequently tossed up to great heights, accompanied by a noise like the rattling of hail. Eruptions of this sort continued for periods varying from ten minutes to an hour, and were separated by intervals of rest, during which the aqueous vapours ascended in perfect silence.

The prefixed woodcut, copied from a sketch by M. Kellin, an Italian artist, shows the appearance presented by the island at the beginning of August. On the 4th of that month it had attained, at its highest point, an elevation of about 200 feet, while its circumference had increased to about three miles.

The eruption of solid matters ceased on the 12th of August, after which the island began rapidly to decrease in size by the invasion of

GRAHAM'S ISLAND, 29TH SEPTEMBER 1831.

the sea. It was visited on 29th September by the French geologist, M. Constant Prevost, accompanied by M. Edmund Joinville, a skilful artist, from whose drawings the accompanying woodcuts have been copied. The first shows the appearance of the island at a short distance, and the second the aspect of the crater.

CRATER OF GRAHAM'S ISLAND, 29TH SEPTEMBER 1831.

At the time it was examined by them, the crater was found to be a nearly circular basin, about 180 feet in diameter, and it contained a lake of fresh water of a reddish colour, and having a temperature a few degrees below the boiling point; but it appeared as if it were actually boiling, from the quantity of gas that was being continually disengaged from its surface. Great clouds of steam rose from fissures near the margin of the lake and in other parts of the soil, the heat of which was considerable.

This remarkable volcano, which in England is known as Graham's Island, did not long maintain its position above water. Towards the end of October, it was reduced nearly to the level of the sea, and not long afterwards it disappeared altogether. When soundings were taken in 1833, there was found a dangerous reef where the island had been. It is composed of a central mass of black rock, surrounded by banks of sand and volcanic stones—the highest point of the rock being only from 9 to 11 feet under water. More recent soundings show that this shoal remains in the same state.

In May 1783, about a month before the great eruption of Skaptár Jokul in Iceland, there was, at a distance of about thirty miles south-west from Cape Reykianas, a submarine eruption, resulting in the formation of a new island, which the King of Denmark named Nyoë. It consisted of high cliffs, within which were several craters, whence the usual volcanic ejections were thrown out. So great was the quantity of pumice discharged from the volcano, that the ocean was covered with it to a distance of 150 miles, and that to such a degree as to disturb the navigation of ships. This new island, however, remained above water not more than a year; and the only existing remnant of it is a reef of rocks, the highest point of which is about five fathoms from the surface. Another small volcanic island was raised in 1830 by a submarine eruption, also off the coast of Iceland, near Reikiavig.

In 1811, near the coast of St. Michael's in the Azores, there was in a similar manner formed, by a submarine eruption, a new island, which was named Sabrina, but which proved equally temporary in its duration. There was in this case thrown up a cone about 300 feet high, with a crater in the centre, which displayed the usual volcanic phenomena.

A permanent addition, however, was made to the Aleutian group of islands, by the action of a submarine volcano in 1806. This new island has the form of a volcanic peak, with several subsidiary cones. It is four geographical miles in circumference. Another rose in 1814 out of the sea in the same archipelago, the cone of which attained a height of 3000 feet; but at the end of a year it lost a portion of this extreme elevation. Again, in 1856, in the sea in the same neighbourhood, Captain Newell, of the whaling bark *Alice Fraser*, witnessed a submarine eruption, which was also seen by the crews of several other vessels. There was no island formed on this occasion; but large jets of water were thrown up, and the sea was greatly agitated all round. Then followed volcanic smoke, and quantities of stones, ashes, and pumice—the two latter being scattered over the surface of the sea to a great distance. Loud thundering reports accompanied this eruption, and all the ships in the neighbourhood felt concussions like those produced by an earthquake. These phenomena ended in the formation of some great submarine chasm, into which the waters rushed with extreme violence and a terrific roar.

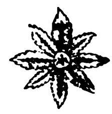
Occurrences similar to this last have been several times observed in a tract of open sea in the Atlantic, about half a degree south of the equator, and between 20° and 22° of west longitude. Although quantities of volcanic dross have been from time to time thrown up to the surface in this region, no island has yet made its appearance above water.

CHAPTER XIX.

CORAL ISLANDS.

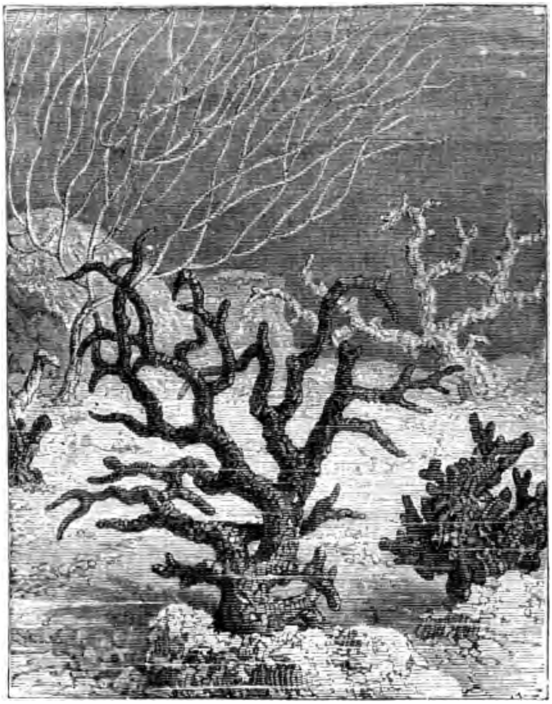
STRANGE as it may at first sight appear, there is an intimate connection between submarine volcanic action and the formation of coral islands in the Pacific.

The coral is a minute polyp, discernible only under the higher powers of the microscope. Its appearance, with its expanded tentacles, when viewed by this instrument, is shown in the annexed woodcut.


CORAL POLYP.

There are numerous species of the coral polyp; but all of them are endowed with a power, which seems to reside in their skin, of separating lime from water holding it in solution, and so forming for themselves a hard crust of the carbonate of lime mixed with a little animal matter. This crust, which differs much in form and appearance in the diverse species, serves the polyp for a habitation, and for a protection to its soft body.

Like other polyps, the coral grows by putting forth buds, much in the same manner as a tree. These buds grow close together, so as to form a



CORAL.

large mass termed a polypidom, each chamber in which communicates with all the rest—See woodcut. The polypidoms, like the cells compos-

CORAL REEF.

ing them, vary greatly in shape and aspect in the different species of coral. After a while, the older polyps die, their cells become obliterated, and the coral stem acquires additional hardness. In this manner large beds are formed of the diverse species under the sea, where the water is not of too great a depth. These beds compose what are called coral reefs—See woodcut. They are often of immense extent, and very dangerous to mariners.

Coral reefs abound in the Red Sea, the Indian Ocean, and more especially in the Pacific. They are distinguished by Mr. Darwin into three sorts:—1st, Barrier reefs, or those which run parallel to the lines of coast of continents or islands, but at some distance from the shore—there being always an intervening space of deep sea. 2nd, Fringings reefs, or those which border the shores of continents or islands, without any intervening interval of sea, except a narrow channel only a few feet in depth. 3rd, Atolls, which are large rings of coral rock, having each a lagune or salt-water lake in its centre.

The coral islands of the Pacific consist for the most part of such atolls. Nothing can be more singular or beautiful than the aspect they present. The ring of coral reef generally rises only a few feet above the high-water mark, and is seldom more than half a mile broad—the average breadth being only three or four hundred yards. The form of the ring is generally either circular or oval; but in every case it is interrupted by a deep narrow channel, always situated on the leeward side of the island—that least exposed to the prevailing winds. This channel forms a direct communication between the outer ocean and the inner lagune, the depth of which is very various, sometimes as much as twenty, or even thirty-eight fathoms. The width and depth of the channel is usually sufficient to admit the passage of the largest ships afloat, which are thus enabled to sail into the still waters of the lagune, there to find shelter from the storm.

The windward side of the island is always the highest, and the slope towards the leeward is gradual. In some cases the ring is interrupted by a few narrow and shallow channels besides the great one; but it is more frequently continuous save at the latter. The soil upon it is of great richness and fertility—supporting a most luxuriant vegetation, chiefly of cocoa-nut palms. It is this rich vegetation that adds beauty to the singularity of their appearance, and renders them such agreeable places of abode that many of them are inhabited. The number of those islands is enormous, and they are the chief constituents of the great archipelago, or rather group of archipelagoes, in the Pacific named Polynesia. There are also several groups of them in the Indian Ocean.

The Radack group, in the Pacific, is somewhat of a rectangular form, 520 miles long by 240 broad. The Low Archipelago is of an elliptical form, 840 miles in its longer, 420 in its shorter axis. These two, together with intervening smaller groups, extend to a length of 4000 miles—all the islands in this space presenting the same characteristics. The atolls are also sometimes individually of great size. One, named Rimsky, is 54 miles by 20; Suadiva is 44 by 34, Bow 30 by 6.

The mode in which these islands may have been formed, has long been a subject of curious speculation among philosophers. The opinion which for a long time prevailed was, that these reefs had been reared by their tiny architects on the rims of the craters of submarine volcanoes; and this view possessed a great deal of plausibility. Not only are volcanoes numerous in the Pacific, but the general outline of the ring bears a remarkable resemblance to that of the margin of steep rugged rocks which usually surrounds a volcanic crater. Even the great channel, which all these islands possess, was easily explicable on this supposition; for almost all the margins of volcanic craters are broken on one side—the breach being caused by the overflow of lava-streams.

Granting the existence of a submarine crater at the requisite depth, the explanation became easy. The corals erected their polypidoms on the margin of the crater—building it up until the top reached the surface at low water. Beyond this point they could not ascend, because the polyps die immediately on their exposure to the air. At this stage the top of the reef becomes thickly covered by the shells of mollusca, and by the action of the sea the coral formation is triturated into fine powder, which, with the aid of the water, forms a cement that agglutinates the shells into a mass. The upper portion of this mass, and of the reef itself, becomes gradually rent by the action of the sun and the weather, so that there are formed large loose fragments, which the waves toss up on the crown of the reef. There is thus by degrees accumulated a ridge, which remains dry at the highest tide; and a sloping beach of shingle, with calcareous sand of dazzling whiteness, is gradually formed on its outer side. On the inner side of the ridge, the agglomeration of shells, broken corals, and calcareous sand, goes on accumulating over the crown of the reef, until the whole of it is raised above the level of the inner lagune. The surface of this dry portion erelong becomes a friable soil, in which stray cocoa-nuts washed ashore by the tides readily take root. The seeds of other plants are brought by birds, and there are often cast upon those low beaches logs of timber, in which are the eggs of insects and lizards. Thus by degrees the flat surface of the coral-ring becomes covered with vegetation, and offers to the Polynesian who may happen to be drifted towards it in his canoe, a temptation to make it his home.

Notwithstanding the plausibility of the theory that these reefs have been based on the rims of volcanic craters, several great difficulties stood in the way of its acceptance. The first arose out of the enormous dimensions of some of these rings—far exceeding those of the craters of any known volcanoes. Secondly, their great number, and the close proximity of many of them, were against the probability of their being the summits of craters. Thirdly, there was the uniformity in the position of the channel leading into the lagune. Fourthly, a yet stronger objection lay in the fact, ascertained by Mr. Darwin and others, that the coral-polyp cannot live and build its polypidom when the depth of water exceeds 120 feet. It will easily be perceived how extreme is the improbability that all the volcanic craters should have risen to within this depth from the surface, so as to afford a foundation for the polypidoms. But, what was still more conclusive against this hypothesis, the depths to which the reefs themselves extend were found greatly to exceed 120 feet, being in some ascertained cases 900, or even 1200 feet, and in others probably much more; but in all such cases the coral below the depth of 120 feet is dead.

These facts suggested to the mind of Mr. Darwin another explanation, now much more generally adopted. While studying the structure of the fringing reefs—those which surround an island with only a very narrow piece of shallow water between the reef and the shore—it occurred to him that, were such an island gradually to subside, it would eventually become an atoll. For the reef would continue to ascend while the central portion of the island was subsiding, until the latter might become entirely covered with water, and so form the internal lagune. This view was strengthened by his finding some islands in a transition state—that is, with a small islet in the centre of the lagune—the subsidence having not yet been sufficient to submerge the whole of the interior portion of the island.

This hypothesis obviates much of the difficulty connected with the other. It accounts for the vast depth to which the outer portion of the reef extends—far beyond the limits at which the coral can grow. It explains why the entrance to the lagune is always on the lee-ward side, this channel being at first formed owing to the greater elevation of the reef to windward, and the scour of the tide between the lagune and the sea passing through at the lowest point, where its action would prevent the growth of the coral. The minor interruptions to the continuity of the ring Mr. Darwin explains by supposing them to have had their origin in the mouths of fresh-water streams, flowing from the interior of the island before its submergence. The uniformity of the height of the reefs above the sea-level, the enormous extent of some of them, and the manner in which they are clustered together, all become equally explicable on this hypothesis.

It is not difficult to account for the supposed subsidence by volcanic agency. If we imagine that the bed of the Pacific is a thin crust covering large reservoirs of liquid lava, and that portions of this crust had been ages ago upheaved by the volcanic forces, so as to form numerous clusters of volcanic islands, these would gradually become surrounded by fringing reefs. The great addition thus made to their weight would cause a rupture in the crust at their base immediately surmounting the liquid lava underneath, so that the entire mass would sink down a little. As the weight of the reef increased, the mass would sink lower and lower, and the reach of water between the central portion and the fringing reef would thus become wider and deeper. In this manner the fringing reef would be converted into a barrier reef, with a wide and deep space of water between its inner edge and the shore of the island. The height and weight of the reef still increasing, the island would sink still further, and be more and more invaded by the sea, until at length its very central portions would become quite submerged, and form an uninterrupted lagune. In some instances, however, peaks might remain above water—forming in the lagune islets such as are sometimes observed. From the growth of the reef's being the cause of the subsidence, it results that these two generally keep pace the one with the other.

With respect to the lagune itself, it is always in the course of being gradually filled up, partly by the growth of corals finer and more delicate than those which build the outer reef, and partly by the shells of mollusks and crustaceans, mixed with the broken and powdered coral, which, by becoming a marly paste, tends to agglomerate them into a solid mass. In this manner, the top of the atoll ultimately becomes a dry flat, wholly covered with vegetation.

To explain all the phenomena, however, presented by the islands of the Pacific, it is needful to suppose not a few of them, after having been formed into atolls, to have again been upraised by volcanic forces operating from beneath. There are some islands which have evidently been at one time atolls, whose lagunes have been gradually filled up in the manner above described, so as to present an uniform flat surface covered with vegetation; but their edges stand high out of the water, forming precipitous cliffs of coral rock—thus giving evidence that the entire island has been gradually upheaved. In other cases, however, where the island presents a similar precipitous wall of coral rock for its coast, the interior is occupied by mountains of obvious volcanic origin—occasionally by volcanoes in a state of activity. In these latter cases the upheaving forces have been more energetic.

It thus appears that, while one set of islands is sinking, another is rising by the operation of the volcanic forces—the one phenomenon being probably the cause of the other. For the subsidence of the sinking islands must increase the pressure on the surface of the reservoirs of liquid lava underneath them, and cause them to seek relief in some other direction. The lava may either insinuate itself horizontally between the strata under some of the islands, so upheaving them gently; or, having made vertical fissures in the strata, it may be forced right up, and escape by forming a volcanic vent.

It will thus be perceived how intimate is the relation between the play of volcanic forces and the formation of coral islands, and how marvellous are the changes wrought by the operations of this tiny polyp.

CHAPTER XX.

MUD AND AIR VOLCANOES.

IN the account previously given of igneous volcanoes, it has been mentioned that those mountains not unfrequently throw out quantities of mud instead of lava. This often happens among the South American volcanoes and those of Java; while even Vesuvius appears to have thrown out mud before it began to eject lava. There are volcanoes, however, from which nothing is ever ejected but mud and water—the latter being generally salt. From this circumstance they are sometimes called salses; but they are more generally termed mud-volcanoes. Some varieties of them throw out little else than gases of different sorts, and these are called air-volcanoes.

One of the best known mud-volcanoes is at Macaluba, near Girgenti, in Sicily. It consists of several conical mounds, varying from time to time in their form and height, which ranges from eight to thirty feet. From orifices on the tops of these mounds, there are thrown out sometimes jets of warmish water and mud mixed with bitumen, sometimes bubbles of gas, chiefly carbonic acid and carburetted hydrogen, occasionally pure nitrogen. The mud ejected has often a strong sulphurous smell. The jets in general ascend only to a moderate height; but occasionally they are thrown up with great violence, attaining a height of about 200 feet. In 1777, there was ejected an immense column, consisting of mud strongly impregnated with sulphur, and mixed with naphtha and stones, accompanied also by quantities of sulphurous vapours. This mud-volcano is known to have been in action for fifteen centuries.

Very recently a small mud-volcano has been formed on the flanks of Mount Etna. It began with the throwing up of jets of boiling water, mixed with petroleum and mud—great quantities of gas bubbling up at the same time.

In several of the valleys of Iceland there are similar phenomena—the boiling water and mud being thrown up in jets to the height of fifteen feet and upwards—the mud accumulating around the orifices whence the jets arise.

A mud-volcano named Korabetoff, in the Crimea, presents phenomena more akin to those of the igneous volcanoes of South America. There was an eruption from this mountain on the 6th of August 1853. It began with there being thrown up from the summit a column of fire and smoke, which ascended to a great height. It continued for five or six minutes, and was followed by two similar eruptions at short intervals. There was then ejected with

MUD-VOLCANOES NEAR BELA, BELOOCHISTAN.

a hissing noise a quantity of black fetid mud, which was so hot as to scorch the grass on the edges of the current. The eruption lasted about three hours, and the ejected mud covered a considerable space at the foot of the mountain.

There is a group of mud-volcanoes on a very extensive scale in the district of Lus, to the southward of Bela, on the south-eastern coast of Beloochistan. They are very numerous, and are said to extend over an area of nearly a thousand square miles. The prefixed woodcut, copied from one in Lyell's "Principles of Geology," shows the remarkable appearance presented by a portion of this district. The height of one of the cones is estimated at 400 feet. The phenomena much resemble those at Macaluba.

There is in Java a mud-volcano which has a somewhat different mode of operation. It is thus described by Dr. Horsfield:—

"On approaching it from a distance, it is first discovered by a large volume of smoke, rising and disappearing at intervals of a few seconds, resembling the vapours rising from a violent surf. A loud noise is heard, like that of distant thunder. Having advanced so near that the vision was no longer impeded by the smoke, a large hemispherical mass was observed, consisting of black earth mixed with water, about sixteen feet in diameter, rising to the height of twenty or thirty feet in a perfectly regular manner, and as it were pushed up by a force beneath, which suddenly exploded with a loud noise, and scattered about a volume of black mud in every direction. After an interval of two or three, or sometimes four or five seconds, the hemispherical body of mud rose and exploded again. In the same manner this volcanic ebullition goes on without interruption, throwing up a globular body of mud, and dispersing it with violence through the neighbouring plain. The spot where the ebullition occurs is nearly circular, and perfectly level. It is covered only with the earthy particles, impregnated with salt water, which are thrown up from below. The circumference may be estimated at about half an English mile. In order to conduct the salt water to the circumference, small passages or gutters are made in the loose muddy earth, which lead to the borders, where it is collected in holes dug in the ground, for the purpose of evaporation.

"A strong pungent sulphurous smell, somewhat resembling that of earth-oil, is perceived on standing near the explosion, and the mud recently thrown up possesses a degree of heat greater than that of the surrounding atmosphere. During the rainy season these explosions are more violent. The mud is thrown up much higher, and the noise is heard at a greater distance."—*Batavian Transactions*, vol. ix.

As in the case of igneous, so in the case of mud volcanoes, instances have occurred of their having been thrown up from the bottom of the sea. On the 10th of May 1814 there rose out

AIR-VOLCANOES OF TURBACO.

of the Sea of Azof, with a loud report, a column of flame and dense black smoke, accompanied by masses of earth and large stones, which were thrown to a great height. There was a succession of ten explosions of this kind, at intervals of about a quarter of an hour. After a considerably longer period of repose, they recommenced during the night, and next morning it was perceived that there had been upheaved an island between nine and ten feet high, surrounded by a lower level of stiff mud. The erupted matter had a strong and disagreeable smell.

A similar phenomenon occurred in the peninsula of Abscheron, east of Baku, in the Caspian Sea, on the 27th of November 1827. The eruption of mud was preceded by the ascent of flames to a great height, and was accompanied by the ejection of immense fragments of rock, which were thrown to a vast distance. This volcano is named Jokmali.

There is a set of small volcanoes discovered by Humboldt at Turbaco, in South America, from which there is little else ever emitted than gases, chiefly nitrogen. The prefixed woodcut, taken from his sketch, shows the appearance presented by those diminutive air-volcanoes.

In Guatemala, Central America, there is a lofty mountain, which might perhaps be classed among mud-volcanoes. It is named Volcan di

Agua, and near it is another high mountain named Volcan di Fuego. From the latter the eruptions have been of the usual description, and volcanic fumes are constantly emitted from its summit; but from the former the only sort of recorded eruption has been of water, whether accompanied by mud or not does not appear. Of this mountain, whose estimated height is 12,500 feet, an ascent was made in January 1865, by a party of English and natives, headed by Mr. William Brown Richardson, superintendent of a silver mine in the neighbourhood. They found on the summit a nearly circular crater, about 180 feet in diameter. Its floor is quite flat, and without any open vent communicating with the interior of the mountain. Its walls are very steep and lofty—at one point nearly 300 feet in height. There is, at one side, a break in the continuity of the wall, whence, according to tradition, there issued an immense flood of water, which scooped out a deep valley in the side of the mountain, and devastated the country at its base, destroying the first Spanish settlement which had been established there. This phenomenon, however, may have been simply the bursting of a lake which had filled an ancient volcanic crater of the usual kind.

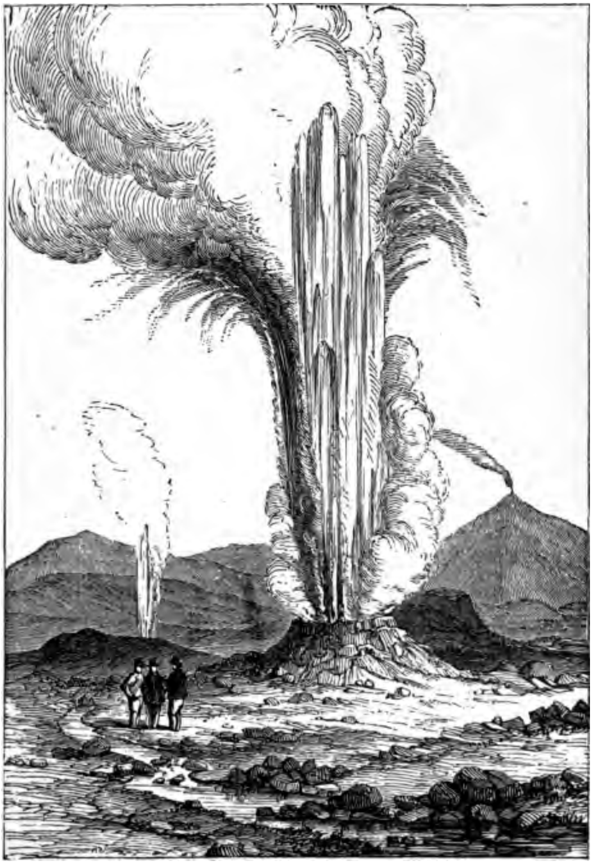
CHAPTER XXI.

GEYSERS, HOT SPRINGS, AND LAKES.

THERE is a close connection between mud volcanoes and those intermittent boiling springs named geysers. A good many of the mud-volcanoes throw out jets of boiling water along with the mud; but in the case of the geysers, the boiling water is ejected alone, without any visible impregnation. Nevertheless, it for the most part contains some mineral substance in solution, be it silica, carbonate of lime, or sulphur.

The largest and best known geysers in the world are those of Iceland. The Great Geyser, in particular, has a most imposing appearance of which some idea may be formed from the annexed woodcut. Silica is the mineral with which the waters of this fountain are impregnated, and the substance which they deposit, as they slowly evaporate, is named siliceous sinter. This material is what composes the mound of 6 or 7 feet in height, on which the spring is situated. On the top of the mound is a large oval basin, about 3 feet in depth, measuring in its larger diameter about 56, and in its shorter about 46 feet. The centre of this basin is occupied by a circular well about 10 feet in diameter, and between 70 and 80 feet deep.

It is out of the central well that the jet of boiling water springs, at intervals of six or seven hours. When the fountain is at rest, both the basin and the well appear quite empty; nor is there even any steam to be seen rising out of the latter. On the approach of the moment for action, the water rises in the well, till it flows over into the basin. Then loud subterranean explosions are heard, and the ground all round is violently shaken. Instantly, and with immense force, up springs the jet of boiling water, of the full width of the well, and ascending to a great height in the air. The top of this large column of water is enveloped in vast clouds of steam, which diffuse themselves through the air, rendering it misty. The jets succeed each other with great rapidity to the number of sixteen or eighteen—the fountain remaining thus in play for only about five minutes at a time. The last of the jets thrown up generally ascends to the greatest height—usually to about 100, but sometimes to about 150 feet; while on one occasion it was ascertained to have risen to the amazing height of 212 feet. The fountain, having ejected this



THE GREAT GEYSER, CELAND.

great column of water, sinks down into the well, and all that had filled the basin retires rapidly down the same channel; so that both basin and well become empty as before, and thus remain till the arrival of the time for the next eruption, when the same phenomena are repeated. It has been found that, by throwing large stones into the well, the period of the eruption may be hastened, while the loudness of the explosions and the violence of the action of the fountain are at the same time increased. The stones are thrown out with great force along with the water.

Besides the Great Geyser, Iceland contains several others of smaller dimensions. The phenomena are similar, but the eruptions are more frequent and less violent.

There have recently been discovered in California a set of geysers much resembling those of Iceland, yet differing from them in certain particulars. Their waters are impregnated not with silica, but with sulphur, and they thus approach more nearly in their character to mud-volcanoes, whose ejections are, in like manner, much impregnated with that combustible. They are also, like them, collected in groups—there being no less than one hundred openings within a space of flat ground a mile square. Owing to their number and proximity, their individual energy is nothing like so violent as that of the geysers of Iceland. Their jets seldom rise higher than 20 or 30 feet; but so great a number playing within so confined a space produces an imposing effect. The jets of boiling water issue with a loud noise from little conical mounds, around which the ground is merely a crust of sulphur, like that in the Poison-crater of Tangkuban-Prahu in Java. When this crust is penetrated, the boiling water may be seen underneath. The rocks in the neighbourhood of these fountains are all corroded by the action of the sulphurous vapours. Nevertheless, within a distance of not more than 50 feet from them, trees grow without injury to their health.

There are some fountains of boiling water which, instead of being intermittent and throwing up jets at intervals, allow the liquid to flow from them in a perpetual stream. The most remarkable example of this sort occurs at a place called Roto Mahana in New Zealand. There is here a lake of considerable dimensions, whose waters are maintained nearly at the boiling point by the continual accession of boiling water from numerous springs. The most abundant of those sources is situated at the height of about 100 feet above the level of the lake. It keeps continually filled an oval basin about 250 feet in circumference—the margins of which are fringed all round with beautiful pure white stalactites, formed by deposits of the carbonate of lime, with which the hot water is

BOILING WATERS OF ROTO MAHANA, NEW ZEALAND.

impregnated. At various stages below the principal spring are several others, that contribute to feed the lake at the bottom, in the centre of which is a small island. The prefixed woodcut represents this remarkable group of springs, and the lake which they unite to form. Small bubbles continually escape from the surface of the water with a hissing sound, and the sand all round the lake is at a high temperature. If a stick be thrust into it, very hot vapours will ascend from the hole. Not far from this lake, there are several small basins filled with tepid water, which is very clear, and of a blue colour.

All the central parts, indeed, of the northern island of the New Zealand group are of a highly volcanic character. There is here a mountain named Tongariro, on whose snow-clad summit is a deep crater, from which volcanic vapours are still seen to issue, and which exhibits other indications of having been in a state of greater activity at a not very remote period of time. There is also, at no great distance from this mountain, a region containing numerous funnel-shaped chasms, emitting hot water, or steam, or sulphurous vapours, or boiling mud. The earthquakes in New Zealand, which have been mentioned in our annals, had probably their origin in this volcanic focus.

Hot springs are numerous in all quarters of the globe—especially in the neighbourhood of active or extinct volcanoes. Few, however, are so abundant and at so high a temperature as are those of Roto Mahana. As respects temperature, those next highest in the scale are the hot springs of Comangillas, near Guanaxuato in Mexico, and of Trincheras, between Porto Cabello and New Valentia on the coast of Venezuela. Both of these springs have a temperature a little over 206° F. The heat of by far the larger number is much below this point. It depends in a great measure on the depth from which the waters ascend—the deeper the hotter. This arises from their proximity at great depths to reservoirs of molten lava and highly heated strata, which, by converting into steam the water that percolates down to them, provide an agency for forcing the water to the surface, and at the same time for supplying it with its increased amount of heat. That some thermal springs are very deep seated, and are connected with subterranean volcanic forces, is proved by the remarkable effects produced upon the springs at Töplitz in Bohemia during the great earthquake in Lisbon, of which mention has already been made. Instances also of the origination of hot springs, or of their being altered in temperature, or stopped altogether, have been noticed in connection either with earthquakes or volcanic eruptions.

CHAPTER XXII.

SUPPOSED CAUSES OF EARTHQUAKES AND VOLCANOES.

ALL volcanic phenomena—whether those of volcanoes proper, of earthquakes, mud volcanoes, or hot springs, are due, as stated in the outset, to one and the same cause—namely, underground heat. To explain the origin of that heat and its manner of action, several theories have been proposed.

There is reason to believe that the interior of our globe may retain a large proportion of the heat which it acquired at the period of its first formation, unknown ages ago. Many experiments have been made to determine the rate at which the temperature increases on descending into wells and mines. The average result may be stated at 1° F. for every sixty feet of descent. It has been estimated that, were this rate to continue uniform, the heat at a depth of sixty or seventy miles would suffice to melt any of the rocks with which we are acquainted. But Mr. Hopkins has shown by experiment that the rate of increase of temperature probably becomes slower in descending; consequently, that the depth at which the rocks may exist in a molten condition is probably far greater than it would appear to be if estimated from the rate near the surface. He has further, from astronomical considerations connected with the precession of the equinoxes, proved it to be highly probable that the earth continues solid to a depth of three or four hundred miles. Beyond this point, however, it seems not improbable that much of the materials composing the interior of the globe may be in the molten state. It is nevertheless far from certain that, at a depth exceeding 400 miles, the substance of the earth is a continuous liquid, or that the overlying crust is continuously solid. The probability appears greater that the latter is very cavernous in its structure, and that many of its cavities may be wholly or partially filled with molten material—the solid parts being composed of less fusible substances. Nor is it by any means unlikely that this cavernous structure may descend to a depth far exceeding 400 miles—the solid parts consisting of the very infusible earths or metallic oxides, and the fluid portions which occupy the cavities consisting of more readily fusible minerals or metals—perhaps also of water under strong compression having a great density and a high temperature, and of gases reduced by pressure to the liquid form.

Those earthquakes which are felt over a very large extent of surface, and which consequently arise from a cause of disturbance operating at a great depth, have most probably their origin in this central source of underground heat. Attempts have been made, and with very considerable success, as already mentioned, to establish a connection between the earthquakes of this class and the motions of the sun and moon—more especially of the latter. It is supposed that the molten materials in the interior of the earth are acted upon by these bodies much in the same manner as are the waters of the ocean—that, as in the latter there are spring, mean, and neap tides, so there may be in the fiery seas underneath. To the tidal waves thus produced are attributed those upheavals or subsidences of the ground, and the attendant oscillations, which are characteristic of deep-seated earthquakes.

The movements of these molten materials lying at great depths, have also been accounted for by the mere increase of pressure on particular areas, caused by the accumulation of solid matter at the bottom of the sea. By the action of great rivers and of the ocean's waves themselves, the land is being perpetually worn down, and the fine sediment is being continually spread over the bed of the mighty deep. In course of time the material thus accumulated, being specifically heavier than water, adds to the pressure before exerted by that liquid on the spots which it overspreads. The underlying strata, and the molten seas which they cover, having previously adjusted themselves to a certain distribution of pressure, any great disturbance of that distribution will entail the necessity of a new adjustment. The over-weighted portions will sink down, and press on the surface of the melted materials, which will thus be forced to seek relief in some other direction. They will accordingly be thrown upwards into any fissure that may have been formed; and should any portion of the overlying strata have been lightened since the last adjustment took place, these will probably be upheaved by the pressure of the molten masses beneath them. Operations of this kind can hardly fail to produce considerable commotions in the strata, and earthquakes more or less violent will ensue. Even volcanic eruptions might be caused by large displacements in the strata caused in this manner, and there being a very unequal degree of pressure exerted on the molten masses, causing them to be forced upwards through volcanic vents.

Whenever the strata become dislocated from the cause above assigned, or any other, it is probable that there may be formed deep clefts, through which the waters of the ocean or of great lakes or rivers may percolate, until they come into contact with the highly heated matter underneath. The waters, on descending to a comparatively moderate depth, will be raised above the boiling point; so that, if on their passage downwards they encounter any deeply seated underground cavity, they will instantly burst into steam with explosive force. The effect will exactly resemble that of an explosion of gunpowder. All the superincumbent strata will be upheaved and violently shaken; while the tremors will spread themselves in ever widening circles from the centre of disturbance. It is probably in some such manner that those earthquakes which are accompanied by loud underground explosions are produced. Some volcanic eruptions may also have their origin in the explosive power of steam, generated by the access of water to molten material accumulated in underground cavities.

At very great depths, and under very heavy pressure, water will retain its liquid form when raised to a red or even a white heat. In like manner, several of the gases—such as chlorine, sulphurous acid, and carbonic acid, all of which issue from volcanic vents—may be reduced to the liquid condition under the strong pressure exerted by the superincumbent strata at great depths, and may retain their liquidity even when raised to an intense heat. Any sudden diminution of the pressure over particular spots would cause the red-hot water and the liquified gases to assume the aeriform state with sudden and explosive violence, so producing an enormous underground disturbance.

Another cause of an occasional and partial production of intense heat, at comparatively moderate depths, may arise out of the nature of the materials occupying certain parts of the solid crust of the globe. Some philosophers suppose that the metals potassium, sodium, calcium, magnesium, aluminium, and others similar, which are the bases of the alkalies and earths, may, either in their pure state or in combination with sulphur, exist in veins or beds in the rocks at considerable depths in the crust of the earth. The two first-named metals take fire and burn rapidly on being brought into contact with water; and the same happens with the others, provided the contact with water takes place at a high temperature. The access of water to such beds and veins would therefore set them on fire, and evolve so much heat as to melt all the rocks in the neighbourhood. That sulphur performs an important part in promoting volcanic activity, is evidenced by the abundance of that combustible in the products of all volcanoes. Titanium also, whose presence has been detected in the erupted matters of some volcanoes, may be set on fire by contact with nitrogen gas; and the same property is exhibited by boron, whose presence in the form of boracic acid is also characteristic of some volcanic ejections.

There is great probability that certain volcanoes, at least, may be thrown into action in the manner here indicated. A very large proportion of volcanic mountains are situated in the neighbourhood of the sea or of great lakes. That extensive fissures should be formed in the strata from time to time, through alterations in the distribution of pressure, is no marvel. When such fissures are once opened, water will find its way into them; and if it should percolate down to fresh veins of the readily inflammable metals or their sulphides, a great amount of underground disturbance must ensue. Vast quantities both of steam and other vapours may thus be generated, and these may be the effective agents in throwing up the stones, ashes, dross, lava, and other substances ejected by volcanoes. The earthquakes accompanying such volcanic eruptions will be due to the same cause; and even some of those earthquakes which, while very violent, are yet partial in their extent, and consequently not deep seated, may be reasonably explained in this manner, notwithstanding they may have no apparent connection with any volcanic eruption.

There are volcanoes, however, situated at so great a distance from the sea or great lakes, that their eruptions can hardly be explained on the supposition of the access of sea or lake water. Such are those in the central parts of Mexico and in central Asia. Nevertheless there may be fresh waters percolating to great depths in such regions. Even the atmospheric waters imbibed by a large tract of porous strata may suffice for the purpose; or, in the case of these very inland volcanoes, the elastic forces may be otherwise brought into play.

Some relation has been occasionally found to subsist between earthquakes and the pressure of the atmosphere, especially in those cases where the earthquake is in intimate connection with a volcano. It has long been observed, as already mentioned, that the restless volcano of Stromboli is always most active when the pressure of the atmosphere is lowest. This fact is easily comprehensible; for the removal of the pressure of the outer air gives greater freedom to the expansion of the imprisoned gases or vapours which cause the eruptions of Stromboli. It is in like manner conceivable that a great fall of the barometer, operating simultaneously over a large tract of country under which there may be elastic vapours or gases imprisoned at great depths, perhaps in the liquid form, should allow of their suddenly expanding, so giving rise to underground explosions resulting in earthquakes.

There is a class of earthquakes, however, to which reference has already been made, and which some philosophers have been led to attribute to a totally different cause. That class can therefore, according to this view, be scarcely reckoned among volcanic phenomena. Such earthquakes are distinguished by peculiar atmospherical conditions, and in particular by the air's being highly charged with electricity immediately before the shock. These phenomena appear to have been particularly remarkable in the earthquake which occurred in Illinois, U. S., in 1857. During the earthquake in Wales in 1852 also, a remarkable degree of electrical tension in the atmosphere was observed, the shock being likewise accompanied by a sort of underground thunder. From these phenomena it has been inferred that earthquakes which are thus accompanied by a violent electrical disturbance, may be caused simply by an accumulation of electricity in air contained in some deeply seated cavity, while the outer air happens to be highly charged with electricity of an opposite kind. The consequence of such a state of matters will be a vertical discharge of electricity passing through the strata, either from below upwards, or *vice versâ*. The violent tremors and the underground thunder are supposed to be the results of this discharge. In proof of this hypothesis, it is cited as a remarkable circumstance that, in such cases, permanent magnets lose their magnetism for a short time, and drop their keepers before the shock is felt. There is much uncertainty, however, attending this theory, and even if admissible at all, it can apply only to a few earthquakes, and those of a very mild character.

There remains to be noticed a third but very partial cause of underground heat, namely, the slow burning of beds of coal or collections of petroleum. A sufficient heat to cause the inflammation of these substances may be produced through water's obtaining access to iron in combination with sulphur, a material of frequent occurrence in the strata. A constant supply of air, however, to the coal or petroleum would be necessary to maintain the combustion; so that the rate at which the operation proceeds must be very slow, and the area over which it extends very limited. Nevertheless, some of the eruptions of mud volcanoes, more especially where the mud is mixed with petroleum, or where the eruption is accompanied by the extrication of much carburetted hydrogen, or coal gas, may have their origin in the underground combustion of coal or petroleum; the eruption being caused by the access of water to the heated materials, and the consequent generation of explosive steam.

When the mind reflects on the immense

destructiveness of earthquakes, the cities they have overthrown, the multitudes of human beings they have suddenly deprived of life or reduced to destitution, it is apt to be startled, and to ask, How can these phenomena be reconciled with the Divine benevolence? But it must be remembered that "it is appointed unto men once to die," and that the manner of their death is a matter of minor importance. Earthquakes are to be classed with the other causes of the sudden destruction of human life on a great scale, with various pestilences, with shipwrecks, with hurricanes. All these things tend merely to show the transitory and unstable nature of our present existence. The earthquake, in particular, proves that even the globe which we inhabit is in a transitional state, and has not yet attained its final condition of repose, or its ultimate perfection as a habitable globe, destined for the inheritance of rational and immortal beings. The shock is merely a secondary result, arising from the operation of forces which are doubtless designed to accomplish some great and important end.

Volcanoes, again, may be regarded as safety-valves, which tend very considerably to mitigate the violence of the underground forces, by providing a way of escape for the elastic vapours that are generated or set free. Their design is therefore ultimately beneficent. Nevertheless, their immediate effects are often exceedingly destructive, as evidenced by the entombment of Pompeii and Herculaneum in the ashes of Vesuvius. But these effects are trifling compared with the destruction that might be wrought, were the forces in operation not to find vent through the volcano; while the injuries inflicted by the erupted matters are, in some cases and to a certain extent, compensated by the exceeding fertility of the soil produced by their subsequent exposure to the weather.

In like manner, although in their immediate effects, as exhibited in earthquakes, the underground forces are awfully destructive, they have nevertheless a beneficent tendency in another direction; for they are the means provided for making additions, from time to time, to the habitable area of the surface of the globe. Save for the operation of these underground forces, the habitable dry land would be in a constant state of diminution from the corrosive action of the waters. But what is lost from this cause is compensated partly by the land upheaved above the level of the sea by the forces acting from beneath, and partly by the subsidence of parts of the bed of the ocean, by which its average depth is maintained—the latter being probably the more effective of these two causes. Nor do there appear to be any other conceivable means by which additions to the habitable area could be made, or its curtailment prevented. Now, the commotions in the strata, which give rise to destructive earthquakes as their secondary effects, are inseparable from the existence, or at least from the activity, of the forces capable of effecting the needful upheavals and subsidences.

Nor are the additions made to the habitable dry land the only benefits which compensate the destructive effects of earthquakes; for the medicinal virtues of the hot springs, which result from the operation of the same underground forces, are a lasting benefit to mankind.

There is yet another important view to be taken of these phenomena. They are evidences of the existence of magazines of fiery force, which, if brought into operation on a great scale, seem quite capable of giving a literal and physical fulfilment to the prophecy bequeathed to us by the Apostle Peter: "But the day of the Lord will come as a thief in the night; in the which the heavens shall pass away with a great noise, and the elements shall melt with fervent heat, the earth also and the works that are therein shall be burned up" (2 Pet. iii. 10). The volcanic forces have not abated in their activity since this prophecy was uttered, nay, the frequency and violence of their manifestations seem rather to have been increasing. There is therefore much in these phenomena tending to enhance the probability that our globe may yet be destined to undergo some great change by the action of fire. Among other changes designed to be wrought by this agency, may be a large increase in the superficial extent of the globe at the expense of its specific gravity, enabling it to accommodate a much larger number of rational beings than could with comfort subsist upon it in its present condition.

Whether this view be correct or not, whether the prophecy be to receive a physical or merely a metaphysical fulfilment, it is well for us, while musing on this solemn subject, to lay seriously to heart the exhortation by which it is followed: "Seeing then that all these things shall be dissolved, what manner of persons ought ye to be in all holy conversation and godliness?" Let us, however, at the same time hopefully cling to the expectation which the apostle holds out for our comfort: "Nevertheless we, according to his promise, look for new heavens and a new earth, wherein dwelleth righteousness."

APPENDIX.

SINCE the completion of the Earthquake Annals, contained in the earlier part of this work, there have occurred, besides several minor shocks, three disastrous earthquakes, and three considerable volcanic eruptions.

The earthquakes happened in the Island of St. Thomas and smaller islands adjacent; in the island of Hawaii, and other members of the Sandwich group; and along the coasts of Ecuador and Peru, in South America. In all three cases the earthquake was accompanied by a great sea-wave, which, along the Peruvian coast, did immense damage. This last earthquake, which took place on 13th August 1868, about five P.M., was by far the most disastrous and extensive of the three—the destruction of cities and ships having been enormous, while the loss of human lives was appalling, being variously estimated at from 20,000 to 40,000. At Arica there was opened in the earth a fissure several inches wide, whence issued great clouds of dust, accompanied by a horrible stench, and the air throughout a considerable space became darkened like midnight.

It is needless to dwell on the details of human misery and suffering, which have been given in the public journals. The course of the earth-wave is stated to have been from south to north, but to have been varied by minor transverse waves from east to west. The principal undulation is said to have taken about ten minutes to traverse a distance of one hundred and forty-five miles, giving a mean velocity of between fourteen and fifteen miles in a minute. The violent shocks were repeated several times during six or seven minutes. The observations as yet made to ascertain the permanent effects of this earthquake are partial and imperfect; but from soundings taken on board the United States ship *Powhatan*, it appears that opposite to the headland of Sama, near Arica, the depth of water has decreased from forty to six or seven fathoms—thus indicating a considerable permanent elevation of that portion of the Peruvian coast.

By recent accounts from the Sandwich Islands, it appears that, as a consequence of the earthquakes which have occurred there, the south-eastern shore of Hawaii has sunk several feet—from three to four in some parts, and from six to seven in others. The oscillations of the sea at Port Hilo on the 14th, 15th, and 16th of August were very remarkable—the tide rising and falling from three to four feet every ten minutes. A considerable amount of smoke had been observed issuing from the crater of Kilauea.

Of the volcanic eruptions, one proceeded from Skaptarjökul, in Iceland, on the 29th of August 1867. The phenomena were of the usual character—quantities of white ashes, black pumice-dust, and sublimated sulphur having been ejected, and wafted to a great distance. There was on the second day of the eruption the appearance of a great flame, of a bluish colour, having an estimated breadth of half a mile at the base, and rising to a great height. It seemed to issue from the top of the mountain; but whether it was a real flame or merely the usual reflection of the glare from molten lava is not clearly ascertained, as it was observed only from a great distance. The activity of the mountain does not appear to have lasted more than a fortnight.

The second eruption took place on the 14th of November 1867, from a mountain about eight leagues to the eastward of the city of Leon in Nícaragua. This mountain does not appear to have been previously recognizéd as an active volcano, but it is situated in a very volcanic country. The outburst had probably some connection with the earthquake at St. Thomas, which took place on the 18th of November following. The mountain continued in a state of activity for about sixteen days. There was thrown out an immense quantity of black sand, which was carried as far as the coast of the Pacific, fifty miles distant. Glowing stones were projected from the crater to an estimated height of three thousand feet.

The third eruption was of Mount Vesuvius, which, commencing on the 22nd of November 1867, was unusually violent and prolonged. Large quantities of lava were ejected. The only fact of scientific value, however, hitherto brought to light by this eruption is the tidal action of the moon on the reservoir of lava in the mountain, noticed in the foot-note to page 157 of this work.

October 1868.

Index.