

CHAPTER XXIII.

Earthquakes and their effects—Deficiency of ancient accounts—Ordinary atmospheric phenomena—Changes produced by earthquakes in modern times considered in chronological order—Earthquake in Murcia, 1829—Bogota in 1827—Chili in 1822—Great extent of country elevated—Aleppo in 1822—Ionian Isles in 1820—Island of Sumbawa in 1815—Town of Tomboro submerged—Earthquake of Cutch in 1819—Subsidence of the delta of the Indus—Earthquake of Caraccas in 1812—South Carolina in 1811—Geographical changes in the valley of the Mississippi—Volcanic convulsions in the Aleutian Islands in 1806—Reflections on the earthquakes of the eighteenth century—Earthquake in Quito, 1797—Cumana, 1797—Caraccas, 1790—Sicily, 1790—Java, 1786—Sinking down of large tracts.

WE have already stated, in our sketch of the geographical boundaries of volcanic regions, that, although the points of eruption are but thinly scattered, and form mere spots on the surface of those vast districts, yet the subterranean movements extend, simultaneously, over immense areas. We shall now proceed to consider the changes which these movements have been observed to produce on the surface, and in the internal structure of the earth's crust.

It is only within the last century and a half, since Hooke first promulgated his views respecting the connexion between geological phenomena and earthquakes, that the permanent changes effected by these convulsions have excited attention. Before that time, the narrative of the historian was almost exclusively confined to the number of human beings who perished, the number of cities laid in ruins, the value of property destroyed, or certain atmospheric appearances which dazzled or terrified the observers. The creation of a new lake, the engulfing of a city, or the raising of a new island, are sometimes, it is true, adverted to, as being too obvious, or of too much geographical interest, to be passed over in silence. But no researches were made expressly with a view of ascertaining the precise amount of depression or elevation of the ground, or the particular alterations in the relative position of sea and land; and very little distinction was made between the raising of soil by volcanic

ejections, and the upheaving of it by forces acting from below. The same remark applies to a very large proportion of modern accounts; and how much reason we have to regret this deficiency of information is apparent from the fact, that in every instance where a spirit of scientific inquiry has animated the eye-witnesses of these events, facts calculated to throw much light on former modifications of the earth's structure have been recorded.

As we shall confine ourselves almost entirely, in our notice of certain earthquakes, to the changes brought about by them in the configuration of the earth's crust, we may mention, generally, some accompaniments of these terrible events which are almost uniformly commemorated in history, that it may be unnecessary to advert to them again. Irregularities in the seasons precede or follow the shocks; sudden gusts of wind, interrupted by dead calms; violent rains, in countries or at seasons when such phenomena are unusual or unknown; a reddening of the sun's disk, and a haziness in the air, often continued for months; an evolution of electric matter, or of inflammable gas from the soil, with sulphureous and mephitic vapours; noises underground, like the running of carriages, or the discharge of artillery, or distant thunder; animals utter cries of distress, and evince extraordinary alarm, being more sensitive than men of the slightest movement; a sensation like sea-sickness, and a dizziness in the head, are experienced:—these, and other phenomena which do not immediately bear on our present subject, have recurred again and again at distant ages, and in all parts of the globe.

We shall now begin our enumeration with the latest authentic narratives of earthquakes, and so carry back our survey retrospectively, that we may bring before the reader, in the first place, the minute and circumstantial details of modern times, and enable him, by observing the extraordinary amount of change within the last hundred and fifty years, to perceive how great must be the deficiency in the meagre annals of earlier eras.

Murcia, 1829.—The first event which presents itself in our chronological order, is the earthquake which happened in the south of Spain on the 21st of March, 1829. It appears, by the narrative of M. Cassas, the French Consul at Alicant, that

the accounts of the catastrophe were generally much exaggerated. The district violently agitated was only about four square miles in area, being the basin of the river Segura between Orihuea and the sea. All the villages in this tract were thrown down by a vertical movement, the soil being traversed by innumerable crevices four or five inches broad. In the alluvial plain, especially that part near the sea, small circular apertures were formed, out of which black mud, salt-water, and marine shells were vomited; and in other places fine yellowish-green micaceous sand, like that on the beach at Alicant, was thrown up in jets. No crater sent forth lava, as was asserted in several Spanish journals*.

Bogota, 1827.—On the 16th November, 1827, the plain of Bogota was convulsed by an earthquake, and a great number of towns were thrown down. Torrents of rain swelled the Magdalena, sweeping along vast quantities of mud and other substances, which emitted a sulphureous vapour and destroyed the fish. Popayan, which is distant two hundred geographical miles S.S.W. of Bogota, suffered greatly. Wide crevices appeared in the road of Guanacas, leaving no doubt that the whole of the Cordilleras sustained a powerful shock. Other fissures opened near Costa, in the plains of Bogota, into which the river Tunza immediately began to flow †. In such cases, we may observe, the ancient gravel bed of a river is deserted, and a new one formed at a lower level; so that, a want of relation in the position of alluvial beds to the existing water-courses may be no test of the high antiquity of such deposits to a geologist, in countries habitually convulsed by earthquakes. Extraordinary rains accompanied the shocks before mentioned, and two volcanos are said to have been in eruption in the mountain-chain nearest to Bogota.

Chili, 1822.—On the 19th of November, 1822, the coast of Chili was visited by a most destructive earthquake. The shock was felt simultaneously throughout a space of one thousand two hundred miles from north to south. St. Jago, Valparaiso, and some other places, were greatly injured. When the district

* Férussac, Bulletin des Sci. Nat., November, 1829, p. 203.

† Phil. Mag., July, 1828, p. 37.

round Valparaiso was examined on the morning after the shock, it was found that the whole line of coast for the distance of above one hundred miles was raised above its former level*. At Valparaiso the elevation was three feet, and at Quintero about four feet. Part of the bed of the sea remained bare and dry at high water, "with beds of oysters, muscles, and other shells adhering to the rocks on which they grew, the fish being all dead, and exhaling most offensive effluvia†." An old wreck of a ship, which before could not be approached, became accessible from the land; although its distance from the original sea-shore had not altered. It was observed, that the water-course of a mill, at the distance of about a mile from the sea, gained a fall of fourteen inches, in little more than one hundred yards; and from this fact it is inferred, that the rise in some parts of the inland country was far more considerable than on the coast‡. Part of the coast thus elevated consisted of granite, in which parallel fissures were caused, some of which were traced for a mile and a half inland. Cones of earth, about four feet high, were thrown up in several districts, by the forcing up of water mixed with sand, through funnel-shaped hollows—a phenomenon very common in Calabria, and the explanation of which will hereafter be considered. Those houses in Chili, of which the foundations were on rock, were less damaged than such as were built on alluvial soil. The area over which this permanent alteration of level extended, was estimated at one hundred thousand square miles. The whole country, from the foot of the Andes to a great distance under the sea, is supposed to have been raised, the greatest rise being at the distance of about two miles from the shore. "The rise upon the coast was from two to four feet:—at the distance of a mile inland it must have been from five to six, or seven feet§." The soundings in the harbour of Valparaiso have been materially changed by this shock, and the bottom has become shallower. The shocks continued up to the end of September, 1823: even then, forty-eight hours seldom passed without one, and sometimes two or three were felt during twenty-four hours. Mrs.

* See Geol. Trans., vol. i., second series; and also Journ. of Sci., 1824, vol. xvii., p. 40.

† Geol. Trans., vol. i., second series, p. 415.

‡ Journ. of Sci., vol. xvii., p. 42.

§ Ibid., pp. 40, 45.

Graham observed, after the earthquake of 1822, that, besides the beach newly raised above high-water mark, there were several older elevated lines of beach one above the other, consisting of shingle mixed with shells, extending in a parallel direction to the shore, to the height of fifty feet above the sea*.

Aleppo, 1822.—In 1822 Aleppo was destroyed by an earthquake, and alterations are said to have been caused in the level of the land; but of these we have no exact details. At the same time two rocks were reported by the captain of a French vessel to have risen from the sea, in the neighbourhood of Cyprus, an island well known to be subject to subterranean movements, and almost under the same latitude as Aleppo†. In these and similar instances, where there is no evidence of a submarine eruption, it is not the magnitude of the masses lifted above the sea which are of importance, but the indication apparently afforded by them, that a submarine tract, of which they merely form the highest points, has undergone some change of level.

Ionian Isles, 1820.—In the year 1820, from the 15th of February to the 6th of March, Santa Maura, one of the Ionian isles, experienced a succession of destructive earthquakes. Immediately afterwards a rocky island was observed not far from the coast, which had never been known before‡. No indications of a submarine eruption were observed on this spot: it is, therefore, most probable that this rock was elevated by the earthquake; but an examination of its structure is much to be desired.

Island of Sumbawa, 1815.—In April, 1815, one of the most frightful eruptions recorded in history occurred in the mountain Tomboro, in the island of Sumbawa. It began on the 5th of April, and was most violent on the 11th and 12th, and did not entirely cease till July. The sound of the explosions was heard in Sumatra, at the distance of nine hundred

* Geol. Trans., vol. i., second series, p. 415.

† Journ. of Sci., vol. xiv., p. 450.

‡ Allgemeine Zeitung, 1820, No. 146. Verneul, Journal des Voyages, vol. vi., p. 383; cited by Von Hoff, vol. ii., p. 180.

and seventy geographical miles in a direct line; and at Ternate in an opposite direction, at the distance of seven hundred and twenty miles. Out of a population of twelve thousand, only twenty-six individuals survived on the island. Violent whirlwinds carried up men, horses, cattle, and whatever else came within their influence, into the air, tore up the largest trees by the roots, and covered the whole sea with floating timber*. Great tracts of land were covered by lava, several streams of which, issuing from the crater of the Tomboro mountain, reached the sea. So heavy was the fall of ashes, that they broke into the Resident's house at Bima, forty miles east of the volcano, and rendered it, as well as many other dwellings in the town, uninhabitable. On the side of Java, the ashes were carried to the distance of three hundred miles, and two hundred and seventeen towards Celebes, in sufficient quantity to darken the air. The floating cinders to the westward of Sumatra formed on the 12th of April a mass two feet thick, and several miles in extent, through which ships with difficulty forced their way. The darkness occasioned in the daytime by the ashes in Java was so profound, that nothing equal to it was ever witnessed in the darkest night. Although this volcanic dust when it fell was an impalpable powder, it was of considerable weight, when compressed, a pint of it weighing twelve ounces and three quarters. Along the sea-coast of Sumbawa, and the adjacent isles, the sea rose suddenly to the height of from two to twelve feet, a great wave rushing up the estuaries, and then suddenly subsiding. Although the wind at Bima was still during the whole time, the sea rolled in upon the shore, and filled the lower parts of the houses with water a foot deep. Every prow and boat was forced from the anchorage, and driven on shore.

On the 19th of April, says one of Raffles's correspondents, "we grounded on the bank of Bima town. The anchorage at Bima must have altered considerably, as where we grounded the Ternate cruiser lay at anchor in six fathoms a few months before." Unfortunately no facts are stated by which we may judge with certainty whether this shoal, implying a change of depth of more than thirty feet, was caused by an accumulation of ashes, or by an upheaving of the bottom of the sea. It is

* Raffles's Java, vol. i., p. 28.

stated, however, that the surrounding country was covered with ashes. On the other hand, the town called Tomboro, on the west side of the volcano, was overflowed by the sea, which encroached upon the shore at the foot of the volcano, so that the water remained permanently eighteen feet deep in places where there was land before. Here we may observe, that the amount of subsidence of land was very apparent *in spite of the ashes*, which would naturally have caused the limits of the coast to be extended.

The area over which tremulous noises and other volcanic effects extended, was one thousand English miles in circumference, including the whole of the Molucca islands, Java, a considerable portion of Celebes, Sumatra, and Borneo. In the island of Amboyna, in the same month and year, the ground opened, threw out water, and then closed again*. We may conclude, by reminding the reader, that but for the accidental presence of Sir Stamford Raffles, then governor of Java, we should scarcely have heard in Europe of this tremendous catastrophe. He required all the residents in the various districts under his authority to send in a statement of the circumstances which occurred within their own knowledge; but, valuable as were their communications, they are often calculated to excite rather than to satisfy the curiosity of the geologist. They mention that similar effects, though in a less degree, had about seven years before accompanied an eruption of Carang Assam, a volcano in the island of Bali, west of Sumbawa; but no particulars of this catastrophe are recorded †.

Cutch, 1819.—A violent earthquake occurred at Cutch, in Bombay, on the 16th of June, 1819. The principal town, Bhooi, was converted into a heap of ruins, and its stone buildings thrown down. The shock extended to Ahmedhabad, where it was very destructive; and at Poonah, four hundred miles farther, it was feebly felt. At the former city, the great mosque erected by Sultan Ahmed nearly four hundred and fifty years before, fell to the ground, attesting how long a period had elapsed since a shock of similar violence had visited that point. At Anjar, the fort, with its towers and guns, was hurled to the ground in

* Raffles's Hist. of Java, vol. i., p. 25.—Ed. Phil. Journ., vol. iii., p. 389.

† Life and Services of Sir Stamford Raffles, p. 241. London, 1830.

one common mass of ruin. The shocks continued some days until the 20th, when, thirty miles from Bhooi, a volcano burst out in eruption, and the convulsions ceased. Although the ruin of towns was great, the face of Nature in the inland country, says Captain Macmurdo, was not visibly altered. In the hills some large masses only of rock and soil were detached from the precipices; but the eastern and almost deserted channel of the Indus, which bounds the province of Cutch, was greatly changed. This estuary or inlet of the sea was, before the earthquake, fordable at Luckput, being only about a foot deep when the tide was at ebb, and at flood tide never more than six feet; but it was deepened at the fort of Luckput, after the shock, to more than *eighteen feet at low water**. On sounding other parts of the channel, it was found, that where previously the depth of the water at flood never exceeded one or two feet, it had become from four to ten feet deep; and this increase of depth extended from Cutch to the Sindh shore, a distance of three or four miles. The channel of the Runn, which extends from Luckput round the north of the province of Cutch, was sunk so much, that, instead of being dry as before during that period of the year, it was no longer fordable, except at one spot only. By these remarkable changes of level, a part of the inland navigation of that country, which had been closed for centuries, became again practicable.

The fort and village of Sindree, situated where the Runn joins the Indus, was overflowed; and, after the shock, the tops of the houses and wall were alone to be seen above the water, for the houses, although submerged, were not cast down. Had they been situated in the interior, where so many forts were levelled on the ground, their site would perhaps have been regarded as having remained comparatively unmoved. From this circumstance we may feel assured that great permanent upheavings and depressions of soil may be the result of earthquakes, without the inhabitants being in the least degree conscious of any change of level.

Cones of sand, six or eight feet in height, were thrown out of the lands near the Runn. Somewhat farther to the east of the line of this earthquake lies Oojain (called Ozene in the *Peryplus Maris Erythr*). Ruins of an old town are there

* Ed. Phil. Journ., vol. iv., p. 106.

found, a mile north of the present, sunk in the earth to the depth of from fifteen to sixteen feet, which sinking is known to have been the consequence of a tremendous catastrophe in the time of the Rajah Viermaditya.

Caraccas, 1812.—On the 26th of March, 1812, several violent shocks of an earthquake were felt in Caraccas. The surface undulated like a boiling liquid, and terrific sounds were heard underground. The whole city with its splendid churches was in an instant a heap of ruins, under which ten thousand of the inhabitants were buried. On the 5th of April, enormous rocks were detached from the mountains. It was believed that the mountain Silla lost from three hundred to three hundred and sixty feet of its height by subsidence; but this was an opinion not founded on any measurement. On the 27th of April, a volcano in St. Vincent's threw out ashes; and on the 30th, lava flowed from its crater into the sea, while its explosions were heard at a distance equal to that between Vesuvius and Switzerland, the sound being transmitted, as Humboldt supposes, through the ground. During the earthquake which destroyed Caraccas, an immense quantity of water was thrown out at Valecillo near Valencia, as also at Porto Cabello, through openings in the earth; and in the Lake Maracaybo the water sank*.

Although the great change of level in the mountain Silla was not distinctly proved, the opinion of the inhabitants deserves attention, because we shall afterwards have to mention some well-authenticated alterations in the same district during preceding earthquakes. Humboldt observed that the Cordilleras, composed of gneiss and mica slate, and the country immediately at their foot, were more violently shaken than the plains.

South Carolina, 1811.—Previous to the destruction of Laguiria and Caraccas in 1811, South Carolina was convulsed by earthquakes, and the shocks continued till those cities were destroyed. The valley also of the Mississippi, from the village of New Madrid to the mouth of the Ohio in one direction, and to the St. Francis in another, was convulsed to such

* Humboldt's *Pers. Nar.*, vol. iv., p. 12; and *Ed. Phil. Journ.*, vol. i., p. 272. 1819.

a degree as to create lakes and islands. Flint, the geographer, who visited the country seven years after the event, informs us, that a tract of many miles in extent, near the Little Prairie, became covered with water three or four feet deep; and when the water disappeared, a stratum of sand was left in its place. Large lakes of twenty miles in extent were formed in the course of an hour, and others were drained. The grave-yard at New Madrid was precipitated into the bed of the Mississippi. The inhabitants related that the earth rose in great undulations; and when these reached a certain fearful height, the soil burst, and vast volumes of water, sand, and pit-coal, were discharged as high as the tops of the trees. Flint saw hundreds of these deep chasms remaining in a tender alluvial soil seven years after. The people in the country, although inexperienced in such convulsions, had remarked that the chasms in the earth were in a direction from S.W. to N.E.; and they accordingly felled the tallest trees, and, laying them at right angles to the chasms, stationed themselves upon them. By this invention, when chasms opened more than once under these trees, several persons were prevented from being swallowed up*. At one period during this earthquake, the ground not far below New Madrid swelled up so as to arrest the Mississippi in its course, and to cause a temporary reflux of its waves. The motion of some of the shocks was horizontal, and of others perpendicular; and the vertical movement is said to have been much less desolating than the horizontal. If this be often the case, those shocks which injure cities least may often produce the greatest alteration of level.

Aleutian Islands, 1806.—In the year 1806 a new island, in the form of a peak, with some low conical hills upon it, rose from the sea among the Aleutian Islands, north of Kamtschatka. According to Langsdorf †, it was four geographical miles in circumference; and Von Buch infers from its magnitude, and from its not having again subsided below the level of the sea, that it did not consist merely of ejected matter, like Monte Nuovo, but of solid rock upheaved*. Another extraordinary eruption happened in the spring of the year 1814, in

* Silliman's Journ., Jan., 1829.

† Bemerkungen, auf einer Reise um die Welt, bd. ii., s. 209.

the sea near Unalaska, in the same archipelago. A new isle was then produced of considerable size, and with a peak three thousand feet high, which remained standing for a year afterwards, though with somewhat diminished height.

Although it is not improbable that the earthquakes accompanying the tremendous eruptions above mentioned may have heaved up part of the bed of the sea, yet we must wait for fuller information before we assume this as a fact. The circumstance of these islands not having disappeared like Sabrina, may have arisen from the emission of lava. If Jorullo, for example, in 1759, had risen from a shallow sea to the height of one thousand seven hundred feet, instead of attaining that elevation above the Mexican plateau, the massive current of basaltic lava which poured out from its crater would have enabled it to withstand, for a long period, the action of a turbulent sea.

We are now about to pass on to the events of the eighteenth century ; but, before we leave the consideration of those already enumerated, let us pause for a moment, and reflect how many remarkable facts of geological interest are afforded by the earthquakes above described, though they constitute but a small part of the convulsions even of the last thirty years. New rocks have risen from the waters ; the coast of Chili for one hundred miles has been permanently elevated ; part of the delta of the Indus has sunk down, and some of its shallow channels have become navigable ; the town of Tomboro has been submerged, and twelve thousand of the inhabitants of Sumbawa have been destroyed. Yet, with a knowledge of these terrific catastrophes, witnessed during so brief a period by the present generation, will the geologist declare with perfect composure that the earth has at length settled into a state of repose ? Will he continue to assert that the changes of relative level of land and sea, so common in former ages of the world, have now ceased ? If, in the face of so many striking facts, he persists in maintaining this favorite dogma, it is in vain to hope that, by accumulating the proofs of similar convulsions during a series of antecedent ages, we shall shake his tenacity of purpose,

Si fractus illabatur orbis
Impavidum ferient ruinæ.

* Neue Allgem. Geogr. Ephemer. bd. iii., s. 348.

Quito, 1797.—On the morning of February 4th, 1797, the volcano of Tunguragua in Quito, and the surrounding district, for forty leagues, from south to north, and twenty leagues from west to east, experienced an undulating movement, which lasted four minutes. The same shock was felt over a tract of one hundred and seventy leagues from south to north, from Piura to Popayan; and one hundred and forty from west to east, from the sea to the river Napo. In the smaller district, first mentioned, every town was levelled to the ground; and Riobamba, Quero, and other places, were buried under masses detached from the mountains. At the foot of Tunguragua the earth was rent open in several places; and streams of water and fetid mud, called “moya,” poured out, overflowing and wasting everything. In valleys one thousand feet broad, the water of these floods reached to the height of six hundred feet; and the mud deposit barred up the course of the river, so as to form lakes, which in some places continued for more than eighty days. Flames and suffocating vapours escaped from the lake Quilotoa, and killed all the cattle on its shores. The shocks continued all February and March, and on the 5th of April they recurred with almost as much violence as at first. We are told that the form of the surface in the district most shaken was entirely altered, but no exact measurements are given whereby we may estimate the degree of elevation or subsidence*. Indeed it would be difficult, except in the immediate neighbourhood of the sea, to obtain any certain standard of comparison, if the levels were really as much altered as the narrations seem to imply.

Cumana, 1797.—In the same year, on the 14th of December, the small Antilles experienced subterranean movements, and four-fifths of the town of Cumana was shaken down by a vertical shock. The form of the shoal of Mornerouge, at the mouth of the river Bourdones, was changed by an upheaving of the ground†.

* Cavanilles, Journ. de Phys. tome xlix., p. 230. Gilberts, Annalen, bd. vi., p. 67. Humboldt's Voy., p. 317.

† Humboldt's Voy., Relat. Hist., part i., p. 309.

Caraccas, 1790.—In the Caraccas, near where the Caura joins the Orinoco, between the towns San Pedro de Alcantara and San Francisco de Aripao, an earthquake on St. Matthew's Day, 1790, caused a sinking in of the granitic soil, and left a lake eight hundred yards in diameter, and from eighty to one hundred in depth. It was a portion of the forest of Aripao which subsided, and the trees remained green for several months under water*.

Sicily, 1790.—On the 18th of March in the same year, at S. Maria di Niscemi, some miles from Terranuova, near the south coast of Sicily, the ground gradually sunk down for a circumference of three Italian miles, during seven shocks; and, in one place, to the depth of thirty feet. It continued to subside to the end of the month. Several fissures sent forth sulphur, petroleum, steam, and hot water; and a stream of mud which flowed for two hours, and covered a space sixty feet long, and thirty broad. This happened far from both the ancient and modern volcanic district, in a group of strata, consisting chiefly of blue clay†.

Java, 1786.—About the year 1786 an earthquake was felt at intervals, for the period of four months, in the neighbourhood of Batur, in Java, and an eruption followed. Various rents were formed which emitted a sulphureous vapour; separate tracts sunk away, and were swallowed by the earth. Into one of these the rivulet Dotog entered, and afterwards continued to follow a subterraneous course. The village of Jampang was buried in the ground, with thirty-eight of its inhabitants, who had not time to escape. We are indebted to Dr. Horsfield for having verified the above mentioned facts‡.

* Humboldt's *Voy., Relat. Hist.*, part ii., p. 632. † Ferrara, *Campi. fl.*, p. 51.
‡ *Batav. Trans.*, vol. viii., p. 141.