An introduction to geology, illustrative of the general structure of the earth

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Chapter X.

CHAPTER X.

ON EARTHQUAKES AND VOLCANOES.

Phænomena preceding and attending Earthquakes, their effects on Water,—on Land—their connection with distant Volcanoes; more severely felt in mountainous Countries. Indications of their Cause.—Volcanoes.—Phænomena preceding an Eruption.—Duration and intervals of Volcanic Eruptions.—Submarine Volcanoes.—Number of active and dormant Volcanoes.—Source of Volcanic Fire deep below the surface.—Opinions respecting it.—Hot Springs.—Volcanic products—Solid, Fluid, and Volatile.—Compact and porous Lava.—Pumice, Obsidian, Volcanic Tufa, Puzzolano.—Inflammable Substances emitted from Volcanoes.

ACCUSTOMED to view the hills in our own country in a state of profound repose, presenting the same unvaried outline in each succeeding year, we can scarcely conceive the possibility of a whole district being covered with new mountains and another soil in the space of a single night. Yet such changes have been produced by the united agency of earthquakes

quakes and volcanoes within the limits of authentic history. I must refer the reader to the works of Dolomieu, Spallanzani, Sir William Hamilton, Humboldt, and other travellers who have attentively examined volcanic countries, for a description of these changes. The present chapter will be confined to the effects more particularly indicative of the connection between earthquakes and volcanoes, and the circumstances which may elucidate the cause of these awful phænomena.

Earthquakes and volcanoes may be considered as different effects produced by the agency of subterranean fire. They frequently accompany each other; and in all instances that have been observed, the first eruption of a volcano is preceded by an earthquake of greater or less extent. Volcanoes do not make their appearance in every country where the shock of an earthquake is felt: but earthquakes are more frequent in volcanic districts than in any other. Earthquakes are almost always preceded by an uncommon agitation of the waters of the ocean, and of lakes. Springs send forth torrents of mud, accompanied with a disagreeable

able stench. The air is generally calm, but the cattle discover much alarm, and seem to be instinctively aware of approaching calamity. A deep rumbling noise, like that of carriages over a rough pavement,—a rushing sound like wind,—or a tremendous explosion like the discharge of artillery, immediately precede the shock, which suddenly heaves the ground upwards, or tosses it from side to side, with violent and successive vibrations. The shock seldom lasts longer than a minute; but it is frequently succeeded by others of greater or less violence, which continue to agitate the surface of the earth for a considerable time. During these shocks, large chasms and openings are made in the ground, through which smoke and flames are seen to issue: these sometimes break out where no chasms can be perceived. More frequently stones, or torrents of water, are ejected from these openings. In violent earthquakes the chasms are so extensive that large cities have in a moment sunk down and for ever disappeared, leaving a lake of water in the place. Such was the fate of Euphemia in Calabria, in 1638, as

described

described by Kircher, who was approaching the place when the agitation of the ocean obliged him to land at Lopizicum: "Here (says he) scenes of ruin every where appeared around me; but my attention was quickly turned from more remote to contiguous danger, by a deep rumbling sound which every moment grew louder. The place where we stood shook most dreadfully; after some time, the violent paroxysm ceasing, I stood up, and turning my eyes to look for Euphemia, saw only a frightful black cloud. We waited till it had passed away, when nothing but a dismal and putrid lake was to be seen where the city once stood."

The extent to which earthquakes produce sensible effects on the waters of springs and lakes in distant parts of the world, is truly remarkable. During the earthquake of Lisbon in 1755, almost all the springs and lakes in Britain and every part of Europe were violently agitated, many of them throwing up mud and sand, and emitting a fœtid odour. This circumstance indicates that a great quantity of gas or elastic vapour was suddenly generated

nerated and endeavouring to escape. From the fœtid odour perceived in some situations, it may be inferred that this gas was hydrogen or sulphuretted hydrogen. In other instances it may be steam, which condensing again would produce a vacuum, and occasion the external air to press downwards; which has been observed in mines immediately after the shock of an earthquake.

The space over which the vibration of the dry ground is felt is very great, but generally wider in one direction than another; and where a succession of earthquakes has taken place in the same district, it is observed that the noise and shock approach from the same quarter. The connection which earthquakes have with distant volcanoes, and their frequency at particular periods, are further remarkable. About the middle of the last century, when the earthquake at Lisbon took place, Europe, Africa, and America were repeatedly agitated by subterranean explosions; which may be seen by referring to the journals of that time. Ætna, which had been in a state of profound repose for eighty years, broke out with

with great activity, and, according to Humboldt, some of the most tremendous earthquakes and volcanic eruptions ever recorded in history were witnessed in Mexico. In the night of the 19th of September 1759 a vast volcano broke out in a lofty cultivated plain, a tract of ground more than twelve miles in extent rose up like a bladder to the height of 524 feet, and six new mountains were formed higher than the Malvern hills in Worcestershire. It may be inferred from these circumstances that the cause of earthquakes and volcanic eruptions is seated deep below the surface of the earth. During the earthquake at Lisbon nearly all Europe and the northern parts of Africa felt the shock more or less severely : the moving force must have been inconceivably great, and acting from an immense depth. It is observed also that earthquakes are more severely felt in mountainous than in low countries. This might be expected from the structure of the earth*.

* See a paper on earthquakes by the Rev. Mr. Mitchell, Philosophical Transactions, 1759.

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In alpine districts, the primary mountains are not pressed with the incumbent mass of secondary rocks, and in such situations the resistance to a force acting from beneath will be much less, as all the weight of secondary rocks is removed. That an expansive force acting from beneath is the proximate cause of earthquakes can scarcely be denied; and the prodigious power of steam, when suddenly generated, seems equal to their production, if the quantity be sufficiently great. It is said that a single drop of water falling into a furnace of melted copper, will blow up the whole building. Now if we conceive a current of subterranean water to find access to a mass of lava many miles in extent, and most intensely heated, it would produce an earthquake which would be more extensively felt in proportion to the quantity of steam generated, and its distance from the surface. When the hydrogen gas lately exploded in a mine near Workington in Cumberland, a shock like that of an earthquake was felt by ships in the river at two miles distance.

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The horrid crash like the rattling of carriages, which precedes earthquakes, is occasioned I conceive by the rending of the rocks, or parting of the strata through which the confined vapour is forcing a passage.

VOLCANOES are openings made in the earth's surface by internal fires; they regularly, or at intervals, throw out smoke, vapour, flame, large stones, sand, and melted stone called lava. Some volcanoes throw out torrents of mud and boiling water. Volcanoes generally exist in the vicinity of the sea or large lakes, and also break out from unfathomable depths below the sea, and form new islands with the melted lava and stones which they eject. When a volcano breaks out in a new situation, it forms a vast rent or fissure through which lava and stones are thrown out that soon choke up the passage, and confine the eruption to one or more openings, round which a conical mountain is formed, the open part of which is called the crater. The indications of an approaching eruption are an increase of smoke from the summit, which sometimes rises to a vast height, branching in the form of a pine tree.

tree. Tremendous explosions, like the firing of artillery, commence after the increase of smoke, and are succeeded by red-coloured flames and showers of stones: at length the lava flows out from the top of the crater, or breaks through the sides of the mountain and covers the neighbouring plains with melted matter, which becoming consolidated, forms a stony mass often not less than some hundred square miles in extent, and several yards in thickness. The eruption has been known to continue several months. The quantity of volcanic powder called ashes thrown out, is inconceivably great. During one eruption of Ætna, a space of 150 miles in circuit was covered with a stratum of sand twelve feet thick. When the lava flows freely, the earthquakes and explosions become less violent; which proves that they were occasioned by the confinement of the erupted matter both gaseous and solid. The smoke and vapour of volcanoes are highly electrical.

The long period of repose which sometimes takes place between two eruptions of the same volcano is particularly remarkable. From the building of Rome to the 79th year of the

Christian æra, no mention is made of Vesuvius, though it had evidently been in a prior state of activity, as Herculaneum and Pompeii, which were destroyed by the eruption of that year, are paved with lava. From the 12th to the 16th century, it remained quiet for nearly 400 years, and the crater was overgrown with lofty trees. It was descended by Bracchini, an Italian writer, a little time prior to the great eruption of 1631: the bottom was at that time a vast plain surrounded by caverns and grottoes. Ætna has continued burning since the time of the poet Pindar, with occasional intervals of repose seldom exceeding 30 or 40 years.

Submarine volcanoes are preceded by a violent boiling and agitation of the water, and by the discharge of volumes of gas and vapour, which take fire and roll in sheets of flame over the surface of the waves. Masses of rock are darted through the water with great violence, and accumulate till they form new islands. Sometimes the crater of the volcano rises out of the sea during an eruption. In 1783, a submarine volcano broke out near Iceland, which formed a new island;

island; it raged with great fury for several months. The island afterwards sunk, leaving only a reef of rocks. In December 1720 a violent earthquake was felt at Tercera, one of the Azores; the next morning a new island nine miles in circumference was seen, from the centre of which rose a column of smoke: it afterwards sunk to a level with the sea. Another island has recently been formed near the Azores by a submarine volcano: it is a mass of rock. The captain of the Sabrina frigate, who landed on the island soon after its formation, describes the highest part to be equal to the rock called the high Tor at Matlock.

Near Santorini, in the Græcian archipelago, submarine volcanoes have repeatedly burst forth during the last 2000 years, and formed several new islands: three of the antient eruptions are recorded by Pliny, Strabo, and Seneca. The last eruption was in the year 1767.

The number of volcanoes has been estimated at near 200; but they may be supposed greatly to exceed this estimate, if we consider

consider those volcanoes as only dormant and not extinct, which still present indications of subterranean heat.

In the Azores there are no less than 42 active or dormant volcanoes; almost all the islands in the Atlantic, and many in the Pacific Ocean and the Indian Seas, are volcanic. A range of active and dormant volcanoes extends from the southern extremity of America to the arctic circle. Numerous volcanoes exist in Iceland; and the hot sulphurous exhalations from craters in various parts of Italy prove that their internal fires are not extinguished. Of the volcanoes in northern Asia, or the interior of Africa, we have little information, and the volcanoes covered by the sea cannot be estimated; but, from the above statement, we are authorized in believing that volcanic fires are more extensively operative on the surface of the globe than many geologists are disposed to admit. Their source is deep under the surface of the earth, and many circumstances indicate that a connection exists between volcanoes at a vast distance from each other. In 1783, when the submarine volcano near Iceland suddenly ceased, a volcano broke out 200 miles distant, in the interior of the island, and at the same time the great earthquakes took place in Calabria. On the night in which Lima and Callao were destroyed by an earthquake, four new volcanoes broke out in the Andes. Other instances of the apparent connection of earthquakes with distant volcanoes have been before stated.

Were the source of volcanic fires near the surface, the country in their vicinity would sink down*, and it is impossible to conceive how the same volcano could continue its eruptions incessantly for more than 2000 years, which is the case with Stromboli situated in the Lipari islands. Fragments of rocks, such as lime and gypsum, are thrown out of volca-

* Since the period of authentic history no great changes have taken place in the country round Ætna ; but it appears from Virgil that a tradition existed of a sudden separation of Sicily from Italy.

"Hæc loca, vi quondam et vastâ convulsa ruinâ
Dissiluisse ferunt : cùm protinus utraque tellus
Una foret, venit medio vi pontus, et undis
Hesperium Siculo latus abscidit : arvaque et urbes
Littore diductas angusto interluit æstu."—Æn. l. iii.

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noes unchanged by fire; which proves that the source of heat was deep below the range of these rocks: they have been merely driven up by the subterranean explosion, which forced a passage through them.

From the various phænomena which volcanoes present, we may with probability infer that the internal part of our planet is in an igneous state, however difficult it may be to explain in what manner this heat is generated and confined. In every department of nature, our inqui ies are terminated by ultimate facts, beyond which further research becomes vain. The constant generation and emission of light from the surface of the sun is more inexplicable and surprising than the constant generation of heat in the centre of the planets; but we cannot refuse our assent to the fact, though it is far beyond the power of the human mind to conceive by what means the particles of light are propelled through space with such astonishing velocity. We are too apt to measure natural operations by their coincidence with the received system of philosophy, and to make our own ignorance the standard of truth.

truth. Had all the volcanoes in the world been dormant for the last 2000 years, and were we only acquainted with their existence by the writings of ancient historians, we should discredit the fact, and prove its impossibility by an appeal to established chemical principles; we should further accompany the proof with a pathetic lamentation over the credulity of former times.

The descent of stones from the atmosphere was denied during a longer period, though the fact is now established beyond all doubt: this should teach us to be less confident in our own knowledge, for there are still remaining "more things in heaven and earth than are dreamed of in our philosophy."

Admitting the existence of central fire in the earth, it is not difficult to conceive that there may be determinate causes, by which its intensity is increased or diminished at certain periods. We know little respecting the operation of electric or Voltaic energy in the laboratory of nature; but from the existence of electric light at the poles we may infer that electric currents are passing through the earth, and are important agents in many subterranean phænomena. Perhaps the different beds of rock which environ the globe may act like a series of plates in the Voltaic pile, and produce effects commensurate with their vast magnitude. Voltaic energy is capable of supporting the most intense degree of heat, without access to atmospheric air, and even in vacuo; and this for an indefinite time.

Whatever origin we ascribe to subterranean fire, there can be no doubt that it will make its way through the surface in those places where the incumbent rocks offer the least resistance, or where they are most fusible. By the access of water to this fire, the sudden evolution of steam, hydrogen gas, and many phænomena of volcanic eruptions, will admit of an easy explanation. All active volcanoes being situated near the sea or great lakes, we may infer that water is in some way necessary to the production of volcanic phænomena. Boiling fountains and hot springs may be classed with volcanic phænomena; for, it can scarcely be doubted that the Geysers in Iceland,

Iceland, which throw up columns of boiling water at intervals, to the height of seventy or eighty feet, are occasioned by the subterranean fires which extend under that island; and the hot springs in Italy, and other parts of the world, probably derive their heat from the same cause. The unvaried equality of their temperature for centuries, seems to prove that the source of heat lies far below any of those causes which operate on the surface. It has also been remarked that they are most frequent in basaltic or volcanic countries*.

The volcanoes in South America throw out water and mud, and stones of enormous magnitude; but for particular information respecting them I must refer the reader to the interesting descriptions of Humboldt, to Ulloa's Travels, and Molina's History of Chili.

The substances emitted or ejected from volcanoes are either solid, fluid, or volatile. Among the first, we may mention masses of rock ejected at the commencement of an erup-

* Maclure's Geology of the United States, Journal de Physique.

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tion without being acted upon by fire; or masses which have been calcined, and the more fusible parts softened: these require no particular description. Among the melted substances may be enumerated lava, pumice, and volcanic glass. Lava is poured out of the crater or sides of a volcano, and descends in currents of red-hot liquid matter, of a pasty tenacious consistence like that of melted ore, or slag from a furnace. The quantity of lava ejected during a single eruption is sometimes inconceivably great. The current which flowed from Ætna in 1669 is two miles in breadth, fifteen miles in length, and two hundred feet in depth; it retains a portion of its heat to the present day; Ferrara says that in 1809, when this lava was perforated at Catania, flames broke out, and it continued to smoke at the surface after rain, at the beginning of the present century, or 130 years after its eruption.

Lavas have generally a base* of hornblende, or of felspar. Compact lavas with a base of

* The mineral substance which forms the principal part of any compound stone is said to compose its base.

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hornblende have a near resemblance to basalts: they contain a considerable portion of iron, and attract the magnet: they melt into black scoriæ with the blowpipe: they have a dark or black colour, and are hard, sonorous, and heavy.

Lavas are frequently porphyritic, and contain crystals of felspar and mica, and crystals called by mineralogists garnet, leucite, olivine, augite, and vesuvian. Many of the lavas from Ætna are porphyritic, and receive a good polish. A small tablet in my possession contains thirty-six polished specimens of the lavas of different eruptions from that volcano, all varying in colour and external appearance.

Lava with a ground of felspar is generally gray. Compact lava commonly occupies the central parts of volcanic currents, and porous and vesicular lava the superficial part. The cavities in vesicular lava vary in size from that of a pea to a small nut: they are round or elliptical, and often contain a white radiated mineral called zeolite. Some lavas resemble the slags or scoriæ from furnaces; and

and the upper parts of currents of lava are often vitrified.

The light-coloured or whitish porous lavas become fibrous, and pass into a light spongy stone called pumice. The island of Lipari contains a mountain entirely formed of white pumice: when seen at a distance, it excites the idea that it is covered with snow from the summit to the foot. Almost all the pumice-stone employed in commerce is brought from this immense mine. The mountain is not one compact mass, but is composed of balls or globes of pumice aggregated together, but without adhesion. From hence Spalanzani infers that the pumice was thrown out of a volcano in a state of fusion, and took a globose form in the air. Some of these balls of pumice do not exceed the size of a nut, others are a foot or more in diameter. Many of these pumices are so compact that no pores or filaments are visible to the eye; when viewed with a lens, they appear like an accumulation of small flakes of ice. Though apparently compact, they swim on water. Other pumices contain pores and cavities, and are composed of shin-

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ing white filaments. By a long continued heat pumice-stone melts into a vitreous semi-transparent mass in which a number of small crystals of white felspar are seen. In all probability pumice is formed from felspar by volcanic fires.

Immense quantities of pumice are sometimes thrown up by submarine volcanoes. It has been seen floating upon the sea over a space of 300 miles at a great distance from any known volcano; and from hence it may be inferred that submarine volcanoes sometimes break out at such vast depths under the ocean, that none of their products reach the surface except such as are lighter than water.

Obsidian or volcanic glass so nearly resembles lumps of black glass, that they can scarcely be distinguished by the unpractised observer. Its broken surface is smooth, conchoidal, and shining: the most common colour of obsidian is a velvet black. The thinner pieces are translucent. It is harder than glass, and strikes fire with steel. It is common in the neighbourhood of volcanoes, and in some basalts which are most probably the products

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of volcanic fires now exitnguished. In Lipari, one of the volcanic isles, the mountain de la Castagna, according to Spalanzani, is wholly composed of volcanic glass, which appears to have flowed in successive currents, like streams of water falling with a rapid descent and suddenly frozen. This glass is sometimes compact, and sometimes porous and spungy. Obsidian appears to be lava suddenly cooled: if a mass of lava or basalt be exposed to the heat of a glass furnace, it melts into a shining black or greenish black glass. Numerous veins of obsidian are said to intersect the cone of Mount Vesuvius, and serve as a cement to keep together the loose materials of which it is composed. Obsidian is sometimes ground and polished, and used for mirrors.

The mud ejected from the American volcanoes, becoming indurated, forms a solid mass of earth, and makes a new soil or surface frequently of vast extent and considerable depth. Volcanic sand and fine dust or powders are generally thrown out of volcanoes during great eruptions, and are spread over distant regions.

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In some instances, the quantity is so great as to form a covering of many feet in thickness, which becomes consolidated by rain and moisture, and is converted into a substance called tufa. In its most indurated state tufa is used for building-stone: the softer kinds which have a basis of clay form tarras and puzzolano, substances of great use for making a cement which hardens under the sea; it is previously mixed with two thirds of common lime. Puzzolano is not only found in countries that are the seat of active volcanoes; but in places where volcanoes have long been extinct, as in Auvergne and other parts of France. According to Mr. Kirwan, artificial tarras or puzzolano is made by burning slate or clay that abounds in iron, and grinding them to a fine powder.

The volatile products emitted from volcanoes are sulphur and mineral oil, which sometimes distils from the fissures of lava. Muriat of ammonia (sal ammoniac) forms an incrustation on lavas soon after they cool. Muriat of soda, of copper, and of iron, and also sulphat of iron, or green copperas and alum, with specular iron ore, are among the pro-

ducts

ducts which are found in the craters of volcanoes.

Sulphureous and sulphuric acids are formed by the combustion of sulphur during eruptions: these act upon lavas and rocks, and produce different combinations of which the most important are alum, sulphat of magnesia, gypsum, and green copperas.

Hydrogen and sulphuretted hydrogen are emitted from volcanoes in vast quantities. Whether phosphorus be a product of volcanoes is unknown: its extreme inflammability prevents it from being discovered in a concrete form; but the dense white clouds resembling bales of cotton which sometimes cover Vesuvius resemble the fumes produced by the combustion of phosphorus. Among the products of volcanoes we find only three substances which are combustible in the atmosphere, sulphur, hydrogen, and a small portion of carbon; but it has been conjectured by Sir H. Davy that the earths and alkalies which form lavas exist in the centre of the globe in a metallic state, and take fire by the access of water. This property of the newly discovered

discovered metals, to inflame instantly on the access of water, by which they are converted into earths or alkalies, offers an easy explanation of the origin of volcanic fires, could we suppose that substances so extremely inflammable and oxydable have remained for ages in a metallic state. There may, however, be processes in the vast laboratory of the globe that constantly separate the earths from oxygen, and prepare them for the support of volcanic fires, by which they are thrown upon the surface, and a connection is established between the internal and external parts of the planet.

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Pl. 5.

Basaltic Columns on the N. Side of Cader Idris Sep.^{r} 17.th 1812.