'wind moving through a fubterraneous paffage. 'Near this place, we find two fources of hot 'water. . . The ground, in which fire has long 'exifted, is neither depreffed nor elevated. . . 'Near this fire we fee no volcanic ftones, nor 'any mark which indicates that fire has ever 'been thrown out. However, fome little hills 'in the neighbourhood have every appearance 'of having been formed, or at leaft changed 'by volcano's. . . . In 1767, fuccuffions of an 'earthquake were felt in the environs; but 'no change was produced on the fire, neither 'was the fmoke increafed or diminifhed. . .

'About ten leagues from Modena, at a 'place called *Barigazzo*, there are five or fix 'openings where, at particular times, flames 'appear, which are extinguifhed by a ftrong 'wind: There are likewife vapours which in-'flame by contact with fire. . . . But, notwith-'ftanding the unequivocal veftiges of extin-'guifhed volcano's which fubfift in moft of thefe 'mountains, the fires feen there are not new 'volcano's forming, becaufe they never throw 'out any volcanic matter *.'

Hot waters, as well as the fountains of Petroleum, and other bituminous and oily fubftances, fhould be regarded as another fhade between extinguifhed and active volcano's.

* Mem. fur le Pétrole, par M. Fougeroux de Banderoy, dans ceux de l'Acad. des Sciences, année 1770, p. 45.

When

When fubterraneous fires exift near ftrata of coal, they diffolve the coal, and give rife to moft fources of bitumen: They likewife occafion the heat of the hot fprings which run in their neighbourhood. But thefe fubterraneous fires now burn with tranquillity; and we only recognife their ancient explofions by the fubftances they have formerly rejected. They ceafed to act when the fea retired from them; and, as already remarked, I believe there is no longer any reafon to dread the return of thefe direful explofions, fince every obfervation concurs in fhowing that the fea will always retire farther and farther.

IV.

Of Lavas and Bafalts.

TO what we have faid on the fubject of volcano's, we fhall add fome remarks on the motion of lavas, and on the time neceffary for their cooling and their converfion into vegetable foil.

The lava which runs from the foot of the eminences formed by the matters rejected by the volcano, is an impure glafs in fufion. It is a tenacious, vifcous, and half-fluid fubftance.

Hence

Hence the torrents of the vitrified matter, when compared to torrents of water, run ſlowly; and yet they often proceed to great diſtances. In theſe torrents of fire, however, there is another movement than what takes place in thoſe of water: This movement tends to elevate the whole running maſs, and is produced by the expanſive force of the heat in the interior parts of the burning torrent. The external ſurface cools firſt; the liquid fire continues to run below; and, as heat acts equally on all ſides, the fire, which endeavours to eſcape, elevates the ſuperior parts that are already conſolidated, and often forces them to riſe perpendicularly. This is the origin of thoſe large maſſes of lava in the form of rocks, which are found in the courſe of almoſt every torrent where the declivity is not great. By the efforts of this internal heat, the lava makes frequent exploſions; its ſurface opens, and the liquid matter ſprings up and forms thoſe maſſes which we ſee elevated above the level of the torrent. Le P. de la Torré, I believe, is the firſt perſon who obſerved this internal movement of burning lavas, which is always more violent in proportion to their thickneſs and the gentleneſs of the declivity. This effect is common to all matters liquified by fire, and every man may ſee examples of it in our common founderies*. If

* The lava of iron founderies exhibits the ſame effects. When this vitreous matter runs ſlowly, and accumulates at the baſe, we

If we obſerve thoſe large ingots or maſſes of melted iron, which run in a mould or canal with a very ſmall declivity, we ſhall perceive that they have a tendency to riſe like arches, eſpecially when the ſtream is very thick*. We have formerly ſhewn, by experiments, that the time of conſolidation is always proportioned to the thickneſs of the ingots, and that, when their ſurfaces are hardened, the interior parts ſtill continue to be liquid. It is this internal heat which elevates the ingots and makes them bliſter. If their thickneſs were greater, there would be produced, as in the torrents of lava, exploſions, rup-

we ſee eminences ariſe, which are bubbles or concave hemiſpheres of glaſs. Theſe bubbles increaſe, when the expanſive force is great, and the matter has little fluidity: It then ſuddenly explodes into a flame, and makes a conſiderable report. When the liquified matter is ſufficiently adheſive to ſuffer a great dilatation, theſe ſuperficial bubbles acquire a volume of eight or ten inches in diameter, without breaking. When the vitrification is leſs complete, and the matter is viſcous and tenaceous, the bubbles are ſmaller, and in cooling form concave eminences called *toads' eyes*. What happens in miniature in our founderies, is likewiſe exhibited upon a larger ſcale in the lavas of volcano's.

* I have not mentioned ſome particular cauſes which frequently produce a curvature or ſwelling in our melted ingots: For example, when the matter is not very fluid, or when the mould is too moiſt, the ingots bend conſiderably; becauſe theſe cauſes concur in augmenting the effect of the firſt. Thus the humidity of the ground, on which the torrents of lava deſcend, and the internal heat concur in raiſing the maſs, and in producing exploſions, which are always accompanied with thoſe jets of matter formerly mentioned.

O 2 tures

tures in the furface, and perpendicular jets of metallic matter pufhed out by the action of the fire inclofed in the interior parts of the ingots. This explication, drawn from the nature of the thing itfelf, leaves no doubt concerning the origin of thofe eminences fo frequent in valleys and plains, which have been over-run or covered with lava.

When, after defcending from the mountain and traverfing the fields, the burning lava arrives at the margin of the fea, its courfe is fuddenly interrupted, the torrent advances, and, like a powerful enemy, makes the water at firft retire: But the water by its immenfity, by the refiftance of its cold, and by its power of arrefting and extinguifhing fire, foon confolidates the torrent of burning matter, which can now proceed no farther, but rifes up, accumulates new ftrata, and forms a perpendicular wall, from the top of which the lava falls and applies itfelf to the face of the wall thus formed. It is this falling and arrefting of the burning matter that gives rife to bafaltic prifms * and their jointed columns. Thefe prifms have generally five, fix, or feven fides, fometimes only three or four,

* I fhall not here inquire into the origin of the term *bafalt*, which M. Defmarets of the Academy of Sciences, a learned naturalift, believes to have been applied by the ancients to different kinds of ftones; but fhall limit myfelf to the *bafaltic lava*, which appears under the form of prifmatic columns.

and fometimes eight or nine. The bafaltic columns are formed by the perpendicular fall of the lava into the fea, whether it falls from high rocks on the fhore, or from a wall raifed by its own accumulations. In both cafes, the cold and humidity of the water arreft the burning matter, and confolidate its furfaces the moment it falls; and the fucceffive bundles or maffes of lava apply themfelves to each other. As the internal heat of thefe maffes tends to dilate them, a reciprocal refiftance is created; and the fame effect is produced as happens in the fwelling of peafe, or rather of cylindrical grain, when fqueezed in a clofe veffel filled with boiling water. Each of thefe grains would affume a hexagonal figure by reciprocal compreffion. In the fame manner, each bundle or mafs of lava affumes feveral fides by dilatation and reciprocal refiftance; and, when the refiftance of the furrounding bundles is ftronger than the dilatation of the bundle furrounded, inftead of becoming hexagonal, it has only three, four, or five fides. But, if the dilatation of the furrounded bundle is ftronger than the refiftance of the furrounding bundles, it affumes feven, eight, or nine fides, which are always longitudinal.

The tranfverfe articulations of thefe prifmatic columns are produced by a caufe ftill more fimple: The bundles of lava fall not in a regular and continued ftream, nor in equal maffes.

Hence, if there are intervals in the fall of the matter, the fuperior furface of the forming column being partly confolidated, is hollowed by the weight of the fucceeding mafs, which then moulds itfelf into a convex form in the concavity or depreffion of the firft. This is the productive caufe of thofe joints or articulations which appear in the greater part of prifmatic columns. But, when the lava falls in an uninterrupted ftream, then the bafaltic column is one continued mafs, without any articulations. In the fame manner, when, by an explofion, fome detached maffes are darted from the torrent of lava, thefe maffes affume a globular or elliptical figure, and are even fometimes twifted like cables. To this fimple explication, all the forms of bafalts and figured lavas may be eafily referred.

It is to the rencounter of lava with the waves, and its fudden confolidation, that the origin of thefe bold coafts, which border all the feas at the foot of volcanic mountains, is to be afcribed. The ancient ramparts of bafalt found in the interior parts of continents, fhow that the fea has been in the neighbourhood of thefe volcano's when they had thrown out lava. This is an additional proof of the ancient abode of the waters upon all the lands now inhabited.

The torrents of lava are from a hundred to two and three thoufand fathoms broad, and fometimes one hundred and fifty, and even two hundred

hundred feet thick: And, as we have found by experience, that the time of the cooling of glafs is to that of the cooling of iron as 132 to 236, and that the times of their refpective confolidation are nearly in the fame proportion, it is eafy to infer, that, to confolidate the thicknefs of ten feet of glafs or lava, 201 $\frac{21}{59}$ minutes would be neceffary, fince it requires 360 minutes to confolidate ten feet thick of iron, confequently it will require 4028 minutes, or 67 hours eight minutes, to confolidate 200 feet thick of lava: By the fame rule we fhall find, that 30 days $\frac{17}{24}$, or a month, will be requifite before the furface of this lava of two hundred feet thick be fufficiently cold to admit of being touched. Hence a year will be neceffary to cool a lava of two hundred feet thick, fo as to admit of being touched, without burning, at the depth of one foot; and, at ten feet deep, it will be ftill fo warm, at the end of ten years, as not to be tangible; and a hundred will be requifite to cool it to the fame degree in the middle of its thicknefs. Mr. Brydone relates, that, more than four years after the lava had flowed, in the year 1766, at the foot of Ætna, it was not perfectly cool. Maffa, a Sicilian author worthy of credit, tells us, 'that, being at Catania, eight years after 'the great eruption in 1669, he found, that the 'lava in feveral places was not entirely cool*.'

* Voyage au Sicile, tom. i. p. 213.

About the end of April 1771, Sir William Hamilton dropt pieces of dry wood into a crevice in the lava at Vefuvius, and they were inftantly inflamed: The lava iffued from the mountain on the 19th of October 1767, and had no communication with the fire of the volcano. The place where this experiment was made, was at leaft four miles diftant from the mouth from which the lava iffued. He is firmly perfuaded, that many years are neceffary to cool a lava of this thicknefs (about 200 feet).

I have had no opportunity of making experiments upon confolidation and cooling, but with balls of fome inches in diameter. The only method of making experiments on a larger fcale would be, to obferve lavas, and to compare the times exhaufted in their confolidation and cooling, according to their different thickneffes. I am fatisfied that thefe obfervations would confirm the law I have eftablifhed for the cooling of bodies from the ftate of fufion to the common temperature; and although thefe new obfervations are by no means neceffary to fupport my theory, ftill they would help to fill up that immenfe gap between a cannon-ball and a planet.

It now remains for us to examine the nature of lava, and to fhow, that, in time, it is converted into fertile earth; which recalls the idea of the firft converfion of the fcoriæ of the primitive glafs that covered the whole furface of the globe after its confolidation.

'Under the denomination of lava, we comprehend not,' fays M. de la Condamine, 'all the matter thrown out by a volcano, fuch as afhes, pumice-ftones, gravel, and fand; but folely thofe reduced to a liquid ftate by the action of fire, and which, by cooling, form folid maffes, whofe hardnefs furpaffes that of marble. This reftriction notwithftanding, many other fpecies of lava may be conceived, according to the different degrees of fufion in the mixture, the greater or fmaller quantity of metal, and its greater or leffer intimate union with the various matters. Befide many intermediate kinds, three fpecies are eafily diftinguifhable. The pureft lava refembles, when polifhed, a ftone of an obfcure dirty grey colour. It is fmooth, hard, heavy, and interfperfed with fmall particles fimilar to black marble, and whitifh points. It feems to contain metallic particles. At firft fight, it refembles ferpentine, when the colour of the lava does not tend to green. It receives a pretty fine polifh, which is more or lefs vivid in different parts. It is made into tables, chimney-pieces, &c.

'The coarfeft kind of lava is rugged and uneven. It refembles the fcoriæ or drofs of iron. The moft common fpecies holds a middle rank between the two extremes: 'It

'It is that which we every where find in large 'masses upon the sides of Vesuvius and in 'the adjacent fields, where it has run in torrents. 'In cooling, it has formed masses similar to 'ferruginous and rusty rocks, which are often 'many feet thick. These masses are frequent-'ly interrupted and covered with ashes and 'calcined matter. . . . . It is under several 'alternate strata of lava, ashes, and earth, the 'whole of which forms a crust of from 60 'to 80 feet thick, that temples, porticos, sta-'tues, a theatre, and an entire city have been 'discovered *.'

M. Fougeroux de Bondaroy remarks, 'that, 'immediately after an eruption of burnt earth or 'of a kind of ashes, Vesuvius generally throws 'out lava, which runs down the fissures or fur-'rows made in the mountain. . .

'The mineral matter inflamed, melted, and 'flowing, or lava properly so called, issues through 'cracks or crevices with more or less impetu-'osity, and in greater or smaller quantity, ac-'cording to the violence of the eruption. It 'spreads to a greater or smaller distance, accord-'ing to the degree of fluidity, and the declivity 'of the mountain, which more or less retards 'its cooling. . .

'That which now covers a part of the land 'at

* Mem. de l'Acad. des Sciences, année 1757, p. 374.

'at the foot of the mountain, and which some-'times stretches as far as Portici, consists of 'large heavy masses, bristled with points on 'their upper surface. The surface which rests 'on the ground is flatter: As these pieces lie 'above each other, they have some resemblance 'to the waves of the sea. When the pieces are 'larger and more numerous, they assume the 'figure of rocks. . .

'In cooling, the lava affects various forms. . . 'The most common is that of tables or boards 'of greater or smaller dimensions. Some pieces 'are six, seven, and eight feet long. It breaks 'into this form in cooling and consolidating. 'This is the species of lava which is bristled 'with points. . .

'The second species resembles great ropes: 'It is always found near the mouth of the vol-'cano, and appears to have been suddenly fixed, 'and to have rolled before it hardened. It is 'lighter, more brittle, more bituminous, and 'softer, than the first species. By breaking it, 'we likewise perceive that its substance is not 'so close and compact. . .

'At the top of the mountain, we find a third 'species of lava, which is brilliant, and com-'posed of threads which sometimes cross one 'another. It is coarse, and of a reddish violet 'colour. . . . Some fragments are sono-'rous, and have the figure of stalactites. . . 'Lastly, 'Laftly, in certain parts of the mountain, we 'find lavas of a fpherical form, and appear to 'have been rolled. It is eafy to conceive how 'the figures of thefe lavas might be varied by a 'number of accidental circumftances*,' &c.

Matter of every kind enters the compofition of lavas. Iron and a fmall quantity of copper have been extracted from the lava found on the fummit of Vefuvius. Some fpecimens are fo impregnated with metallic fubftances as to preferve the flexibility of metal. I have feen two large tables of lava of two inches thick, which were polifhed like marble, and bended with their own weight. I have feen others, which were bended by a weight, and refumed their horizontal pofition by their own elafticity.

All lavas, when reduced to powder, are, like glafs, fufceptible of being converted, by the intervention of water, firft into clay, and afterwards, by the mixture of duft and corrupted vegetables, into excellent foil. Thefe facts are apparent from the vaft and beautiful forefts which furround Ætna, and grow upon a bottom of lava covered with feveral feet of good earth: The afhes are more quickly converted into earth than the powder of glafs or of lava. In the craters of old extinguifhed volcano's, as well as on the ancient rivers of lava, we find very fertile foils. Hence the devaftations occafioned by volcano's are limited by time; and, as Nature is always more difpofed to produce than to deftroy, fhe, in a few ages, repairs the devaftations of fire, and reftores to the earth its former fertility by the very fame materials fhe had employed for the purpofes of deftruction.

* Mem. de l'Acad. des Sciences, année 1766, p. 75.