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ON THE SITE

OF THE

ANCIENT CITY OF THE AURUNCI,

AND ON THE VOLCANIC PHENOMENA WHICH IT EXHIBITS;

WITH SOME REMARKS ON CRATERS OF ELEVATION, ON THE DISTINCTIONS BETWEEN PLUTONIC AND VOLCANIC ROCKS, AND ON THE THEORIES OF VOLCANIC ACTION WHICH ARE AT PRESENT MOST IN REPUTE.

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ON THE SITE

OF THE

ANCIENT CITY OF THE AURUNCI.

THE lively interest, which, of all classes perhaps of physical phenomena, the operations of a volcano are best calculated to inspire, has been my principal motive for undertaking three journeys, at intervals of nearly ten years apart, to the south of Italy; on my return from each of which, I felt it a matter no less of duty than of inclination, to communicate some account of what I had observed, to such Members of my own University as felt any curiosity in researches of this description.

Accordingly, soon after I came back from my first visit to Italy in 1824, I submitted my views, with respect to the general nature and origin of volcanos, in some Lectures delivered in this place, which have been incorporated in a work afterwards published by me, but for some time past out of print[a].

[a] Description of active and extinct Volcanos, 1 Vol. 8vo. London, 1826.

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In these Lectures I maintained, by an appeal, more particularly to the operations now proceeding, about Vesuvius, in Sicily, and in the Lipari Islands, that hypothesis, which was first propounded by Sir H. Davy, but which, towards the close of his life, that great chemist, like *an unnatural parent*, appears to have cast aside.

And although Dr. John Davy, in the Life he has published of his brother, has taken me rather severely to task, for venturing to suggest, that this *cruel abandonment of his own progeny* was, on the part of Sir Humphrey, a matter of taste, rather than of deliberate judgment, as though I had almost impeached his moral conduct by attributing to him such a change of sentiment on a scientific question,[b] yet I am still prepared to contend, that inasmuch as this illustrious philosopher, at the very time when he avowed his preference for a rival theory, acknowledged that the one he had originally advocated was adequate to account for all the phenomena which are known to accompany a volcanic eruption,[c] the opinion he expressed is not entitled quite to the same deference which it would otherwise command, nor to be regarded of sufficient weight to bias us against the reception of the evidence, which may be

[b] See Davy's Life, vol. ii. pp. 124, 5.

[c] Phil. Trans. for 1828, p. 250. "Assuming the hypothesis of the existence of such alloys of the metals of the earths as may burn into lava in the interior, the whole phenomena may be easily explained from the action of the water of the sea and air upon those metals; nor is there any fact in any of the circumstances which I have mentioned in the preceding part of this Paper, which cannot be easily explained according to this hypothesis."

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offered in support of that hypothesis which I have ventured to espouse.

In my first visit then to Naples, my attention was almost exclusively directed, as that of most travellers is, to the operations of the active, or semi-active volcanos round about this Capital; but on my second, I extended my examination to an extinct one in Apulia, situated near the eastern declivity of the Appennines, and bearing, as it would seem, the same relation to the Adriatic, which Vesuvius does to the Mediterranean.

This volcano, known to the ancients as the Mount Vultur, a name which it still retains, preserves to the present day unimpaired the form as well as the structure of those portions of the earth's surface which have been once the theatre of igneous operations; the medium of communication, as it were, between the atmosphere and the interior of the globe.

Yet no manifestations of activity are recorded as having been exhibited by it during those periods of Roman History, when such phenomena would have excited attention.

On the contrary, it appears, from the testimony of Horace, to have presented then the same luxuriant vegetation, the same wooded slopes, which we observe at present, so that the inference seems inevitable, that the grand display of volcanic activity, which must have accompanied the formation of so considerable a mountain, was limited to a period long anterior to the existence of historical records.

Of this locality, as well as of the allied phenomena exhibited in a spot on the Appennines intermediate between it and mount Vesuvius, and

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in a line parallel with both, called of old the lake Amsanctus, where, just as was the case nearly 2000 years ago, in the time of Virgil, copious volumes of carbonic acid gas are constantly given off into the atmosphere from some internal focus of volcanic operations, I gave an account on my return at one of the meetings of this Society, and the particulars are contained in a brief memoir since published in our Transactions.[d]

One other volcano however, or rather, I should say, another distinct system of volcanic operations existing within the Neapolitan territory, remained to be explored, I mean that of Rocca Monfina, near Sessa, at a distance of about 30 miles to the north of Naples.

This mountain accordingly it was my particular object, in the third and last journey I undertook to the south of Italy, to investigate, and as it proved in some respects more interesting, and more instructive, even than any of those which I had previously examined, I conceive that a brief account of it will form a suitable appendix to the reports on volcanic phenomena, which I have on former occasions presented at these Meetings.[e]

Those who have travelled from Naples to Rome by the lower and more frequented road, which passes by Mola de Gaieta, Fondi, and Terracina, may recollect, that after reaching Capua, they soon lose sight of the volcanic tuff or peperino, which

[d] Narrative of an Excursion to the Lake Amsanctus and to Mt. Vultur in Apulia, 1835.

[e] The little map appended gives the relative positions of the three volcanos alluded to.

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constitutes the subsoil in all directions around Naples. They then find themselves upon a calcareous marl, which upon examination will appear to belong to the tertiary period, until they approach the hills which are ascended before arriving at the post house of St. Agatha. They there perceive that the rock is again a kind of tuff, but one possessing a different character, and therefore derived from another source from that surrounding Naples, and that it may be traced to a mountain called Rocca Monfina, which lies between the two towns of Sessa and Teano, one of which, Sessa, stands at a distance of about half a mile from the inn of St. Agatha already noticed, whilst Teano is situated on the eastern flank of the mountain looking towards the central chain of the Appennines.

Both these cities will be familiar to the readers of Livy, the first as Suessa Auruncorum, the last hold of the nation of the Aurunci, the second as the seat of the rival state of the Sidicini.

The Aurunci however, in the earlier periods of Roman history, had their capital at the summit, and not on the declivity, of the mountain. Though they at one time appear to have possessed themselves of a considerable tract in the level country both of Campania and of Latium, yet their original site was the hilly country intervening. Thus they are noticed by Virgil as a hardy race of mountaineers

——— et quos de collibus altis
Aurunci misere patres.

and those who like myself have ascended the mountain, will regard it as admirably well adapted for the stronghold of a warlike and predatory clan.

We first read of them indeed, soon after the

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expulsion of the Tarquins, as having formed a confederacy against Rome with two Latin cities, Pometia and Cora, when, being defeated with great slaughter, they are said to have taken refuge within the walls of Pometia. The following year Pometia was besieged without success, and one of the consuls being severely wounded, the invading army sounded a retreat.

A second army was however quickly dispatched, and Roman perseverance at length triumphed, Pometia being taken by assault, after which it was so completely destroyed, that though it had ranked as the principal town in the Pontine Marshes, to which indeed it gave its name, no vestige of it can now be discovered, and its very position is unknown.

Still the Aurunci remained unmolested in their capital on the summit of Rocca Monfina, to which the Romans, as it would appear, did not think it prudent to pursue them, and, although a few years afterwards, when this same people, in consequence of the taking of the town of Suessa by the Romans, joined the Volscians, they were again defeated in battle, their independance was still preserved to them within the range of the mountain fastness alluded to.

For the next century and a half the Aurunci appear to have kept aloof from collision with the Roman power, but in the year A. U. C. 410, they made a predatory incursion into the Roman territory, which excited so much alarm, from the fear lest, if unchecked, the whole Latin nation might rise, and make common cause with them, that a dictator was appointed to head the army sent to oppose their march. They were indeed promptly

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repulsed, but nevertheless, in the great Latin war which commenced about five years afterwards, they again took part against the Romans, and shared in the defeat which attended the arms of the confederates.

At the peace which followed, they were admitted into the alliance of the Romans; but from this moment may be dated their ruin; for soon afterwards, the hostile nation of the Sidicini, either by surprise or treachery, effected that, which the Romans appear never to have attempted, namely, the expulsion of this people from their stronghold on the summit of Rocca Monfina, which, with its walls and fortifications, was utterly demolished, the inhabitants being compelled to seek refuge in the town of Suessa, the modern Sessa, in the plain below.

After this event, all we read of the Aurunci is, that they took part with the Samnites in their second war against the Romans, and in consequence of their defeat were obliged to submit to receive a Roman colony, so that their existence as a separate state was from this period destroyed.

That they should so long have resisted the Roman power, and not been finally subdued, until deprived of their original fortress on the top of Rocca Monfina, will be less a matter of surprise, when I have described the structure of this remarkable mountain.

After a rather steep ascent of about 2000 feet, we find ourselves all at once within a very regular crater, the brim of which is perfect on the west, where it forms the lofty and precipitous Monte Cortinella, and may be traced in other parts throughout its entire circumference, except on the

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side which we enter on coming from Sessa, where it is so far broken away, that there is scarcely any sensible descent before arriving within its precincts. The circular form and extent of the crater is however better observed from some point near to its centre, than from its margin, and a remarkable conical protuberance which rises up from the midst of the crater, and reaches an elevation of 3200 feet [f], considerably exceeding the highest point which the margin of the latter attains, gives us an excellent opportunity of surveying its internal dimensions.

Its diameter is estimated at two and a half Italian miles, and its circumference at seven and a half, but a large portion of its interior is occupied by the conical hill above noticed, the structure of which I shall describe immediately.

It is no novelty to the traveller in Italy, to observe the country increasing in verdure and fertility, in proportion as he ascends to a higher elevation, so that, after toiling up a laborious ascent, unapproachable perhaps, except on foot, or by beasts of burden accustomed to mountain paths, he may often find himself all at once in a valley, exhibiting, instead of the sombre and lonely aspect which in colder countries is characteristic of mountain scenery, a display of those softer and lovelier features, which the intense heat of the sun soon banishes elsewhere from the landscape of southern latitudes, and teeming with a population, more healthy, more vigorous, and apparently more thriving, than he had left in the plain below.

Such is found to be the case in crossing the

[f] Abich, über die Natur &c. der vulkanischen Bildungen. Braunschweig, 1841.

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mountain chain that separates Amalfi from the towns that lie scattered along the Bay of Naples, after we have climbed up the flights of rude steps, which often form the only medium of communication between the villages situated on the slope of the hill, and the sea that flows at its base.

And in like manner, Rocca Monfina, isolated as it may appear, and remote from any great thoroughfare, comprehends within its precincts two or three populous villages, several churches, and more than one convent; whilst its surface, so far from presenting the rugged aspect which volcanic rocks usually assume, is so uniformly clothed with vegetation, and in a state of such complete culture, that, but for the amphitheatre of hills which encloses the table-land on its summit, the circular form of which betrays the origin of the mountain of which it forms the outer margin, no one could for an instant dream, from its general physiognomy, that the whole was of igneous formation.

And yet, when we look back to the accounts given by the Roman writers of the state of Vesuvius, or rather of Monte Somma, just before that mountain returned to a state of activity in the second century of the Christian æra, we may see reason to believe, that its condition must then have been nearly similar to that of Rocca Monfina at present[g], if we only except the crater, which, not being composed of tuff, was entirely barren, even in the time of Strabo[h].

[g] See the Engravings which represent, the supposed form of the mountain in the time of Strabo, and its appearance subsequently to the time of Pliny.

[h] See Martial IV. Ep. 44. Strabo, V. 24.

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In one respect indeed even here the analogy held good; for like the crater of Rocca Monfina, that of Monte Somma seems to have been broken away on one side, by which the troops of Spartacus must have entered it when besieged by the Roman legions; and it was by climbing up the sides of that portion which continued entire, that the army alluded to contrived to escape from their dangerous position, and to take the enemy in the rear[i].

If such then was the condition of Rocca Monfina during the early periods of the Roman Republic, we can hardly imagine a position better calculated for the stronghold of such a nation as the Aurunci are described to have been.

Their outpost Suessa, situated, as we have seen, near the bottom of the mountain, commanded the approach to it on that side where it was most accessible, and secured to them a communication, with the sea, with the cities of the Pontine Marshes, and with their possessions in Campania.

If driven from thence, they had only to retreat to the summit of the mountain, where, posted on the external margin of the crater, they would watch the movements of any invading force, long before it could gain the top of a mountain of such height, and so difficult of access. In case of an attack, they could drive their flocks and herds within the crater, where they would find ample space and good pasturage, without danger of molestation, unless indeed the invading force were powerful enough to dislodge them from the vantage ground, which their army would occupy on the brim of

[i] Plutarch, in vit. Crassi. Florus, III. 20.

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the crater, itself a natural fortress, inclosing within its ample boundaries a large tract of fertile land.

Even if forced to relinquish this stronghold, they still had it in their power to take refuge on the conical and precipitous mountain which rises up from the very centre of the crater, where a small force might easily set at defiance a host of invaders.

On this mountain, called, from a cross which till lately stood on its summit, the Monte de la Croce, they accordingly appear to have placed their citadel; for an Italian archæologist[k] first pointed out, on a level spot nearly at the top of this eminence, as vestiges of the ruined city, pavements of streets, corners of apartments, foundations of buildings, three cisterns for containing water, together with heaps of hewn stones, and remnants of very strong walls.

Some of these were perceived by myself in the course of my rambles over the mountain, and I found that they consisted of the same material which composes the rock on which they had been erected.

No better proof than this could be adduced of the antiquity of the volcanic operations to which the mountain owes its actual configuration; for, as sir William Gell observed to me, when I once descanted with him on the extreme disproportion which exists between the length of period embraced within the several epochs of human and geological history, a nation like the Aurunci, to whom it was of essential importance to have near their city good pasturage for the flocks and herds on which they depended for

[k] Perotta, Sede degli Aurunci, as quoted by Romanelli, vol. iii. p. 444.

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support, would never have selected Rocca Monfina for their capital, not only if the volcano itself had been in activity, but had not the stone which constitutes the interior of the crater been already in such a state of decomposition, as to be covered with herbage, and to yield abundant crops.

With regard to the geological structure of the mountain, I may remark, that with the exception of the conical mass of rock in its centre which constitutes the Monte della Croce, it is almost entirely composed of beds of volcanic tuff, which differs however from that met with round about Naples, in the inferior degree of its compactness, in its more earthy appearance, in the more frequent presence of mica, and the rarer occurrence of the darker varieties of pumice.

I remarked a red ferruginous variety of tuff, sometimes in beds alternating with the commoner kinds, and in one instance forming a kind of vein running vertically through the strata.

The tuff continues from the town of Sessa till we approach the outer brim of the crater, covered over with loose uncompacted aggregates of volcanic sand, and of stones promiscuously heaped one upon the other.

In this tuff are often imbedded, not only its usual concomitants, sand and rapilli, but also large blocks of a kind of porphyry, peculiar, as it would seem, to the products of the ancient volcanos of Monte Somma and of Rocca Monfina in the Neapolitan territory, and of Acquapendente and Viterbo in the Roman, characterised by crystals of leucite, which, at the spot now under consideration, are often of

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extraordinary dimensions, sometimes two inches and a half in diameter, and are accompanied by minute crystals of augite, both imbedded in a felspathic basis. As the felspathic portion was more readily decomposed than the imbedded crystals, these latter might often be detached from their matrix in a state of great integrity.

Near the little village of Tuoro de Sessa, which is situated very little below the external margin of the ancient crater, we observe a continuous bed of this leucitic porphyry, resting upon the tuff, and extending for some distance along a ravine which runs obliquely down the sides of the mountain. This was the only instance that occurred to me, in which the above rock appeared in any other form than that of detached blocks.

The most remarkable feature however in the physiognomy of this mountain, and that which distinguishes it from every other volcano I had seen, is the protrusion from the interior of the crater of a conical mass of a rock resembling trachyte[1], large enough to fill up two thirds of the area comprehended within the walls of the crater, and so lofty as to rise considerably above the most elevated point in its margin; constituting indeed, when observed from a distance, the most conspicuous object embraced within the compass of the mountain.

[1] See the Section and Ground Plan of Rocca Monfina, the former reduced from a sketch taken by the artist who accompanied me on my visit to the mountain; the latter borrowed from a Memoir by Professor Pilla, who however has represented the crater as though it were entirely effaced on the east, whereas it appeared to me there distinctly traceable, although undoubtedly much lower than it was on the west.

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This trachytic rock is much more abrupt than the tuff through which it appears to have been protruded. In its centre is a hollow plain, which may possibly have once been a kind of crater, as there are still on three of its sides points of rock that rise considerably above the central concavity, of which the highest was formerly marked by a cross; a circumstance which, as I have stated, served to give the name of Santa Croce to the entire mountain.

The rock is generally of a reddish brown colour, its base sometimes gray, fine-grained and compact, but not of very close texture, intimately interwoven with small felspathic portions, which frequently shew a glassy fracture, as if from fusion.

Much green augite, never however accompanied by even a trace of hornblende, penetrates the whole mass, and brown mica, generally in hexagonal tables, is a predominant ingredient. Abich regards the rock in the aggregate as forming a link intermediate between trachyte and greenstone.

Pilla informs us, that the summit of this cone is exactly equidistant from all parts of the crest of Monte Cortinella, the only portion of the original crater that stands absolutely intact, shewing, that it stands exactly in the centre of the inclosed area; a singular and improbable coincidence, unless it had upheaved the rest of the mountain, but one presenting no difficulty if we admit this supposition.

The rock alluded to, abrupt as it is, seems to be everywhere covered over with vegetation, and a fine chestnut forest occupies a considerable portion of its flanks.

From its summit the eye embraces, on the one hand, Mola di Gaieta, the range of mountains termi-

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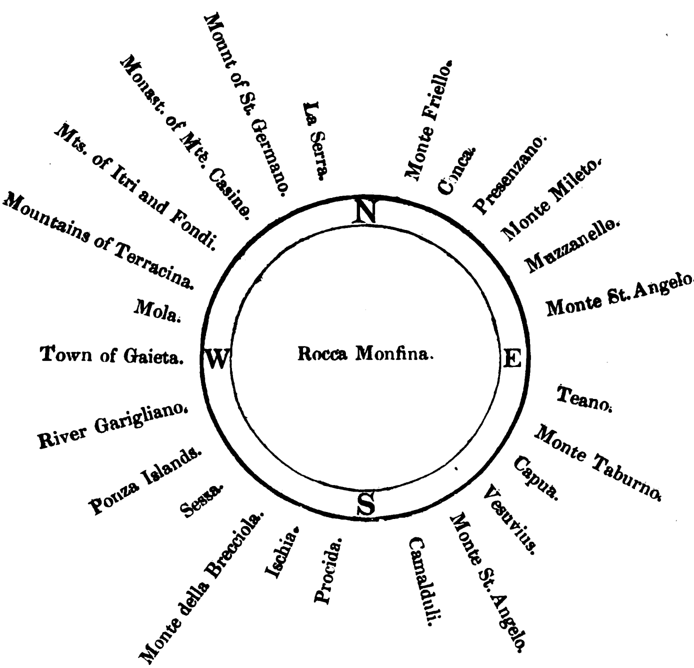
nating in Cape Circello, and the whole extent of coast as far as Ischia and Vesuvius; whilst on the other, the line of the Appennines, including the monastery of Monte Casino, and other places built upon the slope of these mountains, appears conspicuous.

The artist who accompanied me executed, from this and other points of the mountain under consideration, a panoramic view of the whole circuit which the eye comprehends, of which the following ground plan may serve to present some idea :



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Now the circumstance which, in a geological sense, attaches the highest interest to the structure of this mountain, is the support which it appears to afford to the *theory of elevation;* the view, that is, which regards volcanic mountains, as formed in the first instance by such a sudden upheavement, as might have brought the masses of rock of which they consist, from a nearly horizontal position, into their present inclined one, and at the same time caused them to occupy a much higher relative level than they had done antecedently.

This view of the original formation of volcanic mountains has been maintained by some of the most distinguished of modern geologists; by Humboldt, by Von Buch, by Elie de Beaumont, by Dufrenoy, and by Abich.

But as it has met with able opponents, in Lyell and Scrope in this country, and in Mons. Prevost in France, it is satisfactory for those who adopt such a theory, to be able to justify their belief in it, by pointing out facts, which, like the *experimenta crucis* in chemistry, seem irreconcilable with any other hypothesis.

Of this description, as it appears to me, is the protrusion of a compact mass of trachytic rock through the centre of a mountain mainly consisting of materials so different from it, as leucitic porphyry and volcanic tuff; and its attaining moreover a height so considerable, as it has done in the instance before us.

The first difficulty in the way of supposing it formed by the same operations as those which produced the mass of the surrounding mountain, arises

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from the constitution of its component parts, which is such as to imply a different origin for the two. Moreover it may be remarked, that if the Monte della Croce had consisted of heaps of incoherent scoriæ, or of large fragments of slaggy lava piled one above the other, like the cone which is now forming in the centre of the crater of Vesuvius, its existence might then indeed have been explicable by an appeal to the every day operations of which we are eyewitnesses in volcanos now in activity.

Had it even formed part of a stream of lava, which might still be traced down the external flanks of the mountain, although we should have wondered at its ample dimensions, we might nevertheless have referred it to the same cause; but a conical mass of rock so considerable, and yet so completely circumscribed within the area of the crater, could only, as it would seem, have been brought into the position which it is seen to occupy, by being upheaved *all at once* from the interior of the globe, whilst in a semi-fluid or pasty state, but not in a condition of actual liquidity.

We have therefore before us an Agent, which would not only be competent to uplift the surrounding strata of tuff, but which must necessarily have done so, if the latter had been at the time of its eruption in an horizontal position; and to suppose them gradually formed by successive showers of loose incoherent ejected materials, before the trachytic rock in its centre was protruded, seems to imply a forgetfulness of the height which the tuff has attained, and of the high angle at which its beds are inclined.

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Alternating strata of tuff and lava may indeed be imagined to build up in the course of time a mountain of considerable elevation, but a hill consisting of tuff alone, as appears to be the case with a large part at least of Rocca Monfina, could only have attained its present height, which is at least two thousand feet above the sea, in consequence of some elevatory movement subsequent to its ejection; and if this be admitted, we have before us in the central trachytic rock of Monte della Croce, an agent calculated to cause such an upheavement, and itself hardly to be accounted for without such a supposition.[m]

I have not time at present to enter into the general discussion of the subject, and will therefore only allude to two facts relating to the volcanos of Etna and Vesuvius, which seem to shew that even there, where analogy would most lead us to suppose that the whole of either mountain has

[m] Although Rocca Monfina presents the best instance with which I am acquainted, of a trachytic rock that has protruded through the centre of a crater, without forming a current of lava extending down the external slope of the mountain, yet we have something of the same kind in the crater of Astroni, and, on the road from Rome to Florence, we may observe near Rosciglione, in the Lake of Vico, the Lacus Cimini of antiquity, and an undoubted crater, a conical hillock rising from its centre, the real structure of which is concealed from the passing traveller by being covered over with trees, but which may very probably be of similar formation.

Amongst extinct volcanos however a still more striking parallel is presented in Auvergne by the Puy de Dome, a conical mountain consisting of that friable description of trachyte called domite, which rises from the midst of an amphitheatre of volcanic rocks of quite a different character from itself, and of a much darker colour from the intermixture of augite. See my Work on Volcanos.

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been formed by a succession of the same ejections which are continuing to increase it, the stubborn evidence of facts compels us to adopt the elevatory theory.

The first of these facts is the circumstance so lucidly pointed out by Elie de Beaumont, and substantiated by him through a most laborious induction of particulars; namely, that a stream of lava, having an inclination of more than six degrees, cannot form a continuous mass, and therefore that the upper portion of Mount Etna, which rises with an inclination of 29° and 30°, must have been produced in some other way.[n]

The second is the discovery of the same marine shells in the tuff of Monte Somma which exist in that of the Phlegrean fields[o]; seeming to shew, that the former, as well as the latter, had once been

[n] See also Von Buch on volcanos and craters of elevation, Edin. Phil. Journ. vol. xxxv. for Oct. 1836.

[o] Professor Scacchi, in the Guida di Napoli (a valuable present made by the king of Naples to each of the Scienziati who attended the Italian Congress held at his Capital in the autumn of last year) enumerates the following shells as existing amongst the erratic blocks of Monte Somma, some of which he states also to occur in the tuff of the same locality.

	Marl.	Limestone.		Marl.	Limestone.
Pecten Jacobæus	+	+	Cardium echinatum ..	+	
——— varius	+		——— tuberculatum ..	+	+
——— sanguineus ..	+	+	Volvaria triticea	+	
Ostrea cristata	+		Buccinum mutabile ..		+
Nucula margaritacea ..	+		——— macula		
Mytilus	+		Pleurotoma varia		
Solen legumen		+	Scalaria communis ..	+	
Tellina donacina		+	Turritella communis ..	+	
Tellina exigua		+	Natica Valenciennerii ..	+	
Erycina Renieri		+	Dentalium dentalis ..	+	
Corbula nucleus	+		——— coarctatum ..	+	+
Mactra stultorum		+	Siliquaria anguina ..	+	
Venus exoleta	+	+	Serpula cereolus		+
——- Chione..		+			

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under water, and consequently could only have attained their present elevation by being upheaved.

The reluctance indeed which certain eminent geologists in this country have evinced to the admission of this theory, seems to have proceeded from an undue reliance upon the truth of their favourite principle, that all the phenomena on the earth's surface, which geology has revealed to us, are brought about by a repetition of the same cycle of operations which we are eyewitnesses of at present—that in the natural, as well as in the moral world, there is a kind of circle of events continually reproducing each other, and bringing us back after an interval of time to our original starting place.

For my own part, I am inclined to think, that the analogy of the moral world might lead to more hopeful conclusions; the laws of matter indeed, like the passions and capacities of man, have at all times no doubt continued the same, but it does not therefore follow, that the former may not have produced different effects in ancient times, by operating upon a different condition of the external world, and that the same series of events which we witness at present, must have taken place formerly, or will be repeated hereafter; any more than we need anticipate the recurrence of the same conditions of civil life which we read of in ancient history, or deny, that in the midst of continual alternations of retrocession, as well as of advancement, the general tendency of human society is in the direction of progress.

Waving however these general considerations, I

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will just point out certain facts which seem to demonstrate, that these geologists must, in spite of themselves, admit of processes, which, though all included under the general category of igneous operations, are nevertheless distinguished from those brought about by the influence of subterranean heat at the present time, and of which therefore they can have no actual experience.

Few of us in the present day will question the igneous origin of granite, and least of all those belonging to the school of geology to which I allude; it is impossible indeed to conceive, in what manner the particles of silex, alumina, and alkali, composing this rock, could have been brought into such close juxta-position, as to be able to exert their mutual affinities, and to form crystals of felspar and mica, unless the mass had been in a state which admitted of a certain freedom of motion in its constituent elements, for which an approach to a state of fluidity seems absolutely requisite, whilst for this fluidity we know no other probable cause than heat.

Nevertheless it is an undoubted fact, that on the one hand the igneous operations, whose effects we witness, have never been found to give rise to ejections of granite; and on the other that those extensive rock formations, apparently resulting from igneous processes, which, themselves destitute of all traces of organic life, lie at the base of those strata which contain the earlier manifestations of the same, and are therefore considered to have preceded them, never present to us

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the characters either of sub-aereal, or of sub-marine volcanos, whether we regard their geological structure, and relations to other rocks, or their constitution, as determined by chemical analysis. For the first element in the consideration I would appeal to the testimony of Professor Keilhau of Norway, who, by a long series of elaborate observations, has at least succeeded in shewing the difficulties of identifying granitic rocks with modern igneous products, and I am happy to find Sir Roderick Murchison, in his recent work on Russia, adding the testimony of his extended experience to the soundness of those views with respect to the *primogeniture* of granite, which were prevalent in the earlier times of geology. For although its occurrence superimposed on secondary and even on tertiary strata cannot be denied, yet it does not therefore follow, that those extensive formations of the same kind, which lie below the most ancient fossiliferous rocks, are to be placed with them under the same category.

We may therefore appeal to the production of a granitic compound, as an example of a mode of igneous operation, differing from any which we witness at present, and brought about under conditions which seem in the later periods of the earth's history to be, to say the least, but of unfrequent occurrence.

But this is not all, for by reference to the discoveries of modern chemistry we shall be enabled, if I mistake not, to trace a very beautiful series of transitions, by which the primæval granite has been

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converted, first into trachyte, and afterwards into the various kinds of lava, &c. which characterise modern volcanos.

On this point I will enlarge a little, as a full explanation of it may tend to impart to you, as it has done to myself, clearer notions as to the real nature of the products which we are accustomed somewhat vaguely to designate under the names of granites, trachytes, and the like.

Ask, for instance, a geologist what he means by the term granite, and he will tell you, that he understands an aggregate of three minerals, namely quartz, mica, and felspar, in a state of intimate mixture.

But in order to learn what these several minerals really are, the chemist is the fittest person to be consulted, and from him we may collect, that quartz is nearly pure silex coloured by indefinite, but minute, quantities of certain foreign matters, but that mica and felspar are definite compounds, formed of an acid and a base in exact atomic proportions. The same indeed applies to all crystallized minerals consisting of more than one ingredient, as was first laid down by the illustrious Berzelius—a generalization, by the by, which ranks perhaps, next to the great Daltonian law of definite proportions, highest in the scale of importance amongst scientific truths of this class, and was arrived at by him at a time when so many difficulties lay in the way of its adoption, that we cannot sufficiently admire the penetration required for its discovery, as well as the boldness which he evinced in promulgating it. Indeed, until the celebrated Prussian chemist Mitscherlich had developed his original views on the

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subject of what he has called Isomorphism, we were stopped at the very threshold of Berzelius' theory, by finding the same mineral to contain, sometimes one base, sometimes another, without any other apparent limitation, except that the proportions they severally bore to each other should be as their atomic weights. Thus garnet might contain alumina, peroxide of iron, lime, magnesia, protoxide of iron, severally combined with silica, or any one or more of these bases might be absent, provided only there was one base with three atoms of oxygen combined with two of the negative element, and another with one atom of oxygen united with one of the latter, present in the compound.

The difficulty which this occasioned was however removed, when Mitscherlich had shewn, that several bases admitted of being substituted one for the other without destroying the essential character of the crystallization, or producing any further change in it than a slight difference in the angle; the only necessary condition being, that each of the bases so replacing each other should contain an equal number of atoms of oxygen. Thus potass, soda, lime, magnesia, protoxide of iron, &c. may replace each other, as containing each an atom of oxygen, to an atom of the radical present; as likewise may alumina, peroxide of iron, and peroxide of manganese, since they each contain three, to two of base, so that the same mineral admits of a considerable diversity of composition, whilst still retaining its own peculiar crystalline form [p].

[p] Rammelsberg, a disciple of Rose, has proposed a chemical classification of siliceous minerals founded on this principle, which

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But later researches have carried us a step further; they shew that crystallographers have often confounded several minerals, which analysis proves to be distinct; thus Henry Rose of Berlin, and other chemists of the school of Berzelius, proved, that whilst one kind of mica contains a certain definite amount of potass, in another a portion of that base will be replaced by lithia, and in a third by magnesia.

In the two first the mineral, when examined by polarized light, exhibits only one axis of double refraction, or one set of rings, whilst in the last it displays two such sets, so that the magnesian mica deserves to be distinguished as a separate species on crystallographical grounds alone.

In like manner Henry Rose has asserted on the faith of chemical analysis, that mineralogists had designated by the name of felspar several distinct substances, a statement, which the more exact examination of their respective angles of crystallization has since proved to be correct.

There is indeed such an analogy between them with respect to their chemical composition, as well as to their external characters, that they may perhaps be conveniently considered as different species of the same genus, to which the term felspar is applicable, the new terms which have been affixed to them by way of distinction being regarded as designating the species.

I shall give in the Appendix, as it seems to me the best attempt that has been made, to reduce to order the confused mass of species containing various proportions of these earths which mineralogy presents.

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Thus the genus felspar may be defined as indicating a mineral, the primary form of which is an oblique rhombic prism, and its chemical constitution that of two compounds of silica united together; the first consisting of silica united with any base which contains only one atom of oxygen, the second compound of silica, one where that body is united to a base in which the proportion of oxygen to the radical is as three to two.

But this definition gives scope for a considerable diversity of chemical composition, since silica is capable of entering into chemical union with bases in the proportion of one, two, and three atoms, and accordingly I may enumerate the following species of the felspar family as distinguished by Rose and his disciples. In this enumeration however I will endeavour to simplify the matter as much as possible, by pointing out in the first place merely the relation which the silica bears to the base which contains three atoms of oxygen to two of radical, and in order to avoid an inconvenient circumlocution, will speak of this base, as though it were *in all cases* alumina, that being the negative element possessing the above composition, which is most commonly found in union with silica in this class of minerals.

In anorthite then, and in labradorite, the silica is to the alumina in the proportion of atom to atom, the difference between these two minerals consisting, in the former being composed of three proportionals of this combination; in the latter of only one.

In the andesin, or the felspar from the Andes,

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as well as in oligoklase, the silica is to the alumina in the proportion of two to one; the difference between the two consisting in the proportion which the silica bears to the base with one atom of oxygen.

Lastly, in pericline, albite, glassy felspar, adularia, and orthoklase, the proportion of silica to alumina is as three to one, the largest amount in which it is capable of entering into chemical union with any base whatsoever.

The chemical differences between these four minerals consists in the nature of the base with one atom of oxygen united to silica, which it contains; this in orthoklase is chiefly potass; in albite wholly soda; in pericline partly potass but chiefly soda; and in adularia chiefly potass, though a small amount of soda is also present.

Thus we have in the felspar family three several gradations in the proportion which the silica bears to the alumina with which it is combined, namely, one, two, and three atoms to one of base, as may be seen by the following table, for which I am indebted to Abich.

It is observable that the specific gravity of the mineral is, in these cases, as well as in most other of the products of igneous action, inversely as the amount of silica, and directly as that of the other bases, so that a near approximation may be often obtained to their chemical composition by merely ascertaining their weight.

This accordingly is the method proposed by Abich, in order that we may appreciate the real mineralogical composition of a rock, in which the component parts are so blended together, that it

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is impossible to separate one from the other for the purpose of examination.

In these cases the specific gravity will often give the proportion of silica, supposing iron and other of the heavier metals not to be present in quantity sufficient to affect the result, and from the proportion of silica the nature of the felspathic mineral present may be in general estimated with sufficient precision [q].

Now it is important to observe, that the kinds of felspar commonly found in granite are those which contain the largest proportion of silica, namely either orthoclase, adularia, or albite. Where, as is often the case, orthoclase and albite are both present, the basis is generally composed of the latter, whilst the imbedded crystals consist of the former.

Such is the case at Carlsbad, and this fact affords perhaps the true solution of a question

			per Cent.
[q] Thus, Trachytic porphyry, having a specific gravity of	2.5783	contains of silex	69.46
Trachyte	2.6821	——	65.85
Domite	2.6334	——	65.50
* Clinkstone	2.5770	——	57.66
Andesite	2.7032	——	64.45
* Glassy andesite	2.5851	——	66.45
Trachyte-dolerite	2.7812	——	57.66
Dolerite	2.8613	——	53.09

The only exceptions being clinkstone and glassy andesite, the former having the same composition as trachyte-dolerite, but an inferior specific gravity; the latter corresponding nearly with clinkstone in both these particulars. It is to be remarked however, that clinkstone, although chemically resembling trachyte-dolerite, has a different mineral composition, for it appears to be a mixture of a zeolitic mineral with glassy felspar. Probably the same may apply to glassy andesite.

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Tabular View of the Chemical Constitution, Specific Gravity, &c. of the Mineral Species comprehended in the Felspar Family.

Name.	Locality.	Sp. Gravity.	Principal Constituents. Silica.	Alumina.	Lime.	Potass.	Soda.	Formula.
1. Anorthite...........	Monte Somma	2.7630	43.79	35.49	18.93	0.54	0.68	$\dot{R}\,\dddot{Si} + 3\,\underline{\dddot{R}}\,\dddot{Si}$
2. Labradorite	Mount Etna	2.7140	53.48	26.46	9.49	0.22	4.10	$\dot{R}\,\dddot{Si} + \underline{\dddot{R}}\,\dddot{Si}$
3. Andesin	Popayan, Andes......	2.7328	59.60	24.28	5.77	1.08	6.53	$\dot{R}^3\,\dddot{Si}^2 + \underline{\dddot{R}}\,\dddot{Si}^2$
4. Oligoklase	.. ..	2.6680	62.61	24.11	2.74	0.75	8.89	$\dot{R}\,\dddot{Si} + \underline{\dddot{R}}\,\dddot{Si}^2$
5. Perikline	Pantellaria..........	2.6410	67.94 68.23	18.93 18.30	0.15 1.26	2.41 2.53	9.98 7.99	}
6. Potass-albite..........	Drachenfels	2.6223	70.22	17.29	2.09	3.71	5.62	} $\dot{R}\,\dddot{Si} + \underline{\dddot{R}}\,\dddot{Si}^3$
7. Albite	.. ..	2.6140	69.36	19.26	0.46	?	10.50	}
8. Ryakolite	Monte Somma	2.6180	50.31	29.44	1.07	5.92	10.56	$\dot{R}\,\dddot{Si} + \underline{\dddot{R}}\,\dddot{Si}$
9. Glassy (or Soda) Felspar	Ischia	2.5970	66.73	17.56	1.23	8.27	4.10	}
10. Adularia	St. Gothard	2.5756	65.59	17.97	1.34	13.99	1.01	} $\dot{R}\,\dddot{Si} + \underline{\dddot{R}}\,\dddot{Si}^3$
11. Orthoklase	Baveno	2.5552	65.72	18.57	0.34	14.02	1.25	}
12. Artificial Felspar......	Made at Sangershausen	2.5600	65.03	16.84	0.34	15.26	0.65	}

N. B. The first seven Species belong to the *ein und eingliedriges Krystallsystem* of Weiss, or the *anorthotype* one of Mohs, the axes of crystallization being unequal, and not mutually related: whereas the last five Species belong to the *zwei und eingliedriges System* of the former, and the *hemiorthotype* of the latter, two of the unequal axes bearing a certain relation to each other, so as to constitute a pair.

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which I started in my Report on Mineral Waters, (British Association Reports, vol. v. 1836, p. 24.) namely, why these and other thermal springs which issue from granitic chains, hold carbonate of soda in solution, but not carbonate of potass.

Now by considering the nature of its felspathic material, it being one of those varieties of the mineral in which the silica is in the proportion of three atoms to only one of base, we may see the reason, why in granite a certain proportion of quartz, or uncombined silica, is almost universally present.

Its amount in fact represents the excess of silica existing in the rock over and above that which could combine with the alumina, and hence it implies, that at the time, and at the place, where the granite was formed, there was not a sufficient quantity present of the several bases to combine with the whole of the silica.

And if we examine the composition of the various rocks which have been produced by the operation of volcanic forces in ancient and in modern times, we shall be able to trace a gradual scale of diminution in the proportion of silica, and a corresponding increase in that of the bases present.

The first great division of them is comprehended under the name of trachyte, a general term for a class of rocks of igneous formation characterised, mineralogically by their harsh and gritty feel, together with the frequent presence of crystals of glassy felspar, and chemically as being trisilicates, with or without an excess of silica.

They are divided by Abich, who follows in a great degree the classification of Beudant, into

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1. Trachytic porphyry, in which quartz is present, but neither hornblende, augite, nor titaniferous iron appear. It is found, not only in Hungary, but also in the Ponza, and in some of the Lipari islands.

2. Trachyte properly so called, in which no quartz occurs, but which contains crystals of hornblende and even of augite, together with mica.

3. Andesite, the trachytic rock of the Andes, described by Abich as being of various degrees of compactness and consistency, possessing a coarse conchoidal fracture, and containing a large number of small white crystals, resembling albite, in a crystalline base of a darkish colour. Small crystals of glassy felspar are rare in this variety of trachyte, but those of hornblende are common, and augite is also present. It sometimes passes into greenstone or diorite.

Thus the rock composing the summit of Chimboraço, the basis of which resembles pitchstone, and which is destitute of hornblende, though rich in augite, is called by Von Buch an andesite. Antisana also, and Cotopaxi are said to consist of the same, and it is probable that this rock, in connection with trachyte properly so called, constitutes the greater part of those volcanic mountains in South America which are destitute of craters.

4. Obsidian and pumice, which are so connected, both physically and mineralogically, that they must be placed under the same head, and regarded merely as expressions for two different conditions which the same original material has been made to assume, by the agency of volcanic forces. Both indeed have been regarded, rather as particular states which many

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different minerals are capable of assuming, than as distinct species; but it is to be remarked, that simple silicates and bisilicates of alumina are incapable of assuming, either a vitreous condition such as that of obsidian, or those cellular and filamentous forms which we observe in the different varieties of pumice.

It is necessary therefore that the rock should be rich in silica, or be a trisilicate; and hence if with Abich we divide pumices into two groups, namely into cellular and filamentous, the former being dark green, poorer in silica, and richer in alumina; the latter white, and containing more silica; we shall find that the former is derived from clinkstone, trachyte, and andesite, and the latter from trachytic porphyry [r].

5. Pearlstone, a rock frequent in Hungary, and characterised by the presence of crystallites, or little globular concretions more or less vitreous, and generally scaly, with a pearly lustre arising from the commencement of a kind of crystallization in the mass, or where this is wanting, passing into a stony structure, or into a semivitreous one corresponding with that of pitchstone, which latter mineral seems to be nearly allied to it.

5. Trachytic tuff, the principal rock covering the Phlegrean fields, the analysis of which proves that it is, like pumice, only a metamorphosed condition of trachyte. Thus tuff, pumice, and obsidian are all modifications of the same volcanic basis; and all, except obsidian, contain water chemically combined —yellow tuff three atoms—white tuff two atoms—pumice one.

[r] For further remarks on the formation of obsidian and pumice, see Appendix.

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We must therefore regard the three former, as caused by water operating in a different manner from the steam which accompanies a flow of lava, inasmuch as the latter never contains any water in a state of chemical composition.

Now lava, although commonly accompanied by abundance of steam at the time of its eruption, and containing, even for several months afterwards [s], entangled within it a large quantity of aqueous vapour, holds no water in chemical combination, so that the fact stated with respect to tuff and pumice shews, that these formations have been placed under circumstances in some respects different from modern lavas.

All these varieties then of volcanic products, which Abich has classed under the general name of trachyte, approximate to granite in the circumstance of containing a trisilicate of alumina or of some corresponding base, and hence may be supposed to be more immediately derived from the latter rock, than other igneous formations are. Nevertheless in one variety of it, namely in the species distinguished by Beudant as trachytic porphyry, quartz is present, and accordingly this modification would seem to present the nearest approximation to granite, the chief difference indeed between the two being the partial substitution of glassy felspar for orthoklase, minerals of analogous constitution, though of different external characters, and with different relative proportions of the two alkalies present in them.

In trachytes properly so called there would appear

[s] See my Memoir on the Eruption of 1834, in Ph. Trans. for 1835.

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to have been such an accession of alkali and of earths, that the whole of the silica entered into combination, and consequently no quartz exists in the rock.

But when we proceed to the lava-currents which have been emitted from actual volcanos, or to the analogous trap formations which are regarded as the effects of submarine eruptions, we find a still further diminution in the proportion of silica, indicated by the substitution of labradorite for orthoklase, or in other words, of one atom of felspar instead of three, coupled with the presence of hornblende or augite[t], in both which minerals the silica bears a still smaller proportion to the base with which it is combined.

In these last minerals two new elements also make their appearance, which are seldom or never present, except in small quantities, in granite or in trachyte—I mean lime and magnesia; thus evincing already a change in the nature of the igneous operations, or in the materials upon which they were exerted.

Thus the modern lavas of mount Etna have been determined by Lowe[u] to consist of an intimate mixture of labradorite and of augite, and a lava which had recently flowed from Stromboli was as-

[t] Hornblende is $\dot{R}\,\dddot{Si}+\dot{R}^3\,\dddot{Si}^2$, where $\dot{R}$ is generally lime, but sometimes protoxide of iron, or soda; and $\dot{R}^3$ is generally magnesia, but sometimes protoxide of iron. In some hornblendes the silica seems to be partially replaced by alumina. *Bonsdorff.* Augite is $\dot{R}^3\,Si^2$, where $\dot{R}$ is either lime, magnesia, protoxide of iron, or protoxide of magnesia. The silica is sometimes replaced by alumina, as is the case also in hornblende. See Rammelsberg's Dictionary of Mineralogy, Berlin 1841.

[u] Jameson's Journal, 1837.

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certained by Abich to possess the same composition.

Greenstone, or dolerite, is composed of nearly the same materials, its compactness being merely the effect of the greater pressure to which it was subjected during the act of cooling.

Abich however has found it necessary to distinguish a class of formations intermediate between trachytes and greenstones, which he denominates trachyte-dolerite. To this he refers the rocks which encircle the peak of Teneriffe, those of one of the volcanos in Kamscatka, of the little cluster of islands between Lipari and Stromboli described by Hoffmann, and above all the material which constitutes the Monte della Croce, the central cone of Rocca Monfina already alluded to. Abich considers the felspar present in this rock to be oligoklase, which by reference to the table will be found to be a bisilicate, and the many green specks of augite which pervade it indicate a further change in the composition of the mass, and a nearer approach to greenstone. With this latter material, which, as we have seen, is a compound of augite with one of the species of felspar poorest in silica, the rock called basalt must not be confounded; as in it we may recognise a still further step in the elaboration of the constituents, this substance being composed of an intimate mixture of augite and magnetic iron, with a mineral of the zeolitic family. The composition of the latter is such as to imply, that it may have been formed out of labradorite with the addition of water, the presence of which in all zeolites

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is the cause of that bubbling up under the blowpipe, which has occasioned them to be distinguished by that general appellation.

We perceive a similar change in the rock called clinkstone, which has been shewn by Gmelin to be an intimate mixture of glassy felspar with a zeolite.

Thus as we proceed towards the more modern groups of volcanic formations, we find new ingredients successively coming into play; first the alkalies increasing, then lime and magnesia becoming part of the constitution of the mineral mass, and lastly water entering into combination with the earthy materials.

The gradual increase of soda is likewise a remarkable circumstance, modern lavas appearing to contain a much larger quantity than the volcanic products of ancient periods, and hence various minerals being produced in which this alkali is predominant [x].

These facts may perhaps suffice to shew, that the original material out of which volcanic rocks of whatever age have been elaborated was of a granitic nature—a strong confirmation, as it appears to me, of the old opinion, that this rock stands lowest in the series of Formations, and serves as the foundation upon which the rest repose.

The same circumstances may likewise be alleged as proofs, that the igneous operations actually going on are in many respects different from those which produced the primæval granite, to which conclusion we shall also be led, by considering the differences that exist between the composition of the ancient

[x] As natrolite, nepheline, thomsonite, &c.

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volcanic products of the Monte Somma, and those resulting from the operations of Vesuvius at the present day.

Thus if we go back to the period when the materials which constitute the tuff about Naples were ejected, we shall find that pumice was then one of the principal products; whereas it is now never found amongst the ejected masses at Vesuvius.

Now pumice has been shewn to be merely an altered condition of trachyte, and not to be derivable from felspars so poor in silica as labradorite, or anorthite. Moreover Mons. Dufrenoy has ascertained, that the lavas of Monte Somma are almost unattackable by acids, whilst in those of Vesuvius the proportion of the soluble to the insoluble part is in general about as four to one. The former contain a larger proportion of potass, whilst in the latter soda predominates.

It is also a well ascertained fact[y], although disputed in an English work of authority, that this volcano was formerly much more prolific in minerals, than it appears to be at present, very few at least out of the large number of species found within the range of Vesuvius existing in its

y For this I need not go further than the Guida de Napoli already quoted, the geological portion of which was contributed by professor Scacchi, a very accurate mineralogist, who has done a service to science, not only by the discovery of many new species at Vesuvius, but also by identifying several of those which Monticelli had created with substances previously discovered. From his enumeration of the minerals found about Vesuvius, it will be perceived that, with the exception of felspar, augite, hornblende and brieslakite, they all appear to be derived from the extinct volcano of Monte Somma.

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modern lavas, whilst they abound amongst the ejected masses imbedded in the tuff of Monte Somma.

Having now endeavoured to trace the particulars in which the processes of an igneous character going on at the present day differ from those which gave rise to the rocks commonly called plutonic, I will next briefly consider, which of the commonly received theories of volcanos is most reconcilable with the phenomena which have just been pointed out.

I may remark in the first place, that there are only two modes of explaining volcanic action, which deserve a moment's attention, when viewed by the lights of modern science.

One set of philosophers, inferring from the oblate spheroidal figure of the globe, that it was once in a state of fluidity from igneous fusion, and again, presuming, from the increasing temperature observed as we descend deeper and deeper into its recesses, that it may retain enough of its heat at the present time to be preserved in a state of fusion below certain depths, propose a very simple mode of explaining the evolution of melted matter from volcanos, by attributing it to the contraction of the crust of the globe upon its fluid contents, by which a portion of the latter is from time to time expressed at the points of least resistance.

Others, considering—that all the matters ejected from a volcano contain an inflammable base united with oxygen—that the latter need not be supposed to have been present in the interior of the earth

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in quantity sufficient to combine with all the principles for which it could exert an affinity—and therefore that these bases may without violence be supposed to exist in an unoxidised state at a certain distance from the surface—have proceeded to shew, that assuming such to be the fact, all the phenomena of volcanic action may be explained according to the received principles of chemistry, by the access, first of sea water, and afterwards of atmospheric air, to the interior of the globe.

For, granting that no other of the bases which enter into the composition of lava would inflame on the approach of water, the metals of the alkalies at least, which constitute sometimes as much as one tenth of the entire bulk of the ejected matter, would certainly do so, whence must result an evolution of hydrogen, and a generation of heat, sufficient to cause all the other bases present to unite with the oxygen presented to them.

But, without entering into a complete exposition of this theory, I think it must on all hands be admitted, that if its relative merits are to be decided by its capability of explaining the phenomena, it may fairly claim the preference over the rival hypothesis.

If indeed we assume, that the globe was once fluid, and take for granted, that it still retains a sufficiently high temperature to preserve its original fluidity in the interior (although the slight depth to which we have yet penetrated hardly justifies us in speaking decisively as to the state of things which may exist below a certain depth) there is even then but one phenomenon of volcanic action,

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which, so far as I know, can be fairly deduced from these premises—namely the protrusion in certain localities of melted matter from the surface. For the ejection of fragments of rocks, the evolution of steam, and the disengagement of various gaseous compounds, are phenomena of which this hypothesis seems to give no account. Nor does it seem clear, why the lines of least resistance should be found almost invariably near the sea, or why indeed they should occur at all underneath the bed of the ocean, where the controlling pressure must be even greater than in the midst of our continents.

Accordingly most of those persons who profess to hold to the theory of central heat, in reality combine with it some hypothesis into which chemical considerations enter.

They explain, for instance, the evolution of steam, and of muriatic acid, by the access of salt water to the spots where this melted matter is supposed to exist, by the chemical action of which the muriatic acid is separated from its base, and the water converted into steam.

By this addition to the theory we advance, indeed, one step towards the solution of the problem; but there will still, I conceive, be a difficulty in explaining other of the connected phenomena: such, for example, as the generation of ammonia, which so often is present amongst the products of a volcano; the evolution of air usually deprived of its oxygen, which bears witness to the existence of some processes of oxidation going on underneath; and above all, the escape of inflammable gases, into which hydrogen enters as a constituent.

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With regard to the first of these facts, the generation of ammonia cannot be disputed, although the amount formed by volcanic action may still remain a matter of surmise.

Those however, who, with Baron Liebig, deny, that gaseous nitrogen is capable on the surface of the earth of forming any direct combination either with oxygen, or with hydrogen, may be less inclined to condemn the hypothesis, with reference to this subject, which I have thrown out in a former publication[z], and which assumes, that the quantity so formed was once very considerable, as it traces to volcanic processes carried on in the interior of the globe all the ammonia which would be requisite for supplying the first plants with the nitrogen they must have contained; just as others have imagined all the carbon necessary for the primeval vegetation to have been derived from carbonic acid arising from the same internal source.

At least however even those who refuse to go with me up to this point, will admit, on the faith of the evidence which I have adduced, the second fact noticed, namely, the extrication of nitrogen gas, either pure, or with a small admixture of oxygen, from thermal springs in general; since amongst the whole extensive Catalogue of them[a], cited as having been personally examined by myself, in various parts, both of the Old and New World, scarcely one could be fixed upon which does

[z] Three Lectures on Agriculture, page 97.

[a] See, for those in the Old World, Report on mineral waters, Br. Associat. Reports for 1836, for those in the New, my Sketch of the Geology of N. America.

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not present this phenomenon, excepting indeed a few in the island of Ischia, the origin of which is manifestly nothing more than the rain water, which had collected in internal reservoirs at a small depth beneath the surface, and had then become heated by the rock still partaking of the high temperature it had acquired by recent volcanic operations.

And with respect to the last fact mentioned, it is one so inexplicable by the mere access of water to an incandescent body, already saturated with oxygen, such as lava, that the opponents of the chemical theory have no other resource than to deny its reality.

"If inflammable gases were present," they say, "they would burn on coming into contact with the air, and hence flames would be commonly seen issuing from the orifices of an active volcano.

"But the appearances which have been taken for flames turn out to be illusory, being due merely to the reflection of the light radiated from the red hot stones ejected, and not derived from gaseous matter in a state of combustion."

Now that flames should not be of ordinary occurrence in volcanos may be explained without much difficulty.

In the caverns and fissures through which the gases evolved had to pass before they reached the circumference of the earth, and escaped from the orifice of the volcano, they must often come into contact, either with oxygen, or with oxidized bodies from which they would be able to abstract the same principle. In both these cases the hydrogen would recombine with oxygen, and return to the focus of the volcano, as water.

But supposing oxygen gas to be absent, or not

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to exist in sufficient quantity to unite with all the inflammable matter evolved, the latter would in most cases be accompanied with such volumes of steam, as alone must prevent it from entering into combustion when it came into contact with the external air, for it is well known from the researches of Davy, that a certain percentage of any uninflammable gas, or vapour, prevents such bodies from taking fire.

It is therefore far more easy for the advocates of the chemical theory to account for the general *absence* of flames about the orifices of active volcanos, than for the supporters of the contrary hypothesis to explain their occasional *presence;* and that they are sometimes observable seems to be now ascertained, not only from the testimony of Sir H. Davy himself, who states that he observed at Vesuvius, during a small eruption, the existence of a real jet of flame, and that of Mons. Elie de Beaumont, who assures us of the same fact as witnessed by himself at Mount Etna, but more recently by the observations made by Professor Pilla of Pisa[b], who has given us a circumstantial account of three several occurrences of this kind in the years 1833 and 1834 at Vesuvius.

My own persuasion therefore is, that hydrogen gas, derived from the decomposition of water, most generally in combination with sulphur, is evolved in enormous quantities from all volcanos, but that a comparatively small proportion of it usually finds its

[b] See his "Discorso sopra la produzione delle fiamme nei Vulcani, &c." read at the 5th Italian Scientific Congress, held in 1843, and translated in Jameson's Journal for April, 1844.

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way upwards to the surface; since if sulphurous acid be present likewise, the two gases will decompose each other, so that only the excess of the one most abundant will remain, and if it meet with oxygen in its progress upwards, it will combine with this principle, and water will consequently result.

Nevertheless I hold, that the sulphuretted hydrogen which impregnates the mineral waters, in various ignigenous, and even in certain primary districts, is derived from some volcanic *focus;* I am inclined to believe, that the beds of sulphur met with in various parts of the world, where igneous agents have been at work, as in Sicily, owe their origin to the decomposition of sulphuretted hydrogen disengaged from the same source; and conclude therefore, that it is not unfrequently evolved from the orifices of volcanos, although for the most part prevented from inflaming by the large intermixture of aqueous vapour which usually accompanies it.

But without entering at this advanced period of the evening into a general discussion of the question, I will merely point out to you, how completely this theory squares with the manner, in which I have shewn the several products of volcanic action to be successively produced from the constituents of granite.

We have seen that these changes of form and structure have been produced by the addition of lime, magnesia, potass, soda, oxide of iron, water, &c. to the mica, quartz, and felspar, present in the original material.

Now it is evident that, besides the water, only one of these bodies, namely the soda, could have been

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supplied in sufficient quantities by the sea; the access of which to the focus of the volcano there are so many reasons for supposing an immediately exciting cause of the operations we witness. Is it not therefore reasonable to suppose the other constituents to have existed in their unoxidised state below, and thus to have contributed by their oxidation to the high temperature, as well as to the generation of those inflammable gases which arise during the process?

Again, it is not an unimportant circumstance to remark, that the iron found in lavas and in trap is usually magnetic, or partly in the state of protoxide; whilst in granite it exists wholly as a peroxide. May not the partial change from peroxide to protoxide be brought about by the action of the hydrogen disengaged, and does not the presence of protoxide of iron sufficiently explain, why none of the more oxidisable metals are ever found in lava, except saturated with oxygen[c]?

These considerations, if they do not persuade you of the truth of my hypothesis, may at least plead my excuse for having ventured to maintain it, even though it be one which seems to have been repudiated by Sir H. Davy, and which a geologist of reputation once, I think, stigmatized, by designating it as *smelling of the laboratory*.

c This is alleged by Dr. John Davy, as a circumstance which operated on his brother's mind in inducing him towards the close of his life to abandon the chemical theory. I cannot, however, agree with him in thinking, that the presence of potassium, sodium, or even calcium, amongst the ejections of a volcano, ought to be expected according to the conditions of this hypothesis.

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With respect to the former ground of discouragement, I have already given my reasons for not regarding it as absolutely fatal; and with respect to the latter, as we all, I hope, in the 19th century, are aware, that modern Chemistry is not confined within the limits of the apothecary's shop, I consider it the highest testimony in favour of any geological theory, to be able to say of it, that it has been submitted to the severe ordeal of chemical examination, and has not been found wanting[d].

In conclusion then, I will remark, that my three visits to Naples have afforded me the materials for laying before you, on this and on two former occasions, a sketch of the phenomena presented by the three great volcanic systems which exist within the compass of that territory, and thereby, as it so happens, exhibiting a picture of three different phases or conditions of igneous action, exemplified in the three localities which I have successively brought to your notice, namely in the country im-

[d] On this subject however it behoves me to speak with some diffidence, when I see the contrary maintained by so eminent a chemist as Professor Bischof of Bonn. All I can say is, that the objections he had originally put forth to this hypothesis have been answered, in a manner which to my mind at least appeared satisfactory, in Jameson's Journal for April, 1839. The Professor however having, in his memoir on the Natural History of Volcanos and Earthquakes published in the very same number of that Journal, reiterated some of these, and added a few other remarks, I will refer to the Appendix for a statement of the grounds on which I conceive my original views to remain still unshaken; although it may be suggested, that the Professor's remarks referred to must, from their date, have been written, before he could have seen my reply to his original memoir. *See Appendix.*

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mediately round about Vesuvius, at Mount Vultur, and at Rocca Monfina.

The first of these localities exhibits no doubt the most striking, the most varied, and perhaps altogether the most instructive series of phenomena; inasmuch as it has constituted a permanent vent for the products of the chemical actions going on in the interior of the globe, ever since the cessation of those kindred phenomena which we read of as having been displayed formerly within the compass of the Phlegrean Fields, and which had rendered that district an object of terror to the early Greeks, invested their inhabitants the Cimmerians with a kind of vague and mysterious awe, and led the poets to place the entrance to the infernal regions amongst their caves and forests.

But our knowledge of the subject would be incomplete, if we did not extend our observation to such mountains as Mount Vultur and Rocca Monfina.

In the former of these we perceive a volcano which was extinguished, as it were, by the very throes that accompanied its birth; for the volcanic energy which heaved up the materials of which the mountain is composed, and produced a crater in the midst of it, seems to have been expended in that very effort, and never afterwards to have exhibited any signs of vitality, either by emitting streams of lava or ejections of scoriæ.

It is an example therefore of a simple crater of elevation, not converted, like Vesuvius, into a permanent volcano, by having become the vent for

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successive eruptions of igneous matter at any period subsequent to its formation.

In Rocca Monfina on the other hand, we are enabled to observe the precise agents which Nature calls into operation for the purpose of elevating volcanic hills in general, whether the latter be destined to remain merely as monuments of what she has accomplished at a distant period of time, or to serve likewise in after-ages as chimneys for her subterranean laboratory, the trachytic rock of Monte della Croce being here seen actually protruding through the crater, in the centre of the mountain, which it has no doubt contributed to upraise.

Rocca Monfina also appears to have given off one, if not two streams of lava, but the volcanic processes would seem to have soon been transferred to some other quarter, as from a period long antecedent to historical records, it has sunk into complete inactivity.

Thus we observe in these three mountains three successive developments of volcanic activity, evinced,

1st, in the elevation of an entire mountain,

2nd, in this elevation being accompanied by the protrusion of a trachytic rock through its centre,

3rdly, in the elevation of a mountain being followed, after a long interval of apparent tranquillity, by the establishment of a permanent vent, through which lavas, fragments of rocks, and elastic vapours, continue from time to time to be discharged.

All these however are derived from subaëreal volcanos, having been formed on dry land, under no

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greater pressure than that of the atmosphere, and are consequently of later date than the beds of tuff which are spread on all sides around them, the latter being products of the action of volcanos which existed when the country was yet under the bed of the Mediterranean, and consequently being modified in their characters and structure, by admixture with the sea water in which they appear to have been deposited.

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APPENDIX I.

Rammelsberg's Classification

	Definition of the Classes.	Symbols representing the Classes.	Subclasses.
1st. Class	Silica alone	$\dddot{Si}$	without water with water
2nd. —	Silica united with a single Base, having 1 Atom of Oxygen	$\dddot{Si}\,\dot{R}$	without water with water
3rd. —	Silica united with a single Base, having $1\frac{1}{2}$ Atoms of Oxygen ..	$\dddot{Si}\,\underline{\dddot{R}}$	without water with water
4th. —	Silica united with several Bases, all with 1 Atom of Oxygen....	$\dddot{Si}\,\dot{R}+\dddot{Si}\,\dot{R}$	without water with water
5th. —	Silica united with several Bases, all with $1\frac{1}{2}$ Atoms of Oxygen ..	$\dddot{Si}\,\underline{\dddot{R}}+\dddot{Si}\,\underline{\dddot{R}}$	without water with water
*6th. —	Silica united with several Bases, both with 1 and $1\frac{1}{2}$ Atoms of Oxygen....................	$\dddot{Si}\,\dot{R}+\dddot{Si}\,\underline{\dddot{R}}$	without water without water with water with water
7th. —	Silicates united with Aluminates	$\dddot{Si}\,\dot{R}+\underline{\dddot{Al}}\,\dot{R}$	....
8th. —	Silicates united with other salts ..	....	with Sulphates with Fluorides with Borates

* As the minerals comprehended under this Class are numerous, the Subclasses are again subdivided according to the proportion which the Silica in each of the two binary compounds of which the mineral consists, bears to the bases with which it is united.

Thus the Subclass without water is divided as follows :

1st. Division. Both Silicates neutral—example Albite.
2nd. ——— One Silicate neutral ; with one $\frac{2}{3}$—example Spodumene.
3rd. ——— One Silicate neutral ; with one $\frac{1}{3}$—example Ryakolite.

page 27.

f Siliceous Minerals.

Examples of the Class and Subclass.	Symbol of the Mineral.
Quartz	$\overset{\cdots}{Si}$
Opal	$\overset{\cdots}{Si} + \dot{H}$
Tablespar	$\dot{Ca}^3\ \overset{\cdots}{Si}^2$
Meerschaum	$\dot{Mg}\ \overset{\cdots}{Si} + \dot{H}$
Cyanite	$\underline{\overset{\cdots}{Al}}^2\ \overset{\cdots}{Si}$
Kaolin	$\underline{\overset{\cdots}{Al}}^3\ \overset{\cdots}{Si}^4 + 6\dot{H}$
Augite	$\dot{R}^3$ (viz. $\dot{Ca}$; $\dot{Mg}$; $\dot{Fe}$; $\dot{Mn}$) $\overset{\cdots}{Si}^2$
Apophyllite	$\dot{R}^3\ \overset{\cdots}{Si}^4 + 6\dot{H}$
Beryl	$\overset{\cdots}{Be}\ \overset{\cdots}{Si}^4 + 2\underline{\overset{\cdots}{Al}}\ \overset{\cdots}{Si}^2$
Bole	$\overset{\cdots}{R}^2$ ($\underline{\overset{\cdots}{Al}}$; $\underline{\overset{\cdots}{Fe}}$) $\overset{\cdots}{Si}^3 + 9\dot{H}$
elspar	$\dot{R}$ ($\dot{K}$; $\dot{Na}$) $\overset{\cdots}{Si} + \underline{\overset{\cdots}{Al}}\ \overset{\cdots}{Si}^2$
arnet	$\dot{R}^3$ ($\dot{Ca}$; $\dot{Mg}$; $\dot{Fe}$; $\dot{Mn}$) $\overset{\cdots}{Si} + \underline{\overset{\cdots}{R}}$ ($\underline{\overset{\cdots}{Al}}$; $\underline{\overset{\cdots}{Fe}}$; $\underline{\overset{\cdots}{Mn}}$) $\overset{\cdots}{Si}$
esotype	$\dot{R}$ ($\dot{Ca}$; $\dot{Na}$) $\overset{\cdots}{Si} + \underline{\overset{\cdots}{Al}}\ \overset{\cdots}{Si} + 3\dot{H}$
ross-Stone	$2\dot{R}^3$ ($\dot{Ba}$; $\dot{K}$) $\overset{\cdots}{Si}^4 + 7\underline{\overset{\cdots}{Al}}\ \overset{\cdots}{Si}^2 + 36\dot{H}$
renatite	$3\underline{\overset{\cdots}{Al}}\ \overset{\cdots}{Si} + \dot{Fe}^3\ \overset{\cdots}{Al}^2$
auyne	$Ca^3\ \overset{\cdots}{Si}^2 + 3\underline{\overset{\cdots}{Al}}\ \overset{\cdots}{Si} + 2\dot{K}\ \overset{\cdots}{S}$
epidolite	$4\underline{\overset{\cdots}{Al}}\ \overset{\cdots}{Si}^2 + K\ Fl^2 + 2Li\ Fl$
ourmaline	$\dot{R}\ \overset{\cdots}{B} + \underline{\overset{\cdots}{Al}}\ \overset{\cdots}{Si}$

h. Division. Both Silicates $\frac{2}{3}$—example Leucite.
h. ——— One Silicate $\frac{2}{3}$; one $\frac{1}{3}$—example Scapolite.
h. ——— Both Silicates $\frac{1}{3}$—example Epidote.
h. ——— One Silicate $\frac{1}{3}$; one $\frac{1}{6}$—example Lievrite.
h. ——— One Silicate $\frac{1}{2}$; one $\frac{1}{3}$—example Nepheline.
h. ——— Both Silicates $\frac{4}{3}$—example Petalite.
th. ——— One Silicate $\frac{4}{3}$; one $\frac{1}{3}$—example Murchisonite.

The same is the case with the Subclass containing water.

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APPENDIX II. to page 34.

Abich's Observations on the formation of Obsidian and Pumice.

The mode in which pumice and obsidian have been formed can only be cleared up, through a more exact scrutiny into the nature of the volatile materials which both these bodies in greater or less quantity contain. Humboldt and others have remarked upon the swelling out which certain obsidians undergo at a white heat, and have found a great difference in this respect to exist between specimens taken from different localities.—Abich has further ascertained, that the poorer in silica, and the richer in alkaline bases obsidian is, the more in short its composition approaches to clinkstone, the more readily it may be made to pass by heat into the condition of pumice.

It being admitted, that the immediate cause of the change is the extrication of some volatile principle, the nature of this latter becomes the next subject for inquiry.

Abich found, that in order that the mineral should swell out into a porous mass, it must be submitted to heat in lumps; for if it be in powder, it does not undergo any such tumefaction by exposure to a high temperature, but only changes to a dark red or brown colour; losing during the process twice as much weight as the same had done in lumps; from which it would appear, that only a portion of the volatile ingredients which escape from the powder is in the former case disengaged.

By comparing the analysis of obsidians with that of pumices obtained from the same locality, it would appear, that although the sum of the alkaline bases is in both very nearly the same, yet that there is more potass in obsidian, more soda in pumice, the increase in the one alkali corresponding with the deficiency in the other.

This might lead one to conjecture, that during the formation of pumice a certain amount of potass was dissipated, and a proportionate quantity of soda introduced

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from without, and that from the disengagement of the former, the cellular condition of the mineral might have resulted.

It will be readily supposed, that both obsidians and pumices are often very widely different one from the other in their constitution, and that of the latter the darker and more cellular varieties may arise from a predominance of earthy and alkaline bases, the white and silky looking kind from a larger amount of silica.

When felspathic rocks, rich in alkali, pass into a state of fusion in the presence of some earthy base, the latter displaces a portion of the alkali, and thus causes the mass to swell out.

It is worthy of remark, that chlorine and water are present in all pumices and obsidians, and that from many, certain inflammable gases are also disengaged. This latter fact indeed has led some chemists to imagine, that the cellularity of pumice may have been caused by the disengagement of carburetted hydrogen, derived from the bitumen which Knox discovered in certain obsidians; but this cannot be the case, as the presence of bitumen is an exception rather than the rule. It is more probable, that the formation of pumice is connected with the disengagement of chlorine, derived from sea salt, which may be decomposed by the heat, its soda being seized upon by the mineral, and entering, as before explained, into its composition.——A portion of this chlorine however adheres most tenaciously to the mineral mass, as is proved by the fusion of pumice into glass, as even then it retains a portion of this volatile ingredient. With respect to obsidian, Abich conceives, that the greater and more continued the pressure to which the melted material has been subjected may be, the greater tendency will be shewn by the mass, both to assume a stony rather than a vitreous texture, and to form definite and distinct minerals, rather than one homogeneous amorphous compound.. Hence from the same material lithoide lavas may be produced under pressure, vitreous ones in the open air.

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APPENDIX III. to page 46.

On the Chemical Theory of Volcanos.

Professor Bischof justly observes, "that the close connexion between volcanos and hot springs would lead us to refer both to the same cause." "But," he continues, "thermal springs are too universally distributed to be accounted for by chemical processes going on in the interior of the globe. They seem to occur everywhere where the water rises from a great depth. They must therefore be attributed merely to the high temperature which generally pervades the interior of the globe."

To this I would reply, that no one questions that the high temperature of a spring is acquired immediately from that of the rock from whence it proceeds, or supposes the rock, when it lies at a distance from any volcano, to derive its heat from chemical processes taking place within itself. From a mineral mass so circumstanced, as well as from a water simply thermal, we can collect nothing which should lead us to give the preference to either theory; it is only from analogy, that the heat either of the one or of the other can be explained. But more commonly hot springs, like volcanic eruptions, are accompanied with other products, which seem to imply the existence of chemical action—hot springs, for instance, with carbonic acid, sulphuretted hydrogen, and azote—ejections of lava, with steam, muriatic acid, sulphuretted hydrogen, and ammonia. The carbonic acid indeed might be evolved from limestone by the mere access of heat, but I cannot agree with Professor Bischof in attributing the sulphuretted hydrogen to a decomposition of sulphates by organic matter. Sulphuric salts do not occur in the majority of these springs, and the small quantity of baregine there existing (the only organic matter which is present) appears to be generated after the water has

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reached the surface. Neither can the almost constant escape of azotic gas be accounted for, without supposing some process of oxygenation to be going on in the interior.

Now these springs usually make their appearance, where other evidence of volcanic action is exhibited, in the dislocation and elevation of the surrounding strata, and the latter phenomena occur so extensively over the earth's surface, that volcanic operations, if assumed to be their cause, may have been widely enough distributed to produce a general increase of temperature throughout that zone in the interior of the globe in which they are carried on. What may be the condition of the earth lower than this we surely have no data for ascertaining, for it is evident, that if this supposed zone lie below the level which mining operations have ever reached, it would itself elevate the temperature of all those portions of the earth's crust of which we have any actual cognizance.

I am however unwilling to dogmatise, either with respect to the general cause of the internal heat of the globe, or the limits to which this heat may be confined.

All I have ever sought to prove is, that, be the existence of a central heat ever so well established, its assumption does not advance us towards the explanation of the phenomena, either of volcanos, or of thermal springs in general, and that a process of oxidation is going on, often with intense energy, in the interior of the globe, of a different nature from that usually occurring on the surface, as being attended with an evolution of hydrogen gas, a phenomenon which can be most readily explained by the decomposition of water, through the action of the metals of the earths and alkalies upon that liquid.

I would finally remark, that Professor Bischof will find his objection to the supposed existence of these bases in the interior of the globe arising from their low specific gravity, answered by anticipation in my Reply to his former Paper, as I have there shewn, that the specific gravity of one hundred parts of the metallic principles

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present in a mass of ordinary lava, would be quite as considerable as that of the same amount of these same bodies united with oxygen, so that the difficulty, be it small or great, which attends the fact of the high specific gravity of the globe, as compared with that of the materials composing its surface, is the same to those who reject my hypothesis, as to those who embrace it.

Lest however it should be imagined, that I have attached an undue weight to this theory, or have done more than to advocate it as the most plausible account that can at present be given of the facts before us, I will in conclusion extract the remarks which I made nearly ten years ago, in my Report on Mineral and Thermal Springs, undertaken at the request of the British Association.

"We ought carefully to distinguish between that which appears to be a direct inference from observed facts, and what at most can advance no higher claim than that of being a plausible conjecture. The general occurrence of volcanos in the neighbourhood of the sea, and the constant disengagement of aqueous vapour and of sea salt from their interior, are facts, which establish in my mind a conviction, that water finds its way to the seat of the igneous operations, almost as complete, as if I were myself an eyewitness of another Phlegethon discharging itself into the bowels of the earth, in every volcanic district, as in the solitary case of Cephalonia.

Nor is the access of atmospheric air to volcanos more questionable than that of water; so that the appearance of hydrogen united with sulphur, and of nitrogen, either alone or combined with hydrogen, at the mouth of the volcano, seems a direct proof, that oxygen has been abstracted by some process or other from both.

Having satisfied our minds with regard to the fact of internal oxidation, we naturally turn to consider, what principles can have existed in the interior of the earth, capable of abstracting oxygen from water as well as from

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air; and this leads us to speculate on the bases of the earths and alkalies as having caused it. But in ascribing the phenomena to the oxidation of these bodies, we ought not to lose sight of the Baconian maxim, that in every well established theory, the cause assigned should be, not only competent to explain the phenomena, but also known to have a real existence, which latter circumstance cannot of course be affirmed of the alkaline and earthy metalloids as occurring in the interior of the earth."

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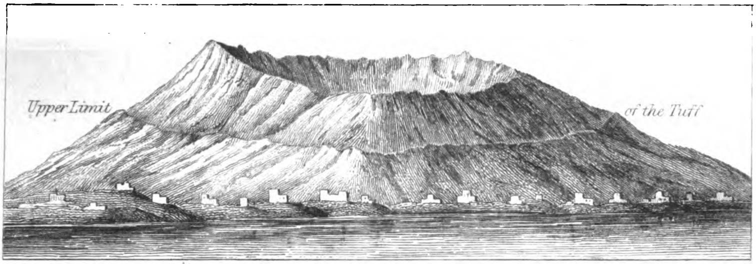
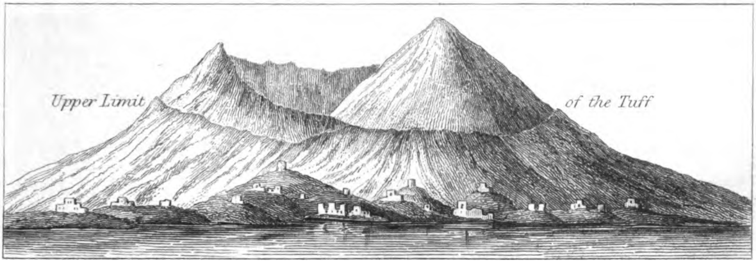
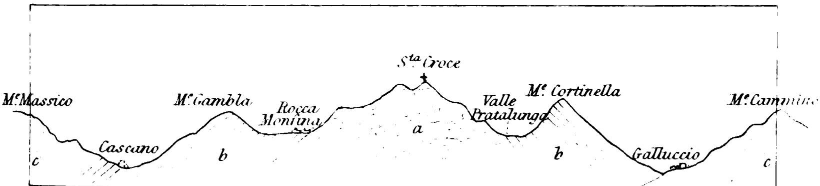


Vesuvius, or Somma, according to Strabo.

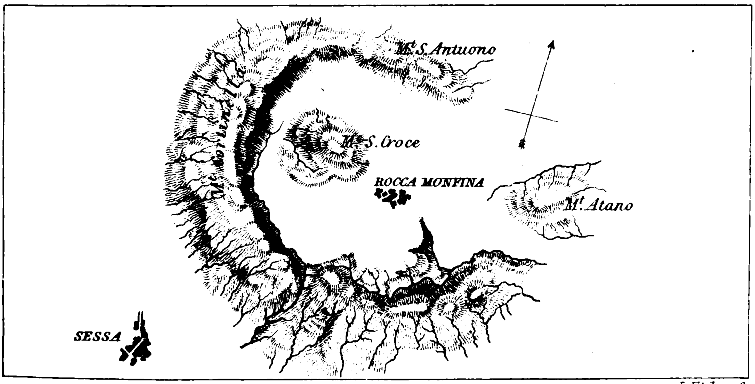


Somma and Vesuvius after the time of Pliny.



a. Trachyte. b. Tuff. c. Appenine Limestone.

Section of Rocca Monfina.



J. Fisher fc.

Ground Plan of Rocca Monfina.

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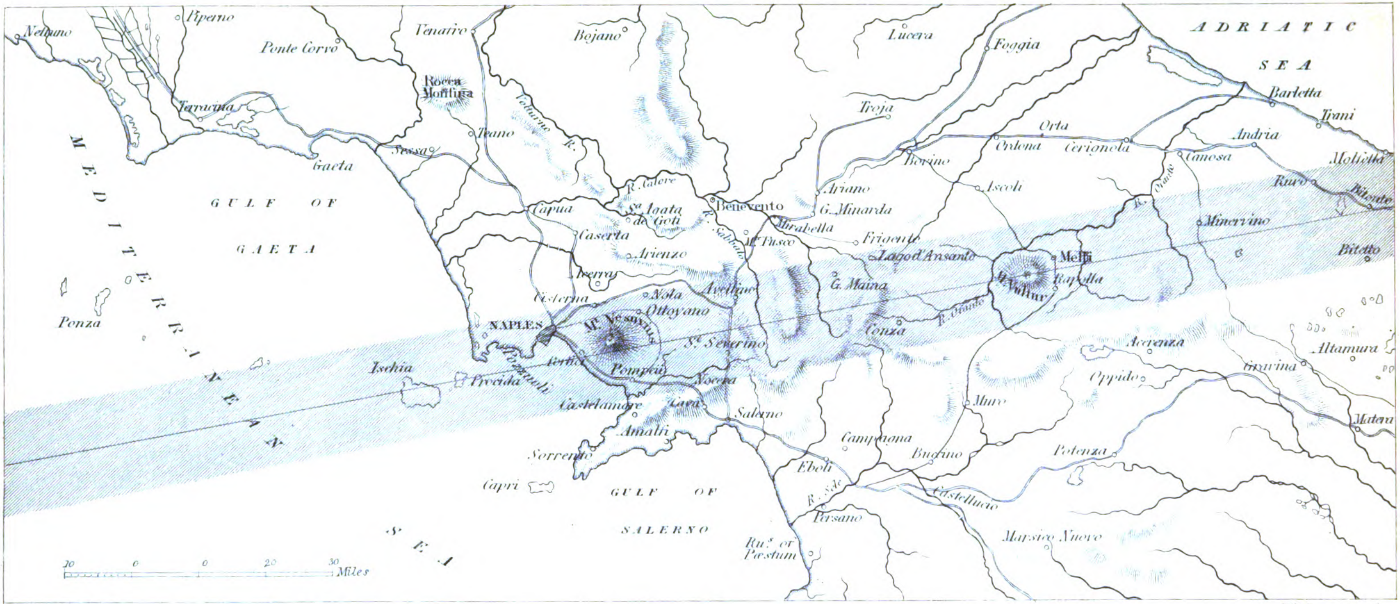

J.W. Lowry sculp.

MAP OF A PORTION OF THE KINGDOM OF NAPLES.

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