(27.)

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THE MECHANISM OF STROMBOLI.

By G. POULETT SCROPE, F.R.S., F.G.S.

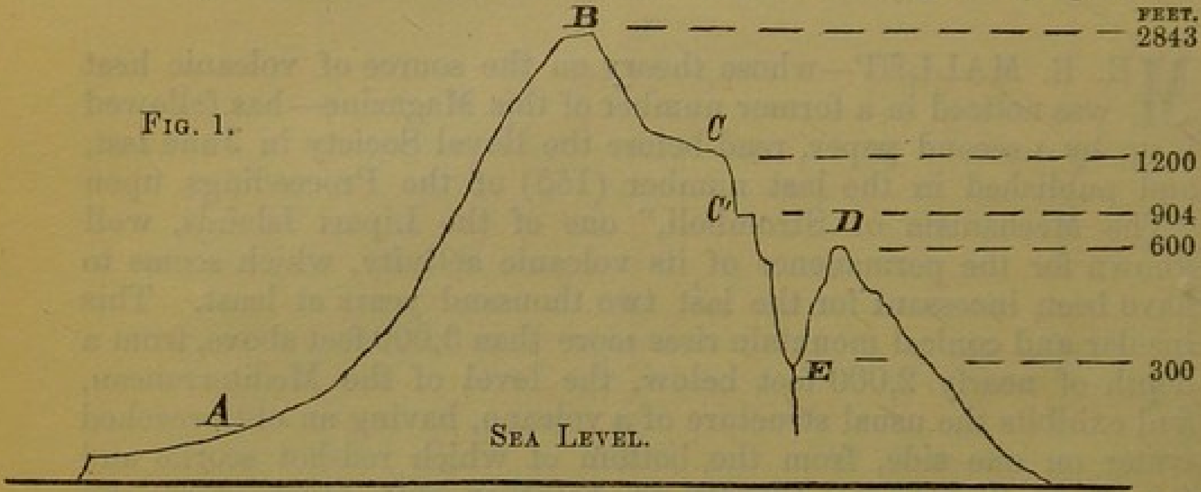
MR. R. MALLET—whose theory on the source of volcanic heat was noticed in a former number of this Magazine—has followed it up by a second paper, read before the Royal Society in June last, and published in the last number (155) of the Proceedings, upon "The Mechanism of Stromboli," one of the Lipari Islands, well known for the permanence of its volcanic activity, which seems to have been incessant for the last two thousand years at least. This insular and conical mountain rises more than 3,000 feet above, from a depth of nearly 2,000 feet below, the level of the Mediterranean, and exhibits the usual structure of a volcano, having an old breached crater on one side, from the bottom of which red-hot scoriæ and fragments of lava are thrown up, together with much steam, by explosions occurring at irregular intervals of from two or three to thirty or even occasionally forty minutes.

Stromboli has been visited and its phenomena described, with the most careful and precise accuracy, by many geologists of the highest eminence, whose descriptions Mr. Mallet, *more suo*, dismisses contemptuously, as neither full nor accurate (p. 497). To any one, however, acquainted with the history of Geological Science, especially of that portion of it which deals with the phenomena of volcanic action, the names of the distinguished observers given below will be a sufficient guarantee for the value and truthfulness of their accounts. And a reference to their writings will show how clearly and conscientiously these accounts are given.[1]

[1] 1768. Sir W. Hamilton with Signor Fabris.
1766–81. Stromboli seen twice by Dolomieu.
1781. 19th and 20th July, ascent by Dolomieu.
1788. 20th of August, 1st and 4th October, Spallanzani.
1810. Francesco Ferrara.
1813. Several visits by Admiral Smyth.
1819. May, G. Poulett Scrope.
1824. Dr. Daubeny.
1825. M. Biot.
1829. M. Virlet and the Members of the Commission visiting the Morea.
1831. M. Constant Prevost.
1831(?–2). Friedrich Hoffmann studied Stromboli during three weeks. Three ascents, December 21st, etc.
1836. 24th and 25th July. H. Abich collected and examined its products.
1844. June. MM. de Quatrefages, Edwards and Blanchard.
1855. May, June, and October, } M. Charles Ste.-Claire Deville.
1856. July, }
1866. M. Fouqué.
1867. M. Jansenn. 1870. Dr. Julius Schmidt.

Mr. Mallet's own observations are obscured by a singular amount of incorrectness in the measurements given by him as taken with the aneroid, which not only err to the extent of more than a hundred per cent., but are also wholly inconsistent with the sectional diagrams by which the text is illustrated. Lest I should be supposed rashly to dispute Mr. Mallet's professional ability in the measurement of heights and the construction of diagrams, I annex an accurate copy of his principal diagram representing the island, with the heights as given by him in the text placed alongside (Fig. 1).

Fig. 1.



A glance at this figure is sufficient to show that, if Mr. Mallet's estimate of the extreme height of the mountain, viz. 2,843 feet, be correct (the English and French Admiralty Charts, however, give it at 3,090 feet), all the other heights in the diagram *must* be at least 1,000 feet below the truth;—the point C, for example, being visibly about three-fourths of the whole height of the mountain, and therefore about 2,143 feet, instead of 1,200, which Mr. Mallet says he found it. All the lower points are in error to the same amount or more. Mr. Mallet's diagram, however, is not so far wrong as the measurements given in his text, since the best authorities concur in stating the height from the sea of the upper lip of the crater (C in the diagram) as about 2,200 feet, instead of 1,200 only, which Mr. Mallet assigns to it. It might be supposed that the several heights given in the text are, by a typographical error, made 1,000 feet less than the author intended. But this is inadmissible, not only on account of their number, but because (as will be shortly shown) Mr. Mallet's whole theory hangs upon the proximity of the bottom of the crater, marked E, to the sea-level, estimated by him as only 300 feet in vertical distance, whereas in fact it is nearly if not quite 2,000!

In correction of these errors of Mr. Mallet, I give the following from the highest authorities:—

Extreme Height of the Mountain.

By French Admiralty Chart (Dumondeau)	942 mètres	(= 3,090 feet).
By English Admiralty Chart...		3,090 feet.
By Italian Government Map...	921 mètres	(= 3,022 feet).
By Hoffmann (Barometrical measurement) confirmed by Abich	2,775 German feet	(= 2,853 English feet).

The latter measurement agrees, it will be seen, very closely with that of Mr. Mallet; not so the following, which is far more important, having a direct bearing upon the structure of the mountain, and especially on Mr. Mallet's theory of its phenomena.

HEIGHT OF THE LIP OF THE CRATER (presumably Mr. Mallet's point C in Diagram).

Hoffmann (by Barometrical measurement) 600 feet below the summit	= 2,253 feet above the sea.
Abich (from repeated measurements) 2,178 German feet ...	= 2,239 English feet.
(Mallet, by aneroid measurement and estimate	1,200 feet !)

Taking then 2,245 feet (the mean of MM. Hoffmann and Abich's figures) as the true height of C in Mr. Mallet's Diagram, and admitting his own estimate of 600 feet as the vertical difference between C and D, it is seen that the height of the latter point cannot be less than 1,650 feet, instead of 600, which Mr. Mallet makes it. While, if we accept the measurement of the several Government Charts for the summit of the mountain, 245 feet must be added to 1,650, making about 1,900 as the true height of D from the sea.

The relative heights of the summit and lowest crater rim (D in Diagram) are seen in the drawings attached to the English and French Admiralty Charts, in that of Abich (copied in Woodcut, Fig. 2), that of Sir W. Hamilton, of myself, and in every other published drawing of the island, as well as by several taken by my friend Mr. J. W. Judd, F.G.S., in the spring of this year, to be in proportion of about 3 to 2.

Indeed it is difficult to understand how Mr. Mallet himself can have seen the island from the sea at any distance on the north side, without perceiving this.

These gross errors of height-measurements make the following passage from Mr. Mallet's paper more remarkable (p. 502) :

"The statements which have been" (hitherto) "made as to the relative heights of the different points of the island appear to be only derived from guess, and are greatly in error."

I might add, that Mr. Mallet seems incapable even of reading correctly the measurements given by others ; since he expressly says in reference to the depth of water immediately beneath the crater-slope (p. 509) :

"The Admiralty Charts indicate that for some miles in the offing here, the Mediterranean does not exceed 100 fathoms in depth."

I have, however, the Admiralty Chart before me, which gives soundings at more than one point within half a mile of the base of the crater-slope of 258 fathoms ; which the French Admiralty Charts confirm, giving 480 mètres, at a little distance from the same base.

Mr. Mallet visited Stromboli in 1864. He was unfortunate, it seems, in the state of the atmosphere on the occasion of his visit, and was consequently unable to see to the bottom of the crater, through the clouds of vapour that filled it. He witnessed, however, as every other visitor had done, a series of intermittent explosions, throwing up red-hot scoriæ, bombs, and fragments of lava, together with steam, from what was evidently the crater of a volcano. And now, after ten years of mature deliberation, he has brought forward a theory to account for these explosions, which has at least the merit of novelty. He seems, indeed, to have formed his opinion, without the slightest reference to the *modus operandi* of other active volcanos, and without inquiring whether in any, or if so, in what respects the phenomena of Stromboli differ from those of an ordinary volcanic vent.

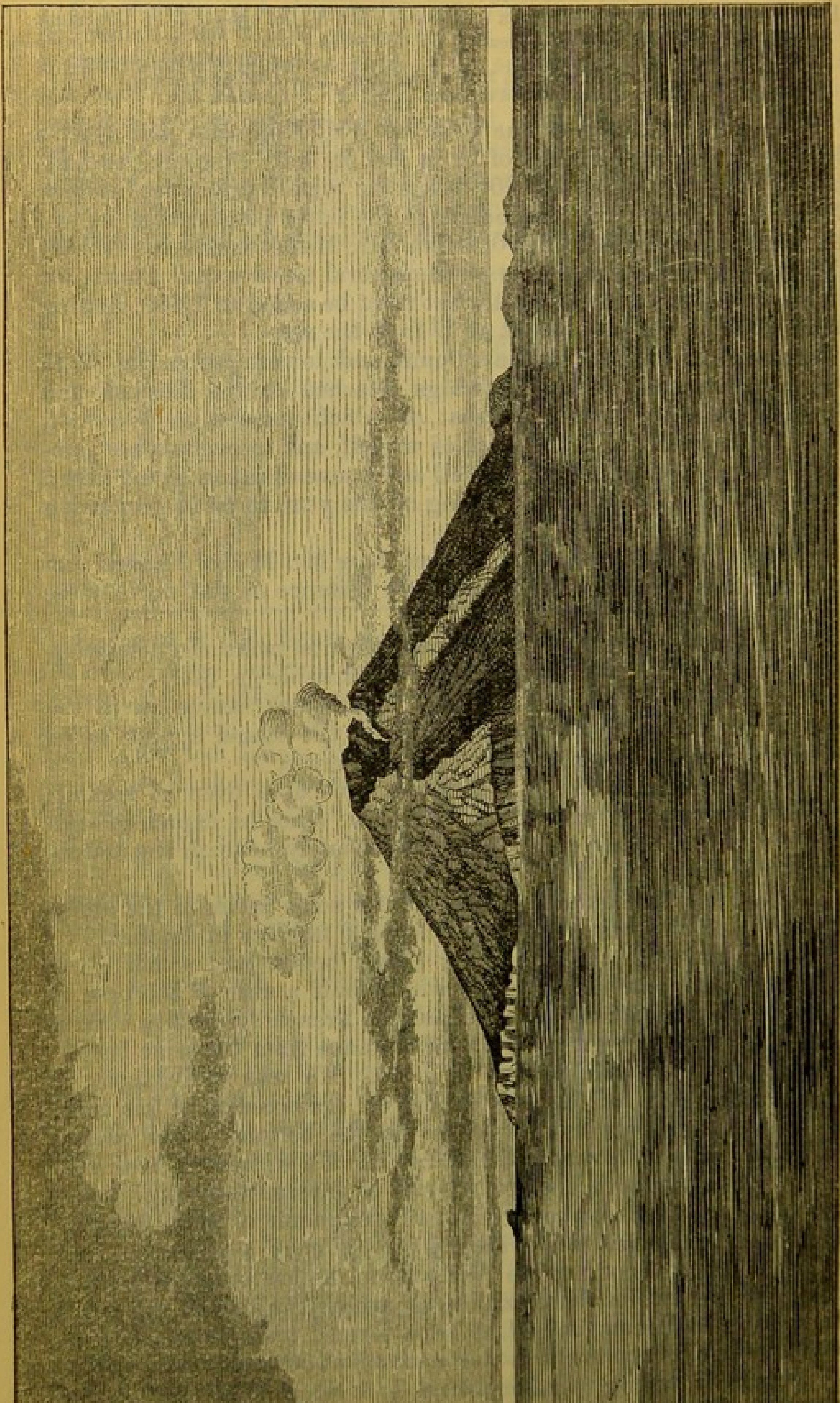


FIG. 2.—STROMBOLI VIEWED FROM THE NORTH (*after Abich*).

In reality, there is positively nothing in the recurrent explosions of Stromboli essentially different (as I shall presently show by ample testimony) from the similarly recurrent outbursts of any ordinary volcano during prolonged eruptions of moderate violence. There is, therefore, no call for any extraordinary explanation of these "rhythmical" outbursts in this particular case. And if Mr. Mallet, instead of setting his imagination to work upon the possible cause of their more or less regular occurrence, had adopted the humbler but more legitimate course of inquiring whether Stromboli stands alone in this respect, or whether other volcanos do not exhibit at times phenomena exactly similar—though rarely continuing for so long a time—he might have seen it to be quite unnecessary to invent a peculiar "mechanism" for Stromboli, unless, indeed, he means to apply it to all other volcanos likewise, which he has not gone the length of doing yet.

Mr. Mallet's theory is, that this celebrated island, which has hitherto been considered by all geologists as a typical volcano, is no volcano at all—at least, not of the usual igneous type—but a geyser, or intermittent fountain of boiling water, which, by some extraordinary chance, is situated at the bottom of a crater immediately beneath the mass of white-hot and liquid lava, which here, as in other volcanic craters when in activity, occupies that position, and is consequently tossed up into the air, in the shape of scoriæ, etc., at each outburst of the water. The tube of the supposed geyser is represented as occupying the place of the axial chimney of the volcano, and as alternately filled and emptied by the rise and escape from its mouth of a jet of boiling water and steam derived from some ducts or channels beneath the sea-level. The lava, which even Mr. Mallet cannot dispense with, since its projection into the air is the most obvious of all the phenomena, is supposed by him to flow to the mouth of the tube through lateral ducts from some undefined quarter, and the steam to be derived from a third kind of duct at a still greater depth below the sea than that which produces the water (page 512, Diag. 4). I submit that such a fortuitous concurrence of water, steam, and lava, proceeding from different sources or ducts, is a complicated and wholly imaginary supposition, without example, and unsupported by any facts or reasoning of the slightest value. Such an hypothesis could hardly have been expected of Mr. Mallet, who, in page 500 of his paper, justly says, "It may be taken as certain that in explaining all natural phenomena, the simplest explanation is the true one."

The simplest explanation of the phenomena of Stromboli would be to refer them to the ordinary mode of action of other volcanos. And certainly Mr. Mallet does not give any adequate, or even plausible, grounds for ascribing them to any different and extraordinary "mechanism." Mr. Mallet, I may remark, does not venture to say that he saw any column of water, like that of a geyser, thrown up from the crater's bottom, nor that any one else had ever witnessed such a sight. He admits that he could not see the bottom of the crater, owing to the clouds of vapour that obscured it, nor could he form a guess as to its depth, nor as to what was going on there, except from the detonations he heard, and the jets of red-hot stones, accompanied with steam, which pierced these clouds at each outburst. But other observers, especially Spallanzani in 1788, Hoffmann in 1831, and myself in 1819, were more fortunate, and saw at the bottom of the crater nothing in any respects resembling a geyser, but an orifice some seven or eight yards wide, full to the brim of seething white-hot lava, which swelled up from time to time in a dome-like form, and then fell again by some few feet below the mouth of the orifice, after giving issue to a burst of vapour mingled with scoriæ. That in its normal condition the throat of the volcano is so filled with fluid lava almost to the brim, is conclusively proved by the strong light reflected from the vapour-cloud above at every outburst of the red-hot scoriæ, which is seen nightly in the offing, and renders Stromboli a valuable lighthouse to mariners. This is, in fact, the ordinary condition of every volcano when in eruption. Such, for example, were the phenomena presented by the crater of Vesuvius on several occasions, as described by Deville, Roth, Abich, and other trustworthy observers.

The utter improbability of a geyser occupying the axial chimney of a volcano in more or less active igneous eruption, never seems to have occurred to Mr. Mallet's mind. Is it then a geyser that from the beginning has thrown up the volcanic agglomerates and lavas of which the island is wholly composed? Was it the geyser that blew away one large segment of the mountain, and formed the great breached crater? Or does the existence of the geyser only date from that paroxysmal eruption, when the present phase of moderate or sluggish eruptive activity probably began? Geysers occur in considerable numbers in Iceland, New Zealand, and other volcanic districts. But who ever saw one in the crater of a volcano, or throwing up red-hot lava? The geysers of Iceland are found in numbers close together upon a slightly raised platform in a valley —evidently the surface of a deep bed of lava which has flowed from Hecla, or some neighbouring volcano—the internal heat of which lava is still sufficient to produce the phenomena. The Great Geyser is about 70 feet deep. But if we correct Mr. Mallet's measurements of heights to make them agree with the truth, we shall find the depth of his imagined geyser tube from its mouth at the bottom of the crater to the sea, to be not 300 feet, as he represents it, but near 2,000. And this prodigious tube we are called on to believe is filled with hot water, and emptied again to the bottom at every explosion (p. 511). But, again, what is to prevent the heavy liquid lava, together with the fragmentary matter that falls or rolls to the bottom of the crater after each outburst, from entering the open mouth of the water-tube the moment it has been emptied of everything but air or vapour at the atmospheric pressure (which is Mr. Mallet's assertion), and filling it up so as to put an end to his geyser? Mr. Mallet tries to meet this obvious objection, by suggesting a *jam* of the coarser fragments cemented by lava and acting as a stopper. But is it conceivable that such an accidental jam should have occurred not once or twice only, but about ten times in every hour for the last 2,000 years or so? It is scarcely worth while, after these conclusive objections, to remark, that no siliceous sinter is found on the walls of the crater of Stromboli, such as geysers all over the world plentifully deposit, wherever their waters splash. On the other hand, the gases evolved from the crater, and the products of their action on its rocks, have been shown by the chemical analyses of Abich, Deville, and Fouqué, and the spectroscopic observations of Jansenn, to agree with those of ordinary volcanos.

As already mentioned, Mr. Mallet was not able to see to the bottom of the crater, owing to the vapour, which, he says, "nearly filled the cavity and obscured the bottom, even between the outbursts." Nevertheless, he guesses it to be 300 feet in depth below the rim (D in his Diagram). On what grounds he makes this guess he does not state. There is good reason to believe that the floor of the crater is but little below the lip D. Signor Salino estimated it (of course it is unapproachable) at 2,215 feet above the sea. The deep funnel-shaped cavity represented in Mr. Mallet's diagram may then be considered as wholly imaginary. My own estimate of 2,000 feet is declared by Mr. Mallet (p. 504), to involve "a physical impossibility;" his argument being founded on his own measurements of relative heights, which I have shown to be wholly erroneous. But then Mr. Mallet is in the habit of denouncing as "physical impossibilities," all alleged facts that do not square with his theories.

Mr. Mallet is evidently under the impression that the intermittent explosions of Stromboli, which he calls rhythmical, but which, as he himself admits, occur at very irregular intervals, are of an extraordinary and elsewhere unexampled character. But so far is this from the case that it forms the usual feature in every volcanic eruption of moderate violence. And of this Mr. Mallet would be aware if he had ever seen any other volcano than Stromboli in this phase. For example, M. Charles Ste.-Claire Deville thus summarizes his observations of Vesuvius in 1856, "Voila *le Vésuve actuellement dans la phase strombolienne.*" Monticelli thus describes the phenomena of Vesuvius in 1815: "The crater was often quiet *for minutes together*, and then burst out into explosions of considerable violence, sending fluid lava and ignited stones and ashes to a height of several hundred feet into the air." So, too, Sir H. Davy, describing the phenomena of December, 1819, says. "It threw up showers of red-hot stones every two or three minutes." (Phil. Trans. 1828.) I may add that, through several successive months in the years 1817–21, I myself watched nightly from Naples streams of lava which constantly overflowed the summit crater-lip of Vesuvius, and dribbled down the side of the cone, proving that the lava throughout that long time entirely filled the vent of the volcano; while from it successive explosions of steam, throwing up scoriæ, precisely like those of Stromboli, only somewhat more frequent, were continually taking place. Both phenomena—the overflow of lava and the outbursts of steam from it—went on without any apparent interference with each other; though it seemed evident that the continuous rise and expansion of successive steam bubbles *from* *within the vent* was one of the causes of the extrusion of the lava from the same orifice.[1]

The sluggish character of the eruptive action of Stromboli, as of other volcanos in a similar phase, is owing no doubt to the slow and equable rise of intensely heated lava within the vent; so slow as to admit of but one steam-bubble at a time being generated and pushed up; the lava about it losing much heat carried off in a latent form by the steam-bubble as it explodes, and requiring a further addition of heat to bring about, after an interval of more or less duration, the expansion of another steam bubble. During this interval, the surface of the lava remaining in the vent freezes, and by increasing the resistance to the expansive force below, further checks the development of the following steam-bubble. In cases where the increments of lava are forced up more rapidly, the formation of bubbles within the vent is proportionately accelerated, as well as their rise and escape from the mouth, till perhaps the explosions become so rapid and continuous as not to be easily counted. This is the case in every *violent* eruption; the puffs of steam from the vent being as rapid and the intervals between them as short as the very similar puffs from the chimney of a locomotive engine in full work. The first phase, that of sluggish activity, in a volcano, may be compared to the slow ebullition of a kettle on a hob; the phase of greater violence to one boiling over upon a brisk fire.

The volumes of steam which are seen to burst from the exposed lava surface of a volcanic vent in eruption, whether singly and at intervals, or in rapid succession and with tumultuous violence, are generated in the lava itself, and not in any imaginary fountain or pipe of hot water beneath it. The existence of interstitial water, either in a liquid, or a gaseous form in lava, both as it rises in and issues from a volcanic vent, has so long been recognized among geologists as an established fact, that it seems like going back to the scepticism of the Wernerian age to find a different motive force and mode of action brought forward to account for the phenomena of a volcano.

Had Mr. Mallet contented himself with the view expressed by Sir C. Lyell in a passage which I am inclined to believe suggested his theory,—since he refers to the context ('Principles,' 10th edition, vol. ii. p. 220), namely, that the phenomena of geysers "have no small interest as bearing on the probable mechanism of ordinary volcanic eruptions, namely, that the tube itself is the main seat or focus of mechanical force,"—he would have committed no error. But that would have been no novel idea, and he would not have written his paper and astonished the Royal Society with the assertion that the mechanism of Stromboli has not merely some similarity with that of a geyser, but that the volcano actually contains a geyser in its inside, which is the true and only source of the phenomena exhibited there.

[1] I learn from Prof. Owen that on the night of the 3rd October, 1845, he watched the explosions of Vesuvius from the deck of a vessel in the Bay of Naples; and timing them by his watch, he found the intervals to vary between the *maximum* of 6½ minutes and the *minimum* 2 to 2½ seconds: from 3 to 4 minutes was about the average time between the explosions.

The mechanism by which the rise of lava and steam within the vent is effected was explained by myself so early as 1825, in the first edition of my work on Volcanos (pp. 17–20), and more fully still in the edition of 1862 (pp. 39–43). It corresponds precisely with the view taken by Lyell in the "Principles" (tenth edition, vol. ii. p. 225), and also with that given by Dana (Manual, 1863, p. 692) in the following passage, which I quote in preference to my own, as the view of an impartial and unquestionable authority:

"*Volcanic Phenomena.*—The water and other vaporizable substances within the lava" (in the chimney of a volcano) "are under a pressure of about 125 pounds to the square inch for every 100 feet of depth. Owing to the heat, and their consequent expansion, they slowly rise in the heavy viscid liquid. As they rise, they keep expanding, until, nearing the surface, they begin to take the form of bubbles of vapour, and finally break through. . . If the lavas are less liquid, the vapours are kept from escaping by the resistance, until they have collected in far larger bubbles; and when such bubbles burst, the projectile force may be enormous; it carries the fragments far aloft, whence they descend in a shower of cinders of great extent. . . Such bubbles, rising and bursting, were seen by Spallanzani in the crater of Stromboli. In times of moderate action at Vesuvius, the outbursts of cinders occur every three to ten minutes; but in a period of eruption, they are almost incessant. . . As the vaporizable substances (water, sulphur, etc.) and atmospheric air expand while rising in the volcanic vent, they displace correspondingly the lava, and so cause a general expansion of the mass. This alone produces a rise of the lavas in the conduit."

It is then certain that, according to all trustworthy authorities, the outbursts of steam and other vapours, which during volcanic eruptions rise with and carry up to great heights in the air lava drops and fragments of rock, are seen in all cases to proceed from the lava itself, and not from any separate source of hot water, such as Mr. Mallet's ingenuity has invented. This has been recognized by every observer, who has had the good fortune to witness a volcanic vent in eruption from a commanding post, from the time of Spallanzani and Dolomieu to the present day.

Mr. Mallet, however, entertains very different ideas upon this subject. It seems that he is unwilling to admit that the water which, as steam, plays so important a part in volcanic eruptions, is contained within the lava as it rises in the vent from the interior of the volcano, and forces its way out explosively from the exposed surface on reaching the open air. Hence his determination to find or suggest some other sources of water and steam outside of the lava. Hence, too, he is unable to conceive the possibility of successive volumes of vapour struggling upwards within a narrow and intricate volcanic chimney, filled with more or less viscid lava, and successively bursting from its upper surface as they reach the atmosphere in the manner described by Dana in the above-quoted passage. Mr. Mallet asserts (R.S. Proceedings, p. 510): "Whatever be the source of supply of the lava, it can never fill the tube as a solid (*sic*) column of melted matter reaching up to its lip; for in that case, whatever be the mechanism of the volcano, at each outburst the whole of this immense column of melted matter must be blown completely out of the tube, which actually is emptied, at the end of each outburst, of everything but gases and vapours, and these at a tension not greatly exceeding that of the atmosphere." May we not, however, ask Mr. Mallet on what ground he asserts so positively, that the tube (which, in the case of Stromboli, he speaks of as 400 feet in depth, but which, by rectification of his measurements, must really be, if it exists at all there, about five times as much, viz. from the bottom of the crater to the level of the sea, whence the water of his geyser is supposed by him to be supplied) "must be actually emptied at every outburst"? He admits that he was unable to see the bottom of the crater where he places the mouth of his geyser tube. Those who have been more fortunate certainly saw nothing corresponding to Mr. Mallet's idea, but, on the contrary, the usual phenomena of a volcanic vent in moderate activity, as described above. There is nothing, then, in the phenomena of Stromboli so exceptional as to make it necessary to refer them to any mechanism different from that of ordinary volcanos under similar conditions. Intermittent, recurrent, or (if Mr. Mallet prefers the word) *rhythmical* explosions are not peculiar to Stromboli. Dana, as we have seen, and other trustworthy authorities, speak of those of Vesuvius, when the volcano is but moderately active, as taking place every three or ten minutes,—as nearly as possible, the average interval between the outbursts of Stromboli,—though of course, in more violent paroxysmal eruptions, the intervals are reduced to seconds or less, the explosions following one another too rapidly to be counted.

It is, then, evident that if Stromboli is to be supposed to have a geyser under its eruptive lava-vent, on account of the intermittence of its explosions, we must believe the same to be the fact in the case of Vesuvius, and every other volcano when in activity—an absurdity which no geologist can be brought to countenance, and which even Mr. Mallet would (perhaps?) hesitate to affirm.

The peculiarity of Stromboli really consists, not in the more or less rhythmical recurrence of its explosions,—which, as we have seen, is common to all volcanos in the phase of moderate eruptive activity,—but in the permanence of this phase in its instance. This is evidently due to the slow and equable rate at which increments of heat are communicated from beneath, together with fresh lava rising up the chimney, and to the similarly equable dispersion of the matter thus brought up, beyond the circumference of the crater. This equilibrium of supply and waste is an unquestionable fact, since the eruptive phenomena are, as a rule, equable within short periods, and the crater remains always empty to about the same level, notwithstanding the constant return into it of a large proportion of the lava fragments ejected from its bottom. That other portion of fragmentary lava which is carried off as ash by the wind, or falls in larger masses outside the crater lip, evidently balances in general the amount supplied from beneath. Were it not so, the accumulation of matter in and above the crater would probably so far increase the pressure on the steam in the chimney of the volcano as to proportionately check its expansive force, and cause the eruptions to cease for a time far longer than the present intervals, and to be more violent when they did occur, and thus bring the volcano into the more common phase of alternate great activity and prolonged repose. The maintenance of this equilibrium between the expansive and repressive forces is probably due (as I long since suggested) to the peculiar shape of this volcanic mountain (see Woodcut Fig. 3); its axial vent being so close to the ridge of the steeply inclined plane that occupies the breached crater and reaches down to and far below the sea-level, as to admit of a considerable portion of the ejected fragments falling into deep water, instead of accumulating over the vent, as would be the case if the circuit of the crater was complete on that side. Any excess of lava produced by the vent in a liquid form escapes in like manner, either through or over this crater-lip, to the exterior of the slope, and thence into the sea. In this explanation Hoffmann expresses his concurrence. In 1831, this observer saw several minor streams of lava issuing from the summit of the slope, and making their way down towards the sea; and the same fact has been noticed by others. The great depth of the Mediterranean at the base of this slope, assisted by currents, would prevent the accumulation of the ejected matters on that side.

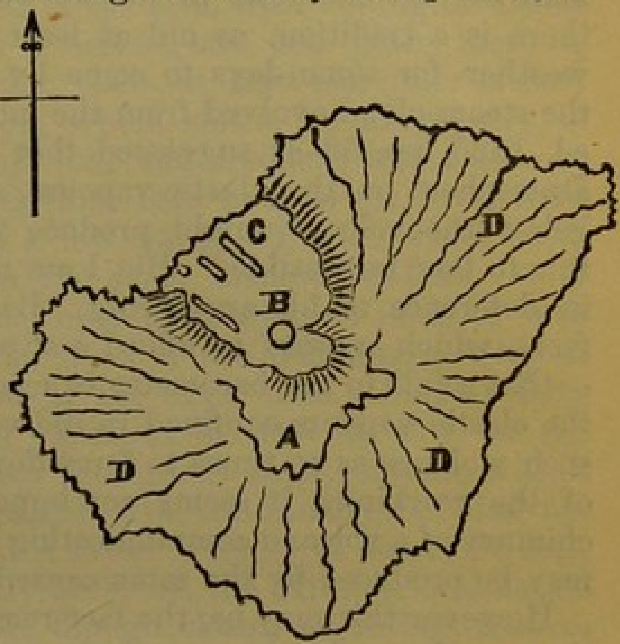


FIG. 3. PLAN OF THE ISLAND OF STROMBOLI.
From the Official Map of the Italian Government.

A Highest summit of the mountain.
B Cratere la Fossa (existing crater).
C Sciarra del Fuoco (the "Schiarazza") with its ridges of lava.
D The furrowed slopes of the mountain.

It is evident, on the whole, that Mr. Mallet's theory cannot stand serious examination. Stromboli is only one of a string of volcanic islands (the Liparis), arranged along radiating lines evidently marking some subterranean fissures, which have all apparently been in eruption within Post-Tertiary times. One of them, indeed (Vulcano), has been several times violently eruptive within the historical period, and is even now in the Solfatara state of activity, sending forth volumes of acid vapours and steam. Last autumn, indeed, a veritable eruption on a small scale broke out at the bottom of its immense crater, luckily not at the point where the sulphur and borax works, established by an enterprising Scotch firm, are situated. It would need, therefore, a very strong proof to lead geologists to believe that the action of Stromboli is essentially different in its character and cause from that of the other ordinary volcanic vents of the series, and such Mr. Mallet, as has been seen, fails entirely to produce.

Although I have hitherto spoken of the explosions of Stromboli as equable, yet they do not by any means occur at precisely similar intervals. These, though usually of from two to ten minutes, are sometimes prolonged to thirty or even forty minutes. Nor is the violence of the discharges always equal. According to information furnished by the inhabitants of the island, the explosions are of a more violent character in stormy weather, especially in winter; and there is a tradition, as old at least as Pliny, that they forecast the weather for some days to come by the condition of the smoke, *i.e.* the steam-cloud evolved from the mountain. I long since (Volcanos, ed. 1825, pp. 53–4) suggested that changes in the pressure of the atmosphere on the elastic vapours, enclosed in the lava within and below the volcano, might produce this effect. Mr. Mallet declares this to be "impossible." But I am not inclined to renounce the idea in deference to his arguments. Bearing in mind the well-known fact—which appears to afford a strong parallel to the case in point —that a fall in the barometer is accompanied by the letting loose of the elastic vapours confined in the vacant spaces of a coal-mine with such violence as at times to force down masses of rock from the roof of the workings, it seems not impossible that within or below the chimney of a volcano communicating with the open air, similar effects may be produced by the same cause.[1]

However this may be, the fact remains that the volcano is at some times and seasons more turbulent than at others. The inhabitants assert that in its eruptions of greatest violence lava is occasionally discharged into the sea from the steep face of the great rent on the north-west side, which bears the local name of the Schiarazza ("the great scar"). Hoffmann, as we have seen, confirms this fact; and Sir W. Hamilton gives a coloured drawing of the island, taken by his friend in the year 1768 (see Campi Phlegræi, plate xxxvii.), when a violent eruption was taking place, apparently from the whole upper portion of the Schiarazza. Mr. Mallet, indeed, doubts that lava can ever, in recent times, have been emitted by Stromboli, on the ground that the crater must have been first filled to the brim, to enable the lava to overflow it. There is reason to doubt the bottom of the crater being much lower than the lowest part of its brim. Even were this the case, it would be quite possible and consistent with facts which I am about to notice, that lava may have flowed into the sea from fissures broken through the bank which separates the Schiarazza from the lowest hollow of the crater. Mr. Mallet,

[1] The attitude of philosophical caution which should be maintained by us with regard to such questions was admirably pointed out by the late lamented Professor Phillips in the following passage:—"It is a common belief among persons who do not require strict proof of propositions which they accept, that the weather has influence on such phenomena as earthquakes and volcanos; the same minds may readily admit the influence of the moon on the weather; and thus we arrive easily at the opinion that Vesuvius is governed in its activity by the phases of the moon. On the other hand, men trained in exact reasoning are apt to deride such notions as quite unworthy of inquiry. Neither of these conditions of mind is right, when the problem is one like that of volcanos, for which a just solution cannot be had without taking into careful estimation all the known forces which may be influential on the epoch, duration, and intensity of the effect."—*Vesuvius*, page 169.

indeed, himself noticed strings of lava which looked like dykes, in the face of the great rent, but is unwilling to admit that they are such, considering them merely long flakes or ropy portions of lava that had fallen from above. The fact I have to mention in support of the contrary view is the remarkable one mentioned by Spallanzani, Hoffmann, myself, and others, that besides the opening at the bottom of the crater which is filled to the brim with boiling lava, and whence the explosive discharges of scoriæ, etc., take place, there is, or was at the several times of our visits, at least one other orifice, empty to all appearance, but from which steam, seemingly dry, is constantly rushing up with a dull roar and frequent stifled detonations. This steam must proceed from lava at a lower level than that of the proximate vent only a few yards off, with which it is evidently not in communication for some distance down. It is therefore easy to believe that other openings may give issue to lava at a still higher level on the outer flank of the Schiarazza, without the crater being necessarily filled at the same time. Similar facts have been often recorded. For example, M. Deville saw on the summit of Vesuvius, in 1856, two contiguous small craters, within one of which a pool of incandescent lava continually bubbled up, while the bottom of the other, at a lower level by at least 300 feet, was empty; showing, as he justly observes, the extreme localization of the ascending lava in separate, though closely adjoining, fissures or chimneys. The parallel between the two cases is complete. Several of the distinguished observers already mentioned have described within the crater of Stromboli a number of additional mouths, sometimes amounting to seven, and discharging either steam, stones, or lava streams, and acting singly or in concert. In short, it appears probable that the bottom of the crater of Stromboli, like that of many other volcanos, is a mere crust of scoriform lava liable to variations both in its level and in the number and character of its openings.

Enough has been said to show that there is no ground whatever for attributing to Stromboli any mechanism different from that of ordinary volcanos. Its activity is sluggish, and has continued for a very long period. But this is a phase by no means unexampled. The volcano of Masaya, in the State of Nicaragua, has been in a similar condition of moderate eruptive activity since the year 1529 at least, (see Volcanos, 1862, p. 33), discharging at intervals of fifteen minutes jets of red-hot lava fragments from its crater. Mr. Squiers, in his recent work on Nicaragua, confirmed this fact. Again, on the Pacific coast of Central America, in the province of Guatemala, another volcano, Isalco, has been in a condition of permanent activity since 1770, in which year a cone was first thrown up on a plain, and has been growing in size ever since. Mr. Squiers represents it as being 2,500 feet high at the time of his visit, and its explosions as regularly recurring at intervals of twenty minutes. This statement is borne out by the diary of my friend Mr. Chas. Eden, written on board the U.S. Packet "Guatemala," in the gulf of Fonseca, in the year 1859, which I have now before me. He states that "eruptions take place from this volcano at intervals of from 10 to 12 minutes; it forms therefore a beautiful beacon by night; its intermittent fires seem like some colossal revolving light." Another permanently active volcano is said to exist in the Kamtschatkan group, and others would appear to occur in the New Hebrides and several of the Pacific Islands.

Mr. Mallet's suggestion, therefore, in the case of Stromboli, of a geyser beneath an active volcanic vent, may be dismissed as wholly unnecessary, as well as improbable, not to say impossible. The promulgation, however, of this strange notion, together with the arguments adduced to support it, may perhaps serve to show that I was justified, when commenting on Mr. Mallet's "theory of Vulcanicity," in saying that he appeared to have no very clear or just notions upon the character of volcanic action, and may therefore excuse the seeming discourtesy of the remark. When a physicist of some reputation—and I am far from denying Mr. Mallet's claim to that title in his own sphere—produces a novel theory of great pretensions, which is, by his own showing, to upset the views previously held by all geologists on the subject, while expressing no small contempt for their opinions and arguments, he must expect his own views, when he deals with geological facts, to be closely scrutinized and estimated at their true worth.

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