III. *Obſervations on the Affinity between Baſaltes and Granite.* *By* Thomas Beddoes, *M. D.*; *communicated by Sir* Joſeph Banks, *Bart. P. R. S.*

Read January 27, 1791.

ALL our opinions on the formation of rocks and mountains, except volcanic mountains, muſt of neceſſity reſt upon analogical reaſoning, ſince we have no direct teſtimony concerning their origin. Hence, whatever portion of the mineral kingdom is but little connected with our experience of the action of fire or water, muſt be ſlightly paſſed over, or ſet aſide for future inveſtigation, while the partizans of the two oppoſite hypotheſes, which at preſent divide the philoſophical obſervers of foſſils, fix their whole attention, and lay all the ſtreſs of their arguments, on ſuch particulars as they are able to connect by ſome analogy with the chemical operations in which either fire or water are principally concerned. For this reaſon, baſaltes has been much more the ſubject of diſputation than granite; the former ſpecies of rock offering appearances that coincide in ſome degree with both kinds of chemical proceſſes, while the latter ſeems to ſtand aloof from the experiments that have given birth to our ſciences. We do, indeed, find opinions on the production of granite by one or other of the cauſes above mentioned; but they are generally * looſe conjectures, thrown out at random, rather than philoſophical propoſitions, laid down in preciſe

* The only exceptions known to me are, Phil. Tranſ. Vol. LXV. p. 5—47. and Edinburgh Tranſactions, Vol. I. p. 255—257.

terms,

terms, and ſupported by proper evidence. In conſequence of information obtained from various ſources, I have been led to conſider this queſtion in a light ſomewhat new; and although I cannot but expect my concluſions to be controverted, however ſtrong may be my own conviction of their juſtneſs, I am encouraged by the hope of communicating ſome original obſervations on the phyſical geography of our own country, and of bringing forward to public notice ſome facts not generally known among us, though they are ſuch as cannot be overlooked in a theory of granite.

Notwithſtanding the recent objections of Mr. WERNER *, I ſhall aſſume the origin of baſaltes from ſubterraneous fuſion as thoroughly eſtabliſhed by various authors †. Several obſervations of my own, which I intend ſoon to offer to the publick, will, I flatter myſelf, corroborate the evidence, though already ſufficiently ſtrong to remove all reaſonable doubt, and add a conſiderable tract to thoſe where the effects of ancient fire have

* Bergmänniſches Journal, March 1789. Among the facts adduced by this celebrated mineralogiſt to prove the watery origin of baſaltes, I cannot diſcover any very new or ſtriking. The appearance of baſaltes between ſtrata is his great argument. But the ſame, or a ſimilar appearance had been noticed by Dr. HUTTON (Edinb. Tr. I. p. 279.); WHITEHURST (Chap. XVI.): FERBER (Italy, p. 51.) mentions the inſertion of lava between calcareous ſtrata; and in LESKE (Reiſe durch Sachſen, 4to, 1785, p. 517.), we have baſaltic columns in ſandſtone. Mr. WERNER alſo inſiſts upon the gradual approximation of the adjacent ſtratum towards the nature of baſaltes.

† DESMAREST, in his well-known Paper in the French Memoirs; RASPE, Extinct Volcanos near Caſſel; FAUJAS, Volcans éteints, &c. and Minéralogie des Volcans; Sir W. HAMILTON, Campi Phlegræi, and Phil. Tranſ.; FERBER, Travels through Italy; DOLOMIEU, in his Account of the Lipari and Pontian Iſles; LESKE, *l. c.*; BEROLDINGEN, in his Account of the Quickſilver Mines in the Palatinate, &c.; HAMILTON, Letters on the Coaſt of Antrim; HUTTON, *l. c.*; VELTHEIM, Etwas über die Baſalt, Leipſig, 1787; are among the chief of theſe authors.

been traced in our times. It may be proper to premiſe, that under the term baſaltes I comprehend that vaſt natural family of rocks which is frequently cracked into regular colonnades, and may be followed in an unbroken ſeries from this perfect form through endleſs modifications to the moſt ſhapeleſs maſs of trapp or whinſtone. Though frequently of an iron-grey colour and uniform texture, this ſpecies of ſtone varies greatly in both theſe characters, even in the ſame rock. In particular, it paſſes, by the moſt inſenſible gradations, both to the porphyries, with which it coincides in appearance, in compoſition, and doubtleſs alſo in origin, and to the *hornſtein* of the Germans; a term including petroſilex and ſeveral ſorts of cloſe grained whinſtone, of which I have found in England varieties with a conchoidal fracture, ſemi-tranſparent at the edges, and in other reſpects faſt approaching * to a ſiliceous nature. Lilleſhall Hill near Shifnal, in Shropſhire, to mention a ſingle inſtance, affords ſuch ſiliceous, beſides *ſemi-granitic*, porphyritic, and common whinſtone, containing agate.

But baſaltes, of which a right knowledge is conducting us faſt to a juſt theory of the earth, is not leſs connected with granite; *inſomuch that we may trace theſe rocks gradually approaching and changing into one another.* I have myſelf had an opportunity of examining many connecting links in this gradual ſucceſſion; and this opinion, which has ſince been confirmed by other conſiderations, was firſt forced upon me by ſpecimens in great variety from volcanic and baſaltic countries. But as it is a point by far too important to be admitted on the mere authority of any mineralogiſt, I ſhall endeavour to ſupport it by the teſtimony of obſervers, who cannot be ſuſpected

* DOLOMIEU, Iſles Ponces, p. 111. 185. &c. deſcribes juſt ſuch lavas.

of any bias towards ſuch an hypotheſis. The firſt ſtep in the progreſſion appears at the Giant's Cauſeway in Ireland. Many of the pillars there conſiſt of fine-grained, dark-coloured whinſtone; that variety which may be conſidered as moſt perfect, and as equidiſtant from porphyry, petroſilex, and granite; but at the promontory of Fairhead, the character of the ſtone is ſeen to alter, and it has lately been deſcribed as an imperfect kind of granite *. Hence we are led by regular approaches to perfect priſms of granite, accompanied by priſms of common whinſtone, and not leſs obviouſly than the different ranges on the Coaſt of Antrim betraying a common origin. The pillars of Les Rameaux, though they rather incline towards the dark colour and uniform hard ſubſtance; "yet, when broken, are unequal both in colour and texture, "and ſometimes interſperſed with irregular pieces and patches, "as it were, of an heterogeneous hard ſubſtance, which, by "its micæ and ſmall rhomboidal cryſtallizations, much re- "ſembles a ſort of granite I have frequently ſeen. The "maſs on which theſe columns ſtand is of the ſame mixed "character †." Other examples will occur afterwards; and for baſaltiform colonnades of granite it is only neceſſary to refer to Mr. STRANGE's deſcription of Monte Roſſo ‡. The general ſhape of the Euganean hills, as if ſuddenly raiſed by

* HAMILTON, 2d edition of his Letters, p. 37. ſays, it "reſembles an imperfect compact granite." I have ſpecimens from an hill near Mallwhyd, in the vicinity of Cader Idris, where the texture inſenſibly changes from an uniform whinſtone ground to grains of mica, feldſpath, ſhoerl, and, I think, ſometimes quartz. They are, I fancy, like thoſe denſe lavas of Etna, "Qui, vues à la loupe, laiſſent appercevoir des ébauches de cryſtallization de ſhörl, de quarz, ou de feld-ſpath. DOLOMIEU, *l. c.* p. 182.

† STRANGE, Phil. Tranſ. LXV. p. 13.

‡ Ibid.

the expanſive and efferveſcent force of heat * from the ſurrounding plain, the lava intermixed with granite, as if both had concreted together, the columns of an uniform texture in the adjacent parts of theſe hills, and the reſt of the phænomena, even then led the author to ſuſpect, "a ſtrong analogy be-"tween granites and many particular volcanic concretions."

From the mountain of Eſterelles, in the South of France, on the road from Frejus to Antibes, I have before me granite, gneiſs, and ſpecimens, in which feldſpath and grains of tranſparent quartz are diffuſed through a paſte of the ſame browniſh red colour and texture as the baſaltic columns at Dunbar in Scotland.

Nothing is indeed more common, or more variouſly modified, than foſſils of this intermediate character †. We frequently find a ground of jaſper, and no doubt alſo of different varieties of whinſtone, as will hereafter appear, with feldſpath and ſhoerl at the ſame time imbedded in them ‡; and again with grains of feldſpath and quartz in ſuch a manner as to leave it extremely doubtful, whether the rock ought to be named granite or porphyry §. The varieties of ſuch rocks will conduct us, by eaſy ſteps, from uniform baſaltes through the porphyries to granite. A chemical examination of the baſis of a number of theſe porphyries would be very intereſting; yet I would not reſt the theory of their formation altogether on the reſult of analyſis.

* The ſight of them impreſſed FERBER alſo with the ſame idea.

† Il n'y a point de naturaliſtes qui ne connoiſſent le genre de roches, placé entre le granit, les gneiſs, et les porphyres, qui tiennent un peu des trois eſpeces. Iſles Ponces, p. 90.

‡ HAIDINGER, Tract quoted below, p. 47.

§ CHARPENTIER (Mineralogical Geography of Saxony, 4to, 1778. in German), p. 50. and elſewhere, finds himſelf in this ſtate of uncertainty.

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The ſame ſtratum is perpetually varying in its mixture; and we ſhould not too rigouroufly adhere to the proportion of ingredients diſcovered by the chemiſt in the hundred grains upon which his experiments may chance to be made. The ſenſible qualities, the ſtile of fiſſure, the accompanying foſſils, and the form of whole rocks, when ſurveyed by an experienced eye, are as good criterions of baſaltes as a certain proportion of iron, and the black glaſs which it yields on fuſion. Should the matter of any given rock contain too little iron to be fuſible by the blow-pipe, and yet have other ſtriking features of whinſtone, would this be a ſufficient reaſon to conclude, that its formation has been different? Chemiſtry, if thus ſtrictly followed, would perplex mineralogy, inſtead of reducing it to order. Characters of minerals, purely chemical, would ſeparate thoſe whoſe natural hiſtory is alike, and bring together ſuch as differ widely in their formation.

The late Mr. FERBER's letters from Italy furniſh ſo many facts, conſpiring in one way or another to ſhew the affinity between baſaltes as well as other products of ſubterraneous fire and granite, that whoever reads them with this view will, I am perſuaded, find himſelf more intereſted and inſtructed. The following are among the moſt ſtriking of theſe facts.

"4th ſpecies of baſaltes. Oriental baſaltes through which "the conſtituent parts of granite are equably diffuſed. Sepa- "rate particles of red feldſpath, quartz, and mica, are "diſperſed through the ſubſtance of this ſpecies: they ſeem to "have been diſtributed through an aqueous ſolution, and to "prove, that this ſpecies had rather an aqueous than a fiery "origin." I ſee neither proof nor preſumption in favour of this ſuppoſition; but in a ſeries of ſpecimens, collected with a view

view to ſhew the tranſition from black baſaltes to granite, this ſpecies and the granite from Eſterelles would form two contiguous links.

"5th Oriental baſaltes, with ſtripes of granite. The "common black baſaltes, faſciated with large ſtripes of red "granite, blended and joined to the baſaltes without any "viſible ſeparation; not as the pebbles in a breccia, or as "fiſſures healed up and filled with granite, but as if both the "baſaltes and granite had been fluid together *."

Thoſe ſpecimens, which ſhew how copiouſly volcanos produce feldſpath, ſhoerl, and mica, eſpecially the two former (ſubſtances common both to baſaltes and granite), tend greatly to eſtabliſh the near relation between theſe two kinds of rock. I was ſurprized, at this day, to find an excellent obſerver ſeriouſly maintaining, that theſe earthy cryſtallizations are merely ejected, and not generated, by theſe fires †.

Attempts, I am aware, have been made to ſet up boundaries between the columnar granite of the Euganean hills, the granite of the volcanic provinces of France, the granitello of the Italians, and ſuch granite as is found to conſtitute high and extenſive ranges of mountains. As to a difference in the ſize of particles, and hardneſs of the ſtone, the firſt diſtinction is neither conſtant, nor by any means calculated to perſuade us, that a cauſe, capable of producing the one, is inadequate to the production of the other. It may probably be explained from the quantity of matter, more or leſs perfect fuſion, a different length of time in cooling; and in the latter character I ſuſpect the obſervers to have been deceived by the

* See FERBER's Travels in Italy, pp. 231, 232. Engliſh tranſlation.

† DOLOMIEU, Iſles Ponces, and Laves de l'Etna, paſſim.

decay

decay of the rocks they inſpected *. At all events, lavas in abundance ſhew, that fire is capable of producing any required degree of compactneſs †.

I ſhall conclude this induction of particulars with an obſervation lately publiſhed by one of our moſt intelligent mineralogical travellers. "Among the ancient black ſtones, the "compound ſpecies are moſt frequent. They often conſiſt of "*a kind of granite*, in which the ſcaly black ſhoerl predominates "ſo much, that the whole maſs appears black. It is accompa- "nied by white feldſpath of ſo ſmall a grain, and ſo entangled "among the ſhoerl, as to be ſometimes ſcarcely diſtinguiſhable. "The feldſpath itſelf is ſometimes tranſparent, and by tranſ- "mitting the colour of the ſhoerl, in which it is imbedded "(empâté) appears black . . . . . Sometimes ſcales of black "mica occur. The conſtituent parts do not always obſerve "the ſame proportion; and when the quantity of feldſpath "increaſes, the appearance of a real grey or red granite is pro- "duced. Hence we have veins and ſpots of grey granite in "almoſt all the dark-coloured rocks that paſs under the "denomination of baſaltes. Theſe veins have very much "embarraſſed thoſe naturaliſts who maintain that all baſaltes "has been produced by fire." This circumſtance, however, according to my view of the ſubject, is far from embarraſſing: I conſider it as a ſtrong proof of my opinion, ſince it ſeems to involve this conſequence, that, if baſaltes proceed from fuſion, granite alſo muſt. Specimens, ſuch as thoſe here deſcribed, I ſhould place near granular baſaltes, like that of Cape Fairhead. "In blocks of ancient baſaltes," proceeds M. Dolo-

* "Though partial ſpots of this granite are often friable, eſpecially about the ſurface, yet in general it is very hard." Strange, ubi ſupra, p. 9.

† See Dolomieu, Iſles Ponces, p. 139.

MIEU,

MIEU, "I have obſerved the tranſition from ſhoerl in a "maſs nearly homogeneous (I ſay, *nearly homogeneous*, be- "cauſe I know of no ſtones, belonging, as theſe do, to the "primitive mountains, without indications of a ſeparation of "ſeveral ſubſtances which were incorporated together in a "paſte, or rather which are generated in that paſte) to black "and white granites, with large grains, and compoſed of "nearly equal quantities of white feldſpath and black ſhoerl. "The tranſition depends altogether on an increaſed proportion "of feldſpath and on the enlargement of its grains; a "phænomenon which leaves no room to doubt, that all theſe "ſtones belong to the ſame ſyſtem of mountains *."

By obſervations like theſe, which the ſpecimens I either poſſeſs, or have examined, corroborate and compleat, I am perſuaded, that when once it becomes an object of attention, perſons who have an opportunity of exploring countries where baſaltes and granite abound, will eaſily find a ſucceſſion of ſpecimens beginning at the former and terminating at the latter. Nor is it perhaps difficult to aſſign highly probable reaſons, why a mixture of different earths with more or leſs of metallic matter, in returning from a ſtate of fuſion to a ſolid conſiſtence, may aſſume ſometimes the homogeneous *baſaltic*, and ſometimes the heterogeneous *granitic* internal ſtructure. No fact is more familiar than that it depends altogether on the management of the fire, and the time of cooling, whether a maſs ſhall have the uniform vitreous fracture, or an earthy broken grain, ariſing from a confuſed cryſtallization. The art of making REAUMUR's porcelain conſiſts en-

* Journal de Phyſique, September 1790, p. 196. I have ſeveral ſpecimens from the whin rocks about Edinburgh perfectly anſwering to this deſcription, and ſo like ſome Veſuvian lavas that it is impoſſible to diſtinguiſh them.

tirely in allowing the black glaſs time to cryſtallize by a ſlow refrigeration; and the very ſame maſs, according as the heat is conducted, may, without any alteration of its chemical conſtitution, be ſucceſſively exhibited any number of times as glaſs, or as a ſtony matter with a broken grain. In the ſlag of the iron furnaces, the ſame piece generally exhibits both theſe appearances; the upper ſurface cools faſt, and is glaſs; what lies deeper, loſes its heat more gradually, and is allowed time to take on the cryſtalline arrangement peculiar to its nature, in as far as a number of cryſtals, ſtarting from various points at once, and crowding each other, will admit of it. Here indeed the cryſtals are uniform, and not of a different form and compoſition, as in granite; ſo that this analogy applies cloſely only to baſaltes; and it perfectly explains why this body in congealing has aſſumed an earthy and not a vitreous grain. But it is eaſy to conceive how, under certain variations of heat and mixture, a melted maſs may coagulate into quartz, feldſpath and ſhoerl, or mica*. The moſt permanent difference between baſaltes and granite, as to mixture, conſiſts in the quantity of iron; for the earths in the innumerable varieties of each vary indefinitely in their proportions; and as to heat, that the latter having been perhaps in general raiſed from a greater depth, and conſiſting of more

* "Il eſt certain que dans les porphyres les criſtaux de feld-ſpath n'exiſtoient pas avant l'époque de la précipitation de leur baſe." He ſuppoſes them to be of aqueous origin; but the fact is much to my preſent purpoſe. "On y ſuit les progrès ſucceſſifs de leur formation: on voit que peu à peu les ſubſtances qui leur ſont propres ſe rapprochent, s'epurent et prennent les formes qui conviennent à leurs molécules; ils étoient comme en diſſolution dans leurs matrices et ils ont d'autant plus de facilité a ſe joindre que la fluidité a été plus parfaite et que le deſſechement a été plus long." Iſles Ponces, 247, 248.

huge maſſes, muſt have cooled more ſlowly, and perhaps they have undergone different degrees of fuſion. Beſides toadſtone, baſaltes incloſing feldſpath, zeolite, &c., various lavas clearly demonſtrate that heterogeneous earthy cryſtals do ſeparate from a fuſed paſte, once undoubtedly as uniform as a metallic calx and its reducing flux before the ſubſidence of the metallic particles. We ſhall, I imagine, be much deceived by a narrow analogy if, becauſe in our proceſſes for glaſs-making an homogeneous product is obtained from heterogeneous materials, we conclude, that an heterogeneous product may not, under other circumſtances, reſult from fuſion; and that fire keeps inſeparably blended whatever it has once reduced to an uniform liquid paſte.

It muſt alſo be carefully remembered, that this difficulty does not preſs the igneous more than the oppoſite hypotheſis. Since the conſtituent parts of granite are cryſtals, the whole maſs muſt once have exiſted in that ſtate of entire diſunion of its particles which is neceſſary to cryſtallization. Now, whether ſuch a ſolution have been effected by the repulſive power of fire, or the intervention of water, it is juſt as eaſy to conceive heterogeneous earthy cryſtals ſhooting from different points of an uniform liquid, according to the former ſuppoſition, as the latter.

In the natural hiſtory of granite and baſaltes, another ſtriking circumſtance occurs: *they lie ſo contiguous, and are ſo involved in one another, that we cannot but ſuppoſe both to have undergone the ſame operations of nature at the ſame time.* This is ſeen with the utmoſt frequency upon every poſſible ſcale, and under a vaſt variety of modifications. The facts already quoted afford inſtances in point. I have before me a ſpecimen from the park at Stockholm, conſiſting partly of trapp and partly of granite. The adjacent parts are as firmly united as the other

parts of the ſpecimen; and when a violent blow is ſtruck, the trapp and granite do not ſeparate, but the fracture takes ſome other direction. They ſeem in ſeveral places of the boundary to run into one another. The whole mountainous diſtrict ſurveyed by Mr. LESKE * with ſuch ſcrupulous accuracy affords multiplied examples of the contiguity and connection between theſe different rocks. "From all theſe minute "deſcriptions," ſays the Author, "it appears, that the baſe "of the whole range conſiſts of granite. On the declivity of "the higheſt elevations, and on the ſolitary ſummits of the "external chain, *corneous porphyry* lies upon the granite, out "of which as well as the granite itſelf, and the ſandſtone at "its foot, baſaltes has been protruded by the force of ſubter-"raneous fire †." The manner of connection will appear from a few examples. The baſaltes of the Spizberg ‡ has a granulated ſtructure, and is imbedded in granite. The ſubſtance of the pillars of the Gikelſberg § is cloſe and granular: in ſome pieces "I found the conſtituent grains of granite *little* "*altered*." Of the columns of the Knorberg, "the ſubſtance "is cloſe, uneven, and conſiſts of diſtinct grains: . . . large "pieces of *imperfectly fuſed* granite are diffuſed through its "ſubſtance. In the Whinſtone of the Hochwald there are "found pieces conſiſting of a mixture of white feldſpath, "quartz, and black ſhoerl ‖." Again, in the Rauberg, the conſtituent parts of granite are ſo diffuſed through the baſaltes,

* Reiſe durch Sachſen.

† Ibid. p. 513. "It is alſo remarkable, that granite in general throughout Velay and Auvergne is frequently intermixed with the baſaltine and other common volcanic hills. I have obſerved the ſame in Italy." STRANGE, p. 14.

‡ Reiſe durch Sachſen, p. 328.

§ Ibid. p. 498. ‖ Ibid. p. 515.

that the Author imagines the rock to be an imperfectly fuſed granite *. I rather conſider theſe as inſtances of imperfectly cryſtallized granite, where ſome unfavourable circumſtance has prevented the conſtituent parts from receding completely from one another. Experiments ſhew, that almoſt all granites melt into a black glaſs †; and perhaps it is no abuſe of analogy, nor inconſiſtent with what I have already remarked, to conclude, that granite, in the ſtate of imperfect fuſion, ſhould preſent a glaſſy ſubſtance, involving the more infuſible parts of which this ſtone conſiſts.

The Scheibenberg, near Königſbruck, conſiſts of a ſtone which Mr. LESKE knows not whether to call hornſlate ‡, or corneous porphyry §. From the deſcription it appears plainly to be a whinſtone. The colour is dark grey; it breaks into columnar fragments; is hard, fine-grained, and *ſonorous*; little veins of quartz croſs it in all directions, and it frequently becomes porphyritic, as encloſing cryſtals of feldſpath. The Author himſelf is afterwards aware || of its affinity to baſaltes, both in ſubſtance and from its aſſuming the columnar form. In this hill a maſs of granite is found imbedded in the whinſtone, and on all ſides ſurrounded by it, and the maſs of granite is in its turn in all directions interſected with veins and ſtripes of whinſtone. Mr. LESKE is much ſtruck by this mutual and intimate incorporation; but he makes no attempt to explain it. In ſome inſtances, he thinks an eruption has

* Reiſe durch Sachſen, p. 330.

† HAIDINGER's Eintheilung der Gebirgsarten. Wien, 1787, p. 11. and the Authors quoted there.

‡ Hornſchiefer.

§ Ibid. p. 24—29. No chemical characters are given.

|| Ibid. p. 513, 514

broke out through the granite; and in others, is at pains to ſhew, that theſe ſubſtances are not thoroughly blended, as in the laſt example, and in that deſcribed by FERBER.

It may be ſaid, and no doubt it ſometimes happens, that ſhivers of granite, broken off by the violence of exploſion, are licked up by melted matter as it moves along; thus, in volcanic breccias an older lava is incloſed in one more recent, and thus what is called primary is ſometimes encaſed in ſecondary granite. But ſuch an hypotheſis is too narrow to embrace all the phænomena. It does not explain the incipient coagulation of the uniform paſte into grains, and thoſe the different grains of granite; nor the diffuſion of the conſtituent parts of granite through the ſubſtance of baſaltes; nor the fifth ſpecies deſcribed by Mr. FERBER.

In the whinſtone rocks of England, which are far more numerous than is commonly ſuppoſed, I have frequently obſerved in the ſame hill, 1. homogeneous dark grey ſtone; 2. feldſpath encloſed in this as in a paſte; and, 3. the paſte diſappearing, and the whole becoming granular, and the grains heterogeneous. Beſides feldſpath, quartz is found in innumerable maſſes of varying magnitude * in many whinſtone rocks, and as proper baſaltes is but a confuſed maſs of cryſtals of ſhoerl, we have all the ingredients of granite; and why

* In the Wrekin, Cader Idris, &c. numerous and large veins filled with quartz occur; but theſe have not been *ſecreted* from the ſubſtance of the rocks in which they lie. They, perhaps, ſhew this moſt ſiliceous ingredient of granite to have been near and in fuſion at the ſame time. About Cader Idris I ſuſpect an incorporation of granite and baſaltes may be found. I have ſeen pieces of granite about that mountain which did not ſeem to have been far removed from the rock to which they belonged; but I had then no particular inducement to make an accurate examination.

may

may we not expect to find them incorporated together, and in every ſtate of diffuſion and ſeparation?

Under this head I ſhall only remark further, that ſeveral late obſervations, from which it has been inferred, that certain extinct volcanos have been ſeated in the heart of granite *, ſeem to admit of a much more eaſy explanation, on the ſuppoſition that granite has cryſtallized from fuſion. 1. Volcanic fires reach to a much greater depth than any at which we have had an opportunity of making obſervations. The focus in different inſtances may be ſeated at a different diſtance from the ſurface; but none are probably leſs than ſeveral miles at leaſt deep. 2. The currents of granitic lava † in the Pontian iſles leave little room to doubt of the power of ſubterraneous fire to produce this ſubſtance. To ſuppoſe them to be rocks of granite fuſed, but otherwiſe unchanged, and that even fiſſile rocks may be made to flow without loſing their laminated ſtructure; is as bold an aſſumption as can eaſily be taken up. In the great igneous proceſſes of nature fire need not be imagined to act otherwiſe ‡

* DOLOMIEU, Iſles Ponces, p. 30, 31. and Iſles de Lipari, in various parts.

† DOLOMIEU, *l. c. paſſim*, and particularly p. 89—97. Inſtructive as the particular facts deſcribed by this excellent mineralogiſt always are, I muſt diſſent from him both on the mode of action of volcanic fires, and on the production of zeolite and other cryſtals, in glandular rocks, for the reaſons aſſigned here and below.

‡ "Le feu produit, dans les laves, une fluidité qui n'a aucun rapport avec la fluidité vitreuſe que nous opérons . . . . . Celui des volcans n'a point d'intenſité; il ne peut pas même vitrifier les ſubſtances les plus fuſibles . . . . il produit la fluidité par une eſpece de diſſolution, par une ſimple dilatation qui permet aux parties de gliſſer les unes ſur les autres (DOLOMIEU, Avant-propos, p. 8.). See alſo p. 84. Fire in a crucible produces fluidity no otherwiſe; and when there is this freedom of motion among the *partieles*, how can we ſuppoſe the cryſtals of granite and the leaves of ſchiſtus to remain unmixed even in a current of lava?

than

than in our ſmall experiments; we actually ſee it producing glaſs and cellular ſpongy ſcoriæ: when the products are of a different character, we muſt have recourſe to acceſſory circumſtances, and not violate the plaineſt rules of philoſophiſing by attributing different effects to the ſame cauſe. The latent motive for ſuch an extraordinary hypotheſis may eaſily be divined; the obſerver took it for granted, that all granite is of aqueous formation; hence he was obliged to reaſon backwards from the unknown, that of the Alps for inſtance, to the known, inſtead of proceeding from the palpable effects of ſubterraneous fire by eaſy ſteps to a general theory of granite. When it is taken for granted, before examination, that granite cannot be formed by fire, there remains no reſource but to ſay, that granitic * lavas are granite rocks fuſed, but not altered in the arrangement of their conſtituent parts. 3. Though the heat of volcanos be ſometimes and in ſome places moderate; in others we have good reaſon to believe, that it exceeds any degree we can produce, except by means of factitious air; we are certain that it forms molten currents of petroſilex and flint exactly the ſame as our gun flints †.

If we admit this reaſoning, the appearance of granite in the boſom of volcanic deſolation may, if duly examined in all its circumſtances, afford ſtrong evidence of its production by fuſion; and it is reaſonable to conclude, that it was once covered to a conſiderable depth by erupted matters, which the courſe of

* "Les laves blanches de l'Ile Ponce paroiſſent appartenir plus particulièrement au granit et aux roches feuilletées granitiques. On reconnoît les ſubſtances qui conſtituent ordinairement ce genre de roche compoſée dans preſques toutes les matières blanches (volcaniques) de cette iſle; ſavoir, le quartz en grain, le mica noir écailleux et le feldſpath plus ou moins pur. Dolomieu, *l. c.* p. 89.

† Idem ibid. p. 107.

time,

time, and the injuries of the atmoſphere, have removed; though I by no means deny that a volcano may force its way through pre-exiſting rocks of granite.

There is ſtill another analogy between baſaltes and granite, more important to the theory of the earth, and leſs liable to controverſy than either of the preceding. *In their ſituation, with reſpect to other rocks, we may obſerve the ſame law.* The general rule of ſuper-poſition, reckoning from below upwards, is, 1. granite; 2. ſchiſtus; 3. limeſtone. This rule has been found to hold good by ſo many mineralogical travellers that, though it may not be abſolutely univerſal, it muſt be allowed to prevail very extenſively. Now, in this iſland there are numerous inſtances where baſaltes is ſubſtituted in the ſeries inſtead of granite, and where it ſeems to alternate with granite as the ſubſtratum of other rocks. On the road from Dolgelly in Merionethſhire, by Mallwhyd and Cann's Office, through Llanfair to Welchpool, ſchiſtus appears always incumbent on whinſtone, except ſometimes when the latter is interjected between the ſtrata, or ſqueezed up through fiſſures. In Wales the country is ſo hilly, that the limeſtone, if it exiſted, has probably been waſhed away; but on the confines of England it comes in. The road from Welchpool to Shrewſbury paſſes over the ſide of the Long Mountain, which conſiſts of ſchiſtus; on the left, or towards the eaſt, riſe ſome conſiderable baſaltic hills. The ſtrata of the Long Mountain point towards the ſummit of theſe hills, as if the narrow valley that intervenes had been cut by water upon the lifted edge of the ſchiſtus. At a ſmall diſtance from the north and ſouth ſides of the baſaltic hills calcareous ſtrata are found. Beyond Shrewſbury, on the road to London, we have, inſtead of the continued ridges of Wales, a number of inſulated, and

generally

generally rugged, points, riſing over the face of Shropſhire and the adjacent counties. Were the plains covered with water a few yards in depth, theſe eminences would appear from diſtance to diſtance like ſo many ſtepping ſtones. They all, except the Malvern Hills, which, though compoſed of granite, I conſider as part of the ſame ſyſtem, conſiſt of whinſtone. Among theſe ſtepping ſtones I reckon the baſaltic hills near Welſhpool, the Wrekin, Lilleſhall Hill, and, at a greater diſtance towards the Eaſt, the riſing grounds near Newcaſtle in Staffordſhire, whence the whin rock, perhaps, communicates by the toadſtone of Derbyſhire, through the hills in the North of England with the whinſtone towards the South of Scotland. In a ſouth or ſouth-weſt direction from the Wrekin, a number of craggy eminences ariſe. They are baſaltes, and form a ſtriking contraſt with the ſmooth, rounded, and lumpiſh ſwells of ſchiſtus in their neighbourhood. From the whin rocks near Stretton we may paſs by the Brown and Titterſtone Clee Hills (on the latter of which are regular priſmatic columns) to the Malvern Hills. About theſe hills lie ſtrata of ſchiſtus and limeſtone, as is ſeen on the road from Much Wenlock to Stretton. To the ſouth-eaſt an extenſive field of whinſtone, with occaſional elevations, is ſpread over the confines of Worceſterſhire, Warwickſhire, and Staffordſhire. Here we have the Rowley ragſtone. Whether the baſaltes proceeds ſouthward by ſuch interruptions till it join the Elvin or whinſtone, and granite of Devonſhire and Cornwall, where I imagine they may be found incorporated, I wiſh for an opportunity to examine. In the plain part of this whole diſtrict, the whin rock appears frequently at the ſurface, or a little below the ſtrata, ſo that the hills have probably a ſubterraneous communication with one another, and there needed

but a little more lifting force to form continued ranges of mountains. The road from Welſhpool to Birmingham, above threeſcore miles, is repaired in a great meaſure with whinſtone. A colonnade of baſaltes has been lately expoſed in digging the Shropſhire canal; and in the mining country around, levels have been driven in the black rock, as it is ſometimes called. As I have ſeen whinſtone and ſlate in various other parts of North and South Wales, the whole weſtern ſide of our iſland has probably been raiſed by the baſaltes on which the ſuperficial ſtrata now reſt, though from particular circumſtances the fuſed maſs has now and then cryſtallized into granite; and as it has been conjectured, that the baſaltes of Ireland once joined that of the Scotch iſles and the main land itſelf, ſo perhaps the baſaltes of North Wales joined the Iriſh coaſt till the ſea worked its way or broke in, and deſtroyed the continuation.

As limeſtone is ſometimes ſaid to reſt immediately on granite *, ſo at the foot of the Wrekin, and at Lilleſhall Hill, no ſlate is interpoſed between the limeſtone and baſaltes; ſo that the analogy extends even to the exceptions.

But another ſeries has been obſerved, which ſeems to connect granite by a cloſer tie with the operations of ſubterraneous fire. In Italy lava ſtands to ſlate and limeſtone in the ſame relation as granite and whinſtone in other countries †. Whole ridges of mountains in the Venetian territory conſiſt of ſolid lava, ſometimes almoſt bare, ſometimes retaining the ſuperincumbent ſtrata, with ſeveral local variations; all of which are reducible to a greater or leſs degree of lifting force. Theſe

* BORN's Letters, p. 207.

† FERBER, *l. c.* pp. 42. 51.; and eſpecially STRANGE, *l. c.* p. 24—32.

chains

chains have a totally different form from the common conical ſhape of volcanos or heaps of looſe ejected matters. They ſeem to afford a clear inſtance of the manner in which long continuations of mountains have been elevated; for it is not eaſy to admit the ſuppoſition of the obſerver, who has ſo accurately deſcribed them, that the limeſtone has been converted into lava; and that the ridges exiſted, ſuch as they appear at this day, before this change was produced by ſubterraneous fire. Chemical and mechanical conſiderations are unfavourable to this hypotheſis; and "ſince moſt of theſe branches, whether "marine, volcanic, or mixed, preſerve nearly the ſame exter-"nal characters, directions, and parallelifm;" it appears highly probable, that they have not pre-exiſted as hills in another ſtate, but owe their elevation to the expanſive force of fire; and that the ſame lava which appears in ſo many places lies alſo under all the limeſtone hills, of which indeed there are evident indications.

Several modern travellers have deſcribed the ſtrata of granite mountains; but neither in their deſcriptions nor drawings have I been able to find ſatisfactory evidence of this arrangement; nor have I obſerved it in nature. A liquid maſs ſwelled by heat muſt crack in cooling. Granite ſeems to me to have cracked moſt frequently like the *baſalte en tables*; and theſe flat maſſes have been taken for ſtrata. A ſtratum, conſiſting of proper materials to form whinſtone or granite, may have been expoſed to the neceſſary degree of heat, and poſſibly have undergone this change without much relative local derangement. Should ſuch a ſtratum be diſcovered, it would afford no proof of the ſtratification of the great mountains of granite or ſhapeleſs whinſtone, which, in conſequence of its nu-

merous fiſſures in all directions, ſometimes aſſumes enough of this appearance to impoſe on an unwary eye.

One conſequence of theſe obſervations is too important to be omitted. They lead us to reject the common diviſion of mountains into primary and ſecondary. The chains of granite, ſchiſtus, and limeſtone, muſt be all coeval; for if the central chain of the Alps burſt as a body expanded by heat from the bowels of the earth, it reared the bordering chains at the ſame effort. But it muſt be recollected, that the mountains no longer wear their original form, vallies having been cut between and through them, and various other effects of dilapidation having taken place. It is by no means difficult to underſtand why no exuviæ of organized bodies are found in theſe imaginary primitive mountains. Riſing from a great depth, they threw aſide the ſuperficial accumulations of the ancient ocean. What was deepeſt is therefore now moſt central; and what lay on the ſurface now ſkirts the high interior chains. Hence the ſtrata reſt indifferently on granite, baſaltes, or lava; all which ſubſtances derive from their ſituation an equal claim to be regarded as primordial materials. It is a little ſurprizing, that this inveterate error, which has effectually barred the way to all great diſcoveries in geology till of late *, ſhould have prevailed ſo long: for, 1. it is well known, that granite is ſometimes found encloſing pieces of ſchiſtus †; nor are long ſtretches of ſlate uncommon in mountains of granite ‡. Now, how can a ſecondary be ſo enveloped in a primitive rock? and how eaſy is this to be underſtood, if we ſuppoſe granite as a fuſed maſs raiſing, rending,

* Till Dr. HUTTON's Theory of the Earth, Edinb. Tranſ. Vol. I. appeared.

† BORN's Letters, p. 207, 208.

‡ HAIDINGER, *l. c.* p. 18.

and ſhivering the incumbent ſtrata, while its heat hardened them into laminated ſtone. 2. Suppoſing granite mountains previouſly exiſting in the ancient ocean, the inclination of the incumbent ſtrata, and their diſarrangement is ſuch that they could never have been depoſited as they appear at preſent; they would have been much more horizontal in their direction. It ſeems impoſſible to attribute the diſorderly deviation, which is ſo general in the mountains of ſlate, &c. from that poſition which all ſediments from water aſſume, to any thing but a force lifting from below, and ſometimes burſting through.

It is moreover certain, that all theſe lifting maſſes, from granite to acknowledged lava *, are found ſqueezed up through fiſſures formed in the ſtrata by their own expanſion. This, and not the infiltration of water, as M. DE SAUSSURE would perſuade us †, appears to be the true origin of ſuch veins of granite.

* FERBER, *l. c.* p. 51.

† Voyages dans les Alpes, 4to, I. 532—536. The whole paſſage well deſerves the notice of thoſe who are intereſted in theſe enquiries. Vertical ſtrata, in one inſtance, lying againſt the foot of a granite mountain, are divided by oblique fiſſures, full of granite. This naturaliſt ſuppoſes them to have filled up gradually by the rain water diſſolving particles of granite, carrying them down and depoſiting them in the form of granite again; two operations which one may ſafely deny to rain water the power of performing. Other inſuperable objections to this theory ſtart up at every ſtep in the deſcription. If water can diſſolve any, it is ſurely but a very ſmall part of all the ingredients of granite. Now, ſuppoſe a fiſſure full of ſuch a ſolution; the water is, I ſuppoſe, to evaporate, and the cryſtallization to take place; the cryſtals muſt be ſmall, on account of the ſmall quantity of matter to form them, and a ſucceeding ſolution can only yield another crop of ſmall cryſtals, it will not enlarge thoſe already formed; but we are told, that the cryſtals of granite in the crevices in queſtion are remarkably large. This has always appeared to me a chemical demonſtration of the falſehood of a very common ſuppoſition, that the cryſtals often occurring in the cavities of the

the amygdaloides rocks have been formed by the infiltration of water. The cryſtals are frequently of ſo large a ſize that you can by no means ſuppoſe the quantity of water, at any one time exiſting in the cavity, could have held the ſolid matter, of which they conſiſt, in ſolution. Now, I think, it is contrary to all our experience in chemiſtry, to ſuppoſe cryſtals built up by ſucceſſive operations. If upon cryſtals of nitre I pour a ſolution of the ſame ſalt, the former cryſtals will not be enlarged and amended, but a new ſet will be formed; ſo ſucceſſive quantities of water, paſſing through theſe cavities, ought to form ſucceſſive ſets of very ſmall cryſtals. Neither can I imagine, what cauſes can produce within theſe cavities a depoſition of the matter once diſſolved by the water. It is not cooled; it does not evaporate; it loſes no fixed air; it comes in contact with no new matter, whoſe attraction may overpower the attraction of the water.

The diviſions, "rather marked out than formed, which croſs each other irregularly (p. 533.), and indicate an incipient retraction," are much more conſiſtent with a ſimultaneous congelation than a gradual appoſition; and the granite is the ſame as that of the contiguous hill in the colour and appearance of its conſtituent parts. This coincidence is a ſtriking fact.

In truth, the philoſophers who attribute the formation of granite to water ſeem not to have advanced a ſtep in their proof beyond the equivocal circumſtance of its being a cryſtallized maſs.