XXIX. *On the Refractive Power of the Two New Fluids in Minerals, with Additional Observations on the Nature and Properties of these Substances.* By DAVID BREWSTER, LL.D. F. R. S. Lond., Sec. R. S. Edin., and Corresponding Member of the Academy of Sciences of Paris.

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IN the Paper which I had the honour of submitting to the Society*, on the Two New Fluids in mineral bodies, I have given the index of refraction for the most expansible of the two, as it exists in the cavities of *Amethyst*; but as I had not then ascertained the refractive power of the second fluid, and as the principal phenomena of the two fluids, especially those which related to their properties when taken out of the cavities, were observed in specimens of *Topaz*, it became desirable to have an approximate measure of the refractive power of both of them, as they exist in that mineral. As the fluid in *Amethyst* had never been examined in the open air, its identity with that in *Topaz* was inferred solely from the equality of their expansion by heat, so that the determination of the refractive power of the latter was necessary to establish either a difference between these two substances, or their perfect identity.

In the repetition of the experiments described in that paper, and in extending my inquiries to different specimens of *Topaz*, I sought diligently for a cavity whose shape and situation in the crystal would enable me to obtain an accurate measure of the refractive power of the two fluids. Such a specimen I have had

* See Page 1. of this Volume.

the good fortune to meet with ; and one of the principal objects of the present paper, is to give an account of the results which it enabled me to obtain.

To those who are acquainted with the doctrines of refraction, it is scarcely necessary to state, that if m is the index of refraction of any substance, such as Topaz, the sine of the angle at which light incident on the second surface of it will suffer total reflexion, will be $\frac{1}{m}$, and if any fluid is in contact with that surface, the sine of the angle of total reflexion will be $\frac{m'}{m}$, the index of refraction of the fluid being m' . Hence

$$m' = m \times \text{Sin. Angle of Total Reflexion ;}$$

so that the index of refraction of the fluid is easily deducible from the angle of total reflexion.

When the surface of the cavity is parallel to a face of cleavage in the plate of Topaz which contains it, the angle of total reflexion cannot be observed without cementing a prism upon one of these faces ; but as this tended to make the experiment more complicated, I sought for a cavity, the faces of which were inclined to the two parallel faces obtained by cleavage. This cavity, shewn in Plate XIX. Fig. 1., consisted of a vacuity V;—of a large portion NN of the highly expansible fluid,—and of a considerable quantity MM of the second fluid, which suffered almost no change by heat. The situation of this cavity in the specimen is shewn in Fig. 2., where C is a section of the cavity perpendicular to its length MM, Fig. 1., and inclined to the parallel cleavage planes EF, GH of the Topaz.

In a room where the temperature was about 60° of Fahrenheit, I fixed this specimen upon a goniometer, and I measured the angle of incidence at the surface EF, when the light of a candle RD, incident on the vacuity, began to suffer total re-

flexion. This angle was $38^{\circ} 42'$. From the index of the ordinary refraction of Topaz, which is 1.620, I computed the angle of refraction CDB to be $22^{\circ} 42'$ and the angle of total reflexion DCP to be $37^{\circ} 38' 35''$. Hence the angle ADC was $67^{\circ} 18'$; the angle ACD $52^{\circ} 21'$, and DAC, the inclination of the face of the cavity to the refracting surface EF, was therefore $60^{\circ} 21'$.

Calling x the inclination of AB to EF, or DAC and ϕ the angle of refraction CDB, we shall have $x = \angle \text{total reflexion} + \phi$. For in the similar triangles ADB, CPB right angled at D and C, we have $CAD = CPB$. But $CPB = DPQ = CDB + DCP$, that is $x = \angle \text{Total Reflexion} + \phi$.

The goniometer remaining steady in its place, the divided circle and the crystal were turned round, till the same ray RD began to suffer total reflexion from the refracting surface of the expansible fluid NN Fig. 1. and the Topaz; and the new angle of incidence KDR', at which this took place, was found to be $26^{\circ} 39'$. The goniometer being turned still farther, the same ray suffered total reflexion, from the separating surface of the second fluid MM and the Topaz, when the angle of incidence KD was $11^{\circ} 52'$.

These results obviously enable us to determine with accuracy the refractive power of the Two New Fluids.

Calling θ the angle of incidence, ϕ, ϕ' the angles of refraction, m, m', m'' the indices of refraction for Topaz, the expansible fluid and the second fluid; then we have $\sin \phi = \frac{\sin \theta}{m}$; $\phi' - x = \text{Angle of Total Reflexion}$, and

$$\begin{aligned} m' &= m \times \sin (\phi' - x) \\ m'' &= m \times \sin (\phi'' - x) \end{aligned}$$

Hence we have the indices of refraction as follows :

$$\begin{aligned} m &= 1.620 && \text{Topaz,} \\ m'' &= 1.2946 && \text{Second Fluid.} \\ m' &= 1.1311 && \text{Expansible Fluid.} \end{aligned}$$

The following Table will shew the relations of the indices of refraction of these two new substances to those of other bodies which I have found to possess a refractive power lower than Water.

TABLE of Refractive Powers lower than Water.

Water,.....	1.3358
Cyanogen * rendered fluid by pressure,.....	1.316
Ice,	1.3085 †
<i>Second New Fluid in Topaz</i> , in a cavity which is filled by the other new fluid, at the temperature of 83°.....	1.2946
<i>New Fluid in Amethyst</i> , which fills the cavity at a temperature of 83½° of Fahrenheit,.....	1.2106
Tabasheer, whitish, from Nagpore, hard specimen,	1.1825
Tabasheer, transparent, from Nagpore,.....	1.1503
Do. do. another specimen,	1.1454
<i>New Expansible Fluid in Topaz</i> , in the same cavity as the second fluid, whose index of refraction is given above	1.1311
Transparent Tabasheer from Vellore, of a yellowish tint,	1.1111
Ether expanded into nearly thrice its original bulk,	1.057

I have not made any attempt to measure the refractive power of the new expansible fluid, after it has filled the cavity, having satisfied myself with observing, that the angle of total reflexion diminished when the fluid was in this expanded state‡. In

* This Cyanogen was made by Dr TURNER. Mr FARADAY, who first rendered it fluid, remarks “that its refractive power is rather less, perhaps, than that of water.” *Phil. Trans.* 1819, p. 286.

† This is a mean between Dr WOLLASTON’s result and mine.

‡ This experiment is a very interesting one to the spectator; the new fluid, appearing quite transparent at a temperature of 60°, seems quite opaque when it is made to fill the tube, by a slight increase of temperature, as if it had become black by heat.

those cavities where the vacuities are so large that the fluid is converted into vapour before it fills them, the refractive power of it, as measured when the cavities are full, will obviously be much less than that which is obtained when the substance retains its fluidity, and it will vary in different specimens, and even in different cavities of the same specimen, according to the proportions which the vacuity bears to the quantity of the expansible fluid.

Additional Observations on the New Fluids in Minerals.

Having had occasion to shew the various phenomena of the new fluids to several distinguished foreigners, and to others who took an interest in the subject, I have thus been led to continue my examination of minerals in relation to these remarkable substances. Some of my scientific friends, who were anxious to repeat these experiments, have experienced great difficulty in obtaining specimens of minerals containing the cavities of fluid. This difficulty has no doubt arisen, from their examining the well crystallised specimens which are generally found in the cabinets of mineralogists. If they had broken up with the hammer only a few of the rounded or imperfectly crystallised white topazes from Brazil or New Holland, they could scarcely have failed to discover, with the compound microscope, innumerable cavities fitted for the purposes of observation. After a little practice in splitting and preparing the specimens, in which, from the perfection of the cleavage planes, the aid of the lapidary is almost never required, the patient observer will experience no difficulty in detecting cavities of every variety of form, and in discovering the fluid as it flows from the opened cavities over the planes of cleavage. Mr SANDERSON, lapidary in Edinburgh, who takes a great interest in every pursuit of a scientific nature, has succeeded in obtaining some of the finest specimens of these new fluids; and by cutting and polishing the Topazes which contain

them, so as to exhibit the cavities to the best advantage, he has been enabled to shew most of the phenomena to those who are interested in such pursuits. Several of these specimens are of great value, as will appear from the drawings and descriptions of some of the most remarkable, which will be given in the sequel of this paper.

In the additional observations which I have now to submit to the Society on this subject, I shall confine myself to the following heads :

1. On the Number and Arrangement of the Fluid Cavities.
2. On the Form of the Cavities containing the New Fluids.
3. On the condition of the Fluids within the Cavities.
4. On the condition of the Fluids when taken out of the Cavities ; and
5. On some miscellaneous phenomena connected with the formation of Fluid Cavities.

1. *On the Number and Arrangement of the Fluid Cavities.*

In a former paper I had occasion to mention, that, in a specimen of Cymophane about $\frac{1}{7}$ th of an inch square, I counted 30,000 cavities. Although this statement occasioned great surprise, and some expressions of scepticism, yet it was too feeble to convey any idea of their number. So minute are these cavities, that the highest magnifying powers are often necessary to render them visible ; and we might as well attempt to number the grains of sand on the sea-shore, as to count these fluid cavities when they appear in this minute state.

The strata in which these cavities are arranged, are not so closely related to the primary and secondary planes of the crystals as I formerly supposed. I have found them in almost every

possible direction, and intersecting one another at angles which cannot be referred to any of the crystalline forms of the mineral. In a specimen of Quartz observed by Mr SOMERVILLE, and now in the possession of Mr SIVRIGHT, they are arranged in hollow groupes somewhat like the cells of a honeycomb ; and when they are viewed by reflected light, the corresponding faces of the cavities are seen to be parallel, though the cavities have every possible variety of position with respect to each other. In other specimens they form planes of variable curvature, and sometimes curved surfaces of contrary flexure ; and in one specimen belonging to Mr SIVRIGHT the longitudinal cavities are grouped and inflected, so as to resemble a curled lock of the finest hair, as shewn in Plate XIX. Fig. 3. In a specimen of Blue Topaz from Brazil, belonging to Mr SPADEN, lapidary in Edinburgh, there are no fewer than four strata of cavities nearly parallel to each other, and in the thickness of one-eighth of an inch. The cavities have a different character in each stratum, and their number is such as almost to destroy the transparency of the plate.

In the distribution of most of these groupes, accident seems to have had the principal share ; but there are certain modes of distribution that appear to be the result of some general principle ; and a more diligent examination of them, as well as of others which may yet be discovered, will probably throw farther light upon the origin of this class of phenomena. In a specimen, for example, belonging to Mr SANDERSON, and shewn in Plate XXI. thirteen times its natural size, an immense number of cavities are arranged in rectilineal groupes, radiating from a centre A. Each rectilineal group consists of *two*, or in some places *three*, rows of cavities, and several of the radiations are bent from their original direction. The spaces between each pair of rows are filled with curiously branching cavities, some of which are half an inch long ; but the remarkable fact is, that these cavities are connected with numerous slender branches, many of which

Fig. 1.

Fig. 3.

Fig. 4.

Fig. 2.

Fig. 5.

Fig. 6.

Fig. 8.

Fig. 9.

Fig. 11.

Fig. 12.

Fig. 10.

Fig. 13.

communicate with a single cavity in the nearest rectilineal row of the radiations between which the long cavities are placed.

They have a resemblance to lakes or rivers, whose branches have been supplied from these rows of cavities; though it is more likely that the expansion of the fluid within the long cavities, and when the substance of the topaz was soft, forced out a great number of globules, some of which continued to adhere to the slender filamentous cavities from which they were discharged.

In all the cavities of this remarkable specimen capable of being examined, there are found both the new fluids, with the exception of the long branching cavity AB, from which they had escaped, in consequence of the end A being cut by the lapidary. The dense fluid always occupies the filamentous branches.

In some cases there is a breach of continuity in the branches, a small part of the cavity being as it were filled up with solid topaz. This fact favours very much the supposition that all the rows of minute cavities had been thrown off from the great ones: though the rows of cavities on the left and lower side of the specimen are hostile to it.

The plane in which these cavities lie is perfectly flat, and is nearly perpendicular to the axis of the prism, the line joining the two resultant axes of double refraction being parallel to MN.

2. *On the Form of the Cavities containing the New Fluids.*

In a former paper I have given drawings and descriptions of some of the most remarkable shapes which these cavities assume: but in the prosecution of the subject, I have met with a variety of new and remarkable forms. In a specimen belonging to Mr SANDERSON, and which is one of the most valuable that I have seen, each cavity (see Plate XIX. Fig. 6, 7, and 8), consists of

a variety of cavities of different lengths and sizes, bounded by parallel lines, and communicating by narrow channels, which almost escape the cognisance of the microscope. In these cavities thus curiously combined, the two new fluids are arranged in the most remarkable manner, the dense fluid occupying all the necks, and angles, and narrow channels, while the expansible one is left in the open and less capillary spaces. When the heat of the hand is applied to the specimen, the fluids in the cavities are all set in motion. The dense fluid quits its corners, and assumes new localities ; and the different portions of the expansible fluid either unite into one, or are subdivided by the interposition of some portion of the dense fluid, which has been expelled from its primitive situation, and drawn into its new position by capillary action. When the specimen is allowed to cool, the two fluids quit their new position ; and, as if they were endowed with vitality, they invariably resume the same positions which they occupied at the commencement of the experiment.

Another form of the cavities still more remarkable occurs in a very fine specimen belonging to Mr SIVRIGHT. These cavities resemble a number of parallel cylinders, as shewn at AB in Fig. 7. Plate XX ; but, owing to some cause which it is difficult to conjecture, a number of them have been afterwards turned aside towards C, so as to be open at one of their extremities. From these extremities, which terminate in the surface ACB, the fluids have made their escape, and have left the interior of the cavities lined with a black and brown powdery residue, which always remains after their evaporation. When the cavities thus inflected and deprived of their fluids are submitted to the microscope, they exhibit the most extraordinary shapes ; some of which are represented in Figs. 1, 2, 3, 4, 5, and 6, of Plate XX. They have the appearance of having been formed by a turning

lathe; and such is the symmetry and beauty of their outline, that it is not easy to conceive that they are the result of any mechanical cause. One of these cavities, which is unconnected with the rest, resembles a finely ornamented sceptre, as shewn in Fig. 2., in which the proportion and forms of the different parts are executed in the finest taste. But what is most remarkable, the different parts of this figure lie in different planes, so that, when it is seen in a direction at right angles to that of symmetry, it appears merely a number of disjointed lines, as in Fig. 10.

The inflexion of the cavities AB into the directions *bC*, &c. and the discharge of their fluid contents at the surface ACB, could only have taken place when the whole mass ACB, though crystallised, had not attained its permanent induration*. This opinion derives great support from the fact, that the lines *bC* are perpendicular to the axes of the prism, and consequently lie in the planes of most eminent cleavage. The direction, therefore, in which the fluids were discharged, was *that of least resistance*,—a result which might have been expected.

In the specimen now under consideration, there is a stratum of fluid cavities, composed of a great number of parallel rows of cavities, and remarkable for their symmetry. One of these rows is somewhat like AB, Fig. 9. If we now suppose that when this specimen had not acquired its permanent state of induration, the fluids in its cavities were expanded by a considerable heat, the fluid in one cavity would force itself into the adjacent ones, so that the row of cavities AB would form one cavity, somewhat like that in Fig. 6. If the cavities lay in different planes, as shewn in Fig. 10., then the expanded fluid would descend to the

* PATRIN, if we recollect rightly, speaks of crystals of Beryl in Siberia, which were so soft that they broke like a piece of apple.

one immediately below it, and connect the whole together as in Fig. 2. We do not mean to say, that the cavities *bC* in Fig. 7. were actually formed in this manner, because this is rendered improbable by their connection with the rectilineal ones *AB*, but merely to explain how cavities having the forms shewn in Figs. 1—7. may have their origin from the union of a great number of cavities arranged as in Fig. 9.

When the cavities are regularly crystallised, which is frequently the case in quartz and topaz, the homologous sides of the hollow crystals are parallel to one another, and also to those of the primitive or secondary form which they resemble. In some very curious but amorphous specimens of quartz from Brazil, belonging to Mr SPADEN, the hollow crystals terminate in six-sided pyramids, *with flat summits*, and the axes of these pyramids is parallel to the axis of the system of polarised rings, and consequently to the axis of the crystal.

3. On the Condition of the Fluids within the Cavities.

The phenomena of the expansible fluid have been so fully described in my former paper, that I have only a few observations to add upon this part of the subject. In some specimens of quartz, the expansible fluid seems to exert a very considerable elastic force, even at the ordinary temperature of the atmosphere, and when a very small heat is applied, it sometimes has sufficient force to burst the specimen. A very remarkable case of this kind happened to a son of Mr SANDERSON, who put one of the Quebec crystals of quartz into his mouth. Even with this small accession of heat the specimen burst with great force, and cut his mouth. The fluid which was discharged had a very disagreeable taste.

The extreme volubility of the expansible fluid, and its power of penetrating even the hard topaz in which it is inclosed, were

exhibited in a very remarkable manner, which I have described and attempted to delineate in my former paper. Upon applying heat to a specimen of quartz, the elastic force of the imprisoned fluid was such as to make it force its way through the solid stone; and when it had made its escape into the open air, not a trace of its path was left behind. This phenomenon, which was too extraordinary to present itself frequently, was afterwards seen both by Mr SANDERSON and myself in a specimen of topaz, when the fluid ascended through its substance with great rapidity, and resembled globules of quicksilver. This metallic appearance was owing to the total reflexion of light, which took place at the refracting surface of the globule and the topaz. That the fluid in this case forced its way through the cleavage planes of the mineral cannot be doubted, and I have in another paper shewn, that fissures in glass may be closed up without leaving the slightest trace of the two surfaces ever having been separated*.

In the various cavities described in my former paper, the whole of the expansible fluid, when exposed to heat, was either driven into vapour †, or retained its fluidity after it had filled the vacuity. Since that paper was published, however, I have discovered cavities in which, after the application of heat, there may be said to be *three different substances*, viz. 1. The expansible fluid in a state of fluidity; 2. The dense fluid; and, 3. The vapour of the expansible fluid. This curious fact will be understood from Fig 5. of Plate XIX, which represents a cavity in a specimen belonging to Mr SPADEN. The cavity is *one-twelfth* of an inch long. The expansible fluid is lodged at NN and N'N',

* See *Phil. Trans.* 1816, p. 73.

† One of the largest vapour cavities that I have seen is *one-twelfth* of an inch every way. It is less than half full of fluid, and hence it is driven into vapour by heat. During the precipitation of the vapour it becomes perfectly opaque.

where there are large vacuities V , V' , and there is a globular portion of it at n , without a vacuity. When heat is applied, the fluid at NN and $N'N'$ quickly goes off into vapour; the portion at n expands into an elliptical globule, but its force is not sufficient to displace the mass of the second fluid between n and N , and n and N' ; and being kept in equilibrio by the opposite and nearly equal expansive forces of the vapour in NN , and $N'N'$, it consequently remains fluid at n *. In a plate of Topaz shewn to me by Mr SIVRIGHT, where the expansible fluid consists of two portions floating in a large quantity of the dense fluid, one of the portions is a spherical drop which expands with heat, and contracts with cold, exhibiting by transmitted light an effect similar to the opening and shutting of the pupil.

In re-examining the phenomena of the second or denser fluid, several very curious facts have come under my notice.

I had previously shewn, that, when several cavities communicated with each other, the narrow necks, or lines which joined them, were filled with the dense fluid, which shifted its position when the equilibrium of the adjacent portions was destroyed by heat; but I have since had occasion to examine the phenomena of the second fluid with more attention. The particles of this fluid have a very powerful attraction for themselves, like those of water, and they are also powerfully attracted by the mineral which contains it. The particles of the expansible fluid have, on the contrary, a very slight attraction for one another, and also for the mineral which incloses them. Hence it follows, that, as the two fluids never in the slightest degree mix with one another, the dense fluid is either attracted to the angles of angular

* In Fig. 4. of Plate XIX, I have represented another vapour cavity, which is remarkable for having a very small portion of the expansible fluid, and also, for having several crystalline forms within the dense fluid.

cavities, or occupies the bottom of round ones, or fills the narrow necks or channels by which two or more cavities communicate with one another. The expansible fluid, on the other hand, occupies all the wide parts of the cavities, and in those which are deep and round it lies above the dense fluid.

If we now apply heat to a single deep cavity containing both fluids, the elastic force exerted by the expansible one, after its vacuity is filled up, will modify the form of the dense fluid, pressing it out of some corners and into others, till the elastic force of the one is in equilibrium with the capillary attraction of the other.

But if there are two cavities, A, B, communicating with each other, as in Fig. 10. Plate XIX., where the dotted part represents the expansible fluid, then the dense fluid will be found in the neck at m, n , and at the angles o, p, r, s . Let us now suppose that there is a vacuity V only in the smaller cavity B, and that heat is applied to the specimen. It is obvious that the greater expansion of the dotted fluid in A, which has no vacuity to fill, will force the dense fluid $m n$ towards V, where it will take up a new position about $b m c$ when the expansive forces are *in æquilibrio*. But if the cavity A is very large compared with B, the fluid $m n$ will be driven out of the neck $b n$, and will find its way to some of the corners o , or p , from which, upon cooling, it will again return to its position $m n$.

Let us now suppose that the cavity A communicates with other cavities which expand slowly into it, while it is expanding into B; then, at every expansion of A, the dense fluid $m n$ will be driven to a side, but it will immediately return, opening and shutting like a valve. This effect is finely exhibited in an irregular branching cavity of a specimen belonging to Mr SANDERSON; but as the expansions and contractions are too numerous and complicated, I shall describe them as existing in a cavity of a more simple structure, represented in Fig. 9. Plate XIX, by A B

C D E. In ordinary temperatures, about 45° , there is a vacuity of the size V, in the expansible or dotted fluid, and the dense, or shaded fluid, occupies the necks *b c*, *d e*, DE, and also the extremity F. By applying the heat of the hand to the specimen, the expanding fluid in the branches V C, V D, finds space for itself, by filling up the vacuity, but as there are no vacuities in the portions of expanding fluid at A B, B, and E F, they must necessarily force out the dense fluid which confines them. The dense fluid in the neck E D, is thus made to appear at D, and the whole of the dense fluid at *b c* is driven off to *d e*, till, accumulating there, it is drawn by attraction to the nearest neck, *m n o p*. Here it first lines the circumference of the hollow neck, from its powerful attraction for topaz; and, as the lining becomes thicker, it appears as a slight elevation between *o* and *p*, and between *m* and *n*. These elevations increase till they leap together by their mutual attraction, and form a column of the dense fluid *m n p o*. The column *b c* of dense fluid has now disappeared entirely, and the space A B C D is filled with the expanding fluid. The heat of the hand being continued, the expanding fluid A B forces itself through the little cylinder of dense fluid *d e*, which resumes its place the moment that a portion of the former has passed. But as the same heat has been expanding the fluid between *n p* and C, which pushes out part of the dense fluid at *m n o p*, this dense fluid, and the surplus of what was displaced from *b c*, moves along the sides of the cavity till it occupies the portion *q r*, of the branch V D. Sometimes the dense fluid is entirely driven from *m n o p*, and part of it sent to the extremity C; though, in general, a very small portion remains at the very neck *m o*.

As the specimen cools, the dense fluid quits *m o* and *q r*, and is gradually transferred through the neck *d e* to the neck *b c*; every portion of it invariably resuming the very position which it had before the application of heat.

A very curious modification of these actions is seen in a cavity of the specimen shewn in Plate XXI., which I have represented separately in Fig. 11. of Plate XIX. The branch bV has always, at common temperatures, a vacuity V , and the cavity A , connected with it by the filamentous channel ob , has no vacuity. At the ordinary temperature, the dense fluid appears at ac , and slightly at o and b , filling the narrow channel ob . By applying heat, the expanding fluid in bV fills up the vacuity V ; and, as the cavity Aac has no vacuity, a portion of its fluid is necessarily driven through the neck ab into bV in small globules; but, owing to the narrowness of the neck at b , the phenomena are not easily observed. Upon cooling, however, the retransference of the fluid that had passed from A to bV , is finely seen. The contraction of the expanding fluid in A causes the dense fluid to appear as at mno , in Fig. 10., and, in a short time, the curved surface mn becomes more flat; and, at last, a straight line, as at $m'n'$, Fig. 12. This indicates a pressure along the canal $b'o'$, in the direction $b'o'$, and a bubble of the expansible fluid instantly issues from o' , as in Fig. 12., and, passing through the dense fluid, joins the expansible fluid in A' . After three or four of these have passed, the equilibrium is restored. In this case, the capillary force exerted by the channel $o'b'$ upon the dense fluid which it contains is too strong to permit the little globule of the expansible fluid in $b'V$ to displace it, as in Fig. 9., so that it passes very slowly in separate globules.

The *fluid valves*, as they may with propriety be called, which thus separate the different branches of cavities, afford ground of curious speculation in reference to the functions of animal and vegetable bodies. In the larger organisations of ordinary animals, where gravity must in general overpower, or at least modify, the influence of capillary attraction, such a mechanism is neither necessary nor appropriate; but, in the lesser functions of the same animals, and in almost all the microscopic

structures of the lower world, where the force of gravity is entirely subjected to the more powerful energy of capillary forces, it is extremely probable that the mechanism of immiscible fluids, and fluid valves, is generally adopted. We must leave it, however, to the physiologist to determine the truth of this supposition.

In the second, or dense fluid, whose motions we have now described, there exist frequently black spicular crystals, which may be made to move to different parts of the cavity. Whether or not these crystals are extraneous bodies, or indicate the commencement of that induration of the fluids which I have described in a former paper, is a point which can only be ascertained by observing the progressive changes which the crystals may undergo.

4. *On the Condition of the Fluids when taken out of the Cavities.*

I have already described so fully in a former paper the singular movements into which the expansible fluid is thrown, when it first flows out of its cavity upon the surface of the plate of topaz which contains it, that I have nothing to add upon this subject *. It did not then occur to me that these movements might be owing to electricity, till I read an account of the following experiment made both by Professor ERMAN and Mr HERSCHEL. When a globule of water, dropped on the surface of a flat dish of mercury, is brought into connexion with the positive pole of a galvanic battery, while the mercury is connected with the negative pole, it instantly flattens and spreads to twice its diameter, regaining its former sphericity when the circuit is broken. This extension and subsequent re-aggregation of the globule of water,

* Some of the fluids in quartz seem to be entirely gaseous, while in sulphate of barytes the fluid appears to be the mineral itself in a fluid state; see p. 425. and note on p. 427.

is precisely the same effect as that exhibited by the drop of expansible fluid ; and it is therefore very likely that the latter is owing to an electrical cause. In separating the particles of bodies, electricity is always produced ; and in the cleavage of Topaz and Mica, even electric light is developed. But experiments are still wanting to determine, whether, in the present case, the electricity is derived from the separation of the cleavage planes, or from the change of condition which the new fluid is undergoing during its rapid evaporation, and its partial conversion into a powdery residue.

5. *On some Miscellaneous Phenomena connected with the Formation of Fluid Cavities.*

In my former paper, I have described the phenomena of a single fluid in the cavities of various minerals and artificial crystals *. Since that paper was written, I have seen many specimens of this kind ; but as the fluid has always, when examined, been found to be water, such specimens possess no peculiar interest, unless their cavities are opened, in the manner first adopted by Sir HUMPHRY DAVY. One of these specimens, however, which was kindly sent to me for examination by W. C. TREVELYAN, Esq. is so peculiar as to deserve notice. In the drawing of it, in Plate XX. Fig. 8., which is of the real size, A B is a cavity in quartz, which is filled with a fluid, excepting the vacuity *a b*, which may be made to move to different parts of the cavity. The

* Mr WILLIAM NICOL, Lecturer on Natural Philosophy and Chemistry, has shewn me some fine specimens of Amber containing cavities. The inner surface of these cavities is rough, like finely ground glass, and many of them contain a fluid with a moveable globule of air. In a specimen of calcareous spar, in the possession of Mr SANDERSON, there is a fluid cavity about *two inches long*, an inch wide, and one-eighth of an inch deep.

fluid does not expand perceptibly by heat, and is in all probability water. When the specimen is shaken, the fluid becomes turbid, and of a whitish colour, arising from a fine white sediment, which settles in the lower part of the cavity.

In a specimen of Quartz from Brazil belonging to Mr SPADEN, there is a cavity with an air-bubble, about the tenth of an inch long. It is nearly one-third full of a white powder, consisting of crystalline particles, which, upon inverting the specimen, flow over the surface of the air-bubble like sand in a sand-glass. In the specimens of quartz already mentioned in page 417. as containing cavities with pyramidal summits, there is only one fluid, in which there is generally an air-bubble. These cavities often contain opaque spherical balls*, which are distinctly moveable; and in one cavity I have counted *ten* of these balls, *seven* of which roll about the cavity when the specimen is turned round †. In a second specimen, spherical balls of the same kind are copiously disseminated in the quartz, and exist also in the cavities. In a third specimen, the balls occur near the summits of the pyramidal cavities, some of them being within and some of them without the cavity.

In the crystallisations of ice several phenomena occur, which are intimately connected with the preceding inquiry. When water is frozen in a glass vessel, the ice is often intersected with strata of cavities, which have the same general form and aspect

* These balls are of the same size as the seeds of *Lycopodium*, which amount to 32 parts of Dr YOUNG's eriometrical scale. Their diameter is therefore $\frac{1}{32000} \div 32 = \frac{1}{960000}$ th part of an inch.

† I have since opened several of these cavities by the blow of a hammer. In a second or two the fluid was entirely gone, without leaving a trace of its existence behind. The spherical balls remained in the cavities. They were not acted upon either by the muriatic or the sulphuric acids.

as those in minerals. I have sometimes observed frozen drops of dew, containing a portion of water which *remained unfrozen even at low temperatures*; and I have recently had occasion to examine some crystallisations of ice, which presented the same fact, under more curious circumstances.

A very sharp frost occurred in Roxburghshire on the morning of the 8th October 1825. The gravel-walks in the garden were raised up about an inch above their natural level by the sudden congelation of the water in the earth mixed with the gravel. All the elevated portions consisted of vertical prismatic crystals of ice of six-sided prisms, with summits which seemed to be triedral. The leaves of plants, &c. were covered with granular crystals, which were in general six-sided tables.

Upon examining with a microscope the prismatic crystals aggregated in parallel directions, they presented some curious phenomena. They had numerous cavities of the most minute kind, arranged in rows parallel to the axis of the crystals, and at such equal distances as to resemble a series of mathematically equidistant points. Some of the cavities were very long and flat, and sometimes they were amorphous; but in general they contained *water and air*.

Upon submitting one of these cavities to a powerful microscope, it appeared as shewn in Fig. 13. of Plate XIX, where ABC is the piece of ice, having in it a long cavity mo , containing water and air. The ice gradually dissolved; and when the end no of the cavity mn was near the edge of the ice CB , the air, in a portion of it no , detached itself, and went off at p , through the solid ice, the cavity closing up again at n . This phenomenon is analogous to the passage of the expansible fluid through topaz and quartz, which has been already described; the air in the one case, and the fluid in the other, finding its way in the direction of easiest cleavage, and the fissure closing up again in the manner already mentioned in a preceding part of this

Fig. 1.

PLATE XX.

Fig.^d for the *Edin^r Royal Society Tran.* Vol. X. p. 415. p. 226

Fig. 6.

Fig. 3.

Fig. 2.

Fig. 4.

Fig. 5.

Fig. 9.

Fig. 10.

Fig. 7.

Fig. 8.

paper. The singular fact, however, is, that the portion *no* of the cavity quitted by the globule of air, was immediately filled up with ice, and the cavity reduced to the dimensions *mn*.

As the formation of ice from water is in every respect analogous to the formation of crystals from a substance rendered fluid by heat, the examination of its cavities is likely to throw some light upon their formation in mineral bodies*.

In concluding these observations, I could have wished to enter into some details respecting their geological relations; but as these would lead us too far into the regions of speculation I shall not enter upon them on the present occasion. It may be proper, however, to state, that the opinion which I hazarded in a former paper, that the discovery of the two New Fluids in minerals attached a new difficulty to the aqueous hypothesis, has been rendered more probable by every subsequent inquiry; and that I can see no way of accounting for the phenomena, but by supposing that the cavities were formed by highly elastic substances, when the mineral itself had been either in a state of fusion, or rendered soft by heat.

* Since this Paper was written, Mr WILLIAM NICOL has shewn me a very remarkable specimen of *Sulphate of Barytes*, with fluid cavities of the same general character with those which I described in my former paper (Trans. vol. x. p. 36.), but much larger than any which I had seen. Upon grinding down on a dry stone, one of the faces of this specimen, the largest cavity burst, and discharged its fluid contents through the fissure upon the ground surface of the specimen. The fluid lay in drops of different sizes along the line of the fissure, and in this condition Mr NICOL put it into his cabinet. Upon looking at the specimen about *twenty-four* hours afterwards, *each drop of fluid had become a crystal of Sulphate of Barytes*. These crystals had the primitive form of the mineral.

This very curious fact is analogous to the uncrystallised water in the ice-cavities mentioned above, the crystallisation in both cases being prevented by pressure. When that pressure was removed, a portion of the water and the fluid sulphate of barytes were immediately crystallised. Mr NICOL distinctly remarked, that the crystals occupied as much space as the drops of the fluid; so that the crystals of sulphate of barytes were not deposited from an aqueous solution, but bore the same relation to the fluid from which they were formed, as ice does to water.