TRANSACTIONS

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TRANSACTIONS

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CONTENTS

OF

VOLUME TENTH.

PART FIRST.

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PART SECOND.

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I. *On the Existence of Two New Fluids in the Cavities of Minerals, which are immiscible, and possess remarkable Physical Properties.* By DAVID BREWSTER, LL.D. F.R.S. Lond. & Sec. R.S. Edin.

(Read March 3. and 17. 1823.)

In the year 1818, my attention was accidentally directed to the subject of water in crystallised bodies, by the explosion of a crystal of Topaz, which I had exposed to a red heat, for the purpose of expelling its colouring matter. This violent disruption of the specimen, which was shivered into a thousand films, of extreme tenuity, arose from the expansion of the imprisoned fluid, and induced me to institute a series of experiments, for the purpose of determining the nature of the fluid, the form of the cavities which contained it, and the arrangement of these cavities in reference to the crystalline form of the mineral *.

Small portions of fluid had been long ago observed by mineralogists in *Topaz*, *Rock-Crystal*, and *Fluor-Spar*. Mr SIVRIGHT found them also in *Calcareous Spar*, *Sulphate of Barytes*, and *Sulphate of Lime;* and I detected them in the *Emerald*, in *Beryl*,

* An account of these experiments was announced for publication in 1819, in the 1st Number of the *Edinburgh Philosophical Journal;* but the desire of obtaining more general results prevented me from publishing it at that time.

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Cymophane, *Peridot*, *Feldspar*, and in the following crystals formed by aqueous solution.

Sulphate of Iron.	Sulphate of Ammonia and Magnesia.
Sulphate of Zinc.	Nitrate of Silver.
Sulphate of Copper.	Nitrate of Strontian.
Sulphate of Nickel.	Muriate of Barytes.
Sulphate of Soda.	Acetate of Lead.
Sulphate of Magnesia.	Oxymuriate of Potash.
Sulphate of Ammonia.	Muriate of Barytes.
Sulphate of Magnesia and Iron.	Oxalic Acid.
Sulphate of Soda and Magnesia.	Tartrate of Potash and Soda.
Sulphate of Alumine and Ammonia.	Carbonate of Potash.

Being persuaded, from these results, that water will be found in *every* crystal deposited from a solution, I was next desirous of finding it in crystals formed by heat, or by sublimation; but in no case have I been able to discover the slightest trace of its existence; and, in the absence of all other information on the subject, I considered this result as highly favourable to the aqueous origin of those minerals in which water has been discovered.

Sir Humphry Davy was, we believe, the first philosopher who conceived the idea of opening the cavities of crystals, and of examining chemically the nature of the fluid which they contain, and of the gas by which it is sometimes accompanied; and the experiments which he undertook for this purpose, were conducted with that sagacity and address which characterise all his labours. Upon opening the cavities in a variety of rock-crystals of different localities, and collecting the fluids in fine capillary tubes, he discovered, that, in every case, except one, the fluid was *Water* nearly pure;—that, in this single case, it seemed to be *Naphtha*;—that the gas was in two cases *Azote*, and was about 65 times more *rare* than that of the atmosphere;—that, in one case, the gas (the nature of which is not mentioned) was *compres-*

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sed about 10 times more than atmospheric air; and that in the naphtha cavity there was almost a perfect *vacuum* *.

Such was the state of the subject, when my attention was again turned to the examination of these cavities.

In resuming this enquiry, I have been fortunate, not only in possessing many excellent specimens of my own, but in having the free use of an interesting collection, belonging to Mr SIVRIGHT of Meggetland; and though I have employed only the microscope, and the agency of heat and of light, I have been led to results of considerable generality and interest. This physical method of determining the properties of minute quantities of matter, though often very difficult, and sometimes perplexing in its manipulations, carries with it a degree of evidence not inferior to that of chemical analysis; while it possesses the advantage of examining the substance in its original and unchanged condition, and may be applied, in many cases, where the chemist cannot avail himself of any of the resources of his art.

When the cavities in crystals are very large, which seems to be the case principally when they contain water, the elegant method pursued by the distinguished President of the Royal Society of London will afford precise results, and may be expected to add greatly to our knowledge of this mysterious subject. Leaving, therefore, this branch of the enquiry in the skilful hands of Sir HUMPHRY DAVY, I have pursued the subject under a more general form, and have studied the phenomena in their various relations to the principles and methods of general physics.

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* *Philosophical Transactions*, 1822, p. 367.

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Sect. I. *On the Existence of a New Fluid in the Cavities of Minerals.*

In examining the cavities of crystallised bodies, I observed the most striking difference in the phenomena presented by the fluids which they enclosed. Impressed with the opinion that the fluid was water, I tried every method of explaining, upon ordinary principles, the phenomena which were thus presented to me, but the results of a more minute examination were incompatible with such a supposition, and rendered it necessary to ascribe them to new fluids, possessing new physical properties. In order to convey to the Society a correct idea of the methods of observation, and the train of reasoning by which I was led to this conclusion, I shall give a detailed account of the phenomena, as exhibited in different minerals.

1. *Topazes from New Holland, Scotland, and Brazil.*

As the cavities in the New Holland topazes are frequently arranged in strata parallel or slightly inclined to its most eminent cleavage, or the one perpendicular to the axis of the prism, they are peculiarly fitted for carrying on this enquiry. The facility with which this mineral may be split, allows us to dispense with the aid of the lapidary, and to study the phenomena through perfectly flat and highly polished surfaces.

In examining these specimens with the microscope, we observe the cavities arranged in strata. These cavities are sometimes beautifully crystallised, and sometimes amorphous, sometimes extremely shallow, and at other times deep. They have often the shape of long canals, with parallel sides and round

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terminations, and at other times their form is not far from that of a circle.

The cavities now described, are filled with a colourless and transparent fluid, as shewn at ABCD, Fig, 1. Plate I., and have almost always a vacuity V, of a circular form, which moves by an inclination of the plate to different parts of the cavity. The depth of the cavity may be easily estimated, by the breadth of its bounding line ABCD, which, in the flat cavities, is generally the same as that of the circle V. In very shallow cavities, this boundary is a narrow line, scarcely visible, and in deep ones it is broad, with a penumbral termination inwards, arising from the deviation of the light at the separating surfaces of the fluid and the topaz, and at that of the fluid and the vacuity.

When the hand is applied to the crystal, the heat of it gradually expands the fluid. The vacuity V consequently diminishes, and being in a short time reduced to a physical point, it entirely disappears. When the fluid again cools, by withdrawing the hand, it of course contracts, and quits the sides of the cavity. The vacuity V reappears, increasing till it resumes its former magnitude; and it deserves particular notice, that the evanescence and reappearance of the vacuity takes place simultaneously in many hundred cavities, of the same general form, which may be seen in the field of view.

In order to obtain an accurate measure of the temperature at which the vacuity reappears, which is almost the same as that at which it vanishes, I plunged the topaz in heated water, and by méans of an accurate thermometer, I obtained the following results:

Nature of the Cavities.	*Temperature at which the Vacuity reappeared.*
1. Topaz from New Holland, with shallow cavities,	74 ½° Fahr.
2. Blue Topaz from Aberdeenshire, with cavities of different forms, - - -	74 77 78 ½ 82

Nature of the Cavities.	*Temperature at which the Vacuity reappeared.*
3. Colourless Topaz from Brazil, with only one cavity $\frac{1}{20}$th of an inch long, $\frac{1}{62}$d of an inch broad, and $\frac{1}{72}$th of an inch wide, -	79 $\frac{1}{2}$
4. Topaz from New Holland, with large and rugged cavities, - - -	79 $\frac{3}{4}$
5. Topaz from New Holland, with a very flat cavity, - - -	81 $\frac{1}{4}$
A very long and very irregular cavity in the same crystal, - - -	82 $\frac{1}{4}$
6. Another colourless Topaz from Brazil, -	83 $\frac{1}{5}$
7. Another colourless Topaz from Brazil with a deep cavity,	83 $\frac{3}{4}$

The reappearance of the vacuity at different temperatures in different cavities of the same crystal, admits of an easy explanation. In those which are of the same size and form, and equidistant from the cooling surface, the vacuities disappear at the same time; but in those which are deep, and in those which, though shallow, are near the cooling surface, the vacuities reappear at a lower temperature. In very shallow cavities, the adhesion of the fluid to the sides of the cavity prevents the vacuity from reappearing so soon as it would otherwise do; while in cavities that have a rough or irregular bottom, they reappear earlier.

When the cavities are very small and narrow, only one vacuity reappears; but when they are large, several small circular vacuities make their appearance, and gradually unite into one, though sometimes they remain permanently separate. When the cavities are deep, a very remarkable phenomenon accompanies the reappearance of the vacuity. At the instant that the fluid has acquired the temperature at which it quits the sides of the cavity, a rapid ebullition takes place, and the transparent cavity is for a moment opaque, with an infinite number of minute

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vacuities, which instantly unite into one vacuity, that gradually goes on enlarging as the temperature diminishes.

In order to determine the expansion which takes place by a given increment of temperature, I measured the relative size of the vacuity, and the cavity at the temperature of 50° and 80°, the temperature at which the fluid had expanded so as wholly to fill the cavity. In many cases this could be estimated with tolerable accuracy, and it may be stated in general, from the estimates and measures taken by myself, and by others, to whom I shewed the cavities, that the fluid expands fully *one-fourth* of its size, by an increment of 30° of heat.

Hence, since water expands $\frac{1}{22}$d of its bulk in passing from 41°, its state of maximum density, to 212°, it will expand $\frac{1}{125}$th of its bulk for 30°, and $\frac{1}{125} \div \frac{1}{4} = 31\frac{1}{4}$; that is, the fluid contained in the cavities is above 30 times more expansible than water, by an increment of 30° of heat at the temperature of 50°.

This extraordinary result proved beyond a doubt, that the substance contained in the cavity was a new fluid, differing from all known fluids in its high expansibility, and resembling in this respect a gaseous more than a fluid body.

In order to confirm this result, I was desirous of examining the other physical properties of this remarkable substance. I could not fail to notice, in the deep cavities especially, the singular volubility of the fluid, and its slight adherence to the sides of the cavity, as indicated by the motion of the vacuity V. In small cavities containing water, the adhesion of the fluid to the stone is so strong, that the air-bubble moves with extreme difficulty, and even when very large, it often changes its place by starts, or remains stationary at the bottom or in the middle of the cavity. In the present case, however, the vacuity moved about with great facility, and in the cavity, $\frac{1}{20}$th of an inch long, by $\frac{1}{58}$th and $\frac{1}{62}$d of an inch wide and deep, the slightest tap of the

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finger on the microscope caused the air-bubble to tremble and oscillate in this miscroscopic level. Hence the new fluid is distinguished by a second physical property, no less remarkable than the first.

Although I now entertained no doubt of the accuracy of the conclusion, that the fluid was a new one, yet I conceived it might be possible to obtain at least an approximate measure of its refractive power, and thus to put its novelty beyond the reach of a doubt. In order to do this, it became necessary to observe the manner in which the total reflexion of the upper surface of the cavity was modified by the contact of the fluid, and, if possible, to measure the angle at which total reflexion was effected, by the separating surface of the fluid and the solid. For this purpose I took a plate of topaz AB, Fig. 2., with a stratum of cavities *m n*, perfectly parallel to the natural surface of the plate. I then placed upon each surface the rectangular prisms ABC, ABD, and introduced between them a thin film of oil of cassia. Rays of light RS, RS were then allowed to fall upon the stratum of cavities *m n*, so that the rays reflected from the upper surface of the cavity could be examined by a microscope whose object lens is LL. Upon making this arrangement, the stratum of cavities was seen in the most beautiful manner. The vacuity V, Fig. 3. of a cavity seen in this way, shone with all the brilliancy of total reflexion, the separating surface of the new fluid ABCD, and the cavity, exhibited a faint grey tint, while the surrounding portions of the solid topaz were comparatively black. The variations which the vacuity V undergoes by heat are now finely seen, and at a temperature of 80° it vanishes in a brilliant speck, leaving the whole of the cavity ABCD of the same uniform tint as in Fig. 4.

The phenomena now described are not so distinctly seen when the stratum *m n* is deeply seated beneath the surface of

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the topaz, in consequence of the duplication and overlapping of the images formed by double refraction.

This inconvenience, however, may be nearly removed, by making the plate of topaz very thin; or it may be entirely remedied, in plates of any size, by causing the incident rays RS RS, Fig. 2., to pass along one of the resultant axes of the topaz, while the reflected rays SL SL pass along the other resultant axis.

In order to compare the angle at which total reflexion took place at the upper surfaces of the fluid and the cavity, with that which would have taken place had the fluid been water, I placed a drop of water on part of the lower surface of the plate AB, and I found that the light reflected at the same angle of incidence, was much more brilliant from the separating surface of the new fluid and the cavity, than from the separating surface of the topaz and the water, a result which indicated, in the most unequivocal manner, that the new fluid had a refractive power inferior to water, and that it differed in this respect from every other known fluid.

Although, in this estimate, I attended carefully to the circumstance, that, in the one case, the light reflected from the bottom of the cavity was combined with that reflected from its surface, and therefore used deep cavities, where the two reflexions could to a certain degree be separated; yet, in order to remove any doubt that might remain on the subject, I took a plate of topaz that contained water, or, to speak more correctly, a fluid which did not expand by heat, and upon comparing the reflexions from the cavities, the difference was most palpable.

In one specimen I measured the difference between the angles of incidence at which total reflexion took place, at the separating surface of the new fluid and topaz, and at the separating surface of water and topaz, and I estimated that the refractive power of the new fluid was below 1.300, that of water being 1.336.

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In one specimen of *Amethyst* I was enabled to determine, that the angle of total reflexion took place at 51° 26′, and, consequently, that the refractive power of the Fluid, or m, was $= m' + \sin 51° 26' = 1.21066$, m' being taken equal to 1.5484, the ordinary refractive power of Amethyst.

Many other details might have been added under the present head, in support of these conclusions; but they are necessarily reserved for the next section, with which they have a more immediate connection.

2. *Cymophane or Chrysoberyl from Brazil.*

In several specimens of this mineral I have discovered strata of cavities, which contain the new fluid. One of these is remarkable for having two strata parallel to one another; one of which, about $\frac{1}{7}$th of an inch square, contains no fewer than 30,000 cavities, filled with the new fluid, which expands and fills the cavity with the heat of the hand. The cavities are in general very small; but I succeeded in determining that the vacuities all reappear simultaneously, at a temperature of $83\frac{1}{4}$°.

3. *Quartz-Crystals from Quebec.*

In examining the crystals of quartz from Quebec, I have found that almost every specimen of it contains cavities with the new fluid.

In one crystal the vacuity reappeared at 76°. Another vacuity in the same crystal reappeared at 80°; while another, almost in contact with this, required a temperature of 125° to make the fluid fill the cavity.

In another specimen of the crystals there are cavities where the new fluid expands fully $\frac{1}{3}$d of its bulk, by an additional temperature of 30°; and though they are very shallow, the vacuities reappear in the form of several smaller vacuities, and exhibit an appearance as if the fluid were thick and viscid.

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While I was applying a heat not above 170° to some of these specimens, they frequently leapt from the plate of glass on which they lay, and at other times threw off, with an explosion, considerable fragments. In one of these experiments, I was fortunate enough to observe a phenomenon which will be considered a very remarkable one. When the compound microscope was adjusted to a distinct view of a stratum of globules containing the new fluid, but particularly to a vast number of minute specks, which the microscope had not power to resolve, a heat of about 150°, which happened to be applied to the specimen, produced a sort of crackling noise, which arose from the bursting of the cavities near the surface. Upon looking into the microscope, I was astonished to observe a great number of *darkish brown* globules rising through the solid quartz, like globules of air in water. In examining them more minutely, I observed, as shewn in Fig. 5., that they took their origin from the minute specks or cavities, which gradually enlarged and went off in the form of a globule. This phenomenon lasted fully five minutes, when the specimen burst into two or three pieces. While examining the cavities of one of the fragments, I found that several of the large ones, with flat faces, had been emptied of their contents, through a fissure parallel to their flat faces, and that the faces of the fissure had closed up, so as to transmit a brownish light, while a bright light was freely transmitted through the polished faces of the cavities as shewn in Fig. 6 *.

Had only one of the cavities shewn in Fig. 6. existed, the fluids which it contained might have escaped through a narrow fissure, not wider than its own breadth; and this narrow fissure

* In a specimen of Topaz which split in the fire, I found that a quantity of the new fluid had got into a fissure, where it has been permanently detained without reaching the surface. It exhibits the same brown tint as the globules, at particular inclinations.

might, in virtue of the elasticity of the stone, have closed up completely, so as to transmit the light as freely as if it had never existed. This process is by no means a hypothetical one. I have repeatedly formed these fissures in glass, and have sometimes seen them close up in a few minutes, without leaving a trace of their existence behind. When they are wide, a day, a week, and sometimes a month was necessary, to effect the reunion of their sides *.

These circumstances enable us to give a satisfactory explanation of the remarkable phenomenon represented in Fig. 5. When the expansive force of the imprisoned fluid was sufficient to make it penetrate the stone, it would probably escape at the weakest point of the cavity, and pass to the surface through a narrow channel, which the elasticity of the stone would immediately close up. These fissures would probably lie in the direction of the cleavage, and this seemed to be the path which the globules took in their oblique ascent, as represented in Fig. 5.

4. *Amethyst from Siberia.*

The greatest quantity of the new fluid which I have yet seen, exists in a specimen of *Amethyst* belonging to Thomas Allan, Esq. This very interesting specimen is represented in Fig. 7., where *a*, *b*, *c*, *d*, *e*, represent five cavities parallel to each other. The largest of these is $\frac{10}{56}$ of an inch in length, and $\frac{1}{27}$th of an inch in breadth; and the vacuity is about one-fourth part of the whole cavity. By the heat of the hand the fluid swells, and fills all the cavities, and when the vacuity has been considerably reduced by heat, it moves from one end of the cavity to the other, with a degree of volubility truly surprising. By a

* A full account of these experiments will be found in the *Philosophical Transactions* for 1816, p. 73.

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careful experiment, I found that the vacuity disappeared at a temperature of 83⅓°; and when it was made to reappear by rapid cooling, an ebullition took place, as in the deep cavities of topaz.

As the cavities in this specimen were terminated with crystallised summits at *a*, *b*, *c*, *d*, I was enabled to observe a curious optical phenomenon, which accompanied the expansion of the fluid. Whenever the vacuity was so much reduced by the expansion of the fluid, that it could be made to occupy one of the crystallised summits, and afterwards to vanish, it left behind it, on that summit, a system of beautiful concentric coloured rings, which were constantly varying in tint, in diameter, and in number. These rings had the highest order of colours in their centre, and continued while the fluid preserved its expanded state; but they invariably disappeared when the fluid was allowed to contract by cold, as if the substance which formed them had assumed a gaseous form, and entered into the vacuity.

Sect. II. *On the coexistence of two Immiscible Fluids, of different Physical Properties, in the Cavities of Minerals, and accompanied with a vacuity.*

Although many of the cavities which have been described in the preceding section, contain only the new fluid, yet in a very great number, particularly in Topaz, another phenomenon presents itself, which requires a very minute examination. This phenomenon, as exhibited in Topaz, is represented in Figures 8, 9, and 10, where V is the vacuity, NNN the new fluid, and WWW another fluid, which we shall distinguish by the name of the *Second Fluid.* This second fluid WW commonly occupies the angles of triangular cavities, as in Fig. 8., or the terminations of longitudinal ones. It is always separated from the new fluid by a curved surface *m n*, *m n*, &c. It never expands perceptibly

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with heat, and never mixes with the new fluid NN. By a little management, the vacuity V may be made to come in contact with the bounding lines *m n*, *m n*, &c.; but it never affects its curvature, and seldom enters the fluid W. When the vacuity V has been made to vanish by heat, these bounding lines remain exactly the same.

Having at first observed this second fluid only in the angles of cavities, as in Fig. 8., I experienced considerable difficulty in establishing its fluidity. The improbability of two fluids existing in a transparent state, in absolute contact, without mixing in the slightest degree, induced some of my scientific friends to refer it to an optical illusion, and to consider the line which separated it from the new fluid as a septum or partition in the cavity. The beautiful curvature of the bounding line, and its perfect similarity to that of two contiguous fluids, rendered this conjecture untenable. It was next supposed to be a vacuity into which the new fluid could not expand itself; but though this idea explained the curvature of the bounding line, it was inconsistent with other facts, and especially with the important one, that the second fluid acted upon light neither like topaz nor a vacuum, but like water.

These difficulties were gradually overcome by more numerous observations.

Although the cavities were generally like those in Fig. 8., where V is the vacuity, NN the new fluid, and WW the supposed second fluid; yet I found several in which the second fluid filled a great part of the cavity, as in Fig. 9., where NN is the new fluid, and W the second fluid, or as in Fig. 10., where a vacuity V also appeared within the globule N of the new fluid.

This great enlargement in the quantity of the second fluid, removed most of the difficulties which had formerly presented themselves; but something was still wanting to prove its fluidity. This desideratum was fortunately obtained in a specimen of to-

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paz belonging to Mr Sivright. In examining this specimen, I observed a very remarkable cavity, of the form shewn in Fig. 11., where A, B and C are three separate portions of the new fluid, insulated by the interposition of the second fluid DEF. The first portion A of the new fluid had four vacuities V, X, Y, Z, while the other two portions B, C, had no vacuity. Having often succeeded in making the vacuities pass from one branch of a cavity to another branch, I did not doubt that the vacuities of the portions B and C had passed over the second fluid into the portion A. In order to determine this, I took an accurate drawing of all the phenomena at a temperature of 50°, as represented in Fig. 11., and I carefully watched the changes which took place, by raising the temperature to 83°. The new fluid at A gradually expanded itself, till it filled up all the four cavities V, X, Y, Z; but as the portions B, C, had no cavities for this purpose, they could only expand themselves, by pushing back the supposed second fluid DEF. This actually happened. The second fluid quitted entirely the edge of the cavity at F. The two portions of new fluid B, C, were immediately united into one; and the second fluid having retreated to its new limit *m n n′ o*, and being itself but slightly expansible, like common fluids, its other limit necessarily advanced to *p q r*. This experiment, which I have often repeated, and shewn to others, involves one of those rare combinations of circumstances, which Nature sometimes presents to us, in order to lay open some of the most mysterious of her operations. Had the portions B, C, of the *new fluid* been accompanied, as is usual, with their vacuities, the interposed *second fluid* would have remained immoveable between the two equal and opposite expansions: but from the accidental circumstance of these vacuities having passed over into the other branch A of the cavity, the *second fluid* is placed in a sort of unstable equilibrium, and, like the arms of a lever, it yields to every variation of the power and of the resistance.

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If any additional evidence were wanted on this subject, we have only to examine the mode in which the two portions of the new fluid B, C, are united into one by a disunion of the second fluid at *g h*, and again separated by its reunion. Upon the application of heat, the summits *g*, *h*, become more acute, and gradually approach to each other, till they suddenly unite, and force back the surface of the second fluid into the line *m n n′ o*. A portion of the second fluid, however, is retained by capillary attraction, in the angular meeting of the planes, between *c* and F, and between *d* and F, and also a small portion at *f*, a phenomenon which affords an ocular explanation of the immobility of the second fluid in the terminations and angles of cavities. When the fluids again cool, the surface *n n′* approaches to *c d*, and when *n* is near *c*, the surface *n n′* of the second fluid and that of the same fluid in *c d*, suddenly start into union, in virtue of their mutual attraction, and the portions B and C are again separated.

By allowing the specimen to rest in particular positions, I have often driven part of the vacuity V towards X, so as to unite all the three vacuities X, Y and Z into one; and in like manner I have caused the vacuities Y, Z and part of X to disappear and unite with the vacuity V.

In order to examine the refractive power of the second fluid, I made the arrangement represented in Fig. 2., and found that the second fluid W always reflected less light than the new fluid, and consequently that its refractive power approached nearer to topaz than the new fluid. By the same means I determined, that the angle at which total reflection took place at the separating surface from the topaz, was very nearly the same as if the second fluid were water.

The fortunate circumstance of the cavities B, C, being without a vacuity, and the consequent mobility of their bounding lines *a b c*, *d e f*, enabled me to compare the optical properties of the two fluids, by means of transmitted light. The sides of the cavity being inclined to one another, like those of a prism, it is manifest, that if *a b c* is the boundary of two fluids of equal refractive power, the image of a luminous object will have the same deviation, by the refraction of both. As the cavity, however, is too minute to permit an image to be distinctly seen through it, it becomes necessary to look with a microscope at the illumination of the surface of the cavity, and if the two refractive powers are *equal*, the portion above *a b c* will be *dark*, when the portion below it is *dark*, and *vice versa*. I found, however, that the portion of fluid B *a b c* was often *dark*, when the second fluid below *a b c* was *light*, and I therefore concluded that this arose from their unequal refraction. To this conclusion it may be objected, that the inclination of the refracting faces might accidentally be different behind B *a b c*, although it is not likely that the portion possessing this difference of inclination would be bounded by a curve line *a b c*. I therefore applied heat to the specimen, and, by expanding the new fluid at B and C, the bounding lines were made to move from *abc*, *def*, to *mnn′o*, and I remarked, that, during this change of position, the boundary of the two fluids was always the boundary of the unequal shades produced by unequal refraction.

As the arrangement of the fluids which enabled me to make these experiments, possesses a peculiar interest, I have carefully looked for similar cavities, but I have not succeeded in finding more than a few examples, one of which is represented in Fig. 12., as it appears at the temperature of 32°. This cavity consists of two wide portions, separated by a narrow channel. The new fluid occupies the portion between *c c*, *d d*, and also that between *a a* and *b b*, these two portions being separated by the second fluid *d d*, *a a*. The whole vacuity exists at V. If we now apply heat, the new fluid at N and N expands, and the boundaries *d d*, *a a* and *b b*, advance towards B. The vacuity V becomes

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an elliptical bubble, and finally vanishes. When this takes place, the boundary *b b* has of course disappeared, and *d d* and *a a* have advanced to *d′ d′* and *a′ a′*, and *c c* is invisible, in consequence of the new fluid having spread over it, as it were, in the manner described in the following section.

Another cavity, consisting of three separate portions, AB, CDE, FGHK, is shewn in Fig. 13., and is remarkable, in consequence of each of these masses being connected with the adjacent one, by a portion of the second fluid, which moves between them like a piston through the extremely narrow channels BC, EF. As the portion of new fluid between *a b* and *e f* expands without having an air-bubble, it pushes the portion of the second fluid B *a b* through BC into C *a′ b′*. In like manner, the second fluid *c d* EF *c′ d* varies its position with the expansion of the fluids on each side of it. When the vacuity V disappears, a portion of the second fluid shews itself in the space D *k h*, and it again withdraws itself when the vacuity V touches the sides of the triangular cavity.

In some cavities where there is a large proportion of the second fluid, the vacuities sometimes form *two-thirds* and even *three-fourths* of the space occupied by the expansible fluid when the cavity is full, and yet these vacuities are filled at the usual temperature of 83°. In these cases, the circular vacuity did not contract by heat, but extended itself till it disappeared. This effect admitted of an easy solution, by supposing the surface of the fluid to rise gradually by expansion; but I found, by optical observations, that the vacuity occupied the whole thickness of the cavity, and that it vanished by extension, when it was held in a vertical direction. This remarkable fact will be fully explained in the 5th section.

In some specimens, the faces of the cavities are accidentally inclined to the surfaces, nearly at the angles of total reflection from the surface of the new fluid, so that all the part of the ca-

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vity which it occupied appears of a brownish-blue colour, while the part occupied by the second fluid is perfectly transparent. This phenomenon explains, in many cases, the apparent opacity of the cavities, which become perfectly transparent by inclining the specimen. When the stratum of cavities is very much inclined, all of them appear like black specks, and hence they have been generally considered by lapidaries as opaque particles.

Two immiscible fluids, possessing the properties now described, exist also in *Quartz*, *Amethyst*, and *Cymophane*, and I have reason to conclude that the one never occurs without the other, as I have in almost every case discovered the second fluid in cavities, where the difficulties of observation had at first prevented me from detecting it.

Sect. III. *On the Phenomena of Two Immiscible Fluids* without a Vacuity *in the Cavities of Minerals*.

The preceding results conduct us gradually to the development and explanation of phenomena, which, had they been observed alone, would have occasioned no inconsiderable perplexity.

In the same specimen of topaz, I have noticed the two classes of cavities which form the subject of the two preceding sections; and, along with them, I have likewise found a third class, such as AB, Fig. 13., which differs in no respect from those of the first class, shewn in Fig. 1., when examined by the microscope alone. Their difference, however, becomes very manifest by the agency of heat and light.

When heat is applied to these cavities, the circular space N, Fig. 14., in place of diminishing, as it does in Fig. 1., actually increases, as in Fig. 15., as if the fluid WW had contracted with

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heat. This perplexing fact induced me to examine the cavity under the circumstances of total reflexion, and it was then apparent, that N was neither a vacuity nor a space filled with gas, but a portion of the new fluid floating as it were on the second fluid WW.

This phenomenon was analogous to what takes place in the right hand portion of the cavity in Fig. 11.; but, as there were here no vacuities into which the expansion of the new fluid could push the second fluid, the difficulty remained unsolved.

It may be proper to mention, that the cavities which present this phenomenon are most frequently connected by a dark line with other cavities, accompanied with vacuities, as shewn at N, in Fig. 16, and 17. In Fig. 16., by a considerable cold, I have caused a small vacuity to appear at V; but it sometimes remains, and sometimes disappears.

As there are cavities, however, such as that in Fig. 14., where no connection can be traced with other cavities, and where the fluid N seems to expand, and WW to contract, it is necessary to seek for some explanation of this singular anomaly. That the expansions and contractions are here only apparent, cannot, we think, be doubted. Let AB, therefore, Plate II. Fig. 18. be a section of the cavity in Fig. 14., where the new fluid NN floats as it were on the other. When NN is heated, the effect of the heat will tend to diminish the cohesive force of the fluid WW, and to make the fluid WW spread itself into a thinner film, as shewn in Fig. 19., so that it seems to occupy a greater space, as shewn in Fig. 15.

In support of this explanation, I may adduce the case of other cavities in topaz, such as those shewn in Figs. 20. and 21., where the globule N of the new fluid never expands with heat,—an effect which is probably owing to its occupying the whole thick-

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ness of the cavity, and not a portion of that thickness, as in Fig. 18 *.

With the view of confirming this explanation, I took a cavity AB, Fig. 22., in which the new fluid N occupied the whole of one side of the cavity, and the second fluid W the whole of the other side. Having made the vacuity vanish, and increased the heat to about 200°, the effect of this was to expand N, and make the boundary *a b* move very slowly towards A; but in a short time, a portion of the fluid W, which had thus been pressed out along the bottom of the cavity, made its appearance at the end B, and gradually increased in quantity as *a b* moved towards A. The new fluid then occupied the space between the dotted lines *c d* and *e f*, which contained a greater area than the space between *a b* and B. The portion *e f* B of the second fluid remained for two hours in the position shewn in the figure; but being connected below N with the other portion *c d* A, it was drawn over to the other side, and occupied its original position, as shewn by A *a b*.

In one of the Quebec crystals of *Quartz*, where the cavities are filled with a slightly yellowish fluid, I observed a very deep cavity, such as that shewn in Fig. 23., where the globule N expanded very considerably to the width of *n n* by a considerable heat. I sought in vain for a vacuity, which, however, might have been concealed in a cavity of such a depth, and of such irregularity of surface; but, upon plunging the crystal in hot water, and applying the microscope, I observed two very minute globules, either of vacuity or something else, floating within N, which gradually diminished and disappeared. During another

* In Figs. 20. and 21. there are small squares, such as S, S, within the cavities, which seem to be filled up with crystallized matter. These squares being sometimes united only by contact with the surface of the cavity, exhibit very brilliantly the colours of thin plates.

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experiment with this crystal, one of the cavities burst, with a heat not above 150°, and the fracture round the cavity was covered with specks of an inspissated fluid *.

The formation of cavities with two fluids, and without any vacuity, admits of an easy explanation, when they are connected with other cavities, as in Figs. 15. 16., as there can be no doubt, from the phenomena already described, that part of the fluid W has passed through the narrow channel which connects the cavities. When the cavities, however, are entirely insulated, the explanation is more difficult.

Sect. IV. *On the Changes which these Fluids have undergone in particular Crystals.*

In the absence of all information respecting the nature and constitution of these fluids, it becomes interesting to ascertain, whether time, or accidental causes, have produced any perceptible changes in their physical properties. With this view, I have examined an immense variety of specimens, and have been led to results of considerable interest.

In some specimens of topaz containing the two fluids, I have observed several cavities in which the new fluid N is quite opaque, as at *a*, Fig. 24., and others in which it has the appearance shewn at *b*.

There are some cavities, such as that shewn at *c*, where the fluid seems to have left a crust, lining the interior of it, and there are others where a sort of black farinaceous matter appears, both within and around the cavities, that appear to have been burst by some accidental cause.

* This crystal is the one referred to in page 11.

The most unequivocal proofs, however, of a change in the fluid, are obtained from various topazes, where the induration of the fluid is perfectly obvious to the eye. It resembles a resinous substance, and has a sort of cellular structure, like that shewn at *d*, Fig. 24., where the vacuity retains its circular form. No change whatever is produced upon these appearances by heat. In the figure at *e*, the fluid N, with its vacuity V, still exists, and the latter vanishing with heat; but the induration is distinctly seen at the lower end of the cavity.

In other specimens the same cellular structure appears, but the vacuity has lost, in different degrees, its circular form, as shewn at *f*.

Similar phenomena occur in *cymophane* and *felspar*, in the last of which the induration of the fluid is most distinct.

Sect. V. *On the Vaporisation and Decomposition of the New Fluid at low Temperatures, when enclosed in the Cavities of Minerals.*

Let ABCD, Plate II. Fig. 30. be the summit of a crystallised cavity in topaz, and let the length of the cavity be in a vertical direction, so that SS is the second fluid, NN the new fluid, bounded by a circular line *a b c d*, and V the vacuity in the new fluid, bounded by the circle *e f g h*. Let the face ABCD be placed under a compound microscope, so that the rays of a luminous body incident upon it, may be reflected at an angle less than that of total reflexion. When the observer now looks through the microscope, the temperature of the room being 50°, he will see the second fluid SS shining with a very feeble reflected light, the new fluid NN with a light perceptibly brighter, and the vacuity VV with a light of considerable brilliancy. The boundaries *a b c d*, *e f g h*, are marked by a well defined outline, and also by

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concentric coloured rings of thin plates, produced by the extreme thinness of each of the fluids at the edges.

If we now raise the temperature of the room gradually to 58°, we shall observe a brown spot appear in the centre of the vacuity V. This spot marks the visible commencement of evaporation from the new fluid below, and arises from the attenuated vapour which attaches itself to the roof of the cavity. As the heat increases, the brown spot enlarges, and becomes very dark. It is then succeeded by white, and one or more rings rise in the centre of the vacuity. The vapour then seems to form a drop, and all the rings disappear, by retiring to the centre, but only to reappear with new lustre. During the application of heat, the circle *efgh* is in a state of constant contraction and dilatation, like the pupil of the eye when exposed to light, being always greatest when the rings disappear, and contracting its dimensions when they are again formed.

When the vaporisation is so feeble as to shew itself only by a single ring of one or two tints of the second order, they may be made to disappear instantly by the slight degree of heat produced by a single breath upon the crystal; aud the same effect is produced by the approximation of a heated body. When the heat reaches the fluid, however, it makes it throw off fresh vapour, and the rings again appear.

If we put a drop of ether upon the crystal when the rings are in a state of rapid play, the cold occasioned by its evaporation immediately causes them to disappear, till the temperature again rises.

When the temperature is perfectly uniform, the rings remain stationary, and it is interesting to observe the first ring produced by the vapour swelling out to meet the first ring at the margin of the fluid, and sometimes coming so near it, that the darkest parts of both form a broad black band.

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As the heat increases, the vacuity V advances to the summit AB, and disappears at $79\frac{1}{2}°$, exhibiting several curious phenomena, which we have not room to describe. One of these, however, is so singular that it deserves to be particularly noticed. After V has disappeared entirely, a brown spot comes from the summit AB, and takes its station in the centre of the ring of the new fluid *a b c d*. This brown tint sometimes rises to higher orders of colours; but disappears by the application of heat. That the coloured rings formed within VV are vapour, and not a film of the fluid itself, may be inferred from its never mixing with the fluid with which it is in immediate contact. It might, however, be a fluid substance, arising either from the decomposition of the fluid itself, or from the condensation of gaseous matter within the vacuity; though this is not very probable, from its constant disappearance when it has accumulated to a certain degree, and its constant reproduction while the temperature remains the same.

These views respecting the vaporisation of the expansible fluid, have been fully confirmed by the discovery of the cavities already noticed, in which the expansible fluid occupies only *one-third* or *one-fourth* of the cavity. Cavities of this kind are represented in Fig. 26., where AB is the cavity, V the vacuity in the expansible fluid *m n o p*, and A *m n*, B *p o* the second fluid. When heat is applied to this cavity, the vacuity V does not contract, as in ordinary cases, but expands, till its circumference coincides with the boundary *m n o p*. This unexpected effect might have arisen from the expansible fluid occupying the lower part of the cavity below V, as in the section, Fig. 27. In this case *c e f d* might have been the vacuity, and the surface of the fluid *e f* might have risen by heat, and gradually filled the vacuity V, while its boundary *c d* retired to *m* and *n* as the surface *e f* ascended. In order to determine if this supposition was true, I placed AB vertically between two rectangular prisms of glass; and having examined in succession the light reflected from the surfaces *m p* and *n o*, I found that it had suffered total reflexion, both from the side *c d* and the side *g h* of the vacuity, and consequently that the vacuity occupied the whole thickness of the cavity. After the heat was applied, the sides *c d* and *g h* continued equally luminous, and when *c g* and *d k* had retreated to *m n* and *p o*, as shewn in Fig. 28., it became quite manifest, that the space *m n o p* was not filled with the *expanded fluid*, but with the fluid *in the state of vapour*. The coloured rings at first appeared both on the faces *c d* and *g h*, and when the whole was converted into vapour they disappeared, and the light reflected from both the surfaces *m p*, *n o*, which was now uniform, was not that of total reflexion, nor yet that of the expanded fluid, but of an intermediate intensity, corresponding to that of a dense vapour, with a refractive power much lower than 1.21066.

There is another set of phenomena of exquisite beauty to an optical observer, which seem to arise either from the decomposition of the fluid, or the condensation of gaseous matter in the vacuity.

When heat is applied to the cavity, the new fluid has its surface in a state of constant agitation, resembling in the closest manner a surface into which a fluid is discharging itself by drops. When the vacuity is just filled up, one or more drops quit the point where the vacuity disappeared, and pass along the surface of the cavity, like a drop of oil adhering to it in close contact, and never mixing with the fluid. Each of these drops begins in a short time to spread circularly, and to exhibit within its disc an immense number of close coloured rings. By slow cooling the drops become thinner, and the rings less numerous, and more completely displayed, till they entirely disappear at a particular temperature. When the cooling is effected quickly, the

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matter which composes the thin plate that exhibits the rings, discharges itself rapidly in gaseous bubbles.

When the drops quit the point where the vacuity vanishes, and pass over one of the summits of the cavity, they often leave an irregular streak, which also gives the colours of thin plates; and sometimes the circular expansion of the drops extends within the circular vacuity, and thus displays two intersecting systems of coloured rings, which proves, in the most incontrovertible manner, that the vapour within the vacuity will not mix with the fluid which composes the drops. The drops now described often quit the vacuity before it is filled up by the expansion of the fluid, and one of them will sometimes remain on the margin of the vacuity, which can be easily seen through it.

Sect. VI. *On the Phenomena of the two New Fluids when taken out of the Cavities.*

From the extreme minuteness of the cavities in topaz, my first attempts to extract the fluid were not attended with much success; but I at last fell upon a method by which I have opened more than a hundred cavities.

When the most expansible of the new fluids first runs from the cavity upon the surface of the topaz, it neither remains still, like the fixed oils, nor disappears, like evaporable fluids. Under the influence, no doubt, of heat and moisture, it is in a state of constant motion, now spreading itself in a thin plate over a large surface, and now contracting itself into a deeper and much less extended drop *. These contractions and extensions are mark-

* A round hemispherical drop often stretches itself into a plane of more than twelve times its original area.

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ed by a very beautiful optical phenomenon. When the fluid has extended itself into a thin plate, it ceases to reflect light, like the most attenuated part of the soap-bubble, and when it is again accumulated into a thicker drop, it is covered with all the coloured rings of thin plates. When one of the drops of fluid is very minute and perfectly circular, it resembles, in the most accurate manner, the small drops which pass from the vacuity, and which have been described in the preceding section.

After performing these motions, which sometimes last for ten or twelve minutes, the fluid suddenly disappears, and leaves behind it a residue of minute and separate particles, which are opaque by reflected, but transparent by transmitted light. Upon examining this residue with a single microscope held in the hand, I was surprised to see it again start into a fluid state, and to extend and contract itself as before. This was owing to the moisture of the hand; and I can at any time revive the indurated substance, by the approach of a moist body. A portion of the fluid, which I took out of a cavity twenty days ago, is still capable of being restored to a fluid state by moisture. This portion was shewn to an eminent naturalist, the Reverend Dr Fleming of Flisk, who remarked, that, had he observed it accidentally, he would have ascribed its apparent vitality to the movements of some of the animals of the genus Planaria.

After the cavity has remained open for one or two days, the second fluid comes out of it, and hardens very speedily into a yellowish resinous-looking substance, which is perfectly transparent. This substance absorbs moisture, but with less avidity than the other. It is not volatilized by heat. It is not soluble in water or alcohol; but it is rapidly dissolved with effervescence by the sulphuric acid. The nitric and muriatic acids also dissolve it.

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The residue of the first fluid is volatilized by heat; and it is also dissolved, but without effervescence, by the sulphuric, the nitric, and the muriatic acids. After standing some time, both these substances acquire a brilliant lustre, as if some metallic body entered into their composition *.

SECT. VII. *On the Existence of Moveable Crystals in a Fluid Cavity of Quartz.*

Although particles of opaque solid matter have been observed in the cavities of crystals containing fluid, as will be described in the next section, yet, so far as I can find, no crystallized body, and, indeed, no matter capable of crystallization, has ever been discovered in them. The quantities of saline impregnation, indicated by a scarcely perceptible cloudiness in solutions of silver and muriate of barytes, were so minute in Sir HUMPHRY DAVY's experiments, that he considered the water as nearly pure. I was, therefore, in no small degree surprised, when I discovered, in a cavity of a quartz crystal from Quebec, from the cabinet of Mr ALLAN, not only insulated crystals, but a tolerably large group, which were moveable through the fluid upon turning the specimen †. The crystal was perfectly sound round the cavity,

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* In opened specimens, which had stood more than a month exposed to the air, I observed small green spheres resting on the surface. They were soft and semi-transparent, like green wax, and varied from $\frac{1}{30}$th to $\frac{1}{200}$th of an inch in diameter. They were not acted upon by any of the above mentioned acids, and were therefore a distinct substance from that of the two new fluids. They occurred in no fewer than 25 out of 40 crystals, *three* being sometimes found in one specimen; and there can be no doubt that they consisted of fluid matter which had oozed out of the crevices of the mineral.

† There were also numerous opaque particles in the cavity, which descended slowly in the fluid.

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which had a sort of triangular form, one of the sides of the triangle being about one-tenth of an inch long. The fluid was quite transparent; and, as the air-bubble was not perceptibly diminished by heat, there is every reason to think that the fluid is water. The crystals were transparent to a considerable degree, and had a white milky tint, when seen by reflected light.

In considering the circumstances of this singular phenomenon, we are led to suppose, that the included crystals had been dissolved in the fluid at the time of its being shut up in the quartz, and had afterwards been deposited from the solution. The ingenious supposition of Sir Humphry Davy, that a liquid hydrate of silica may exist at high temperatures, and may contain small quantities of atmospheric air, will no doubt explain the phenomena of water in rock-crystals; but it is not easy to comprehend how the formation of a group of crystals could either have accompanied or followed the separation of the water and the silex.

As the specimen now alluded to is too valuable to be destroyed, for the purpose of analysing the minute crystals, it is probable, that our information respecting them would have been very limited, had not a circumstance of an accidental nature enabled me to throw some farther light on the subject. Several years ago, when I was examining, along with Earl Compton, a large collection of quartz crystals from Quebec, for the purpose of obtaining remarkable crystallizations, I was much struck with the appearance of several spherical groups of whitish crystals, within some of the specimens. Upon pointing out to Lord Compton this peculiarity, his Lordship agreed with me in thinking that they belonged to the Zeolite Family. Having purchased all the specimens that could be found, I have since repeatedly examined the included crystals, with the view of determining their nature. I found that they did not belong to the zeolites, but consisted principally of carbonate of lime; and, as

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every mineralogist who saw them considered them as something new in appearance, I expected that a greater quantity of them might be found for the purposes of analysis. Familiarised, therefore, with the aspect of these groups, I was convinced that the crystals in the fluid cavity were the same substance; and a more accurate examination has established their perfect identity.

These white crystals sometimes occur in minute insulated spiculæ within the solid mass, but most frequently in spherical groups of extreme beauty, surrounded with the most transparent quartz. Many of the open hollows and crevices of the quartz crystals are filled with them, and numerous aggregated groups adhere to their external surface. These crystals, though very minute, I have found to have a powerful double refraction; and as they are wholly dissolved with effervescence, excepting a little adhering silex, in diluted nitric acid, there can be no doubt that the external crystals and consequently those in the fluid cavity, are *carbonate of lime* *.

SECT. VIII. *On the Phenomena of a single Fluid in the Cavities of Minerals and Artificial Crystals.*

The phenomena which I propose now to describe, are essentially different from those which form the subject of the preceding sections. The fluid which occupies this class of cavities exhibits no properties different from water or mineral oil, which have long ago been detected by mineralogists, and the vacuity which often accompanies these fluids, is either a perfect vacuum, or filled with a gaseous body.

* Since these observations were made, Mr NORDENSKJOLD has confirmed this result by experiments made with the blowpipe.

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This class of cavities might, with propriety, have been divided into three subdivisions: 1. Those where the cavities are entirely filled with fluid; 2. Those which have a perfect vacuum along with the fluid; and, 3. Those where the fluid is accompanied with a gaseous body; but, as several crystals seem to possess cavities with all these characters, I shall describe the different crystals in their order.

1. Amethyst from Ceylon.—This fine specimen, in the cabinet of Mr Thomson of Forth Street, originally belonged to the King of Candy. It is about 3 inches long and 1¾ broad, and has a large cavity, of the size and form shewn in Fig. 29. The bubble V, which I have ascertained to be gaseous, by the reflexion of light, moves by starts from one end of the cavity to the other. It is not sensibly altered by heat. Another cavity C, near the large one, has a small air-bubble in the middle, which refuses to move from its place. There are several pieces of opaque solid mater, which, with a little management, may be seen within the cavity AB, and which may be made to fall from one side of it to the other. This is the largest cavity that I have ever seen in a solid crystal.

2. Rock Crystal.—This mineral abounds with cavities, containing water and mineral oil, which is sometimes black, sometimes of a faint yellow, and sometimes of a rich orange red colour.

The largest cavities are generally amorphous; but there are many crystals with thousands of cavities all regularly crystallized, and of the exact form of the secondary crystal.

The quartz crystals from Quebec contain great quantities of mineral oil, which does not perceptibly expand by the application of heat. There are frequently within the cavities dark little fragments, which are carried about by the motion of the

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fluid. In a crystal of quartz belonging to Mr Allan, and containing a large cavity, with water and an air-bubble, he observed a little black globule which adhered to the air-bubble. Upon looking at it afterwards, he remarked that the black globule had separated into a great number of minute black particles. This opaque matter is likely to have had the same origin as that which is described in page 23.

One of the most remarkable specimens of quartz which I have ever met with, was shewn to me by Mr Sivright. The cavities are of the most singular shape, and are almost all nearly filled with a fluid, accompanied with a small air-bubble, which does not perceptibly expand with heat. Some of the cavities contain a yellow fluid, with various air-bubbles, which seem to be naphtha apparently in a very viscid state. This specimen is shewn, though very imperfectly, in Fig. 30.

3. Topaz.—There are many topazes from Brazil, New Holland, and Scotland, which contain a single fluid, with an air-bubble. In these the fluid does not perceptibly expand with heat; and I have ascertained that it is aqueous, and that the vacuity is filled with a gas.

In several topazes, both from Aberdeenshire and Brazil, the form of the cavities is extremely curious, resembling the writing in Eastern MSS. These grotesque forms generally contain the new fluid; but many of them have no vacuity at all, while some of them contain a fluid of a decided yellow colour, which I have never found accompanied with a vacuity. These cavities are shewn in Fig. 31. The cavities in topaz containing the two new fluids are shewn in Fig. 40.

In a particular specimen of topaz, I observed a regular rhomboidal space apparently filled with particles of dust suspended in it. This rhomboidal space appeared *green* by reflected, and *red* by transmitted, light.

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4. Cymophane.—In several specimens of cymophane, there are strata of cavities apparently containing one fluid, but without any perceptible vacuity. In the crystal containing the stratum with the new fluids, there is another stratum parallel to it, of a very remarkable kind, where the cavities have the form shewn in Fig. 32. The nature of the fluid, however, I have not been able to determine.

5. Peridot.—The largest and finest crystals of this mineral are often intersected, in various directions, with strata of fluid cavities having globules of air. In a set of unusually large crystals a kind of resinous indurated matter seems to have been diffused, sometimes in strata and sometimes throughout the mass of the crystal. These peridots, which are very magnificent, belong to the Countess of Wemyss; but in consequence of their being cut and set in gold, it was impossible to subject them to an accurate examination.

6. Felspar.—The cavities in this mineral are very flat, and irregularly formed. They contain a single fluid and an air-bubble, which neither vanishes nor diminishes with heat.

7. Emerald and Beryl.—The great degree of foulness which is so common in these gems, arises generally from strata of cavities containing a single fluid, and an air-bubble, which do not perceptibly decrease with a temperature of 150°.

8 Fluor-Spar.—The crystals of green fluor-spar from Alston Moor frequently contain cavities with water. I have seen several about half an inch long, and of the form of a triangular pyramid. The air-bubble moves sluggishly even in these large ones, and with great difficulty in the small ones. The apparent air-bubble is gaseous, and the fluid does not perceptibly expand

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with heat. These crystals frequently burst with a heat not above 150°. In several cavities I have observed solid fragments falling through the fluid, by the inversion of the crystal.

9. SULPHATE OF LIME.—In this mineral the cavities have often a very singular form; and in all the specimens which I have examined, the fluid is aqueous, and is accompanied with a gas or a perfect vacuum.

In Fig. 33. I have represented one of the most singular arrangements of cavities that I have met with. In order to determine the thickness of the cavity, I reduced the specimen, so as to give the polarized colours of the second order of Newton's Scale, and, by carefully observing the difference of tint in the cavities, and in the solid parts, I obtained a measure of the thickness of crystalline matter abstracted in these parts. The difference of tint was very obvious, and proved that the thickness of the cavity did not exceed the $\frac{1}{5000}$th part of an inch.

In many specimens, these very shallow cavities occur in long canals. In others they resemble some foreign crystalline matter, shooting out into the most singular forms, as at *a*, *b*, Fig. 34. and sometimes the cavities appear to the eye like tufts of white silk compressed between the laminæ, though they are, in reality, strata of rhomboidal cavities, occurring in thousands, and arranged in the direction of their longest diagonals, while the strata themselves are highly inclined to the surfaces of the laminæ. In other specimens, the cavities have the most singular forms, as represented in Fig. 34. One of the canals in sulphate of lime is shewn at AB, in Fig. 35., where *a b c d*, *e f g h* are two air-bubbles or vacuities. By applying heat to the side B, these air-bubbles shift their places. All the lines *a b*, *c d*, *e f*, *g h*, advance to B, but *c d* and *e f* approach to one another, and the moment they come in contact, the two vacuities are converted into one, which has the position *a′ b′ g′ h′*.

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10. Sulphate of Barytes.—The cavities in sulphate of barytes were first pointed out to me by Mr Sivright. I have since found them in various specimens. They are generally of a very irregular shape, though sometimes they have regular crystalline forms.

Many of these cavities are entirely filled with fluid, but in several a very small apparent air-bubble may be seen. This vacuity does not vanish by the heat of the hand, but it disappears entirely at a temperature of about 150°, and again returns when the specimen has cooled. It is therefore a vacuum.

11. Calcareous Spar.—Cavities filled with water are frequently found in calcareous spar. The apparent air-bubbles, which are very small, occur only in some of the cavities. To some of the cavities I applied a heat of about 150°. The apparent air-bubbles entirely vanished, and, what is very remarkable, they have never again reappeared. This singular fact may be ascribed to the strong cohesion between the fluid and the sides of the cavity, which can only be overcome by a greater degree of cold producing a greater degree of contraction than that of the cabinet in which the specimen has been kept.

12. Rock-Salt from Cheshire.—In this mineral the cavities assume the most beautiful forms. In one specimen, shewn in Fig. 36., they have the form of regular cubes of various sizes, and with numerous truncations on their sides and angles. In other specimens the cavities have the form of octohedrons; while in others they have numerous varieties of forms. The cubical hollows above mentioned are in general perfectly filled with fluid; but some of them have small apparent air-bubbles, which contract to fully one-third of their size by a heat of 120°.

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13. Sulphate of Iron.—The cavities in this salt are sometimes finely crystallized in the form of prisms, with double pyramids, and the sharpest truncations. In the same specimen they are frequently oval, or imperfectly spherical. They sometimes contain apparent air-bubbles, and are often quite filled with fluid. By the application of heat, these vacuities disappear entirely, and reappear by cooling.

14. Sulphate of Nickel.—In this salt the cavities are sometimes amorphous, and sometimes beautifully crystallized. These vacuities frequently disappear by heat, and reappear by the application of cold.

15. Sulphate of Copper.—The air-bubbles move about in this salt by the application of heat, but never vanish. By increasing the heat, they diminish a little in size.

16. Alum.—The air-bubbles in alum do not perceptibly change their magnitude by heat. I have opened several cavities in this salt, but have never found the air to be either in a state of dilatation or compression. The fluid seems to be pure water.

17. Tartrate of Potash and Soda.—The cavities in this salt are both crystallized and amorphous. A considerable vacuity in a large cavity vanished completely with heat; and in others, where the vacuity was very large, it became extremely small when heated. Two separate cavities, with separate vacuities, became one, and united their vacuities. These phenomena, no doubt, arose from the fluid having its dissolving power increased by heat; and it is probable that the disappearance of the large vacuity arose from the dissolved salt occupying more space in its fluid than in its solid state.

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It is unnecessary to extend these details to all the artificial crystals enumerated at the beginning of this paper, as I have not observed in them any phenomena different from those which have already been described.

There is another class of cavities which require to be studied with some attention, namely, those which are entirely full of fluid, or entirely empty. Mr Sivright first observed cavities in the diamond *, and in garnet; but, though I have examined them in various specimens, I have not been able to determine whether they are entirely filled with fluid, or are entirely empty. I have found cavities of a similar kind in *cinnamon-stone*, where they are beautifully crystallized, in *sulphate of Strontian*, in *sulphur*, in *analcime*, and in *chabasie;* but I observed no appearance of air-bubbles, and have no certain evidence that they contain a fluid †.

It would be improper to conclude this paper, without noticing the relations which are supposed to subsist between this class of phenomena and the two contending Geological Theories. The existence of highly rarified gas in the cavities of crystals, has been regarded by the distinguished President of the Royal Society of London, as "seeming to afford a decisive argument in favour of the igneous origin of crystalline rocks;" and the "fact of almost a perfect vacuum existing in a cavity containing an expansible but difficultly volatile substance," (as naphtha), he likewise considers as highly favourable to the same theory. The discovery of compressed gas in similar cavities might have been regarded as neutralizing, in some degree, the first of these argu-

* See the *Edinburgh Philosophical Journal*, vol. iii. p. 98., for an account of the polarising structure which sometimes exists round the cavities in diamond.

† This point may be easily determined by grinding the specimens, and examining the light reflected at the surfaces of the cavities.

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ments: but Sir HUMPHRY DAVY remarks, that it may be explained by supposing the crystal to have been formed under a compression much more than adequate to compensate for the expansive effects of heat *.

Without presuming to combat these deductions, or to suggest any of the numerous explanations by which the Neptunist might reconcile with his own system the compressed and dilated condition of the included air, I shall content myself with stating, that the facts described in the preceding paper appear to me decidedly hostile to the igneous origin of crystals, and, in some points of view, favourable to their aqueous formation. The existence of a fluid which entirely fills the cavities of crystals, at a temperature varying from 74° to 84°, may, upon the principles assumed in the opposite argument, be held as a proof that these crystals were formed at the ordinary temperature of the atmosphere, while the fact of a perfect vacuity existing in *sulphate of barytes*, and capable of being filled up by the expansion of the aqueous fluid, at a temperature not exceeding 150°, authorises the analogous conclusion, that the crystal could not have been formed at a higher temperature. On the other hand, the filling up of the vacuities in *sulphate of iron*, and *sulphate of nickel*, at a temperature much above that at which they were formed, may lead geologists to renounce a species of argument which appeals only to our ignorance, and to withdraw from the defence even of their outworks, those faithless auxiliaries, which are so ready to enlist themselves in the service of either power.

There is one geological relation, however, of the preceding facts, which may deserve some attention. Hitherto the contend-

* As the effects of heat and compression might exactly balance each other, the gas would in this case be atmospheric air, in a common state of density; so that the volcanists are here sheltered against experimental hostilities, amid the generalities of their hypothesis.

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ing theorists have limited their idolatry to two of the elements; but the existence of two new substances in minerals, one of which combines a great degree of fluidity with the high expansive power of the gases, renders it probable, either that these substances existed at the formation of the globe, or that they are the result of laws of crystallographic combination which have escaped the notice of the philosophical geologist. Were such fluids the product of the ordinary processes of crystallization, they would occur in artificial as well as in natural crystals: and, consequently, while they remain undiscovered in the cavities of the first of these classes of bodies, we are entitled to attach a new difficulty to the aqueous hypothesis.

Had the two new fluids occurred only in one mineral, or in minerals of a particular composition, they might have been supposed to have some relation to the elementary principles of the body, and to have arisen either from some accidental irregularity, which prevented them from crystallizing, or from the decomposition of the matter subsequently to its crystallization. The perfect identity, however, of the two fluids, as found in pure Quartz, in Amethyst, in Topaz, and in Cymophane,—minerals brought from the most opposite parts of the globe,—from Scotland, Siberia, New Holland, Canada, and Brasil,—establishes the universality of their existence, and adds to the probability of the supposition, that they have performed some important function in the organization of the mineral world.

While the preceding facts thus obviously connect themselves with our geological theories, they promise also to be of some use in the practical branches of Physics. A fluid possessing such a high expansive power would be invaluable in the construction of delicate Thermometers, and various other philosophical instruments; while its extreme fluidity would enable us to construct levels of singular delicacy. If the resources of the chemist shall

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not enable him to form such a substance, a plate of topaz, with particular longitudinal cavities, might be used, as a delicate thermometer, for certain ranges of temperature; and where slight variations require to be observed, several such plates might be of essential service in many researches, both of a chemical and a physical nature.

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Eng.d for the Royal Soc. Trans. Vol. X. page 42.

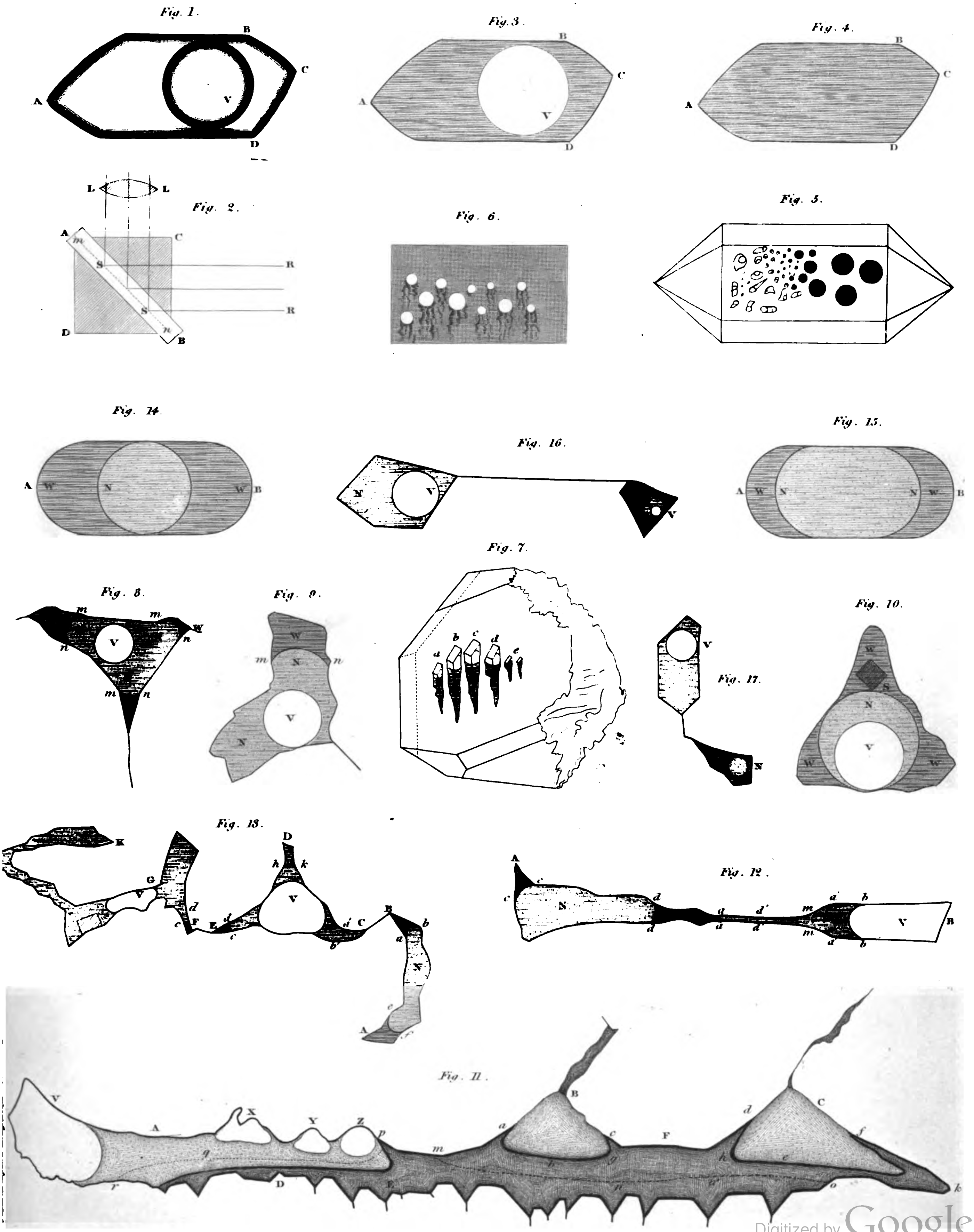

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PLATE II.

Fig. 18.

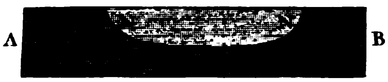


Fig. 20

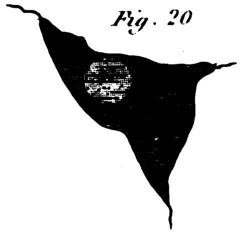


Fig. 19

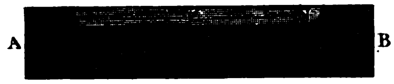


Fig. 23.

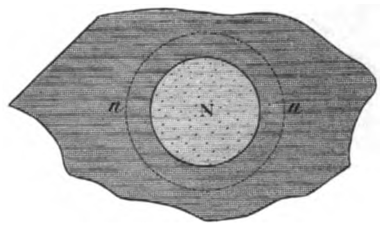


Fig. 22

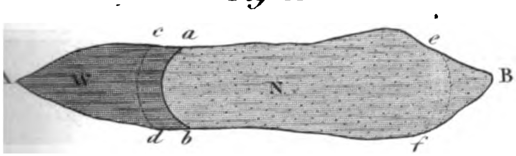


Fig. 21.

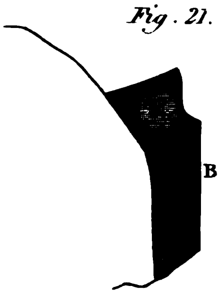


Fig. 26.

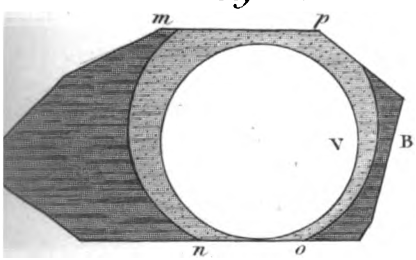
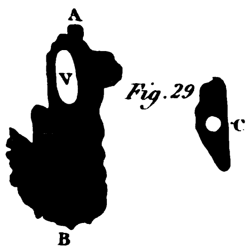


Fig. 29



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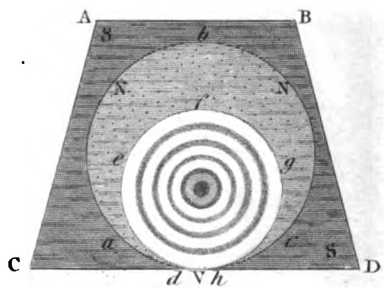


Fig. 30.

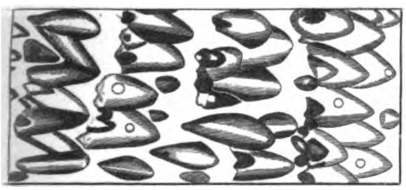


Fig. 32.

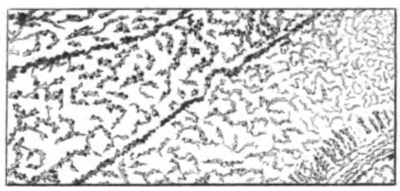


Fig. 31.

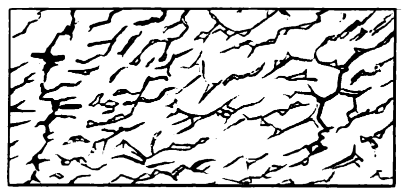


Fig. 36.

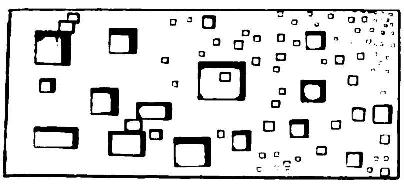


Fig. 40.
Cavities containing both Fluids

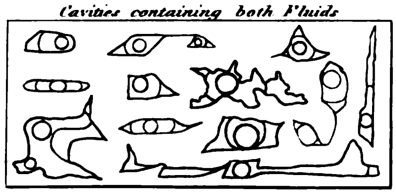


Fig. 34.

Fig. 24.

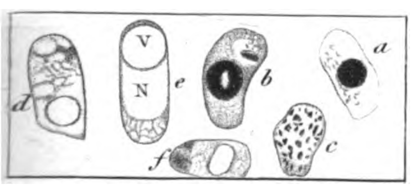


Fig. 27

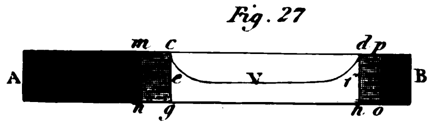


Fig. 28.

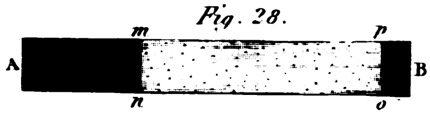


Fig. 33.

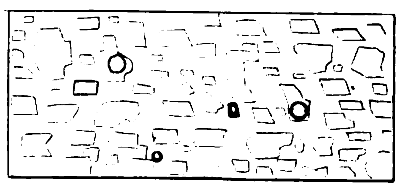
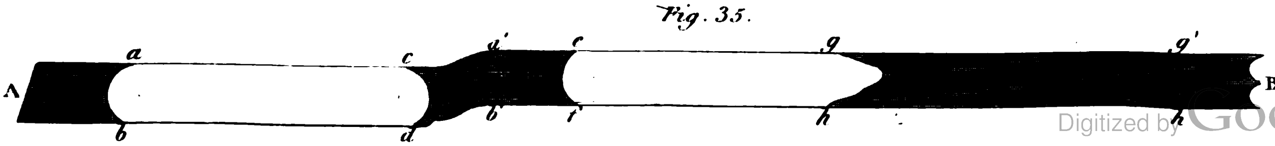


Fig. 35.



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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.

(Read March 6. 1826.*)*

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.

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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-

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

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

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° 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° 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 expansive fluid and the second fluid; then we have $\sin \varphi = \frac{\sin \theta}{m}$; $\varphi' - x =$ Angle of Total Reflexion, and

$$m' = m \times \text{Sin} (\varphi' - x)$$
$$m'' = m \times \text{Sin} (\varphi'' - x)$$

Hence we have the indices of refraction as follows:

m	=	1.620	Topaz,
m''	=	1.2946	Second Fluid.
m'	=	1.1311	Expansible Fluid.

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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 †
Second New Fluid in Topaz, in a cavity which is filled by the other new fluid, at the temperature of 83°..........	1.2946
New Fluid in Amethyst, which fills the cavity at a temperature of $83\frac{1}{5}$° of Fahrenheit,......	1.2106
Tabasheer, whitish, from Nagpore, hard specimen, ...	1.1825
Tabasheer, transparent, from Nagpore,............	1.1508
Do. do. another specimen, ...	1.1454
New Expansible Fluid in Topaz, 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.

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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

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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

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Eng^d for the Royal Society Tran. Vol X p 413.

Fig. 1.

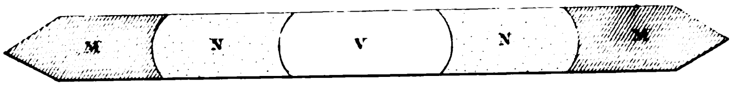


Fig. 2.

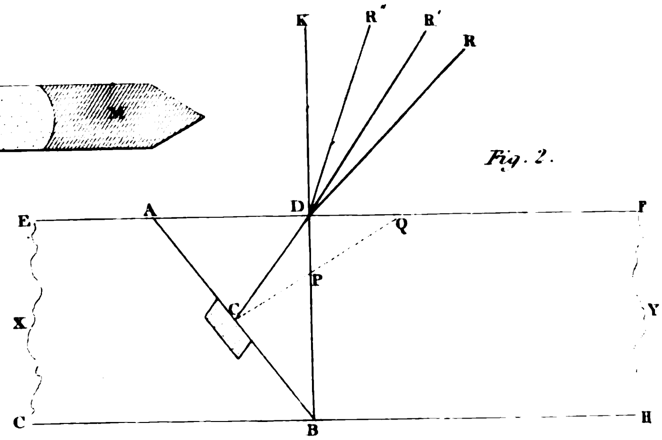


Fig. 3.

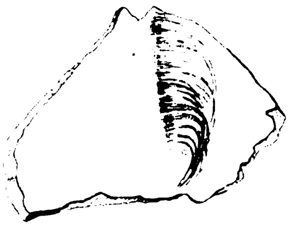


Fig. 4.

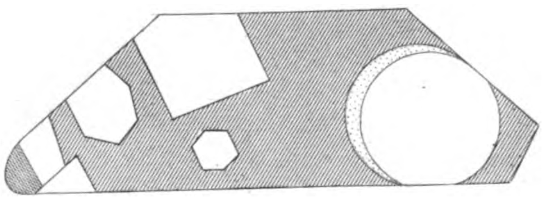


Fig. 5.

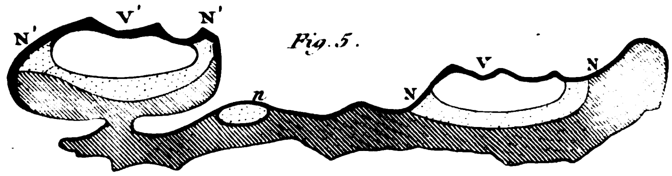


Fig. 7.

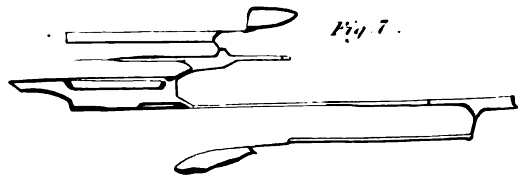


Fig. 6.

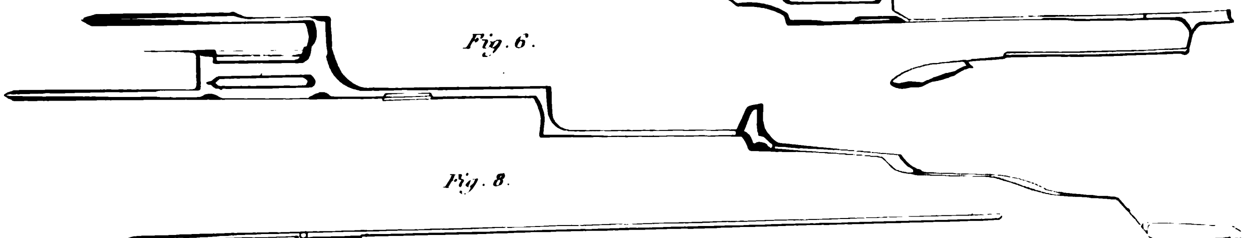


Fig. 8.

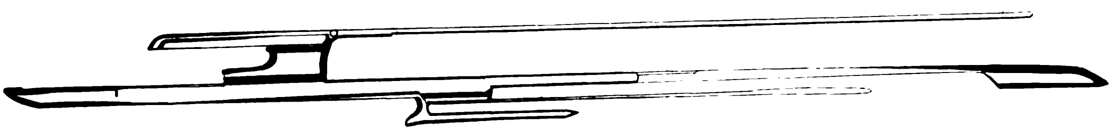
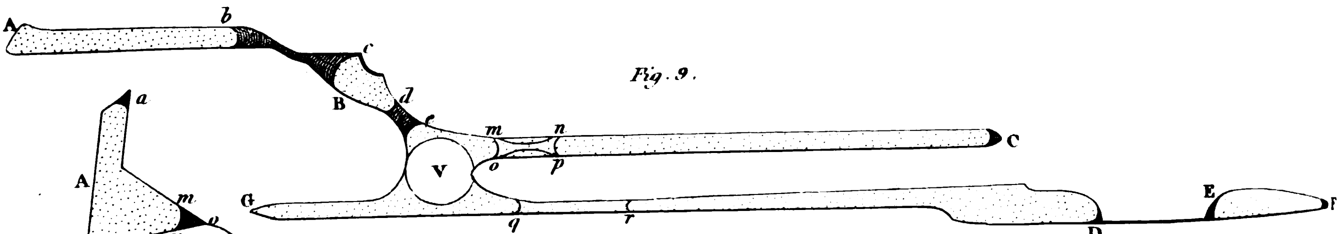


Fig. 9.



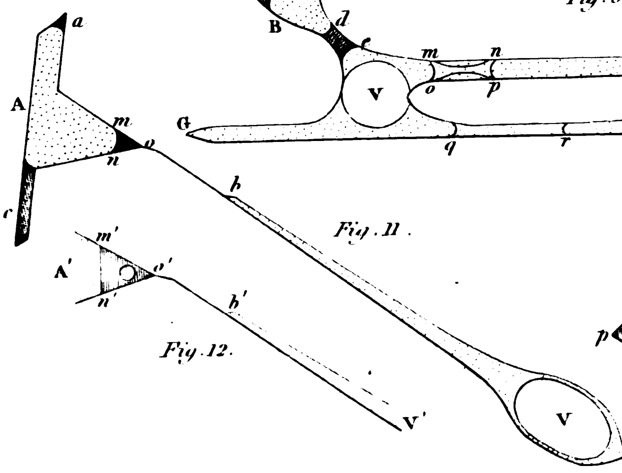


Fig. 11.

Fig. 12.

Fig. 10.

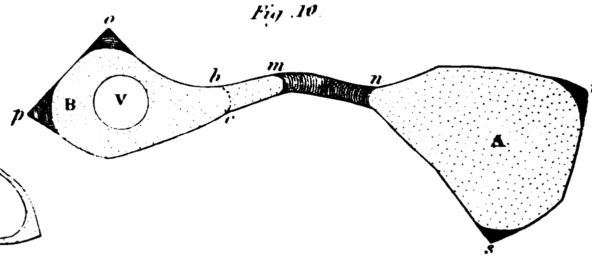


Fig. 13.

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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

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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

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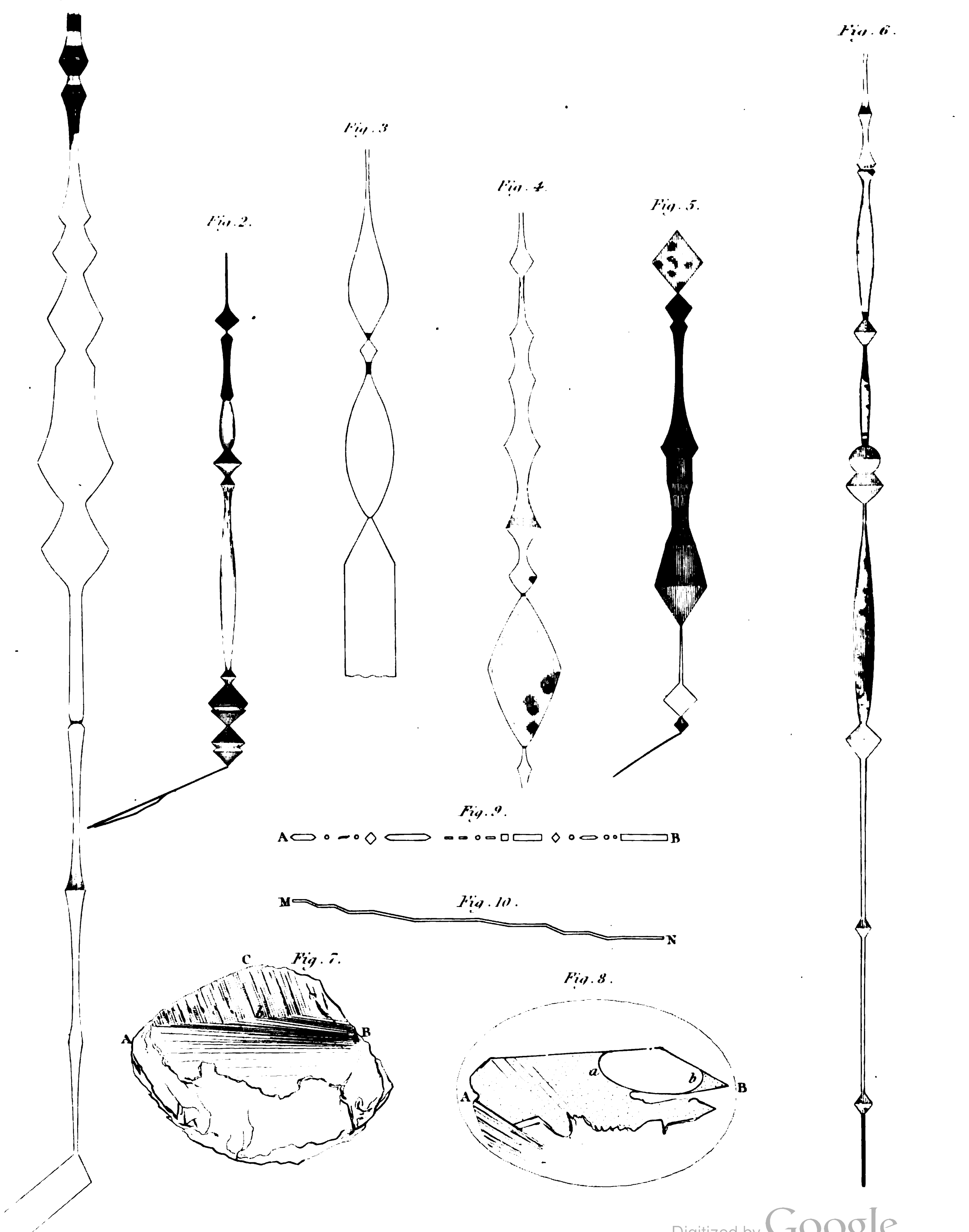
PLATE XX.

Eng.d for the Edin.r Royal Society Trans. Vol. X p. 415 p. 426



W. H. Lizars sc.

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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

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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 *b*C, &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 *b*C 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.

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one immediately below it, and connect the whole together as in Fig. 2. We do not mean to say, that the cavities *b*C 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

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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 N N 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.

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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 N N 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 N N, 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

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* 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. 3

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

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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.

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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 *b* V has always, at common temperatures, a vacuity V, and the cavity A, connected with it by the filamentous channel *o b*, has no vacuity. At the ordinary temperature, the dense fluid appears at *a c*, and slightly at *o* and *b*, filling the narrow channel *o b*. By applying heat, the expanding fluid in *b* V fills up the vacuity V; and, as the cavity A *a o c* has no vacuity, a portion of its fluid is necessarily driven through the neck *a b* into *b* V 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 *b* V, is finely seen. The contraction of the expanding fluid in A causes the dense fluid to appear as at *m n o*, in Fig. 10., and, in a short time, the curved surface *m n* 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

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W.H.Lizars sc.

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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.

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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.

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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

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* 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 $\frac{1}{30000} \div 32 = \frac{1}{937}$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.

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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 A B C is the piece of ice, having in it a long cavity *m o*, containing water and air. The ice gradually dissolved; and when the end *n o* of the cavity *m n* was near the edge of the ice C B, the air, in a portion of it *n o*, 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

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paper. The singular fact, however, is, that the portion *n o* of the cavity quitted by the globule of air, was immediately filled up with ice, and the cavity reduced to the dimensions *m n*.

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.

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* 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.

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