kinds:—first, the annelid growth has determined outgrowth of the coral which has covered in the worm-tube; and second, the establishment of some Hydrozoa on the ectoderm of the coral has sometimes produced the formation of tubes of coral-structure which environ the stalk of the offender and form a useful support to it.

Finally it may be remarked that all the Madreporaria which were brought up with the cable from off this area have an unusual ornamentation.

I have to thank Sir James Anderson for the specimens and for the details of the recovery of the cable.

III. "On Attraction and Repulsion of Bubbles by Heat." By

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Received February 26, 1877.

In my first paper "On the presence of Liquid Carbon Dioxide in Mineral Cavities" ('Journal of the Chemical Society,' February 1876), I mentioned having noticed a remarkable repulsion of the bubbles in fluid-cavities when they were approached by a heated body. I at first regarded these movements as similar to those observed by Mr. Sang and Dr. Hunter (Proceedings of the Royal Society of Edinburgh, 1872–73, p. 126) in cavities of Iceland spar; but with reference to the position of the source of heat, I have since found that they occurred in quite the reverse direction. The motion noticed by Mr. Sang was a repulsion of the liquid; that which I recorded was a repulsion of the gas by the heated body.

Here I may as well say that this refers to the real and not the apparent direction of the motion as seen under the microscope.

Professors Tait and Swan have shown (Proc. Roy. Soc. of Edinburgh, 1873–74, p. 247) that the attraction of the bubble by a heated body is a natural effect if the liquid be of great volatility, in contact only with its own vapour, as would be the case if the cavity were filled with carbonic acid. Distillation of the liquid would take place when one side of the bubble was heated ever so slightly above the temperature of the other, and condensation would occur on the cooler side. This would occasion a movement of the bubble from the cold to the warm side of the cavity; but it is not the original bubble being simply propelled. Professor Tait assumes that the liquid in Mr. Sang's specimens is carbonic acid, and applies this explanation. This might well be the case, because the attracting pieces of metal used were but a very few degrees warmer than the specimens acted on; but from other circumstances, some of which I propose giving in detail, I am of opinion that these were water-bubbles.

The attraction of a gas-bubble in a cavity containing liquid carbonic

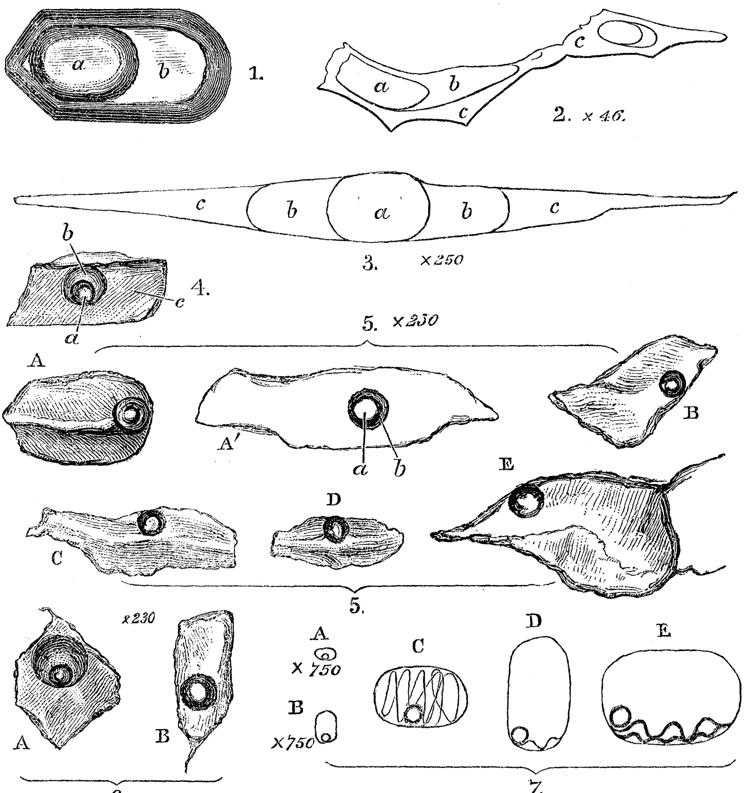
acid will always take place when the proportion of liquid to gas is so small that evaporation is readily effected. If the liquid at 15° C. occupies one half of the space of the cavity, this will occur only under special conditions, because the liquid in such proportions expands by increase of temperature. Thus in the case of a cavity in a topaz, shown in fig. 1, a number of experiments have invariably failed to cause any transference of the bubble from place to place. The approach of a warm substance causes immediate expansion of the liquid and decrease in size of the bubble.

The gas-bubble in a cavity of rock-crystal, shown in fig. 2, behaves quite differently; the proportion of liquid to gas is such that heat causes evaporation instead of expansion; and accordingly the liquid is repelled apparently, and the gas-bubble attracted by a heated body. With the cavity in tourmaline (fig. 3), when the heat is applied in a particular manner, the same movement takes place; ordinarily the liquid expands. To cause distillation and not expansion, the source of heat must be small and the rise of temperature slight, in order that only one end of the cavity may be heated. I have always failed to get this effect with the topaz cavity, probably because the thickness of the section causes the heat to be diffused over the liquid. The tourmaline section is thin and the cavity long and narrow, and is therefore an easy one to experiment with; so likewise is the cavity shown in fig. 5, E; it contains carbonic acid only, and the bubble is easily attracted when the source of heat is properly applied. In the course of some thousands of observations, made within the last two years, I have noticed other movements than such as may be compared with the experiments of Professors Tait and Swan on tubes of liquid sulphurous acid. The circumstances influencing these movements, and the various conditions under which they take place, render it necessary that I should disregard the order in which I observed and originally recorded them; for I have on more than one occasion been bewildered by noticing what appeared to be diametrically opposite facts in experimenting on the same specimen, and even on the contents of the same cavity. I therefore consider it expedient to classify my experiments, in order to make the account of them intelligible.

The attraction of bubbles by heat, water being the only liquid present.

With regard to the attraction of bubbles by heat, I have noticed this take place in some water-cavities when the bubbles were free to move and no carbonic acid was present. In order that no mistake might possibly occur as to the relative positions of the source of heat and the moving bubble, a hot platinum wire was used and always brought into the field of the microscope. Some thousands of cavities have been noticed occurring in sections of rock-crystal and in the quartz of various kinds of granite. The rise in temperature required to cause this movement was measured at first by blowing warm air

with a ball-syringe on to the object, and then directing it on to the bulb of a delicate thermometer. With the most sensitive bubbles three or four degrees Centigrade were found to be amply sufficient.



The letters in italics (*a*, *b*, *c*) within the drawings of fluid-cavities indicate the positions of the gaseous carbonic acid, liquid carbonic acid, and water respectively.

Fig. 1. Cavity in a topaz. × 35 diameters.
Fig. 2. Cavity in rock-crystal. × 46 diameters.
Fig. 3. Cavity in tourmaline.
Fig. 4. Cavity in rock-crystal, containing a bubble repelled by heat. × 250 diameters.
Fig. 5. Six cavities in rock-crystal adjacent to each other. The bubbles in A and A′ are repelled by heat; in B, C, and D they are attracted. These cavities contain water. E contains liquid carbonic acid only. × 250 diameters.
Fig. 6. Two cavities in rock-crystal. The bubbles contain liquid carbonic acid floating on water. These bubbles are repelled or attracted by a source of heat according to the temperature of the specimen.
Fig. 7. A and B are cavities in felstone, containing liquid carbonic acid and a vibrating bubble. C, D, and E are diagrams representing the motion of the bubbles under different conditions of temperature.

The following experiments show the conditions under which such attraction takes place. In a specimen of rock-crystal from which several

sections were cut, there was a multitude of cavities, many of considerable size. They all contained one liquid, water, and what appeared to be a gas-bubble, which was attracted by heat. A slice of the crystal was mounted between pieces of stout sheet platinum, and so placed on the stage of the microscope that it could be easily taken off and replaced at once in exactly the same position, so that the cavity under observation would be within the focus of the object-glass. By immersing the specimen in hot mercury, and instantly after removal examining it with the microscope, I ascertained that at 150° C. the liquid had just expanded so as to entirely fill the space. It is evident, then, that little or no gas is present.

It was next necessary to ascertain the lowest temperature of a body by which the bubble could be attracted. This was accomplished in a most satisfactory manner by selecting a cavity which was plainly visible with a 2-inch objective. A long test-tube, having a diameter of $\frac{3}{8}$ of an inch, was filled with water, immersed in which was a fine thermometer. The tube was heated, and experiments were repeatedly made while it was cooling to find out when it ceased to attract the bubble.

A number of trials showed that at 76° C. attraction was powerful, at 71° C. it was somewhat feeble, but below this temperature there was no action sufficient to overcome gravitation. Further experiments were made in a straight tube-like cavity, which from its size and its regularity of shape was exceptionally good for the purpose. It measured $\frac{34}{1000} \times \frac{7}{10000}$ of an inch, and the bubble was $\frac{6}{10000}$ of an inch in diameter. It moved about on change of position as freely as the bubble in a spirit-level. Proceeding as before, the temperature of the crystal being 16° C. and that of the tube 21° C., the bubble could be attracted in a horizontal direction only; but when the tube was warmed to 60° C. its power of attraction was sufficient to overcome the buoyancy of the bubble, and draw it downwards to the extremity of the cavity.

A piece of rock-crystal was examined which contained both water and carbonic-acid cavities in juxtaposition. These water-bubbles were very easily attracted, as will be seen by the following experiments. A cavity was chosen with a bubble moving as easily as the bubble in a spirit-level; its size was $\frac{1}{250} \times \frac{1}{400}$ of an inch, and the diameter of the bubble $\frac{1}{1500}$ of an inch.

While the section of the crystal was maintained at 16° C. a platinum wire was heated in mercury and applied to the cavity, showing the following effects:—

Temperature of wire.	Effect produced.
25°	Feeble attraction.
27	The same.
29	Strong attraction.
31	Very strong attraction.
65	Just sufficiently strong to overcome gravitation.
71	Attracted strongly in opposition to gravitation.

These numbers were confirmed by using the tube of water as a source of heat.

I have ascertained by experiment that at very slight elevation beyond the ordinary temperature a plug of water is apparently repelled from the surface of a glass tube. Mr. Sang has made similar observations.

A capillary tube, open at both ends, had a short column or plug of water within it, free to move in either direction. A warm body applied to the liquid repelled it with great force, even in opposition to gravitation. The warmth of the fingers (in other words, a rise of 21° C.) is quite sufficient to drive the liquid up a tube held in a vertical position. By sealing water in capillary tubes bubbles are formed which contain very little, if any air; these are likewise attracted by heat. When experimenting on the bubbles in natural cavities it was found that an increase of 44° to 49° C. was required to produce the same effect; but the fact must be taken into account that the heat was more difficult of application to the rock-section than to the capillary tube.

When the tube approaches $\frac{1}{8}$ of an inch internal diameter, the glass may be heated to redness at a point in close proximity to the water without causing motion; the water is, however, instantly converted into steam without previous warming, which causes a sort of slight explosion.

If this experiment be made in smaller tubes of $\frac{1}{70}$ inch internal diameter the repulsion is easily caused, and may be seen; but a very high temperature causes the repelled liquid to be evaporated and scattered in drops at a further distance along the tube.

The liquid is not repelled in a body as a liquid, but gradually as a vapour. If it had only the space of a bubble to condense itself in, the bubble would be attracted in the same way as carbonic-acid bubbles.

The attraction of bubbles in cavities which contain water may be due to two causes:—1. At low temperatures, as, for instance, at 21° C., to a repulsion of the liquid from the glass; 2. At high temperatures, such as 60° and 70° C., to evaporation and condensation on opposite sides of the bubble.

The movements of bubbles in Iceland spar noticed by Mr. Sang may thus be explained, for in that substance water-cavities are of constant occurrence. There is no necessity to assume what seems, from my observations on some hundreds of specimens of Iceland spar, to be highly improbable, namely, that the liquid is carbonic acid. The mineral is so soft and so easily split along its planes of cleavage, that I doubt whether microscope sections could contain a liquid of such high vapour-tension.

The following rocks contained bubbles in water-cavities which were attracted by heat:—Granite from the Mourne Mountains; Aberdeen granite; quartz from Snowdon; quartz-porphyry from Pwlheli, North Wales; granite from Ludgvan and St. Leven, Cornwall. Many other specimens contained immovable bubbles.

The repulsion of bubbles by heat, water being the only liquid present.

With regard to this second point, the repulsion of bubbles by heat. It occurs quite as frequently, if, indeed, not more so, in the specimens which I have examined, than attraction, and it is seen to occur in cavities containing water and liquid carbonic acid. (See fig. 4.)

I have noticed some cavities of a remarkable nature, inasmuch as they were apparent under similar conditions to those which I have already described, though they behaved in an exactly opposite manner. They were water-cavities which adjoined others containing both liquid carbonic acid and water. A blast of warm air, insufficient to vaporize the carbonic acid, is sufficient to propel the gas-bubble to the other end of the cavity. I next ascertained that five puffs of warm air only just warmed the carbonic acid to the critical point, that is to say, from 16° to 31° C. I then took a thin bar of copper, and warmed it two degrees above the temperature of the room; this repelled the bubble easily; and other trials showed that a rise of temperature of less than $\frac{1}{2}$° C. was quite sufficient. It was curious to see that when the gas-bubble touched the walls of the cavity at only one point it moved with extraordinary ease and slowly, but otherwise it was more difficult to stir, and it went with rather a sudden jerk. This subject will be treated more fully later on.

The largest specimen of a bubble readily movable by heat was in a water-cavity in a green crystal of fluor-spar kindly lent me by Mr. James Bryson, of Edinburgh. The cavity measured $\frac{1}{10} \times \frac{1}{20}$ of an inch, the bubble being $\frac{1}{27}$ of an inch in diameter. To my surprise, I found it to be easily repelled by a jet of warm air.

The sinking of gas-bubbles by rise of temperature in cavities containing water as the only liquid.

In a paper which I have lately communicated to the Chemical Society, I have given details of experiments on certain bubbles in water-cavities, which prove that by rise of temperature the bubbles become denser than the water and sink (Journal of the Chem. Soc. vol. i. 1877, p. 245).

When exposed to a uniformly diffused rise of temperature on the microscope-stage the very slow sinking motion of the bubble was remarkable; as the specimen cooled it returned in the same manner. In some cases a temperature of 40° C. was apparently sufficient; but several experiments on an exceedingly good cavity, which measures $\frac{1}{330} \times \frac{1}{410}$ of an inch, and the bubble in which is $\frac{1}{800}$ of an inch in diameter, fixed the temperature for this specimen at 150° C. The cause of this sinking appears to be that the bubble consists of a gas so highly compressed that it is nearly of the same density as water. On heating the water expands, and the gas is contracted until the relative densities of the two substances are reversed. Professor Andrews has shown that a mixture of 3 vols. of carbonic acid with 4 vols. of nitrogen at 7°·6 C. contracts $\frac{1}{378}$ of its original bulk by a pressure of 284 atmospheres. This

must be a gas with a density of ·745 compared with liquid water at unity; hence, in all probability, at a tension of 400 atmospheres this gaseous mixture would be denser than water. I have elsewhere pointed out that carbonic-acid gas which was reduced to $\frac{1}{47}$ of its volume by a pressure of 223 atmospheres, at 63° C. must have been as dense, if not denser, than water (Journal of the Chem. Soc. vol. ii. 1876, p. 250).

Some of those gas-bubbles which I have already mentioned as being readily attracted by heat, I found were made to sink by warming to about 150° C. It is always necessary to rotate or at least reverse the objects when under examination; and this precaution was always strictly regarded to obviate errors of observations. The importance of this is shown by the following experiment. A bubble in a specimen of rock-crystal was seen to descend to the lower point of the cavity when it was uniformly heated from above only; it was found to be attracted by a hot spatula applied to one end of the cavity. It was thought possible that the cavity might have an oblique inclination, and be attracted from the upper end of the cavity, because this motion might bring it nearer the surface where the source of heat was placed. This was evidently the case, for on turning the slide upside down no motion was caused by uniform heating.

The following experiments were made on some good-sized cavities in rock-crystal. On presenting a heated wire to one side there was instant attraction, and then the bubbles remained at the bottom of the cavities, after which they settled slowly into their original positions. A hot spatula was passed over the specimen; the bubbles went to the bottom and there remained, in spite of the attraction of the hot spatula to the other end; they then, after cooling slightly, ascended, but descended again on removal of the spatula, as if jerked back by a spring. After a time they finally ascended slowly. This is a curious effect: it seems that the heat, if strong, causes the bubbles to sink, and that the heat of the spatula cannot attract them up until they have cooled somewhat; that after attraction has drawn them to the upper ends of the cavities, and the source of heat has been removed, they sink once more, and finally take up their original positions after further cooling.

Attraction and repulsion caused by heat in different cavities of the same specimens.

Bubbles attracted by heat and those which are repelled have generally been found in separate and entirely different specimens; and it would appear most improbable that they should exist in the same piece of stone side by side.

Fig. 5 shows six cavities, which, though not in the same field of the microscope, yet exist within a quarter of an inch square of the same section of rock-crystal. The cavity marked A′ contains water and liquid carbonic acid, and cavity E contains liquid carbonic acid only; this might be considered sufficient evidence of other cavities containing a highly com-

pressed gas; actual experiment, however, has proved that the bubbles are spaces left by the contraction of the water on cooling from a high temperature, and therefore contain aqueous vapour and only such gas as may be dissolved in the water. Some obstruction, probably friction or adhesion of the liquid, caused by the flatness of the cavity, prevents the bubble in A′ from moving freely; but it is actually repelled, or there is a tendency to repel it, if a wire very strongly heated be brought near. It is not attracted, however, at any temperature. When repelled it returns as if squeezed back. Capillarity makes the bubble assume a spherular form whenever possible; therefore it returns to such a position as is most compatible with this shape. Sometimes the motion is not a transference of the bubble from one point to another; it seems to be fixed, but flattened at one side, and shaken as if something were pushing and trying to move it. The bubble in A, a deeper cavity, moves very freely and is repelled by heat. The cavities B, C, D contain bubbles which, curiously enough, are attracted by heat.

Another cavity of irregular shape, and at least four times the size of the largest of these, behaved exactly in the same manner. As in the other experiments, the objects were frequently turned about in different directions to prevent mistakes.

A series of experiments were made on these cavities to ascertain the precise difference, if any, between them.

The bubble in A was found to have disappeared at 105° C., and it returned immediately on cooling with a sort of jump, which carried it the whole length of the cavity, and made it rebound from the further end. At 104° C. the bubble had not disappeared. These numbers are the result of sixteen experiments.

The bubbles in the cavities B, C, D did not all behave in the same way. Thus, from ten experiments at different temperatures, it was found that at 85° C. the liquid in C had expanded so as to fill the entire space, at 83° C. it had not done so, while D required a temperature of 123° C. The liquid in B was apparently unaffected by so slight a rise of temperature, but it was made to fill the cavity at 138° C. When heat had been applied so that the bubbles in all the cavities had disappeared, the one in B returned first, that in C generally appeared next, and that in D last.

Sometimes, after very strongly heating the specimen, the bubbles in C and D did not return for half an hour, though two or three minutes was a period quite sufficient for the specimen to become cooled down.

Sometimes the appearance in the cavity on cooling somewhat resembled the sort of ebullition which occurs when carbonic acid is cooled when at a temperature above its critical point; the motion, however, of the bubbles was much slower, and occurred in one direction only, except when the bubbles rebounded from the lowest point of the cavities.

The bubble in B does not roll about when the microscope-stage is rotated; in this respect it differs from those in C and D. Careful

experiments were made with the view of ascertaining the temperature producing repulsion and attraction respectively in the different cavities of this specimen.

Repulsion to the extreme end of the cavity, entirely in opposition to the effect of gravitation, was produced by a temperature of 5° C. above that of the specimen. Attraction in opposition to gravitation in cavity D became active by a rise of 5° C.; in B 14° C. were insufficient to do more than give a lateral motion to the bubble. On cavity C 12° C. acted energetically.

A series of experiments were made on bubbles which contained liquid carbonic acid as well as gas.

By heating the specimen above the critical point of the carbonic acid we know something of the conditions under which subsequent experiments may be made. We know that the liquid is water containing a gas-bubble under a pressure of not less than 109 atmospheres. The following are facts which, like those preceding, were recorded at the moment of observation. Fig. 4 represents a cavity in rock-crystal with carbonic acid in the liquid and gaseous states floating upon water. The bubble is so easily movable that it shifts about like the bubble in a spirit-level. The stage of the microscope holds the section in a vertical position, and when one end of the cavity is raised ½ a degree Centigrade in temperature, the bubble is driven to the opposite extremity; if the specimen be turned over, this will happen in spite of the buoyancy of the bubble. The bubble takes up its original position on cooling. When the specimen is uniformly heated above the critical point of carbonic acid, repulsion by heat still takes place. I have repeated this experiment during the last twelve months an immense number of times, both with fine jets of warm air and with platinum wires, always with the same result. Another exactly similar cavity being under examination, heat was applied by means of a hot wire spatula. When the edge of the spatula was seen to approach, there was an instant repulsion of the bubble from the upper to the lower end, and the liquid carbonic acid was vaporized. After removal of the source of heat, the bubble did not rise (*i. e.* apparently sink) to its original position until after the liquid had condensed again; it then slowly moved back. This experiment was repeated again and again with other bubbles in the same specimen, and notes were made each time to secure a truthful record. The action in every case was precisely the same; repulsion occurred, and the bubbles sank under a uniformly diffused rise of temperature. In another specimen of rock-crystal were seen two cavities, one containing water only, and the other water with carbonic acid; the bubble in the latter cavity was repelled by heat (no experiment was made to ascertain whether it sank on warming), but that in the water-cavity was attracted. In order that there might be no possible mistake about this, the two cavities were brought into the field of view at the same time, and the

heated spatula approached them both from the same side; they then instantly darted in opposite directions. The movements were unaffected by raising the temperature above the critical point of carbonic acid. It is certainly very perplexing to find two cavities in the same section closely adjacent to each other, and nearly of the same size, the bubbles in which are moved in opposite directions by the same source of heat applied from the same side.

Bubbles containing gas at high tension, under different conditions of temperature, are first repelled and then attracted by a heated body.

My work was discontinued for a period of some months; but on being able to look over my specimens once more, I verified all my former observations, and became surprised by the following discovery. A bubble which was repelled by a gentle heat was attracted after it had been heated more strongly, and then on cooling it was again repelled. It appeared to contain some liquid carbonic acid floating on water with the gas. Searching for such other specimens, the cavity, fig. 6, A, was met with; it contained a large proportion of liquid carbonic acid, with a little in the gaseous state floating on water, and the bubble is so movable as to act like a spirit-level. On cautiously applying a warm spatula the bubble was repelled; on heating it a little more, the liquid carbonic acid became gas, and the bubble was again repelled. The spatula was then made almost red-hot and applied; the bubble was then strongly attracted; after cooling somewhat it was again repelled. It was noticed that after the critical point of the carbonic acid had been reached, the bubble sank through the water. It has been shown by the various experiments already related that at only moderate temperatures both repulsion and attraction can occur.

Temperature, then, does not directly cause these opposite effects; it can only be some alteration in the conditions of experiment caused by rise of temperature. Increase of tension or pressure within the cavity is apparently the only condition which has varied; and probability that this is the cause of this contradictory attraction is afforded by the following experiment. The specimen was placed in a water-oven (the temperature it would there acquire would be about 94° C. to 96° C.); the platinum spatula was heated in a beaker of oil to 130° C. The warm specimen insulated by india-rubber was placed on the microscope-stage, and the warm spatula presented to it, when instant attraction was seen. The same proceeding was repeated many times, always with the same result. As the spatula cooled it ceased to affect the bubble at all; of course at the same time the specimen was also cooling. The spatula at the temperature of 130° C. was applied to the cooled specimen, which was, however, still at a temperature above 30° C.; the effect was repulsion as at first.

This seems to show that the temperature which the rock-crystal attained

in the water-oven, and not that communicated to it by the spatula, caused attraction.

To ascertain at what temperature attraction became repulsion, and *vice versâ*, the specimen was placed upon a Stricker's hot stage, and the platinum wire was heated in oil contained in a test-tube.

A succession of experiments yielded the following notes:—

Temperature of crystal.	Temperature of wire.	Effect on bubble.
40° C.	110° C.	Repulsion feeble.
42	110	„ „
45	110	Neither repulsion nor attraction.
50	100	„ „ „
52	100	Feeble attraction.
52	100	„ „

On another occasion the wire was maintained at 100° C., and a number of experiments gave like results:—

Temperature of crystal.	Effect on bubble.
42° C.	Feeble repulsion.
45	Neither attraction nor repulsion.
50	„ „ „
53	Slight attraction.

Above and below these limits attraction and repulsion were feeble.

I next ascertained the critical point of the carbonic acid in this cavity and found it to be as low as 21° C. Prof. Andrews kindly informs me that 14 per cent. of nitrogen lowers the critical point of carbonic acid to about 20° C. It is by no means unlikely that nitrogen is the gas present in this cavity in something like the same proportion, and that the tension is something very considerable.

It seems to be a matter of great interest to know whether the difference in temperature between the attracting wire and the bubble was so slight as when repulsion occurred; the specimen was therefore heated on the Stricker's stage to such a temperature as to ensure attraction by a hotter body. The following is an account of the experiments. The bulb of a fine thermometer was often used as the attracting body; at other times a platinum wire heated in mercury.

Temperatures of crystal.	Temperatures of attracting body.	Effect on bubble.
45° C.	73° C.	Repulsion.
50	83	Attraction strong.
50	78	Bubble attracted horizontally.
57	74	Attraction against gravitation.
55	65	No movement.
55	75	Strong attraction.
60	65	No movement.
65	75	Attraction in any direction.
65	73	" " "
65	70	Attraction.
65	69	No movement.
67	73	Attraction.
67	76	Attraction strong.
68	75	Attraction against gravitation.
65	72	Attraction.
70	75	No movement.
73	78	Attraction.
60	65	Attraction feeble.

Other experiments of the same kind were made on other cavities, which were, however, more difficult to operate on, being smaller in size and of less regular shape.

Temperatures of crystal.	Temperatures of attracting body.	Effect on bubble.
60° C.	130° C.	Neither attraction nor repulsion.
100	180	Very strong attraction against gravitation.
100	160	
100	160	
100	140	Somewhat feeble attraction.
100	140	
100	130	No effect.
Another cavity :—		
75	140	Very strong attraction.
75	130	Attraction feeble.
60	130	Attraction feeble.
60	125	
60	125	

Here let me explain that attraction or repulsion, when expressed as being feeble, should really be understood as causing a slow motion. It was noticed that bubbles without gaseous contents, which were attracted,

moved with a uniform motion, and were kept at the further ends of the cavities until an equilibrium in temperature had been established, so that sometimes the liquid had the deceptive appearance of sinking under the rise of temperature. When gas-bubbles were repelled by heat, their speed appeared to be accelerated after they once commenced to move.

It may be considered an argument against the motions being due to any pyroelectric conditions of the minerals, that they have been noticed in crystals of fluor-spar, and that, no matter in which direction sections of rock-crystal are cut, the movements are all equally well obtained.

Regarding the repulsion of gas-bubbles two facts are striking, namely the very slight rise of temperature (less than $\frac{1}{2}°$ C.) on one side of the bubble capable of causing the movement, and the great tension existing within the bubble.

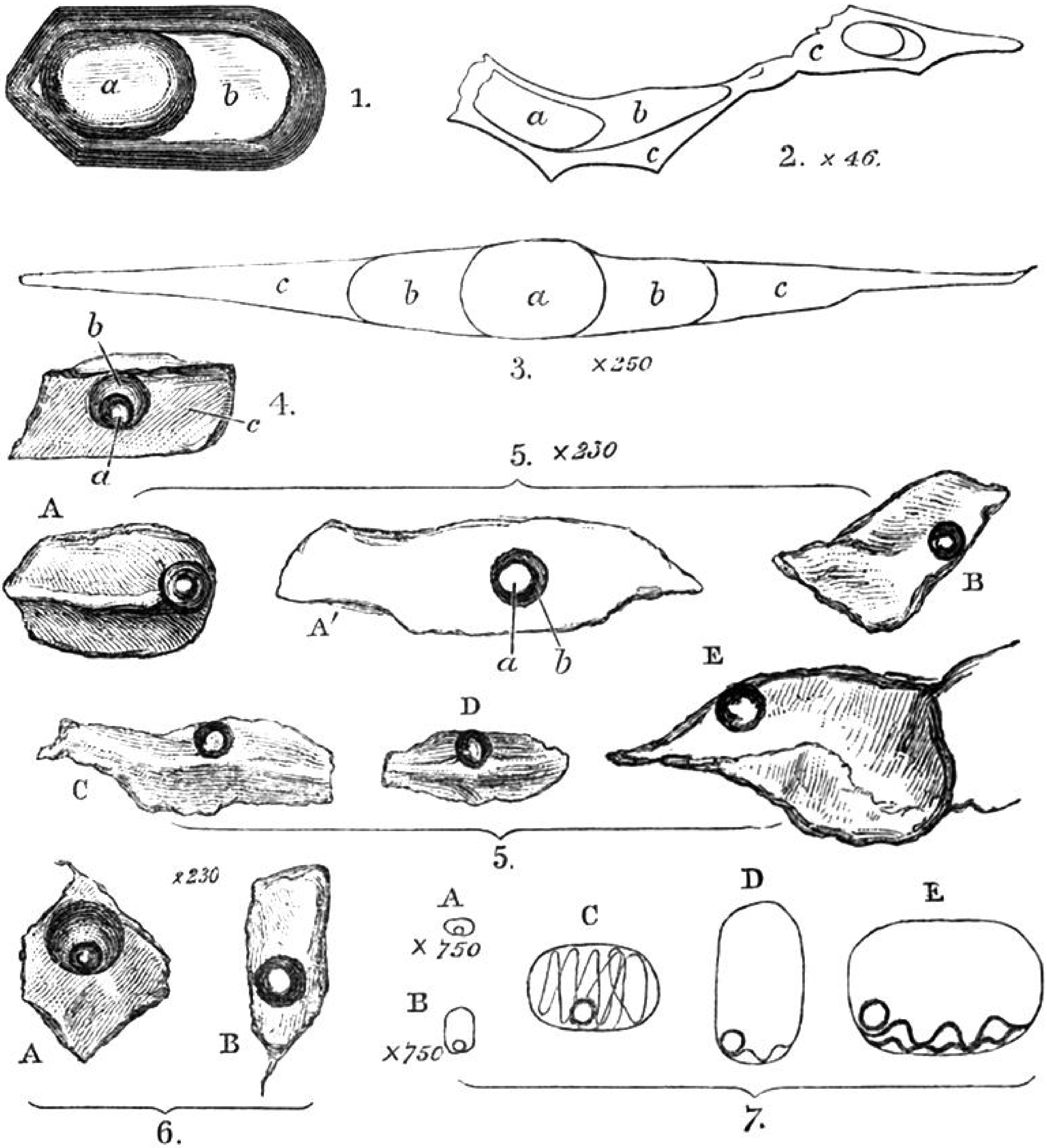
Note.—Received April 13, 1877.

I am much indebted to Prof. Stokes for having furnished an elucidation of the cause of these movements, which is perfectly consistent with all the facts which I have noticed. In consequence of this I have discarded my own explanations, which were originally embodied in the foregoing paper, but which were never perfectly satisfactory to me.

In notes dated April 7th and 12th Prof. Stokes says:—"It seems to me, as far as I can judge without having seen the specimens, that the greater part, if not the whole, of the motions you describe are referable to a cause different from that suggested by Prof. Tait, and that they depend on capillarity. We know that the surface-tension of a liquid is diminished as the temperature is raised. The explanation, according to this view, would be very similar to Professor James Thomson's beautiful explanation of the tears of wine (Reports of the British Association, 1855, Report 2, p. 16), only here difference of temperature takes the place of difference of strength, and the surface of the liquid surrounding a bubble shrinks at the cooler side." The shrinkage of the liquid on the cooler side of the bubble of course propels it towards the source of heat. This explanation seems quite in accordance with all phenomena of attraction of bubbles, whether in carbonic acid or in water, with the movement of water in capillary tubes, and the vibratory movements of minute bubbles described in the next paper.

"In the case of a cavity containing water with a bubble of compressed carbonic acid, the water, of course, containing gas in solution, the repulsion by heat may be accounted for by a slight evaporation of the dissolved gas at the surface weakening the solution, and thereby increasing the surface-tension; and it is quite conceivable that at different temperatures one or other of these opposite effects may prevail."

Conversely, one can understand how different conditions of gaseous tension in bubbles, and the extent to which the surrounding water is charged with gas, may render the effect of heat either repulsion or attraction.—W. N. H.



The letters in italics (a, b, c) within the drawings of fluid-cavities indicate the positions of the gaseous carbonic acid, liquid carbonic acid, and water respectively.

Fig. 1. Cavity in a topaz. × 35 diameters.

Fig. 2. Cavity in rock-crystal. × 46 diameters.

Fig. 3. Cavity in tourmaline.

Fig. 4. Cavity in rock-crystal, containing a bubble repelled by heat. × 250 diameters.

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