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LX. Notice of some experiments on subterranean electricity made in Pennance mine, near Falmouth

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prostration, and the general character of the prostrating force which these may conjointly indicate. The course of induction suggested in my two papers on the tornadoes of Providence and New Brunswick, as taken together, are believed to afford sufficient grounds for a correct determination, when applied to the traces of other tornadoes. It is also satisfactory to find, that in the surveys exhibited in the above cases there are several traces of individual objects moving in the tornado, which fully confirm the accuracy of the more general induction.

As regards Dr. Hare's own views of the electrical origin of storms, some notice has been taken of these in Silliman's Journal for October 1842, p. 261–263. Since the discoveries of Franklin, an electrical origin and character has often been conjecturally ascribed to storms. A want of originality in advancing this hypothesis will not weaken any evidence which shall be adduced in its favour; but until it shall have been satisfactorily supported by observed phænomena, it will probably continue to be rejected by scientific inquirers. And were it possible to show an electrical origin in great storms and tornadoes, it would in no wise alter the known fact that a determinate rotative action has been noticed in these storms.

LX. *Notice of some Experiments on Subterranean Electricity made in Pennance Mine, near Falmouth. By* R. W. Fox, *Esq.**

I HAVE already communicated to the Geological Society of London† some results produced by the electric action of two nearly east and west metalliferous veins which have been partially explored in Pennance mine. I have since made other experiments in the same mine, in which ore-points, consisting of copper and iron pyrites in the two veins, were connected by a pair of copper wires, which in most instances acted on a galvanometer or other apparatus at the surface, an end of each wire having been brought up through a shaft for the purpose; about 50 fathoms of wire were employed, although the ore-points in the different veins were only about 14 to 18 fathoms asunder in a direct line.

A galvanometer of not much sensibility was generally used; the needle, which was 2½ inches long, moved on a pivot, and had a coil of fine wire passed 48 times round it. Another galvanometer, consisting of a suspended astatic needle and 140 coils of wire, was also employed occasionally.

* From the Transactions of the Royal Cornwall Polytechnic Society.

† The communication here alluded to will be found in our report of the proceedings of the Geological Society, pres. vol. p. 457.—Edit.

When the former, which call No. 1, was placed in the circuit, the needle was deflected so as to become stationary at 14° to 15° from zero; and it revolved rapidly round the circle when the circuit was broken and restored a few times, the direction of the electricity being from the south vein to the northern one. The other galvanometer (No. 2) suffered a permanent deflection of about 40° when in the circuit. The interposition of a plate of platinum or zinc at either of the ore-points, or of a *point*, instead of a considerable surface of metal, did not affect the direction or force of the currents; they were, moreover, constant in both these respects during more than eight months that the two veins were connected by the wires, and a part of this time the mine was filled with water in consequence of an accident to the machinery. Ore-points in the two veins situated within two or three feet of the others respectively, were at one time connected by a second pair of copper wires of the same lengths as the first; both sets of parallel wires being kept apart, and insulated from the sides of the levels or galleries by poles stretched across the latter at short intervals.

When galvanometer No. 2 was placed in the second circuit, No. 1 remaining in the other, the needle of the latter receded at least 2°, standing at 12°, instead of 14° or 15°; and the former stood at 5° or 6° less than it did when only one circuit was established. On breaking either of the circuits, the deflection of the needle in the other circuit was increased to its original amount; and when *both* pairs of wires were connected with only *one* of the instruments, the effect was almost precisely the same as that produced by one pair alone,—not greater certainly.

A copper and zinc pair of plates of about 6 inches surface, separated by a piece of cotton cloth moistened with water, was placed in the circuit, and when the currents from this source and the veins *coincided* in direction, the needle of galvanometer No. 1 stood at about 10°, that is, at less than it did when acted upon by the subterranean electricity alone, and when the deflection caused by the latter was afterwards opposed by the action of the plates, the needle went back to zero, and even sometimes passed a little beyond it in the opposite direction. These anomalies may perhaps be referred to the low conducting power of the moistened cotton, which, small as its thickness was, very probably interrupted the transmission of the electricity more than the 14 or 18 fathoms of strata or "*Country*."

On taking the voltaic elements from the circuit and connecting them with the galvanometer, so as to form a separate circuit acting in an opposite direction to the electricity from the mine, the deflection showed a difference in favour of the latter, and indeed this was the case when the interposed cloth was moistened by a very weak solution of common salt.

The electro-magnetic and decomposing effects of these subterranean currents also afforded unequivocal evidence of their energy. A helix of copper wire fixed round a small horse-shoe-shaped bar of iron, was placed in the circuit formed by the wires from the veins, when the bar became so magnetized as to cause a compass needle $1\frac{1}{2}$ inch long, at the distance of nearly half an inch, to oscillate through an arc of about 70°, when the circuit was alternately made and broken a few times.

A solution of hydriodide of potash was found to have been decomposed after it had been left in the circuit for rather more than a day.

The endosmose action occurred in various experiments, but it may be sufficient to give one example. Sulphate of copper in solution was put into both branches of a U-shaped glass tube with clay in the bent part of it, the surface of the fluid in one branch standing half an inch above that in the other. A piece of silver wire was plunged into each of them, the upper end passing out through sealing wax, with which the extremities of the tube were stopped, and the apparatus was placed upright in the circuit, with the wire in the higher column of the fluid connected with the negative wire. In the course of a few days this column was found to have risen one-eighth of an inch, the other having fallen in an equal degree, showing that the greater pressure of the higher column was superseded by the force of the electric action.

When small cylinders of copper pyrites were substituted for the silver wires in the branches of the bent tube, not only did the endosmose action occur, but the copper ore, forming the negative pole, had its surface gradually changed to vitreous copper in the course of two or three days*, the other ore-pole remaining unaltered. The same change was produced, and apparently with equal facility, when solutions of other salts, as carbonate of soda or common salt, were substituted for that of sulphate of copper in both branches of the tube. The cylinders of copper pyrites used in these experiments were long enough for the upper ends to project above the mouths of the tube, where the opposite wires were attached to them respectively, and these were well coated with sealing-wax dissolved in alcohol, to prevent the access of moisture to any part of the metal, and indeed all but the lower portions of the ore were coated in like manner.

* Some of the ore thus changed was at the last Polytechnic Exhibition.

In some instances the cylinders of copper pyrites were allowed to remain in solutions of sulphate of copper in the bent tube for several weeks, when deposits of oxide of iron were found coating the inside of the tube about the negative pole. These results remind one of the ochrey appearance observed in rocks inclosing much vitreous copper, a fact noticed by my friend Joseph Carne; and it may be worth while to inquire how far the proportion of "*gossan*" in copper veins may be connected with the quantity of vitreous ore contained in them.

Since the foregoing experiments were made, I have obtained an electro-type copper plate $1\frac{1}{2}$ inch long, $1\frac{1}{4}$ wide and $\frac{1}{30}$ of an inch thick, by the agency of these subterranean currents. The apparatus consisted of a porous earthenware vessel, resting on wooden legs in a larger one; both were partly filled with solutions of sulphate of copper, an engraved copper plate attached to the negative wire being placed in the outer vessel, and another plate of copper attached to the positive wire in the inner one. After a few days it was observed that crystals of copper had been formed on the negative plate, but it was nearly two months before the apparatus was removed from the circuit, when the deposited metal was detached from the plate, having received its impression, VI INSITA TERRÆ. Whilst this experiment was in progress at the surface, the water, as I have before mentioned, invaded the mine, but without interrupting the process; it appeared, indeed, that the electric action was rather increased than diminished by this circumstance.

Before the influx of the water, an ore-point in the north vein was connected with *rock* near the south vein (generally the wall of the vein), and an ore-point in the south vein was likewise connected with *rock* near the north vein, in both which cases currents more or less feeble were detected passing towards the latter through the wires, which were insulated, as before, by wooden poles stretched at intervals across the galleries. It is probable that the moisture on the rocks conducted the electricity from the ore to the metal, however imperfectly, and when different metals, as platinum and zinc, were successively substituted for the copper in contact with the rocks, the currents were modified in their force according to the metal employed, but were seldom changed in their direction. The action was most decided when the place of contact with the rock was near ore; and sometimes the end of the wire, or rather the piece of copper attached to it, was rubbed by an assistant against the walls of one of the veins or the sides of a "*cross-cut*" between them. Under these circumstances the astatic needle was several times suddenly much deflected, and the parts of the rocks from which this increased action proceeded having been marked, they were broken away, when iron pyrites was in every instance found imbedded in them; and there can be no doubt that the smallest branch of copper or lead ore might have been detected in like manner.

On several occasions the ends of the opposite wires were placed in contact with the rocks near the two veins, when there still appeared to be a tendency in the currents to pass in the same direction, but often they could not be detected, or were too feeble for their direction to be determined with certainty. Pieces of copper pyrites attached to the wires and imbedded in wood, were likewise used instead of the metal for producing contact with the rocks, and with still less effect; and when the contact was made with platinum and zinc in succession, the currents were in opposite directions, and in accordance with the action of those metals respectively; so that the existence of independent currents under the circumstances described, though more than probable, was not clearly proved. Electricity, generated by a pair of zinc and copper plates, was transmitted through the rocks between the two veins from north to south, and also from south to north, in order to detect any independent currents traversing the rocks by a *differential* effect on the needle. This method appeared likely to be a very delicate test of electric action in rocks, but no decided results were obtained, the currents passing in opposite directions apparently with equal facility, at least the few experiments hitherto made in this way have not led to any satisfactory conclusions relative to the point in question. It should be remarked, however, that the astatic needle employed was inconveniently sensitive, and was often set in motion when the cause was not very obvious. With needle No. 1 the case was widely different, as it could scarcely be moved by any subterranean currents that were not tolerably energetic, such as were produced when *both* the wires were in contact with *ore-points*, and then, as has been stated, it often revolved rapidly.

It has been long known that electric currents will traverse a very considerable thickness of rock or strata*; but in what degree this property may be modified by the nature or texture of the rocks, the saline contents of the subterranean water, or the proportion of ores included in the circuit, remains to be ascertained. If the influence of these different circum-

* Many instances of this occur in my paper "on the electro-magnetic properties of metalliferous veins," published in 1830, in the Phil. Transactions, p. 399. I have long ago seen a *very feeble* current act on a sensitive galvanometer after it had traversed nearly a quarter of a mile of strata, and stronger currents would probably be detected in like manner after having passed many times that distance under the surface.

stances should greatly vary, electric currents generated by given elements might be rendered available on various occasions;—to ascertain, for instance, the connection of saline springs not very distant from each other, often appearing at the surface or in mines; or of a metalliferous vein discovered in one place, with a vein which has been worked for ore in another. The conducting power of the circuit at Pennance mine, already described, was in this way found to equal that of a tolerably strong solution of common salt, the current in the latter experiment having to traverse an inch of the solution and short copper wires to complete the circuit. The conducting power of the rocks or strata in this case, therefore, appeared to be very great.

When some sulphate of copper was added to the solution, the conducting power of the latter exceeded that of the strata. Glass tubes filled with solution of salts in different known proportions might be used as tests in experiments on the relative conducting power of different strata, and they might be referred to as standards in describing the results.

LXI. *On the Constitution of the Subsalts of Copper.*—No. I. *On the Subsulphates.* *By* J. Denham Smith, *Esq.**

THE results of several analyses of some of the basic salts of copper made at a former period not agreeing with the constitution ascribed in many instances to these compounds, again directed my attention to their composition, and further experience has confirmed this disagreement, showing either that the analytic results are in one case incorrect, or that the composition of these salts, prepared at various times by the same method, is not constant.

The mode adopted for determining the composition of the subsulphates of copper, was to dissolve one portion of the salt in pure hydrochloric acid, and ascertain the quantity of sulphuric acid by a salt of barytes. To estimate the proportion of black oxide of copper, the course pursued in the experiments alluded to, was solution of another portion of the salt, under examination, in dilute sulphuric acid and precipitation by a caustic alkali from the boiling solution, carefully washing, igniting, and weighing the precipitate. This mode, however, is open to the objection of the possible adherence of portions of the precipitant, or other foreign matter, to the oxide; and as I subsequently found that this class of salts when exposed to a lengthened and bright ignition, care being taken not to fuse the oxide, loses the whole of its sulphuric acid, I adopted

* Communicated by the Chemical Society; having been read April 4, 1843.