OBSERVATIONS

ON

MINERAL VEINS,

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COMMUNICATED TO THE ROYAL CORNWALL POLYTECHNIC SOCIETY,

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ON MINERAL VEINS.

Phenomena of Mineral Veins.

In complying with the request of some of my friends, to state through the medium of the Polytechnic Society's Report, my views relative to the formation of Mineral Veins, I am sensible, that the attempt to theorise on this subject, is somewhat premature, without a more thorough knowledge of facts, than I at present possess. I am, however, encouraged to hope, that an extensive circulation of the Report amongst the miners of Cornwall, may induce many of them to record the results of their experience and observations in our mines; and if so, one object of this communication, however defective it may be, will be accomplished. I propose, at the same time, to give a short account of some of the phenomena which are presented to us by our mineral veins, for the sake of those who are not conversant with the subject.*

I have lately circulated some printed questions relative to mineral veins, among mine agents, in different parts of this County,† hoping that I might be enabled, on their authority, to record and classify many details and specific facts, observed in our different mining districts, distinguishing those which are general, from

* Several papers on mineral veins have appeared in the Cornwall Geological Society's Transactions, among which I need scarcely say, that the memoir by my friend Joseph Carne, holds the most distinguished place; indeed it may be considered as having formed an epoch in the records of Cornish mineral veins.

Another memoir, I understand, may be expected to appear in the next volume of that Society's transactions, by W. J. Henwood, whose indefatigable researches in the mines of this County, are well known.

But the Ordnance Geological Survey of Cornwall and Devonshire, which is now nearly completed under the superintendence of my friend H. T. de la Beche, will form by far the most important document, as it respects the phenomena of mineral veins, which has hitherto appeared, and its value, both in a scientific, and practical point of view, cannot well be estimated.

† See a copy of these questions at the end of this paper.

others which might seem to be more local and peculiar. I have not yet, however, been furnished with sufficient materials to enable me to carry my plan into effect; and, as the Polytechnic Report has been for some time in the press, I must now give up my first intention. But I have to express my acknowledgments to several mine agents, for much valuable information, which they have kindly sent me, in answer to my questions; of some of which I mean to avail myself in this paper, although I do not now profess to give more than an outline of facts.

It is well known, that in Cornwall and Devon, the granite is found to protrude, in apparently isolated masses, through the slate; but as these are inclined, at various angles, under the superincumbent strata, it is presumed that they become united in one general mass, at a greater or less depth. The general range of these granitic masses is toward the north-east, or nearly so.

A large proportion of the "*elvan courses*" or porphyritic dykes, which abound in our mining districts, approximate very nearly to the same horizontal bearing, and dip under the strata, towards the north, more often than towards the south, and frequently at considerable angles from the vertical.* Their width varies from a few feet, to more than fifty fathoms; and they traverse the granite, "killas" (clay slate,) greenstone, &c., without interruption.

The Copper and Tin mines are generally situated at, or near some of the junctions of the granite and killas, or of killas and elvan, &c.; and both these metals have been found in great abundance in each of these rocks; and it is perhaps difficult to decide, in which of them, either metal has, upon the whole, predominated.

The Mineral Veins are divided by the miners of Cornwall, into "*lodes*" or metalliferous veins, and *cross courses*, and *cross flucans*,

* This paper being principally for local circulation, I have in all cases, conformed to the custom of our miners in estimating the dip or underlie of Veins, &c., from the *vertical*, and not from the *horizontal line*: but I have deviated from their plan in giving the horizontal bearings of Veins, as I have referred them to the *true Meridian*, and not to the *Compass* or *Magnetic North*, the latter being nearly 25½° to the westward of the former.

or veins of quartz, or quartz and clay, with detritus of the enclosing rocks; and veins, consisting principally or entirely of clay. I ought, perhaps, to include slides likewise amongst the veins; they resemble cross flucans in their composition which is mostly of clay.

The copper and tin lodes have a general tendency towards an easterly or E.N.E. horizontal direction, although considerable deviations therefrom are not unfrequent in some of our mining districts:—indeed, the tin lodes in the parish of St. Just, near the Land's End, and in some other parts of the County, have nearly a north westerly course, on an average.

Lodes which differ considerably, say 40°, or 50°, from the general strike or bearing of the other lodes in a district, are termed "*caunters*," or "*contra lodes.*" Besides these, there are usually minor veins or branches connected with the lodes, which ramify from them at various angles; and when they spring from parts of the lodes which contain ore, they generally do so likewise; on which account, the miners term them "*feeders.*" These small branches seldom carry ore at a great distance from the lodes; and this remark, I believe, applies also to the flat veins, or rather beds of tin ore, termed "*floors*," which are sometimes found connected with tin lodes.

The cross courses, and cross flucans, have, in the aggregate, a bearing very nearly at right angles to that of the lodes, or towards N.N.W., although many of them differ considerably from this direction; they consequently traverse the lodes at various angles, and with very few exceptions, completely divide or intersect them. These cross veins sometimes contain ore, at and near the points of intersection, especially when they cross the lodes at rather acute angles. This is particularly the case in St. Just, where the cross courses or "*guides*" are nearly N. and S., and the lodes N.W. and S.E., and sometimes even N.N.W.

There are large veins of hæmatite, or other varieties of the oxide of iron, in different parts of Cornwall, and the South of Devon, which have the same strike or direction as the cross courses,* and

* Captain Richard Tregaskis first called my attention to this circumstance.

like them, have been observed in some places, particularly in St. Just, to intersect the lodes.

The lodes and cross veins are sometimes vertical in their descent through the strata, but they are much more often inclined at different angles. The former, however, have generally a greater underlie than the latter, although it seldom exceeds 45°, and is usually much less;—perhaps 20°, on an average. The lodes are then said to have a north or south underlie, (as the case may be,) of so many feet in a fathom in depth; whilst the underlie of the cross veins is said to be towards the east or west; although it is evident from what has been stated relative to their respective horizontal bearings, that their real dip may be considerably on one side, or the other, of the nominal one.

The lodes and cross veins traverse the granite, "killas," "elvan," and other rocks, without interruption in their strike or dip, unless they should happen to cross the line of junction of two rocks, at an acute angle, in which case they are often observed to pass along it more or less, and ultimately to take their previous course. They are all subject to occasional, and some of them, to very frequent irregularities in their strike, and dip, but more especially in their width. Thus if we take a vein of three or four feet, to represent a fair average size, it may be only an inch or two wide in one place, and eight or ten feet, in another. Such extremes not unfrequently occur within a few fathoms of each other. On the other hand, many lodes have been worked for a great distance, without the occurrence of any very considerable changes in size. Some lodes are as much as 30, 40, or 50 feet and upwards, in width, at least in some parts; but under such circumstances, they are generally worked at less profit, as the ore is frequently much disseminated in them, and mixed with earthy deposits, in which fragments or detritus of the containing rocks may probably predominate. Indeed, it may be remarked of lodes and cross veins, that the contents of a large proportion of them, resemble, in some parts, the enclosing rocks: even the clay or "flukan" in veins, commonly partakes, more or less, of the colour and appearance of the rocks traversed. Fragments of these rocks cemented together by ore, quartz, or other matter, are of common occurrence in veins; and it is remarkable, that when the veins traverse different rocks, none of these mechanical deposits are found at any considerable distance from the rocks which they resemble.

Copper and tin lodes generally contain various other metallic ores and earthy substances, which differ from the enclosing rocks, and do not appear to be of mechanical origin. Copper lodes, for instance, abound more or less, with a brown, earthy, iron ochre, mixed with friable quartz, and other substances, termed "*gossan*." It is usually found above, and resting on, the copper ore; and without this indication, a miner would not expect to find copper in a lode; it is, in fact, one of his essential conditions. If the gossan has some tin ore (peroxide of tin,) disseminated amongst it, it is, by many miners, considered a still more favourable sign. And not only does the oxide of tin very commonly occur with the gossan, on the back of a copper lode, but it not unfrequently descends to a greater or less depth, with the copper, and then ceases. There are, however, many instances of its accompanying copper ore to a great depth; and in Dolcoath mine, it is found in a copper lode more than 200 fathoms below the surface, and even under the copper. In this part, the lode consists of tin only, mixed with quartz, and is very hard. In Cookskitchen mine, I understand, that tin has also occurred abundantly under copper. When tin and copper accompany each other, they are, in part, at least, generally more or less intermixed; with a tendency, nevertheless, in the two metals to approximate to the opposite walls or sides of the lodes, and not unfrequently these ores are divided from each other by parallel veins of quartz, clay, or other earthy matter. Tin rarely occurs in any other state than that of a peroxide; in a very few instances, it has been found as a sulphuret, intimately combined with the sulphuret of copper, when it is termed bell metal ore. The red oxide of copper, on the other hand is far from abundant, and although often met with, it is mostly in small quantities: the same remark applies in a still greater degree, to the carbonates and silicates of copper. The arseniates of copper have been found in only one or two localities; and the phosphate has been rarely seen in our mines. The yellow or bi-sulphuret, is by far the most prevailing ore of copper, in Cornwall; and next to it, the sulphuret, or grey and black copper ore of the miners, which varieties are met with, more or less, in most copper mines, and frequently in very large quantities. The sulphuret is usually found nearer the surface, or cross courses, than the yellow ore; but sometimes they are mixed, and occasionally, the former is met with at a great depth. The purple copper, or "*horse flesh*" ore, of the miners, is not very uncommon, but tennantite, and particularly fahlerz are much more so. The sulphurets of iron and zinc, are abundant in most copper lodes, and in parts of some lodes they prevail almost exclusively, the former especially. The sulphuret of lead sometimes accompanies copper ore, but generally in small quantities, and even in minute isolated portions.

Arsenical pyrites occurs in copper and tin lodes; but is most abundant in the latter. Carbonate of iron is found in both: wolfram, or tungstate of iron, principally in tin lodes, and rather sparingly. The sulphuret of iron or "*mundick*," is often abundant in the latter; but gossan is seldom, if ever, found in decided tin lodes which do not also contain much copper ore; for the latter frequently occurs in small quantities, even in regular tin lodes. Tin lodes prevail almost exclusively in some districts, as in parts of St. Agnes, and St. Just parishes, &c.; and copper lodes predominate in others; but in most of our mining districts, tin is found in distinct lodes, by the side of those of copper, or occupying the same lode, either contiguous to the copper ore, or in another part of it, more or less distant from the copper.

Of the foreign or non-mechanical earthy substances in copper and tin lodes, "*spar*," or quartz, is the most general, and the most abundant, particularly in the latter; and when accompanying tin, it is often harder, and more compact than with copper: this, however, is not always the case; but when it becomes more friable and granular, (termed "*sugar spar*,") it is considered by many miners a favourable symptom, as it respects copper ore.

The sides of lodes, especially those of tin, are often principally composed of quartz, combined with "*peach*" (chlorite,) shorl, or disintegrated portions of the containing rock, &c. These sides or boundaries of lodes, are usually termed "*capels*," showing no smooth or regular walls, but penetrating into the enclosing rock or "*country*," and also into the lodes, and mixing with their other contents.

Fluor spar (fluate of lime,) is much more associated with copper, than with tin, and is often in great abundance, so as, in parts of some copper lodes, to form the prevailing vein stone. Peach or chlorite often abounds in tin lodes; but in some districts, it is thought unfavourable for copper.

These vein stones, together with such as are supposed to be of mechanical origin, vastly exceed the metals in quantity, in most lodes, the ores being accumulated in larger or smaller masses, or in veins in the lodes, and very commonly disseminated more or less, in detached portions, among the vein stones. The miners are frequently conducted to large bunches or masses of metal, by following very small veins of ore, clay, or quartz, &c., for some distance. Lodes are often split into numerous branches, particularly when they pass from one rock into another. Sometimes all traces of a lode are quite lost, and another parallel lode or branch is discovered by working a level for a short distance at right angles to the first: in this case, they are said to be "*spliced*," or to overlap each other.

When lodes alter rather suddenly, in the amount of their underlie, they generally exhibit a change in their contents, becoming less productive of ore, when their underlie is increased, and more so, when they are more nearly vertical.

When lodes of the same metal meet at acute angles, they mostly unite for some distance, and then separate again: if this occurs, either in their strike, or dip, they are generally found to increase in their produce of ore, whilst they continue together; but if they cross at very considerable angles, they are usually impoverished.

Lodes are very much influenced in their metallic riches, by the rocks which they traverse, and often change in this respect, very suddenly, in passing from one rock into another: thus many lodes, which yield abundance of ore in granite, are unproductive in killas, and vice versâ:—the same observation applies to killas and elvan. Sometimes, the same lode is rich in different rocks, though in very different degrees. Ores of different metals, however, such as copper, and tin, are very commonly found in adjoining rocks of different kinds, either in the same lode, or in neighbouring lodes: for example, if the granite contains copper, the killas may contain tin, or vice versâ; but this rule is not without numerous exceptions.

Parallel lodes are frequently productive on the lines of the principal cross courses; or ore, as the miners say, is found against ore, in different lodes; and they often yield much ore on both sides of a cross course, or on one side only.

It seems to be generally considered by miners, that the rock or country in the neighbourhood of a lode, is not so hard as at a greater distance from it; and when they cut a level or gallery at right angles to the course or strike of the lodes, they calculate on their being near a lode, when the rock or "*country*" diminishes in hardness.

Cross veins, as I have before stated, consist of quartz, or of clay, or of both these substances, with a considerable admixture frequently of disintegrated portions of the adjoining rock. When quartz prevails in these veins, they are termed cross courses, and when they are composed principlly of clay and friable earthy matter, they are called cross flucans, and it may often happen that the same continuous cross vein is termed a cross course in one place, and a cross flucan in another, in consequence of a change in its contents.

The cross courses mostly intersect, and frequently "*heave*" or dislocate the lodes. The cross flucans not only intersect all lodes, but even such cross courses as they may occasionally meet with. The extent of the heaves or dislocations of the lodes varies from less than a foot, to 60 or 70 fathoms, and upwards.

Some of the cross courses have been traced for many miles in length; and like the principal lodes, they are of unknown depth: they are frequently split into branches, both in their strike and dip, and these branches usually produce minor dislocations, the sum of which may equal that caused by the undivided part of a given cross course.

I apprehend that there are several instances of copper lodes, intersecting cross courses, and that when this happens, the former have a much larger proportion of clay than usual, in their composition.

The quartz in the cross courses is very peculiar in its crystalline structure, having a fibrous, striated, or radiated appearance, with the axes of the crystals, when not much radiated, nearly at right angles to the direction of the sides of the veins. This quartz the miners term "*cross course spar*," to distinguish it from the quartz found in the lodes, or east and west veins, which for the most part, differs entirely from it in texture, being generally either compact, porous, or cellular. The cross course spar usually shows divisions or joints at right angles to its crystals, and consequently parallel to the sides of the veins, as represented by *fig* 18, Plate VI. When cross veins contain quartz, clay, and other substances, these are very commonly arranged in alternate layers parallel to the walls. In lodes also, this symmetrical arrangement prevails more or less, so that a lode often appears to be composed of many smaller veins of different substances, which are frequently furnished with walls, sometimes very smooth, and of the same nature as the principal walls of the lode. These included veins are commonly most distinct near the surface, and occasionally have an oblique direction from one side of the lode to the other: at great depths, they are often irregular, or so confused as to be detected with great difficulty, if at all. It very commonly happens, that the cross veins, when they heave or shift lodes, contain more or less ore between the divided or dislocated parts of the lodes, the ore being sometimes irregularly disseminated amongst the other contents of the cross veins, and sometimes forming small veins, which extend part, or the whole of the way between the shifted portions of the lodes; and it is not unusual to find the ore in the cross veins, at some distance from these boundaries. The dislocated parts of the lodes, are often rather curved towards each other, with their extremities, as well as the enclosing rock, very much disordered, and abounding with small branches which terminate in the cross veins; and the branches near one part of a lode, have no corresponding ones near the other part which has been shifted.

The cross courses in some parts of Cornwall, frequently contain galena (sulphuret of lead,) but this is by no means an abundant metal in this County; it has been found in the largest quantity in an E. and W. vein at Huel Rose mine, to the northward of Truro. Iron ochre also occurs in cross veins, and occasionally some other metals, such as arsenical cobalt, native, and sulphuret of silver; but the latter metal has, I believe, been found in greater quantities in E. and W. veins.

There is another variety of vein which is for the most part composed of clay, called a slide, having nearly the same bearing as the lodes, but it has a much greater underlie, approximating sometimes to a horizontal position. The slides traverse all other veins, and they generally dislocate the lodes, throwing them either upwards or downwards. There is often ore in that part of a slide which is between the disjointed portions of a lode.

I am unwilling to conclude my outline of the phenomena of our mineral veins, without more particularly noticing some of the observations with which I have been favoured by several mine agents, intimately acquainted with practical mining. It is possible that some of their views may be modified by further investigations in different mining districts, or they may be confirmed;—however this may be, I think that they ought to be recorded.

Capt. Richard Jefferey in alluding to the indications of much ore, lays great stress on the appearances exhibited at or near the inferior, or "*foot wall*" of a lode. If the ore in that situation should begin to diminish, he says, that it is a very unfavourable sign, whilst on the other hand, if the ore on the foot wall should not decrease, and there should be a vein or leader of it rather increasing in size in its descent, it may confidently be anticipated that the lode will be productive below.

He mentions that in the western part of the principal lode in Huel Jewel, there is a course of tin ore resting on the foot wall, and of copper ore near the hanging wall, these ores being separated from each other by a small parallel vein of quartz and clay, and that when one metal is abundant on one side, the other is so likewise, near the opposite side. The same facts he has observed in a lode in Huel Squire.

Of other mines I have received similar reports, the copper and tin being generally rich together when they occur near the opposite walls of lodes, the former mostly occurring near the hanging walls, and the latter near the foot walls. But it is premature, without further inquiry, to lay down a general rule on this subject.

Captain Nicholas Vivian has sent me many particulars respecting the formerly very productive copper lode in Huel Towan. It seems that this lode passes into Cliffdown mine, which is situated to the westward of the former, and that here it yielded much tin, and no copper in the western part of the mine. Both these mines are in killas, without any known elvan course near them.

Captain Joseph Vivian states, that in North Roskear mine, there are four lodes producing copper ore, tin, and blende (sulphuret of zinc.) The two former sometimes occur in distinct bunches, and sometimes they are intermixed. One of the most productive of the lodes has not been found near the surface. Blende, quartz, and iron pyrites, are favourable indications; flucan, and killas, otherwise. This mine is in killas, and there are three cross courses which dislocate the lodes, and contain detached stones of "grey ore" (sulphuret of copper,) between the dislocated parts of the lodes, but the latter are very poor near the cross courses.

In South Roskear, he says that there is only one principal lode with some branches which the same cross courses traverse, and that the ore in the lode is generally of a better quality where it approaches two of the cross courses, than when at some distance from them. There are elvan courses in both these mines, and in South Roskear, the lode is not so productive under the elvan, (which underlies much more than the lode,) as it is in, and above it.

Capt. J. Vivian also describes two parallel lodes in Providence mines, near St. Ives, which are situated in granite and killas. One of these lodes, it seems, produces copper only, and the other tin and some copper, in both rocks.

Captain William Petherick, of Dolcoath, is of the opinion, that the lodes in that mine have been, upon the whole, most productive of ore near the hanging walls. In one of the lodes, (the caunter,) the hanging wall is evidently lower than the foot wall. The walls are generally well defined when there is a flucan course in the lode. The cross courses traverse all the lodes except one, which heaves one of the cross courses nine feet, this lode being furnished with the larger flucan; and he remarks generally, that the vein which has the greater proportion of flucan or clay, in its composition, mostly intersects that which has less, to whatever class of veins it may belong. Most lodes, he states, have isolated masses of rock, near cross courses, which are termed "*horses*" in Cornwall. In Dolcoath, arsenical cobalt, and native bismuth, have been found with copper ore in granite, and the sulphuret of silver, and native silver, in killas.

Captain John Rowse, mentions, that a cross course containing a vein of galena, was intersected and shifted two feet, in Huel Mary, near Perran, by a copper lode containing a large proportion of flucan.

Captain Matthew Bray, has furnished me with many particulars respecting the tin lode in Hewas Mine, which is situated in killas, and was worked some time ago to the depth of 160 fathoms. At 60 to 90 fathoms, under the surface, the lode contained bunches or masses of yellow copper ore of one to ten tons each, which were completely surrounded by very poor tin ground, not worth the expense of working, whereas the lode produced much tin above and below, as well as on the eastern and western sides of these bunches of copper ore. At the depth of 130, to 160 fathoms, the lode was divided into numerous branches. It was intersected and heaved six feet by a cross course, and was found very productive of tin on each side of it. The cross course also contained tin between the intersected parts of the lode, and at the distance of ten fathoms on either side.

Captain John Taylor, of St. Just parish, reports, that in Levant Mine, the copper ore is generally found near the hanging wall, and tin on the foot wall. At Huel Owls, in the same parish, the cross courses or "*guides*," have nearly a north and south bearing, and the tin lodes, on an average, rake about N.W. and S.E. The guides are some of them very large, and contain various modifications of the oxide of iron, they also frequently contain tin at, and near the points where they intersect the tin lodes, and they sometimes yield it mixed with iron ochre, in cosiderable quantities. Many of the tin lodes are "*comby*," i. e., are divided into joints parallel to the walls of the lodes, and they have also, very frequently, horizontal joints, when they are termed "*dicey*."

Captain Taylor remarks, that they consider it a good indication of the proximity of a course of tin, when they meet with a considerable stream or jet of water in working a mine. This, I believe, is regarded as a favourable indication of ore, in most mining districts.

Captains James Rowse, and Richard Dunstan, state, that Huel Vyvyan tin and copper mine, is wholly in granite, and has no elvan course, and that the lode varies from two to forty feet wide; it contains large angular masses of granite, with yellow copper ore, and tin frequently between them. The copper prevails mostly near the hanging wall, and the tin near the foot wall, and in many parts these metals are intermixed. There are eleven cross courses in the space of about 170 fathoms; they consist of clay, quartz, and detritus of the adjoining rocks, in separate parallel layers. Some of these cross courses contained more or less copper and tin, and the lode has usually been most productive of ore, near its intersections, and there the copper ore is generally the sulphuret or vitreous ore.

Captain Nicholas Grenfell, Jun., of St. Just, informs me, that at Bottallack Mine, in that parish, there are seven tin lodes, and four lodes containing tin and grey ore intermixed, which have nearly a N.W. or W.N.W. bearing. These lodes are small, varying from four to twelve inches in width, and they are crossed by another lode, or rather guide, which is from two to three feet wide, and has a N.N.W. direction. The latter has been productive of copper whilst in killas, and quite barren in granite. The same fact was observed in the other tin and copper lodes in this mine, although immediately at the junction of the two rocks they had some rich bunches of grey ore (the sulphuret.) The tin, on the contrary, was much more abundant in the granite, than in the killas. Generally speaking, the lodes were larger in the latter than in the former, and he thinks, that upon the whole, they were most productive near the foot wall, and at the depth of from 25 to 100 fathoms. The lodes were often improved for some distance on each side of the intersections of the cross vein or guide, and also in the latter, at and near the places of intersection; and when the lodes crossed, or united in their dip, at small angles, they were more productive than when they met at larger ones. Guides contain oxide of iron and quartz, and often have more or less tin mixed with the iron, at and near where they intersect the lodes. The carbonates of iron, and of lime, as well as arseniate of iron, and fluor spar, were found accompanying copper in the lodes. "*Floors*," or beds of tin have there been generally observed near the surface, on the back of the lodes, and near the junction of the killas and granite.

Captain William Tonkin states, that lodes are generally enriched in the immediate vicinity of cross courses:—at Huel Crebor mine, near Tavistock, for example, a rich course of copper ore, eight or nine feet wide, occurred on the western side of a cross course, whereas, on its eastern side, the lode was quite poor.

He mentions one instance of copper having been found in nearly horizontal floors; viz. at Virtuous Lady mine, near Tavistock, situated in killas; but floors of this metal, are, he thinks, of very rare occurrence in our mines. Some of the lodes near Tavistock, which produce copper in killas, yield only tin, he says, when they get into the granite of Dartmoor. The capels of tin lodes are, in his opinion, mostly harder than those of copper.

Captain John Davy considers, that when lodes have a much larger proportion of clay than cross courses, they intersect the latter. He remembers an instance in Huel Alfred, of a cross course and flucan course having, when united, heaved the large and very productive copper lode at the upper level in that mine, whereas, at a much deeper level, the lode heaved the same cross course, about fourteen feet. Here the flucan had separated from the cross course, and the lode contained a considerable vein of clay.

When Relistian mine was formerly worked, the lode produced copper ore near the hanging wall, and tin near the foot wall.

Captain Davy has visited many copper and lead mines in Ireland, and taken the bearings of the lodes, which he found very nearly to accord with those in Cornwall, i. e., they generally partook, more or less, of an easterly and westerly direction.

Captain Martin Thomas, who had formerly the superintendence of some mines in Chili, informs me that the course of most of the copper lodes, which he had examined, in that country, was from the east, towards the west;—some of them varying to the northward, or southward of west; and he observed that many of them contained gossan. The lodes which produce gold have the same strike, but the silver lodes occur in almost every direction.

From Captain Richard Tregaskis, I have received great assistance in the course of these inquiries, and much valuable information relative to the phenomena of mineral veins. He has observed, that when lodes are nearly at right angles to the beds of killas, the masses of ore which they contain, are generally comformable in their underlie, to the direction or dip of such beds, in other words, they usually take an oblique direction in the lodes, and form what the miners call "*shoots*" of ore: and when the direction of the beds and lodes are nearly parallel to each other, the ore has not usually any independent dip or "shoot" in a lode; it is then termed a "*pipe*" of ore. The large courses of copper ore in killas, in the Consolidated mines, which are so productive at present, underlie in the lode, towards the east, from the summit of the hill on its eastern side, whereas, the ore which has been extracted from the western side of the hill, inclined towards the west, the strata or beds of killas having the same dip as the ore in both instances; and it seems from his inquiries that similar coincidences have been observed in other lodes, in the United mines, Huel Unity, Huel Caroline in Perran Uthnoe, &c., &c.

Where lodes cross the lines of junction of granite and killas, the masses of ore are usually conformable to their direction, and this happens, if the ore be included, either in the granite, or in the killas, and it very frequently is confined almost exclusively to one of these rocks. It does not, however, seem to follow, that other masses, or shoots of ore in the same lodes, further to the eastward or westward of the lines of junction, are parallel to the direction of the ore, at or near the junctions: on the contrary, they not uncommonly dip in opposite directions. Captain Tregaskis refers to examples of both these cases in Huel Jewel, Huel Gorland, Huel Friendship, &c., and he seems to think that shoots often conform in their direction, in some degree, to the inclination of the ground. He considers that lodes seldom produce much ore when they dip into, or under a hill.

He states that Captain Jefferey has remarked to him, that elvan courses are not, in his opinion, sufficiently noticed by writers on mineral veins, since most of the ore in the principal mines in Gwennap parish, have been found in, or near large elvan courses; —for example; Huel Virgin, Huel Maid, Huel Fortune, Huel Squire, Poldory, Ale and Cakes, Ting Tang, Poldice, Huel Unity, Huel Unity Wood, and other mines. Captain Gregor made the same observation to him, relative to many of the mines near Crowan and St. Erth parishes, with which he is connected.

In the eastern part of the Consolidated mines, there is a horizontal elvan course, or bed, of several fathoms in thickness, and at about 150 fathoms below the adit. A lode which traverses this elvan yielded much ore immediately above and beneath it, but was quite unproductive in that part which was included in the elvan.

Captain Tregaskis lays much stress on the intersections of lodes, by cross courses, which he considers often add greatly to their value. He remembers a lode in the Consolidated mines which had a rich course of copper ore close to the eastern side of a cross course, but was quite barren on the western side of it.

I believe it will be found on investigation, that the mineral veins of Cornwall differ very little from those which have been observed in other mining districts, in what may be termed their mechanical characters.

Westgarth Forster * has published some interesting details relative to mineral veins in various parts of the north of England: and as these are *in fossiliferous strata*, I am inclined to give a brief report of some of his statements, in order to prove to such of our miners, as may not be aware of the circumstance, how analogous they are to the phenomena which have been noticed in the mines of Cornwall.

Some of the veins in the northern counties produce the ores of various metals, but especially galena, or the sulphuret of lead, and although the metalliferous veins traverse a great number of horizontal, or rather slightly inclined beds, or stratified rocks of different kinds, they are barren of metal in most of them, and are without comparison, most productive in the limestone.

The fissure, called a *rake* vein, in many instances, cuts all the strata quite through, from the surface to an unknown depth, and some veins have been traced to the extent of many miles on the lines of their bearing.

Sometimes the rake vein is nearly perpendicular, but it commonly overhangs or slopes, more or less, which the miners call "*hading*" (underlying.) The rocks on both sides of the vein are denominated the sides or cheeks; the upper one being the hanging side, and the inferior one, the "*ledger.*"

These veins seem to be of two species; in one case there has apparently been a slip of the strata, and in the other none. The slip veins are seldom wider above than below, but are sometimes narrower. The gash or chasm veins are always wider above than below: in the former case the various horizontal strata show that one side of the vein has slipped, whilst the same evidence in the latter case proves that there has been no slip. The slip veins are subject to checks, or "*twitches*," as they are termed, that is, the hanging side, and ledger or foot wall, come together in some places, so that there is no room for any ore in the twitch: there are, in these cases, corresponding enlargements of the vein; but many veins are nearly regular and uniform in their size, and carry good ribs of ore for a considerable distance. These veins seldom contain

* W. Forster on the strata of mineral veins of the north of England.

any ore in the indurated argillaceous earths, but only a soft clayey substance. Some veins bear solid ribs of ore of one, two, or three feet wide, for a considerable distance, and others have many thin ribs of various dimensions, with spar, or other mineral matter between them.

If a vein bears nearly east and west, or E.N.E. and W.S.W., (the prevailing direction of those veins,) and the south cheek is above the north cheek or side, the hade or underlie will generally be towards the north, and vice versâ. Some veins are quite irregular, or zigzag in their underlie. When two neighbouring metallic veins run in an oblique direction, and meet, they commonly produce a body of ore at the place where they cross, either horizontally, or in their dip, if both contain ore; but if one be poor, and the other rich, they are either united, or are both impoverished at their meeting: in the former case they generally separate again after a time, and continue their original course. When veins branch off into numerous "*strings*" or veins, it is a poor sign, but when these strings are found converging into one vein, it is accounted a promising indication.

Sometimes there are branches in the adjacent strata which enter obliquely or transversely into vein. If these branches are impregnated with ore, and by dipping faster than the vein, overtake or come into it, they are said to enrich it; but if they go off from it, they are considered to impoverish it.

Veins are frequently compressed between hard strata, so as not, perhaps, to be an inch in width; nevertheless, if they have a string of good ore, they commonly turn out well at last, after they get into softer ground. In like manner, it is an encouragement to go on, if the branches or leaders of ore enlarge, either in length or depth.

There are other veins running north and south, which seldom carry ore except at the place where they intersect the east and west, or right running veins, and sometimes the former contain ore for some distance on each side of the points of intersection. When right running veins are intersected by strong cross veins at about right angles, the former are sometimes heaved or shifted a little way to the north or south, perhaps, not more than a fathom: but if the intersection should take place at not a very large angle, the east and west vein is thrown on the side of the larger angle, it may be as much as ten or twenty fathoms.

Some diagrams of remarkable intersections are given by the author; and he observes, that "the curious phenomena which veins present at the places where they intersect each other, are in the present state of our knowledge, perfectly inexplicable."

"*Riders*," or masses of rock in the middle of veins, are of common occurrence. These masses frequently contain a variety of different substances, such as spar, ores of lead, and copper, &c., together with what appear to be fragments of the enclosing rock. Fluor spar, sulphate of barytes, and calcareous spar, as well as black jack, and iron pyrites, commonly occur, in the veins; and there are many cavities or caverns found in them, the interiors of which are often covered with beautiful crystals. Detached ribs of ore in veins in soft country, and frequently various ores, and masses of different kinds of stone, are found in a confused state in very soft parts of veins; and the sides of the latter are sometimes so shaken and loosened, that it is very difficult to distinguish them.

Strings, or weak veins which branch out from the principal vein, frequently terminate in the strata at a small distance, or fall into a parallel vein, if there be one near.

A "*back*" or sweep, often resembles the segment of a circle; it breaks off from the hanging side of a vein, and forming a curve, returns to the same vein again, enclosing a mass of rock between it and the principal vein.

The "*flat*" vein, is the space between two beds of rock occupied by mineral matter; it is sometimes nearly horizontal, or inclined, when the strata are so. Such veins often yield much lead ore, but rarely at a distance from the right running veins; sometimes, however, they seem to be enriched by cross strings. The flat veins are open in some parts, and closed in others, like other veins;—the roof frequently resting on the floor in some points.

A "*pipe*" vein resembles in many respects, an irregular cavern, pushing forward into the body of the earth in a slanting or sloping direction, the slope varying from nearly horizontal, to nearly perpendicular; in fact, they are in most instances, conformable to the position of the strata, but not always.

There is, moreover, an "*accumulated* pipe vein," or conical vein which often contains a great quantity of ore, and appears to be the result of several rake veins crossing at the same point.

The author also describes "*float*" and "*shoad*" ore: the former is water-worn, and mixed with pebbles resting on the surface of the rock, under the soil: the latter ore is not often water-worn; it occurs in the slope of a hill, just under the surface;—and is considered a sure indication of the neighbourhood of a vein, which may be more or less distant, according as the acclivity of the hill is more or less considerable.

This outline of the phenomena presented by mineral veins in some of the northern Counties of England, will serve to show their resemblance to those which have been observed in the Cornish mines; and as the former *exist in rocks abounding with organic remains, which are to be seen even in the cheeks or walls of the veins,* no doubt can be reasonably entertained of their having been originally cracks, fissures, or openings, in the strata, in which mineral substances have been deposited.

Theoretical Views of the origin of Mineral Veins.

I propose now to consider how far the phenomena of mineral veins can be accounted for on known principles. I am aware that it may require much time and research fully to solve the problem, but I trust that I shall succeed in making out a primâ facie case in favour of the probability of its being ultimately accomplished.

I have long been impressed with the analogy which mineral veins seem to present to some voltaic combinations, and have referred to it on various occasions. In one of my papers, "On the temperature of mines," which was read before the Cornwall Geological Society, in 1822, I adverted to the subject in these terms:*

"If electricity, for instance, be evolved when several different "mineral substances are brought into contact, and likewise in the "process of crystalization, &c., may it not in connexion with the "strata and veins, and the almost distinct portions of water which "abound in the earth, also act its part on a larger scale, and not "only excite heat,† but contribute to produce the extraordinary "aggregation and position of homogeneous minerals in veins, &c., "and the beautiful order which exists even under the surface of "the earth?

In 1827, I again alluded to the subject, and to the apparent analogy between electro-magnetism, and the generally prevalent direction of the principal metallic veins, nearly at right angles to the magnetic meridian. Between two and three years afterwards

* The paper from which the extract is made was published in the Annals of Philosophy in 1822. See Vol. IV. p. 447.

† I am quite inclined to believe that there is an independent source of heat in the interior of the earth, although the circulation of water under the surface, and its tendency when heated to ascend, must, I think, render any inferences founded on experiments in mines inconclusive as it respects the true ratio of the increase of temperature at very great depths.

I commenced my experiments on the electro-magnetic properties of metalliferous veins, and proved the reality of the existence of electricity in them.

Scarcely a year, however, has elapsed since my opinions, with regard to the formation of mineral veins, have assumed a shape, definite enough in any degree to warrant my communicating them to the Geological Society of London, which I did last spring; and I have since availed myself of other occasions to enter more fully into some parts of the question.

Formation of Fissures.

I am aware that the prevailing opinion in Cornwall, is rather opposed to the hypothesis of mineral veins having been derived from fissures in the strata; nor can I be surprised at it, as I have participated in the same opinion. I could not conceive how numerous, large, and deep fissures could have remained open, during the formation of mineral deposits in them, uuder the circumstances in which the veins are now found to exist, since they intersect each other in various directions, and their vein, stones when included in a given rock, do not often resemble, or appear to have belonged to any other rocks immediately above, when traversed by the same veins. For reasons such as these, I refrained from adopting any general theory, as those of Werner and Hutton seemed to me to be very unsatisfactory, and indeed inconsistent with many facts.

My objections to the hypothesis of fissures, were, however, removed, when it occurred to me, that many of them might have been very small at first, and become progressively opened and filled with mineral deposits. Moreover, that other secondary and lateral fissures might have resulted from time to time, from the expansion of the former; which I think, obviates any mechanical objections derived from intersections, and from the fact that contiguous veins often include large masses of rock detached and isolated from the neighbouring strata, or "*country.*"

The circumstance of vein stones derived from any given rock, not being found in the vein, whilst traversing an inferior rock, appeared to be easily accounted for, if the fissure, instead of being wide, were contracted enough materially to check the descent of small fragments of rock: and the very frequent subdivision of the larger veins into smaller ones, seemed, moreover, to afford decisive evidence in favor of such a process. *

I admit that the mineral veins in Cornwall, are not more liable to hypothetical objections, such as I have alluded to, than those which occur in fossiliferous rocks, and I should long ago have been satisfied on this point, had I been sufficiently acquainted with the strict analogy, which has been shown to exist between them, in what may be considered their mechanical characters. But it is not now necessary to refer to such evidence, at a distance, since De la Beche has discovered encrenites, and other organic remains, imbedded in killas, (grauwackè,) close to the walls of the eastern part of Great Crinnis copper and tin lode; and this gentleman, moreover, seems to entertain no doubt from the direction of some of the fossiliferous beds, that they must pass under many of the copper and tin mines near St. Austell.

It may not be easy to determine what has given rise to fissures in the earth, but it is likely that different causes have operated, some probably sudden and violent, and perhaps often repeated, producing, at various intervals of time, considerable disruptions of the strata; whilst others may have been more slow, and gradual; but even in this case, I conceive, that the effects upon any given fissure would mostly be intermittent, or by fits and starts; for it may readily be imagined that if the influence of tension were exerted to a certain degree, there would generally be a sudden enlargement of the rent.

Earthquakes, which are even now of such very common occurrence in some countries, may give some idea of the former: and the gradual elevation or depression of vast tracts of land, which is

* Since I first published my views on this subject, I have learnt that Fournet a French geologist, has observed in the mines of France, &c., proofs of the progressive enlargement and filling of fissures, so that the circumstance of our having both arrived at the same conclusions by independent observations, in widely separated mining districts, is certainly favourable to the truth of the hypothesis, as well as to its generality.

found to have taken place in different parts of the world, even in modern times, may be mentioned as an exemplification of the latter. These changes of level may, perhaps, be owing to fluctuations of temperature under the earth's surface.

The phenomena of mineral veins in Cornwall, prove that the various rocks which are traversed by them, must have occupied their present relative positions before the fissures were produced; and I conceive, moreover, that none of these rocks could have been at the time, at temperatures greatly differing from each other, because the veins which traverse them at various angles and inclinations, are neither dislocated nor necessarily altered in size, in passing from one rock into another, being sometimes larger in one kind of rock, and sometimes in another. These remarks apply to the veins, even when they pass through elvan courses which traverse other rocks; whereas, if any of the rocks were at a much higher temperature than those in their vicinity, after the formation of the fissures, the contraction caused by the cooling of the former, surely ought, under some circumstances, to have interrupted the continuity of veins, and to have increased their dimensions.

I think we may, therefore, venture to assume, that fissures have not been produced by any cooling of the rocks from a high original temperature, but that they must be attributed to the operation of other causes.

It is exceedingly probable, however, that changes or alternations of temperature under the surface, may have been one of the processes from which some fissures have resulted, and were afterwards expanded. An increase of temperature would occasion an expansion and upraising of the strata, from which rents would result; and a reduction of temperature, causing a contraction of the rocks, would produce the same effects; in either case, the rents would be in nearly opposite directions, which might have been determined by the structure or joints of the rocks. Now, if the fissures resulting from an upraising of the strata, however produced, were to be partly filled with fragments or detritus of the rocks, or other mineral deposits, they would be wedged open as it were, and would not consequently, return to their original level, after the subsiding of the uplifting cause. In this way cavities might be formed at greater or less depths, and dislocations would probably follow, giving rise to some of the phenomena of faults.

The crust of the earth must, in some places at least, have been subject to great vicissitudes of temperature, if we may judge from the common occurrence of basaltic and trappean rocks, and even of volcanic matter, passing through, and resting upon, different strata.

It appears from the ratio in which the temperature increases in descending into our mines, that the heat may be about 212° Fahr. at something more than a mile below the surface; and I fully believe, for many reasons, that the ratio of increase observed in mines is not so great as that of the earth itself, but that the *aggregate* effect of adventitious causes, operating in the former, has a tendency to reduce the temperature below its natural level.

It is highly probable that many of the veins penetrate to the depth of several miles; for taking them collectively, I apprehend, that their width is not sensibly diminished in our deepest mines, although some of the latter extend to between two and three hundred fathoms below the surface.* Great as this depth may appear to be, it is not a twelve thousandth part of the semi-diameter of the earth, or in about the same proportion as the thickness of common writing paper to a sphere of eight feet in diameter. The minute cracks which are sometimes observable in the varnish of a common globe may serve to give some notion of the size of the most considerable mineral veins in relation to the earth itself, although they may be many miles in depth as well as in length. However this may be, there can be little doubt that many of them penetrate into regions of great heat, and assuming that they have originated from fissures, they must have contained water even in their deepest parts, because the great pressure of the column, equal to one hundred and sixty atmospheres, even at the depth of a

* The bottom of the Consolidated mines is now nearly 290 fathoms under the surface, and about 240 fathoms, I believe, below the sea level.

mile,—would, of course, have prevented its being converted into steam at the bottom of the fissures.

What then must have been the result of this state of things?—It is evident that the heated water, at and near the lower parts of the fissures would ascend through the cooler water above, whilst the latter would descend, and occupy the place of the former, producing a circulation, more or less rapid, according to circumstances. Such circulation of heated water would naturally tend, in some measure, to wear away the sides of the fissures, and may have contributed to produce that degree of smoothness for which some parts of the walls of veins are often so remarkable. If any of the inclined fissures were sufficiently wide and open in some places, the ascending currents would principally act on the hanging walls, and the descending ones on the foot walls; and it remains to be ascertained by careful inspection, whether traces of the results of such action can be detected in the walls of any mineral veins. Stones more or less rounded, and apparently water-worn, are occasionally found in the form of conglomerates in mineral veins, but they are sufficiently rare to render it probable that the latter must have been mostly very narrow, or that the accumulation of matter in them might soon have become so considerable as to obstruct the easy circulation of the water.

Let us suppose that in time, this circulation was almost stopped by mineral deposits, the temperature of the water at the lower parts of the fissures would increase, whilst that of the water above would decrease in a greater ratio. The inferior strata would, under these circumstances, have some tendency to expand, and the superior strata to contract: but if the former happened to be wedged open in any parts, by fragments of rocks and other substances, such expansion would tend to widen the fissures, whilst the contraction of the strata above, would, at the same time, augment this effect. Thus the rents might have admited of the circulation of the water being renewed; and the same process might have been again and again repeated, until the fissures at length, became too much filled from the top to the bottom with mineral deposits, for such action to go forward with any perceptible effect.

I merely allude to this process incidentally, without intending to make it prominent, as it matters not to my present object by what means fissures were formed or enlarged from time to time. It is sufficient to believe that different causes may have operated with greater or less effect, and that they were fully adequate to accomplish the object.

It is, I believe, generally considered by miners, that the temperature of our copper lodes, is greater than that of the surrounding country, at equal depths: * and they regard a copious jet of warm water into their workings as a favourable indication in a lode. Tin lodes are often rather inferior in this respect to those of copper, which is probably owing to their being generally harder and more compact than the latter.

I have, on different occasions, referred to granite being rather below killas in temperature; † and W. J. Henwood has since determined, by numerous experiments, that the temperature of the former in our mining districts, is a few degrees below that of the latter. The difference in these cases, whatever it may be, I have long attributed to the facility afforded by lodes, as compared with the rocks; and of killas, as compared with granite, for the circulation of ascending and descending currents of water; and it is easy to perceive that the deeper lodes, and those parts most abounding with ore, may admit of such circulation more readily than where there is an accumulation in them, of clay and finely divided mechanical deposits with quartz, &c.

Assuming the hypothesis of a progressive enlargement of the greater part of the original fissures, it is not difficult to understand, that the formation of secondary ones, from time to time, would be the natural consequence of the rending force exerted, and of the tendency in the hanging sides of fissures sometimes to break off in vast masses from the adjoining country, thus forming cracks of great-

* From the mean of several observations made in mines, I have estimated this difference to be nearly three degrees. See Cornwall Geological transactions, Vol. II., p. 29, year 1820.

† See Annals of philosophy, 1822, Vol. IV., p. 447; and Philosophical Magazine for 1831, p. 99.

er or less extent. Hence, many lateral and branch veins may have originated, and likewise the masses of rock which so frequently occur in the veins, and which are termed by the Cornish miners, "*horses*." But this subject will be again referred to in this paper.

Filling of Fissures.

It has already been stated, that mineral veins consist of substances resembling the enclosing rocks, and which are assumed to have been mechanically derived from them; and also of other substances which are so different from the contiguous rocks as plainly to indicate another origin; and such deposits, I conceive, may be referred to chemical, or electrical agency.

It is obvious that the splitting of rocks, and further opening of the fissures from time to time, would occasion fragments, and friable portions of the former to fall into the fissures, whilst the flowing of water into the latter, and its circulation within them, would tend to produce depositions of detritus of the rocks, clay, and other finely divided matter. These mechanical deposits would generally be accumulated in the largest proportions, in such parts of a given fissure, as had the greatest underlie; and miners find that lodes are usually less productive of ore in such situations, than in other parts which are more nearly vertical.

I have already explained my reasons for believing that the water at the bottom of some of the deep fissures, must have been at a very high temperature, and must consequently have caused a more or less active circulation in them, of ascending and descending currents. It is well known that the solvent properties of water, as well as of acids, alkalies, &c., are augmented by heat; and there is reason to believe that their power to dissolve matter, and to hold it in solution, increases in some ratio with the temperature.

It seems therefore to follow as a necessary consequence, that the hotter portions of water, &c., in the deeper parts of the fissures, would become charged with matter which it would deposit more and more as it ascended through them, and became gradually reduced in temperature; its partial evaporation, when at the surface would also augment this tendency.

Amongst these deposits it is probable that silica or quartz, was most abundant, and that in many instances, it became intimately mixed with chlorite, and earthy matter, worn off from the sides of the fissures, by the action of the currents of hot water upon them.

The hot springs of Geyser, in Iceland, and Furnas, in St. Michaels, have accumulated silicious deposits around them to a great extent; and other thermal waters in various parts of the world, especially in India, and South America, are more or less charged with silicious matter, which they partly deposit on reaching the surface:—and as quartz is, perhaps, the most general and abnndant substance in the majority of mineral veins, I think, there can be no hesitation in admitting that it may have been collected in the way now suggested. Other earthy substances of difficult solubility, without the aid of great heat, may also have been deposited in like manner, whilst the deposition of the more soluble compounds, and especially of the metallic ones, must be referred to other causes.

It is, moreover, highly probable, that a greater or less proportion of the contents of veins may have been derived, by infiltration, from the neighbouring country; and the circumstance of the rocks in the immediate vicinity of lodes being generally inferior in hardness to those at a distance from them, tends to strengthen this hypothesis. The frequent incorporation of quartz, chlorite, and other matter with lodes themselves, as well as with their sides, so as to obliterate any appearance of walls;—termed "*capels*," seems to afford additional evidence in favour of infiltration. Such solutions, depositions, and changes, might be produced by a slow electro-chemical action, and the present hardness or softness of the sides of veins, and of the rocks adjoining, ought not certainly, to be referred to, as a criterion of what they formerly were in these respects. If it were needful, proofs might be adduced in abundance, of silicious matter having taken the place, and assumed the form of animal, vegetable, and mineral bodies, so as to compose masses, equal in hardness to quartz rock, or to the most compact "*capel*;" there can be no doubt then, that there exists in nature, a power of transference, such as I have alluded to.

I have found that pieces of compact granite and killas taken out of a mine, and without any apparent flaws in them, after having been placed in boiling water in which a small quantity of some salt was dissolved, were rendered conductors of voltaic electricity, although they possessed this property in a feeble degree in comparison with the *liquid* solution itself.

It is evident from this experiment, and from others made in mines, in which parallel lodes acted on each other through very large masses of rock, that rocks become conductors of electricity, especially at considerable depths, where the great pressure of the column of water, and the high temperature, combine to introduce moisture into them. If then, the rocks are thus rendered even feeble conductors of electrity, and contain different salts, they are necessarily, exciters of it also; that is, if contiguous, they become in opposite electrical states: the same remark applies with still more force to moistened clay, because it contains more water.

I have proved by an examination of water taken from different mines, and from various parts of the same mine, that different varieties of saline solutions now exist in neighbouring strata. In some instances, the proportion of foreign matter in the water, was very small, whilst in others, it was considerable; but I have not yet tried any mine water, that would not produce very decided electrical action, when the native sulphuret, and bi-sulphuret of copper, were plunged into it, and the voltaic circuit completed. The very superior conducting power of the saline water in the fissures, in relation to the merely moistened rocks, would always tend to supersede the transfer of electricity, more or less, through the latter. The contact of large surfaces of rock, clay, &c., with water, differing in its saline contents from them, must also have been an efficient source of electrical excitement; and it should not be forgotten, that the circulation of the water would be liable to very frequent changes of velocity, in consequence of obstructions in the fissures, or their occasional enlargement, so that the contents, as well as the temperature of the water, would be subject to many modifications.

In many instances the rocks may have contained, as they now sometimes do, iron pyrites and other metallic substances, and in the deeper parts of the fissures, it can scarcely be doubted, that the sources of electrical excitement were greatly augmented and multiplied, not only on account of the high temperature of the water, which must have materially increased its conducting power, but likewise from the probable existence there, of some of the metals, in a pure, or nearly a pure state. If these points be conceded, it is difficult to assign limits to the extent of the development of electrical action.

Now it is a well known fact, that electric currents, by which I mean voltaic or thermo-electric currents, and magnetic bars, or needles, having freedom to take any position, have a tendency to arrange themselves at right angles to each other, and consequently as has been proved by experiment, an electric current transmitted through a very delicately poised conductor, will cause it to take a position at right angles to the magnetic meridian of the earth. If an electric current be directed from east to west through a metallic wire, a magnetic needle suspended *above* the wire, will have its marked end directed towards the north, but if the direction of the current be reversed, so will be that of the needle also, and the marked end will point toward the south. If the needle be suspended or poised *under* the wire, the order of its positions will be *inverted*.

Ampère has inferred from these—electro-magnetic properties, that the direction of the compass, or in other words, of the terrestrial magnetic meridian, is due to the circulation of currents of electricity round the globe from the east towards the west; and this opinion has, I believe, been very generally adopted. Such currents may, in many places, be more or less oblique with respect to the parallels of latitude. The aurora borealis, it is well known, sometimes appears in the form of an arc, the centre of which is intersected by the plane of the magnetic meridian, or nearly so; and it has been proved by observations, some of which were made by myself, that it has often a tendency to deflect the magnetic needle, and also to diminish the intensity of the earth's magnetism.

The aurora may, therefore, I think, be considered an exhibition of electric currents at a great height, which are connected with others nearly parallel to them, in the interior of the earth. Whether, however, we regard terrestrial magnetism as the effect or cause of the direction of electric currents, it cannot be doubted that these phenomena are in harmony with each other, and that if electricity existed under the surface, it would, if not counteracted by local circumstances, pass more readily from magnetic east to west, than in any other direction.* Hence, if fissures happened to have opposite horizontal bearings, and were equally filled with water charged with saline matter, the electric currents would be determined in preference, through such of them as most nearly approximated to the magnetic east and west points at the time.

Thus, for instance, if *e w fig* 1, Plate IV, were at right angles to the magnetic meridian, and the fissures were formed in the direction *a b* or *c d*, the electricity would pass longitudinally through such fissures rather than through others nearly at right angles to them. The amount of the variation of the compass has been observed, in this country, slowly to oscillate through an arc of at least 36°, it being now nearly 25½° to the westward of the true north at Falmouth; whereas, about 250 years ago, it was noticed in London to be 11° to the eastward of north, which gives a mean magnetic declination of 18° to the westward of the true meridian.

Taking it for granted, therefore, that the electric currents were chiefly confined to those fissures which most nearly corresponded with the magnetic east and west, they would act on the saline substances contained in the water, and gradually decompose them, the metal, or base, being determined towards the negative pole, or the electro-negative rock, and the acid, towards the electro-positive rock.

* If we suppose electric currents to circulate round the earth from the east, towards the west, both above and below its surface, they would tend to deflect a magnetic needle in opposite directions, so that, in fact, terrestrial magnetism would be due to the excess of one over the other; and this hypothesis may possibly be found to be more consistent than any other with various magnetic phenomena, and particularly with the fact that the magnetic intensity has not been found to undergo any sensible change at considerable heights above, or depths beneath the surface.

However slow this process might, at first, have been, the deposition of the metals would cause it to become more and more energetic. The metals and metalliferous deposits would, likewise, naturally react on each other, and give rise to new combinations and arrangements, till they arrived at a state of comparative equilibrium. This may be said to be very much the case in the lodes at present, as most of the ores which are capable of conducting electricity, very nearly approximate to each other in the electrical scale; being more electro-negative than silver, and many of them as much so as platina; indeed, the grey oxide of manganese, and the loadstone are electro-negative in a still greater degree. Arsenical pyrites, iron pyrites, and copper pyrites, hold rather a high place in the scale, and are electro-negative with respect to purple copper, and galena, but more especially to the sulphuret or vitreous copper ore, which will produce a very decided action on a galvanometer, when connected in the voltaic circuit with copper or iron pyrites, &c.

All these ores, as well as some others, are of course, conductors of electricity; whereas the sulphurets of zinc and of silver are non-conductors. This is also the case in regard to other native sulphurets, and to most of the metallic combinations with acids and oxygen.*

It has already been stated, that the productiveness, and general contents of veins, seem materially to depend on the rocks which they traverse. Similar metalliferous deposits are, in some of our mines, principally found in one rock,—in granite, for example; and in other mines, in killas or elvan, although the same lodes may happen, in some instances, to traverse all these rocks, and very frequently copper and tin are found in *different* contiguous rocks: thus the former may chiefly occur in granite, and the latter in killas, or vice versâ.

The character of the different beds of killas seems likewise to have had a decided influence on the deposition of the metals, and the miners lay great stress on the nature of the "*channels*" of

* See my paper in the Philosophical transactions, in 1830, page 399.

ground traversed by the lodes, in their anticipations of their being productive or otherwise. The occurrence of oblique "*shoots*," and of "*pipes*" of ore, descending conformably to the underlie of the beds or laminæ of the killas, as mentioned by Captain Tregaskis, (page 17,) affords additional evidence of the connection between the strata and the contents of lodes. All the facts, moreover, seem to bear a remarkable analogy to some of the results of voltaic action. It is well known that by its means, the chemical affinities of bodies may be superseded, and even inverted; so it may, and it does seem to have happened, that metallic and earthy substances were determined towards certain rocks, and deposited on them, according to the relative electrical states of the latter. These states may have depended, either on the saline or metallic matter which the rocks contained, or on their positions and combinations with respect to other rocks, modified, more or less, by their relative temperatures at the time, as well as by the prevalent direction of the electric currents in their vicinity, and by numerous other accidental circumstances.

Becquerel has shown, that if a long slip of copper be put into a glass vessel partly filled with a solution of copper, and partly with water, or acidulated water, so carefully poured in as not to mix with the former, after some time, a precipitate of copper will appear on that extremity of the slip of metal which is in the solution. It is evident in this case, that the liquids were in opposite electrical states, and that the deposition of copper, was the result of voltaic action; for if the slip of copper had been put into a simple solution of that metal, the precipitation would not have taken place. The same philosopher has obtained, by means of weak and long continued electrical action, many of the metals, metallic sulphurets, and other metalliferous and earthy compounds, not a few of them beautifully crystallized, and precisely resembling those found in nature.

Crosse has, by means of large voltaic batteries excited by water only, also produced a great variety of metallic and earthy minerals, and amongst others, he has, I understand, obtained a crystal of quartz, nearly a quarter of an inch long.

When I learnt from this gentleman the results of his experiments, and persuaded him to communicate them to the Geological section at Bristol, I was, like himself, unacquainted with Becquerel's experiments, or at least, I had no idea of the method which he adopted.

After what has been stated, it might appear almost presumptuous in me to allude to any of my own experiments, did they not seem particularly to bear on, and to elucidate, some of the phenomena which are observed in the mines of Cornwall.

Following the arrangements which nature seemed to present, I placed different ores and metals in different saline solutions, separated merely by walls of clay in imitation of our flucan courses, and I completed the voltaic circuit between the ores, metals, &c., in the different cells so formed, by copper wire.

By these means, I found that yellow or bi-sulphuret of copper, in a solution of sulphate of copper in one cell, and sulphuret of copper ("grey ore,") in water or acidulated water in another cell; connected together by a copper wire, acted on each other, and after some weeks, the bi-sulphuret had a thin coating resembling the sulphuret. When zinc or iron, was substituted for the sulphuret of copper in the water cell, the bi-sulphuret of copper became coated with a considerable crust of the sulphuret, or rather it was changed into the latter to a greater or less depth, according to the duration of the experiment, in consequence of the abstraction of a portion of sulphur, and probably, also of some of the iron which it contained; and beautiful crystals of pure copper, were abundantly deposited upon it, and likewise, in some instances, red oxide of copper.

These experiments seem to bear on the fact of neither metallic, nor red oxide of copper, occuring in our mines in conjunction with yellow copper ore, but often with the sulphuret, or grey and black ore.

When a solution of sulphate of iron, was substituted for the sulphate of copper in the cell containing the copper ore, the latter appeared at first, to have on its surface a deposition of iron, and this becoming oxidated, in time formed an incrustation, which resembled "*gossan*." When the water in the other cell was acidulated by sulphuric acid, and a plate of zinc or iron, put into it, having a metallic connection with the electro-negative copper or iron ore in the solution of sulphate of iron, (or sulphate of zinc, as the case might be;) sulphuretted hydrogen was evolved from the latter, and sometimes in considerable abundance.

In the course of many of my experiments, I observed that the solution of sulphate of copper, for instance, became considerably elevated in the cell containing it, whilst the level of the water in the other cell was much depressed; indeed, in some instances, it was nearly all transferred. Hence it may, perhaps, be concluded, that this modification of electrical agency, or *endosmose* and *exosmose* process, as it is termed, may operate under the surface of the earth, and that water may, by similar means, be raised to different levels, on opposite sides of flucan courses, &c. In some instances, there may happen to be a series of successive elevations, where circumstances are favourable:—the subject, at least, seems to deserve investigation in connection with the height of springs, &c.

I have observed that when the chloride of tin in solution, is placed in the voltaic circuit, part of the tin is deposited in a metallic state at the negative pole, and part at the positive one, in the state of a peroxide, such as it occurs in our mines. This experiment may serve to explain why tin is found contiguous to, and intermixed with copper ore, and likewise separated from it, in other parts of the same lodes, or in other lodes situated near, or perhaps crossed by the copper lodes.

It appears that copper, iron, zinc, and other metals, in solution, are, under ordinary circumstances, determined toward the negative pole; and the fact of "*gossan*" being found in copper lodes, and not in those of tin, is quite in conformity with the ascertained properties of the respective metals.* Some metals, however, like tin, assume the properties of acids, if combined with oxygen, and consequently, when in this state, tend towards the electro-positive pole. It has been remarked that tin lodes are often harder than those of copper, and this is perhaps, owing to the determination, by elec-

* I have already noticed that many large iron lodes are nearly coincident with the magnetic meridian: this direction, when regarded in connection with the magnetic properties of iron, is interesting.

trical agency, of a portion of silica to the electro-positive pole.

Having endeavoured to show that electric currents must have existed under the earth's surface;—that their tendency, on electro-magnetic principles, must have been, *cæteris paribus*, to pass longitudinally through those fissures which most nearly coincided with the magnetic east and west points;—and that in proportion as they decomposed the earthy and metallic salts held in solution or otherwise existing, they would determine their constituent parts toward opposite poles, or rocks in opposite states. I shall next refer to some circumstances, which may have interfered with the full, and undisturbed operation of these laws.

These may partly have been of a mechanical nature.—Clay, or other earthy accumulations in the fissures may, by forming intermediate poles, have arrested the transfer of the metal in given directions, and thus produced depositions of ore in various parts of the fissures, short of the most decidedly electro-negative rock. Suppose, for instance, that the general tendency of the electric currents at any place, were towards the granite *g g'*, *fig* 3, Plate IV, but that the contraction of the lode or fissure, *e w* at *d*, and the accumulation of earthy matter there, checked the transmission of the metals so much, as to produce a deposition of them in the wider part of the fissure, the result might be a bunch of ore, at *f*, connected with the small vein or string at *d*.

There are other causes of an electrical or chemical nature, which may, in some instances, have had a powerful influence in determining the relative positions of mineral deposits.

It is well known that tin in solution has a strong affinity for oxygen, and will rapidly attract it from the atmosphere, forming with it an insoluble peroxide; and hence, may partly have arisen the circumstance of this metal, being commonly found near the surface, on the back of copper lodes, and more or less intermixed with "gossan." This property of tin seems, moreover, to account for its occurring more dispersed than copper, and upon the whole, rather less conformable in its positions to general rules.

Solutions of iron have also a tendency to absorb oxygen from the atmosphere, and to form an insoluble oxide, (iron ochre;) but it is very inferior to tin in this respect; and this circumstance may be another reason why "gossan" is not found on the backs of tin lodes, since the superior affinity of the latter metal for oxygen, when in solution, would naturally interfere with the absorption of this gas, by any iron dissolved with it.

It is to be inferred, from what I have before stated, that sulphuretted hydrogen might have been abundantly generated by the action of electricity on yellow copper ore, or even on iron pyrites; and it is well known that this gas will immediately throw down the metals, except iron, and few others, in the state of sulphurets, in the order of their respective affinities, and tin would be amongst the first to be so precipitated. It may, perhaps, be imagined that this reagent would have precipitated the metals, more or less, throughout the whole extent of a given fissure; but it must be remembered, that its action might have been very much concentrated, near the parts at which it was generated, if there were a sufficient supply of metallic salts in solution in the same vicinity, to absorb it. Moreover, it cannot be doubted, as I have before remarked, that the metallic substances must have reacted on each other: thus a considerable accumulation of an electro-positive metal, such as zinc or iron, at an electro-negative rock, might, for a time at least, have changed, or reversed the direction of the electric currents.

The pseudomorphous crystals of various kinds, and especially of quartz, which are of such common occurrence in our mines, afford decided evidence of reaction. We find, for example, the yellow sulphuret of copper in the form of crystals of carbonate of iron, which it must have gradually displaced; oxide of tin in the form of crystals of felspar; and the sulphuret of lead in six sided prisms,—termed blue lead,—having superseded the phosphate of that metal. *Fig* 20, Plate VI, represents a crystal in my possession, the shaded part of which is blue lead, and the unshaded part translucent phosphate of lead, not yet decomposed.

The appearence of another crystal in my cabinet, is shown by *fig* 21:—the light part represents pseudo-hornstone, projecting through the centre of a crystal of octohedral blue fluor, part of which still remains, and is represented by the shaded part.

Fig 19, represents a group of large quartz crystals, with crystals of iron pyrites on one side, and of copper pyrites on the other, with a line of separation between them. This curious arrangement seems to be due to electricity, and a great many of these crystals were found some time ago in the Consolidated mines.

The enumeration of results of secondary action in veins, might be greatly multiplied, proving, that substances not soluble under ordinary circumstances, have been transferred into, and taken the forms of other bodies; to say nothing of the evidences of secondary action afforded by the numerous metalliferous deposits, which are found in veins, situated in fossiliferous strata, and precisely resemble many of those which occur in the mines of Cornwall. Can it then be doubted that many of the phenomena observable in our mines, are caused by similar actions and reactions;—by such an agent, in fact, as electricity is known to be, seeing that time, and power, on the most extended scale, have not been wanting for their production?

It has been asked, why, if metallic deposits were produced by electricity, they are found in fissures or veins, rather than in the unbroken parts of the rocks? The much more easy transmission of electricity through the fissures is one reason, which has been already urged, and the continual change of the water and salts in them by circulation, may be referred to as another; since it is obvious that the moisture absorbed by the rocks, must always have been in a comparatively stagnant state.

Many of the cross veins, as has been mentioned, abound with quartz of a fibrous or radiated texture. *Fig* 18, Plate VI, represents a fragment of such quartz. At *a*, the crystals of quartz point towards each other; *b* and *d*, seem to be laminæ of killas, or chlorite and quartz intermixed; at c, the division between the quartz appears principally to consist of iron ochre; and at *e* there is a surface of killas and quartz like the outer walls of the including vein.

The quartz may have been chiefly derived from the deeper parts of the fissures, as in the case of lodes, and partly, perhaps, from the neighbouring rocks, by means of infiltration. Its striated arrangement may be owing to the sides of a given fissure having been in opposite electrical states, such as are acquired by the contact of conductors, or by the intervention of a liquid between them; i. e. the electricity, instead of having passed longitudinally through the fissure, may have crossed it from one wall to the other. This inductive state, or tendency in electricity, to traverse a vein at right angles to its direction, may, under given circumstances, be produced even in lodes, in consequence of the action of parallel lodes on each other, as will presently be more particularly noticed.

Does not the remarkable arrangement which has been alluded to, arising apparently from position, rather indicate the existence of some general laws, to which even the directions of the joints of rocks may be referred? It has been proved, that substances which are considered the most insoluble, may be acted upon, and re-arranged by feeble, and long continued voltaic action; so it is possible, that an elementary arrangement may have taken place, even in moist *mechanical* deposits, and have imparted to many rocks, the characters which they possess.

The clay and disintegrated portions of the enclosing rocks which exist in some cross courses, and in flucans and slides, are evidently of mechanical origin.

Intersections and Dislocations of Veins.

Intersections have been supposed to afford certain evidence of the relative ages of veins, the *intersected* vein having been assumed to have had an anterior origin to the *intersecting* one. How far this distinction may be true, generally speaking, I will not pretend to determine; but I think it can be shown, that the mere fact of intersection, ought not, apart from other considerations, to be taken as evidence of the relative ages of veins. On the contrary, I believe, that in many instances, intersecting veins had, at least, as early an origin as those which they traverse: how otherwise are we to account for many very complicated intersections which occur in our mines? To illustrate this point, let us suppose *e w* and *n s*, *fig* 1, Plate IV, to represent small rents or fissures, co-existing in opposite directions, aud that *e w* became gradually filled with mechanical, chemical, and electrical deposits, and *n w*, with mechanical deposits only, or mixed with quartz. It is evident, that the mechanical deposits, and even the quartz derived from the circulation of the water, would have a tendency to accumulate at the points of intersection more rapidly than the metals, &c., would be deposited there, by the agency of electricity. Suppose both veins simultaneously to have undergone a subsequent enlargement as represented by *fig* 2, their contents would be completely separated at *a*, and the opening would be immediately filled, in part, by the debris of the rocks and veins; whilst the descent and circulation of the water, would tend to produce an early deposition of clay and finely divided matter, and thus the intersection of the lode, *e w*, by the more mechanical cross vein, *n s*, would still be apparent.

Hence it may be concluded that when veins, crossing each other, become expanded, the softer and more mechanical vein, will have a tendency to intersect that which is more crystalline and firm in its composition. Thus we find that tin lodes, which are usually harder than those of copper, are intersected by the latter; whilst both are, in most instances, intersected by cross courses, flucans, and slides. It seems, however, that when copper lodes abound with clay, they often intersect the cross courses. On this principle, we are enabled to explain the fact of a vein, *a*, intersecting another *b*, at one level, and being itself intersected by *b*, at another level.

The dislocations, or "heaves" of lodes, may have been sudden, or increased at intervals. If a given heave occurred at, or soon after the first formation of the cross fissure, the laminæ or included veins, would, by their regularity and parallelism, probably indicate successive periods of expansion, as shown in *n s fig* 4, Plate IV, and *fig* 18, Plate VI, but if a dislocation took place when the cross vein had attained its full size, or nearly so, its contents would be disturbed, and the laminæ confused and irregular, if not obliterated; see *n s*, *fig* 5.

At the time of the dislocations of any given lodes, it will readily be admitted, that the violent fracture and disturbance of the rocks, might have produced numerous minor rents, and even very minute cracks, near the dislocated parts, which, when filled with metallic or earthy deposits, would constitute small veins and strings, which *c d* and *e*, *fig* 4, may help to illustrate. Veins so formed, are sometimes so diminutive as to serve for hand specimens, showing intersections in miniature. It has been remarked that such small veins of ore connected with a dislocated portion of a lode, on one side of a cross course, have not, usually, any corresponding veins connected with the part of the lode on the other side of it; in fact, they afford evidence of not having been formed prior to the dislocation. The same observation applies to the frequent accumulation of ore in lodes close to cross courses, either on one side only, or on both sides of the latter. In such cases, it can hardly be doubted, that the ore must have been deposited after the intersection or heave happened, and this hypothesis is corroborated by the frequent occurrence of some ore, in the cross courses, near the intersections. If then, much of the ore, were deposited after the formation of the cross fissures, how does it happen to be accumulated in E. and W. veins, rather than in N. and S. ones, if it be not referred to electro-magnetic agency?

It is obvious, that the progressive openings and dislocations of fissures, might have given rise to other secondary fissures, in consequence of the rending force exerted, or the subsidence of the hanging sides of the former, when their supports in the fissures were disturbed. Thus if the hanging side of the fissure or lode, *m y*, *fig* 4 subsided, the secondary vein or lode, *f g*, might have been the ultimate result; and the breaking off of the hanging side of the cross course, *n s*, *fig* 4, might, in like manner, have produced the vein *h k i*, and the other smaller veins nearly parallel to it. The section represented by *fig* 17, Plate VI, will help further to explain the probable origin of such subsequent fissures, or veins; suppose the whole mass *a b c* to have given way, with the included portion of a tin vein *l o*, the latter will exhibit opposite heaves or throws, upwards and downwards, as at *l o n*.

It may sometimes happen, that an apparent break in a lode, may have arisen from a fissure, in traversing another horizontally, having taken a zigzag direction, as represented in *fig* 6. In this case, the lode *e w*, is supposed to have originally passed a little to the right in the cross fissure *n s*, and then to have resumed its previous course. This case is only to be distinguished from a real dislocation, by its not being found to accord with other shifts, or by there being none in its immediate neighbourhood.

The appearance of a dislocation may have been also produced merely by the enlargement of an intersecting lode: thus let *a b*, *fig* 15, Plate V, represent the section of a copper lode, and *c d*, that of a tin lode, the latter would seem to be dislocated as at *e f*, by the opening of *a b*, in the direction of the dotted lines, after *c d* was formed. The enlargement of the fissure would also be more considerable in its vertical, than in its inclined parts: this will be illustrated by comparing *a* and *b*, with *g*, *fig* 15; commonly, however, I believe it will be found, that the hanging walls of veins have subsided more or less, and exaggerated these phenomena.

Fig 16 may represent a dislocation caused by a diagonal motion of a mass of rock, as it were, on a pivot or axis. Let the dotted lines *a b*, represent the section of a gossan or copper lode, and *c d*, of a tin lode, in their original positions; and suppose them to have fallen over to the positions *a′ b′* and *c′ d′*. The slipping of the walls *a b* against each other, would destroy their parallelism, and cause a considerable dislocation of the tin lode as at *e f*.

It will generally be easy to ascertain the direction of the motion which has produced any given heaves, if other veins, differing in their dip, occur in the same neighbourhood.

Thus let *fig* 7, Plate V. be a ground plan, and *fig* 8, a section of three lodes, one of which is vertical, and the other two dipping towards each other; and let *n s* represent a cross course, by which they have been dislocated. It is easy to perceive, that the phenomena represented in the diagram, can only be accounted for, by a vertical motion, as shown by the dotted lines, *fig* 8. In like manner, *figs* 9, and 10, clearly indicate a diagonal motion on one side of the cross course, in the direction of one of the lodes; and *figs* 11, and 12, a horizontal motion, all the lodes having been equally heaved. *Figs* 13 and 14, illustrate other varieties of heaves, the single lines represent the horizontal bearings of different cross courses, and the double lines those of lodes which have been shifted by the former. Now, as the lodes dip in the direction of the arrows, a small subsidence of *a*, *fig* 13, and a much greater one of *w*, would produce the effects observed; and so would, of course, an elevation of *a*, and of *e*. In *fig* 14, a depression of *e*, and a more considerable one of *b*, or an elevation of *w* and *e*, would account for the relative situations of the dislocated parts of the lodes.

Other explanations might evidently be given, but it is perhaps, unnecessary to enlarge on the subject. It may, I apprehend, be remarked, that the dislocations of the veins in Cornwall do not, generally speaking, indicate that these phenomena are owing to vertical, so much as to lateral, or sliding motion, having a greater, or less degree of obliquity.

The extent of heaves often seems to vary considerably at different depths. This may sometimes be owing to a cross vein having split into branches in descending, as in a case at Huel Jewel, mentioned to me by Capt. Jefferey, or changes in the underlie of the lodes may have produced only an apparent difference in this respect.

The occurrence of large masses of rock in veins which are sometimes quite isolated from the strata or country, cannot well be explained on mechanical principles, except on the hypothesis of the progressive opening and filling of the fissures. Let us suppose the vein, *e f d*, *fig* 17, to have been small at first, and to have been afterwards opened by some rending force, in consequence of which, the mass *m*, became detached from the hanging side of the fissure, and rested on the mineral matter previously deposited in the vein: a fissure between *m*, and the hanging wall, would be the result; and when this became filled with mineral matter, the mass *m*, would constitute what in Cornwall, is termed a "*horse*," and in the north of England, a "*rider*." These "horses" are frequently penetrated in different directions by small veins of quartz, ore, &c. the cracks from which they originated, having probably been caused by the movements and pressure of the superincumbent rocks.

It has been remarked that the mechanical deposits would naturally accumulate in the inclined, rather than in the more vertical parts of fissures; which, as well as the inferior width of the former, will sufficiently account for their being generally less productive of ore. Such mechanical deposits on the foot wall, which may become in time, almost incorporated with it, and the giving way from time to time of portions of both walls, but more especially of the hanging one, may, amongst other causes, well explain why the indications of them are often very undefined, or entirely effaced.

The small veins, or laminæ of different metalliferous, or earthy deposits, included within the walls of a principal vein, are frequently parallel, but sometimes oblique, with respect to the sides of the vein. The former position, as I have before remarked, affords decisive evidence in favour of a progressive opening, and filling of the fissures, and the latter, or oblique position of the included veins, strengthens the hypothesis, as it may be attributed to their having adhered to one wall, in some parts, and to the other wall, in other parts of a fissure, during its expansion; or it may, in some instances, have been caused by cracks or rents across the veins, which were afterwards filled up by mineral matter or clay; see *fig* 15, Plate V. At *h*, it will be noticed that the indications of included veins, are very indistinct, owing to the effect of disturbance under great pressure, and to the metals, reacting on each other and entering into combinations * after their deposition; whereas at *i*, parallel and oblique veins are represented in the lode.

Having thus given my views as to the origin of some of the secondary and branch fissures, I shall next endeavour to account for the deposition of ore in them, even when they happen to be almost at right angles to the prevalent bearings of the lodes.

I have found by experiment, that when the ore contained in two parallel copper lodes are connected by wires, the electricity transmitted through the latter, nearly at right angles to the direction of the lodes, is often very energetic. If the fissure *h h*, *fig* 4, contained water with salts in solution, it would evidently, like the wire, conduct the electricity between *w* and *y*; and the latter would tend

* It is evident that any of the metals found in our mines, which might, at first, have been deposited in a pure state, would quickly enter into new combinations, when reacted upon by copper and iron pyrites. The more electro-positive metals, such as zinc, tin, iron, &c., would of course, be exposed to the influence of such reaction before copper.

to decompose the salts, and deposit the basis at the negative pole or extremity of the fissure; and the deposition would proceed onward in the fissure, till it reached the other extremity, provided a sufficient supply of salts were brought under the electric influence by circulation, or otherwise. This operation might, however, be checked by the accumulation of mechanical deposits in the fissure, or by silica, or other substances, some of which might have been determined towards the electro-positive pole.

On the same principles, minute veins or branches, and "*droppers*,"* which ramify in different directions from lodes, may have been filled with ore, &c. These are sometimes termed "*feeders*," because they are often connected with masses of ore, but they ought, perhaps, rather to be viewed as the effects, than the causes of the productiveness of lodes in their vicinity.

The small veins or "*leaders*" of ore, which are often observed in cross courses, between dislocated parts of lodes; (see *a* and *b*, *fig* 4, Plate IV,) may likewise be referred to the same kind of action between the divided portions of the lodes; and when the ore in the cross courses extends beyond these boundaries, as it sometimes does, it may have been so deposited by the influence of more distant lodes; or in consequence of the acuteness of the angles of intersection which has caused the cross courses to partake, in some degree, of the nature of branches of the lodes.

The arrangement of some of the metallic veins, with respect to each other, is often very remarkable; thus it happens, that in those parts of Cornwall where copper and tin are abundant, lead, and some other metals, when they occur, are found principally in cross courses; whereas, I apprehend, that in some other mining districts where lead greatly predominates over copper, the former is in east and west veins, and the latter in cross veins; but I am not prepared to speak positively on this point, or to lay it down as a rule. If it should be confirmed by further inquiry, the fact may perhaps, be attributed to the well known tendency which is observable in portions of any given metal, to cohere or become aggregated with

* "*Droppers*" are shown at *r*, *s*, and *d*. *Fig* 17, Plate VI.

other portions of the same metal previously deposited; and to the influence of electrical action, between parallel lodes of other metals, which happen to occur in any place, in the greatest abundance.

It has been observed, that when two lodes of the same denomination, unite at acute angles, either in their strike or dip, they generally continue together for some distance, and are enriched whilst in conjunction. This result is quite consistent with the increased electrical action naturally produced by the union of two nearly parellel currents. When, however, lodes cross each other in their underlie at very considerable angles, they are, it seems, usually impoverished at and near the points of intersection. Now, if the electric currents were in opposite directions, in fissures so circumstanced, this ought to be the result, as they would tend to neutralise each other at the parts of intersection; and it is remarkable, that even now, the electric currents seem, in most instances, to proceed from the eastward, in lodes having a north underlie, and from the westward, in others, having a south underlie.* W. Henwood has recently published in "Sturgeon's annals of electricity," a summary of numerous observations made by him, on the electricity of lodes, which, generally speaking, show this tendency, although not so constantly as those which had previously come under my notice; but it is scarcely to to be supposed that local causes should not often modify the direction and energy of such currents.

I am decidedly of the opinion, that the electro-magnetic phenomena which have hitherto been detected in mines, were caused by voltaic, rather than by thermo-electric action. To produce the former, we separate good conductors,—different metals, for instance, by a less perfect one,—such as saline water, moistened clay, &c.; but to generate the latter, we employ a good conductor, such as a piece of metal, uninterrupted by an imperfect one, and heat one extremity of it. Now, it has been ascertained, that the greatest electrical effect was observed in mines when masses of ore, separated by clay, and other imperfect conductors, or parallel lodes, were connected by wire; and if, in a few instances, currents were de-

* See Philosophical transactions, 1830, p. 401.

tected when different parts of apparently continuous masses of ore were so connected, it is highly probable that they were more or less divided by joints, which however minute, would tend to excite voltaic action, and to produce currents through the wire, as being the superior conductor. Nor does the fact of the deeper and warmer parts of copper and lead lodes, having, in most instances, been found electro-negative, seem to accord with the thermo-electric properties of the sulphurets of these metals, which are rendered electro-positive by heat. Upon the whole, it is probable, from the comparatively small difference of temperature between the extremities of any perfectly continuous mass of ore in our lodes, that the influence of thermo-electricity, is too feeble to be easily detected by ordinary means; or at any rate, it must be considered as holding a very secondary place indeed, in producing the electro-magnetic phenomena which have been observed in mines.

Recapitulation.

In the theoretical part of this paper, I have, amongst other things, endeavoured to show:—

1. That admitting the origin of mineral veins to have been derived from fissures in the earth, there is reason to believe that the latter may have been produced by different causes, and at various intervals; also that many of them have been enlarged from time to time.

2. That the accumulation of mineral deposits in such fissures has been likewise progressive; and that the evidences afforded by the resemblance of the vein stones to the several enclosing rocks, and the arrangements and sub-divisions of the contents of veins, are decidedly in favour of both these conclusions; independently of other arguments, based on mechanical principles.

3. That the phenomena of veins seem to indicate that many of the fissures penetrated to a great depth, and into regions of very high temperature; and that consequently the water which they contained must have circulated upwards and downwards with greater or less rapidity.

4. That since the solvent power of water seems to increase in

some ratio to the augmentation of its temperature, it is obvious that it would tend to dissolve some substances at a great depth, which it would deposit, more or less, in the course of its ascent through cooler portions of water; and also in consequence of its partial evaporation on reaching the surface.

5. That a part of the earthy contents of veins, and more especially silica or quartz, was apparently accumulated in this manner, and usually combined, more or less, with matter otherwise deposited.

6. That rocks, clay, &c., containing different saline solutions and metalliferous substances, in contact with water, charged, in many instances, with other salts, were calculated to produce electrical action; and that this action was probably much increased by the circulation of the water, and differences of temperature; but more particularly by the existence of compressed and heated water, metallic bodies, &c., at or near the bottom of the fissures.

7. That since the water in the fissures containing metallic, or earthy salts, was a conductor of electricity, especially when heated, and in a very superior degree to the rocks themselves; it is evident, that in conformity with the laws of electro-magnetism, the currents of electricity would, if not otherwise controlled, pass towards the west, through such fissures as were most nearly at right angles to the magnetic meridian at the time.

8. That the more soluble, metallic, and earthy salts, may have been decomposed by the agency of such electric currents, and the bases been thereby determined, in most instances, towards the electro-negative pole or rock: that tin, however, under these circumstances, is only partly deposited at the electro-negative pole, and partly at the electro-positive pole, in the state of a peroxide; and that these properties of this metal seem to bear on its positions in the lodes, with regard to copper, being sometimes found with it, and sometimes distinctly separated from it.

9. That the position of one rock with respect to another, or to a series of other rocks, may, as well as their relative saline or metallic contents, temperature, &c., have had a decided influence on

the deposition of minerals on them by electrical agency, so that a given rock may have been *electro-positive* in one situation, and *electro-negative* in another, in regard to other neighbouring rocks, as this is quite consistent with voltaic phenomena.

10. That the evolution of sulphuretted hydrogen, and the tendency of some metals, when in solution, to absorb oxygen, and become insoluble, may, in many instances, have interfered with the regular arrangement of the metals, such as electricity would have effected; and that hence, many anomalies may have arisen, especially in relation to tin.

11. That the electrical reaction of the different metalliferous bodies, and of masses of ore on each other, after their deposition in the fissures, may have corrected such anomalies in some instances, and that they may have given rise to them in others, by changing the direction of the electric currents, and thus modifying the relative positions of the deposits; and that the pseudomorphous crystals of various descriptions, as well as other phenomena observable in mines, fully prove that some such secondary action must have taken place.

12. That cross veins may have been filled mechanically, or by the deposition of silica from a state of solution, or by both these means; and that the striated and radiated structure of the quartz, may be owing to the tendency of electricity, under ordinary circumstances, to pass transversly, rather than longitudinally, through N. and S. veins.

13. That assuming the proofs of the progressive opening and filling of lodes and cross veins to be admitted, it seems to follow, that many intersections may have been caused by the more ready accumulation of clay, and other mechanical matter, and even of silica from its solution, than of the more slowly formed metalliferous or crystalline deposits.

14. That the frequent occurrence of a mass of ore in that part of a lode which is intersected by a cross vein; and also of small branches of ore from a dislocated part of a lode on one side of a cross vein, without there being corresponding veins near the other part of the lode, on the opposite side of the cross vein, afford strong evidence

of the deposition of the ore in such cases, after the intersection took place; and that it was accumulated in the E. and W. vein, rather than in the N. and S. one, by the influence of electro-magnetism.

15. That the small veins of copper and tin ore which are often found in cross veins between the dislocated parts of lodes, and the frequent occurrence of more considerable, and yet, for the most part, very limited quantities of these ores in the former, in the immediate vicinity of intersections, are additional arguments in favour of the operation, of the same definite agency.

16. That the secondary fissures, resulting from the cracking off of larger or smaller masses of the hanging sides of veins, may have been partly filled, in many instances, by the electric action of different portions of ore on each other; and that secondary lodes may have been formed at right angles to parallel E. and W. lodes, in consequence of the reciprocal action of the latter.

17. That many other phenomena of mineral veins, including those of a mechanical character, such as the occurrence of horses, heaves, &c., appear to be capable of satisfactory explanation on the principles which have been laid down.

Conclusion.

Imperfect and limited as is our acquaintance with mineral veins, enough is known to excite our admiration of the order and fitness which prevail amongst them.

We observe that many of the most useful metals are the most abundant;—and the fact that they are generally confined to certain veins, and to certain portions of them only, is perhaps, of greater import, than we might at first suppose:—for had they been disseminated in the strata, or even dispersed throughout all mineral veins, the labour required to obtain them, would have rendered them practically useless:—or had they, on the other hand, been much more concentrated, their rapid exhaustion might entail incalculable injury on future generations.

Again, we remark that few metals are found in a native state, and those very sparingly;—were it otherwise, there is good reason to believe that their electric action and reaction would have been so energetic, that some of the electro-positive metals could not have been permanently deposited. Had the metals generally existed in combination with oxygen or acids, their electric action would have been reduced to a minimum quantity; in which case, many metallic, and other solutions, might, from being but partially decomposed, have found their way to the surface, and impregnated the springs with their deleterious qualities. Sulphur appears to be the only component which enables metals to effect all the required conditions, and this proves to be the combination in which they most frequently occur. It has already been mentioned that such of the metallic sulphurets as conduct electricity, are highly electro-negative, and that their reciprocal action, in most instances, is so nearly in equilibrio, as to prevent considerable changes; nevertheless, they seem to possess sufficient electric activity to act upon other bodies, and to decompose saline solutions which may be exposed to their influence:—and who knows how important such electrical filtration of the ascending water may be, to organic existence at the surface of the earth?

Some of the cross courses appear to be channels for conducting the water between different lodes; and the flucan veins, by occasionally intercepting it, tend to prevent the too great drainage of the land which would otherwise attend mining operations, whilst at the same time, they enable the miner to prosecute his labours underground, to a much greater depth than would else be practicable.

Considering the nature and arrangement of mineral veins under the surface, it can scarcely be doubted that the *endosmose* and *exosmose* process must prevail more or less, within the earth, and tend to cause differences in the water level on the opposite sides of flucan courses. This influence, as has been before remarked, may be sometimes exerted in the same direction, through a series of parallel clay veins, so as to produce successive elevations of the water, and thus affect the relative heights of springs. There are good grounds for believing that some of the most curious phenomena connected with respiration, and various animal and vegetable secretions depend on the same process, which is itself apparently, a result of electrical agency. *

This at least, is certain, that the action of electricity is not confined to the surface of the earth ; and it is more than probable that it is inherent in all matter in some modified form ; so that, should the Hand that produced it, suspend its operation but for one moment, animal and vegetable life would be universally extinguished.

I have already alluded to the property which water possesses, in common with all other fluids, to ascend when heated, and to the influence of this property, in conjunction with the high temperature of the interior of the earth, in the filling of fissures with mineral deposits. Thermal springs seem to be also a result of the same causes, and it is unnecessary to enlarge on their uses to mankind. Were it not for this law of fluids, the great ocean-currents which circulate between the polar and equatorial regions, tending to equalize the temperature of the earth's surface, would cease to flow, and the atmosphere would be comparatively stagnant and unfit for respiration.

* Does not the counteracting effect of external irritation in inflammatory cases, appear to be a result of the same principle, which causes an electro-positive metal to preserve an electro-negative one, when they are together exposed to the action of diluted acid ? If this analogy be well founded, it seems to follow, that in order to insure the most beneficial effect, the external irritation should be kept up without intermission.

In the Philosophical Magazine, vol. 5, p. 7, I have suggested that the electric *elements*, (if I may use the term,) may, like electrified bodies, possess opposite poles, and that the *inversion* of these poles, to a greater or less extent, according to the relative conditions of the contiguous substances, may simply and satisfactorily account for *induction*, and other electrical phenomena. I can in no other way conceive, how the changes in the electrical condition of different bodies when brought into contact, and the perfect balance of forces thus induced, are to be explained.—Why for instance, is silver when placed in diluted acid with copper, protected, at the expense of the latter, which, under such circumstances, is acted upon with increased energy ?—and why, when iron is substituted for the silver, is the previously *electro-positive* copper, rendered *electro-negative*, and protected by the iron ;—and this again by zinc ?—In such cases, an actual transference of an electric fluid can scarcely be imagined. The fact of many compound

Evidences might be multiplied, almost without limitation, to show the perfect adaptation of simple general laws to every possible case, in the whole circle of creation. We can, however, detect their existence only by their effects, for our perceptions are far too limited, and our comprehensions too feeble, to understand the elementary constitution even of the simplest form of matter. There is, nevertheless, in all Nature, a harmony of parts, and a consistency of operation, calculated to excite our reverence and gratitude towards her Almighty Author, whose infinite fore-knowledge and goodness thus forcibly manifest themselves, in the perfect adaptation of physical laws to every existing circumstance.

bodies, which are *non-conductors* of electricity when *solid*, becoming *conductors*, when *fluid*, appears to be in accordance with the hypothesis alluded to. In the former case, the poles may, perhaps, be retained with a double force by the components, so as to prevent their inversion, whilst in the latter, the fluid particles may allow a degree of freedom of motion to the poles, and be turned with them.

When I referred to the circumstance of fluids being capable of acting as voltaic poles, pages 32 and 36, I omitted to mention an experiment which I showed to some of my friends early in the autumn. On immersing a bladder containing acidulated water, and zinc, in a solution of sulphate of copper, the copper was deposited in a pure state on the surface of the bladder; hence, I conceive, that the sulphate of copper must have acted as an electric pole, and been electro-negative with respect to the zinc from which it was separated by the bladder. The fluids *within*, and *without* the bladder, were observed, in the course of some weeks, to stand at very different levels, the former being five or six inches above the latter, although the bladder was open at the top.

QUESTIONS RELATIVE TO MINERAL VEINS, SUBMITTED TO PRACTICAL MINERS.

1. Name of the mine, as well as of the parish or district in which it is situated.

2. Number of metallic veins or lodes, and the description of ore which each contains.

3. Average *size*, *direction by compass*,* and *underlie* of each lode, and whether very variable or not in these respects; and do the lodes generally increase or diminish in size in descending into the earth?

4. Nature of the rocks or country traversed by each lode, whether *granite*, *killas*, *elvan*, &c., or all of them; and the bearings of the different rocks with respect to each other.

5. If any *elvan courses*, (porphyritic dykes;) their appearance, hardness, sizes, directions, and underlie.

6. In which of the rocks have the respective lodes been found most productive of ore, and has there been any difference in this respect, between those of copper and tin, or of any other metal?

7. If copper lodes; do they consist of "*yellow*" or "*grey*" ore, or of any other variety, and how are the varieties of the ore situated with respect to each other in the lodes?

8. If copper and tin occur in the same lodes, are those metals in different parts of them, or if near together, are they at, or near the opposite walls of the lodes, or are they intimately mixed?

9. If near the opposite walls of underlying lodes, which of these

* The bearings by the compass was mentioned merely to insure uniformity in the returns, as the proper allowance could afterwards be made for the amount of he variation from the true north.

metals is the nearer to the upper or hanging walls, and which to the lower or foot walls;—are these ores separated from each other by "*spar*" (quartz,) or other substances; and do the hanging and foot walls differ much in hardness?

10. If other metals exist in the lodes, under what circumstances do they occur; and what minerals have a tendency to crystallize, and how are the crystallized masses situated with respect to the contiguous ores?

11. Was there "*gossan*" or other substance observed resting upon, or above the copper ore in the lodes, or if *strictly tin lodes*, were they found to be without gossan?

12. Are the walls or "*capels*" of the tin lodes harder than those of the copper lodes, and if in the case of a copper lode, one wall is harder than the other, is it the nearer one to the copper ore, or that which is the further from it?

13. Are the lodes, generally speaking, more productive of ore on the side of the hanging, or of the foot walls?

14. Is the rock or country immediately contiguous to the walls of any of the lodes, usually softer or harder than at a distance from them: is there any difference in this respect between tin lodes, and lodes of copper, &c.; and is the hardness and softness of the lodes, in any *direct* ratio, or *inverse* ratio, to the hardness or softness of the rock or country contiguous to the walls.

15. Are not the lodes often contracted into small veins or branches, and have any of these been found to open again into large lodes containing ore? In such cases, do not the opposite small veins or branches sometimes overlap each other, or become "*spliced*," as I believe it is termed?

16. Do the lodes materially vary in size in traversing different rocks, and in which rocks are they the largest? Moreover, in passing from one rock into another, from killas, to elvan or granite, for instance, do they suffer any interruption, or break in their course, and if so, how much, and in what direction?

17. Are there any marks in the walls of a given lode, showing that one of its walls is at a lower level than the other, and, if so, to what extent; and is it not usually the hanging wall which is so circumstanced?

18. Are all, or any of the walls, smooth and well defined, or are they imperceptible, or indistinctly marked? In either case, are the lodes more or less hard than the ground in which they occur?

19. Are the hanging or foot walls most indistinct, and which of them are the hardest?

20. When the tin lodes meet other lodes, are they intersected by them, and if the intersections take place in their underlie, are they thrown up by them, and how much?

The same question may be asked, as it respects other lodes.

21. Are there smaller veins *having distinct walls or divisions* included between the walls of the lodes, that is, are the lodes "*comby*" near the surface, or at a greater depth; and are such small included veins parallel, or oblique, as it respects the walls of the lodes, and of what do the former consist?

22. Are there any veins of clay, or veins, or portions of the containing rock, or *country*, in the lodes; and are they respectively near the hanging or the foot walls?

23. Have any masses of rock been found in the lodes, termed "*horses*" by the miners; and did they appear to be completely separated by the branches of any given lode from contact with the outer walls or country?

24. What circumstances or appearances in the lodes are considered the most favourable indications of any given ore, and what the least so?

25. Is not an increase in the underlie of lodes usually less favourable for ore than when they become more vertical, and are they not generally more contracted in size, and more filled with mechanical deposits when their underlie is considerably increased?

26. If any of the lodes have crossed or intersected other lodes, has it occurred horizontally, or in their underlie, and at what angles; and have they been found more productive of ore, at the intersections, or less so?

27. At what depth below the surface have the different lodes been found most productive of their respective ores;—and have many cavities or "*voughs*" been observed in them, and at what depths?

28. Have the arseniates of copper, iron, or lead, or much fluor spar, occurred in any of the lodes; and how were such substances situated in relation to the ores?

22. Is the "*spar*," or quartz immediately contiguous to copper ore, often more porous or friable, (locally termed "*honey-comb*," or "*sugar spar*,") than that which accompanies tin ore, and even more so, than the spar which is at a distance from the copper ore in the same lode?

30. Are there any *cross courses* or *flucans* intersecting any of the lodes, and what are the directions by *compass*, underlie, and average sizes of the former; and are they larger or smaller at the upper, than at the lower levels?

31. Are the cross courses "*comby*," or subdivided into smaller veins of clay and quartz, or other earthy matter?

32. How far do the cross courses partake of the nature of the country through which they pass?

33. Do they dislocate or heave the lodes and elvan courses, and how much each of them; stating the underlie of the two last, at, or near the places of intersection; and are the heaves greater or less at the upper, than at the lower levels?

34. Are there any branches, small veins, or "*leaders*" of ore in any of the cross courses between the dislocated extremities of the lodes, or only detached stones of ore; and are the ores in the cross courses the same, or different in their nature or appearance from those in the lodes?

35. Are the lodes more productive of ore near the cross courses, and on both sides, or only on one side of a given cross course, and on which side?

36. Are there any branch veins of ore nearly at right angles to the bearings of the lodes;—of what ores do such rectangular veins consist;—how far have they been seen to extend;—what is their underlie;—and are they near the hanging walls of any cross courses?

37. Are there any beds or "*floors*" of tin, copper, or other metal, and under what circumstances do they occur?

38. Have the floors, walls like lodes, or are they interposed between the beds or laminæ of the rocks?

39. Are they connected with other veins, or quite distinct from them: in what rocks or country are they most prevalent;—and have any of the ores been observed to occur disseminated, or diffused in the rocks, not as veins, but at a distance from lodes or beds of ore?

40. What are the directions of the joints, heads, or natural divisions of the granite, killas, elvan, or other rocks, and do such joints agree, or not, with the general directions of the lodes and cross courses?

Captain William Bolitho, of Trevenen tin mine, in Wendron parish, has forwarded through the medium of a friend, the following answers to my questions, but they were not received in time to be noticed in the proper place; however, I now give them complete.

1. North Trevenen, in the parish of Wendron.

2. Four lodes;—all of tin.

3. Average size, 11 inches; direction, due east and west, (by compass;)—the four lodes are included within a space of 40 fathoms;—the underlie of the northernmost lode is 9 inches in a fathom;—the next lode is the same;—the third from the northernmost is 2 feet;—the southernmost underlies one foot in a fathom;—underlie pretty regular so far.—As far as can be discovered at present, the lodes are enlarging as they descend.

4. The lodes are all in granite.

5. There is an elvan course;—greyish, soft, two feet wide;—parallel with the lodes;—no underlie.

11. Gossan has been found on the backs of tin lodes, but very rarely.

14. The rock immediately contiguous to the walls of the tin lodes in this mine is softer than the ground at a greater distance;—as the hardness of the ground increases, so does that of the lodes,

and as the country in the neighbourhood of the lodes becomes softer, so do the lodes also.

15. The entire of this question may be answered in the affirmative.

18. In this mine the walls are generally smooth and well-defined, but occasionally a lode is seen to project into one of the walls,—generally the northern or hanging one, and thus it occasions a degree of roughness in it; and the lode is usually softer than the country which it traverses.

19. In this mine the hanging walls are not more distinct than the foot walls, but harder.

21. Small veins are often included within the general walls of the lodes, but no lesser walls are found accompanying them;—and such veins hold a course parallel with the walls of the lodes.

22. No veins of clay or country are observed in this mine within the walls of the lodes.

23. The engine lode has split, and received within its two divisions a mass of granite which is entirely surrounded by the branches of the lode, so as to be in no way connected with the country.

24. With respect to tin in a granite country, one of the most favourable indications is a softness of the lode, another is the branchy or comby state of the hanging wall, admitting, in that state, *droppers* into the lode.

25. An increased underlie is nowise unfavourable for tin in this mine,—for when the underlie becomes rapid, there is generally an increased number of "*droppers*," which usually come in from the north sides of the lodes;—the size does not diminish in consequence, nor is there any greater deposits.

28. Iron and spar have been found mixed with the lodes, and sometimes the spar has been in the greatest quantity near the hanging walls.

30. The cross course runs north and south;—no underlie;—size 4 inches;—the cross course is accompanied by a softness of the surrounding country;—it is larger at the 30 fathom level, than it was at the 12.

31. The cross course is comby.

32. Here the cross course is more yellow, and approaches more to the character of clay than the surrounding country, being much softer and finer.

33. The engine lode in this mine was dislocated by the cross course about a foot:—in the case of the northern lode, the tin lode heaved the cross course a fathom:—the underlie has not been altered by the intersection of the cross course. With regard to depth, it does not seem to affect the distance of the heaves.

35. Lodes are more productive near cross courses;—and in this mine, on each side of it;—but generally, on one side only:—in Old Trevenen, the eastern side of the cross course was always the richer.

36. W. B. has never witnessed any such appearances.

38. Floors of tin have no walls;—sometimes they are deposited between rocks, and at others, under them, or upon them, and sometimes they have no rocks near them,—and are as rich in soft ground as between rocks.—Layers of tin in soft ground are sometimes three or four inches thick, and extremely rich.

39. Quite distinct from all veins,—or connection with veins;—floors more common in granite,—but are found in killas,—and are seen to pass from one to the other;—richest in the granite:—the latter half of this question must be answered in the negative.

40. In this mine the joints run parallel with the lodes.

THE MAGNETIC BALANCE.

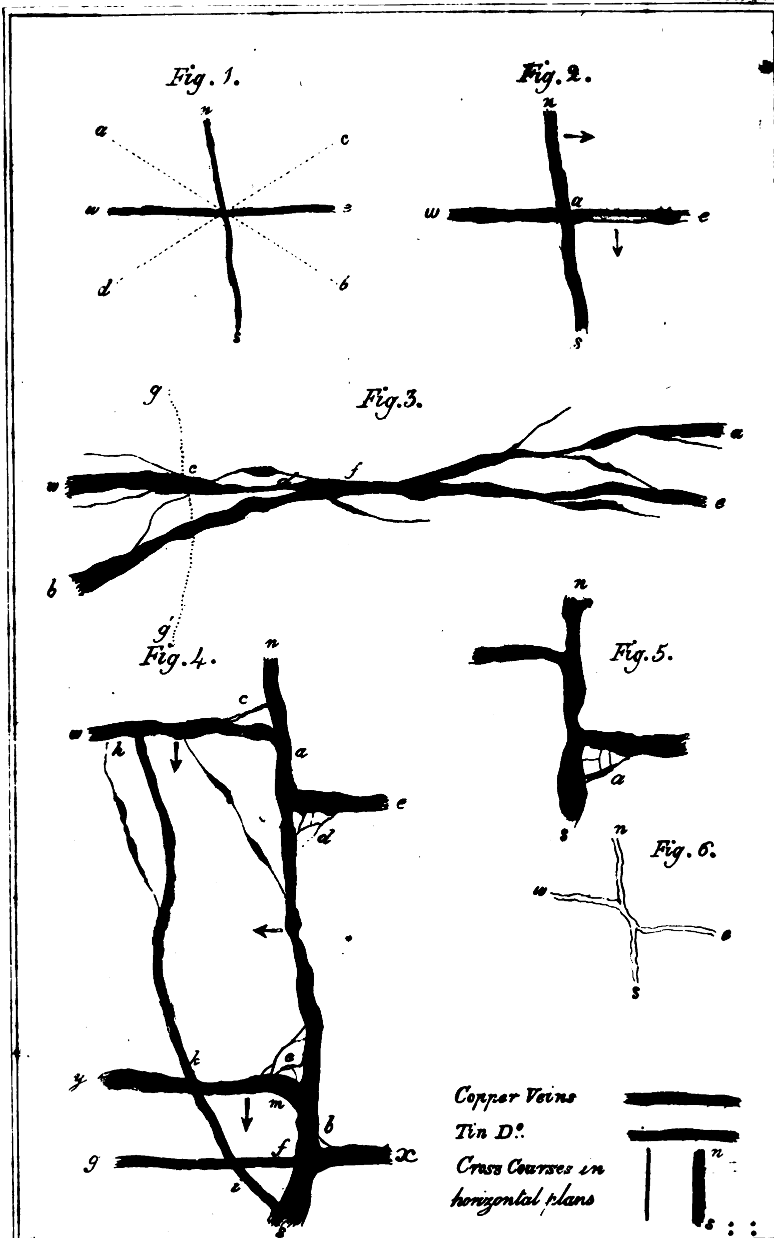
By R. W. Fox.

A front view of this instrument is given at plate VI., *Fig.* 22. The beam is shown at *a b*, having an axis passing through its centre of gravity, which is terminated by fine pivots working in jewelled holes. This beam is itself a magnet, and its position is governed and adjusted by the repulsive action of two other magnets in the lower part of the instrument, situated as shown by the dotted lines at c and *d;* they turn with the axis *a* and *d*, and may be adjusted to any angle by the graduated circles. The scale pans *e* and *f*, are formed of slight silver foil, and suspended from the beam by single fibres of unspun silk; they are, together with the beam, separated from the other parts of the instrument, by slight partitions, to avoid the effect of currents of air; and the weights and materials are put in at the sides, where there are sliding glass doors, which are not shown in the figure. The mode of reading the indications of the instrument, by means of the double scale, is exactly similar to that used in Mr. Fox's Dipping Needle Deflector; in fact, the present is a new application of the pinciples of that instrument, and the experiments tried with it, prove it to be equally successful. The advantages it possesses over the ordinary balance, are extreme sensibility, (it being capable of indicating much less than the ten thousandth part of a grain;)—the facility with which its indications are obtained;—and the comparatively low price at which it can be rendered.

To adjust the instrument for use, it must be carefully levelled by the screws, two of which are shown at *g* and *h*. The beam is then brought to the Zero points by turning the magnets, and when ascertained to be correct, it may be kept in this position by *partly* drawing up the arms *p q*, by the screw *r*, to prevent too much vibration while the weights and materials are being introduced. This done, the sliding doors closed, and the screw *r* carefully released ; the beam immediately takes its position, which is rendered exceedingly accurate by gentle friction applied at the point of a brass pin at the back, showing the difference of the materials and weights, by the small space passed over by the points of the needle ; and as its value should be previously determined by experiment, the weight would be known ; or if preferred, weights may be added till the beam becomes perfectly horizontal. It is evident that this balance will afford great facilities for taking the specific gravity of minute bodies with extreme accuracy ; and for this purpose the scale pan, *h*, *fig*. 23, suspended by a fine wire, may be substituted, and a glass of distilled water placed in the drawer to receive it.

This instrument is manufactured by T. B. Jordan, of Falmouth.

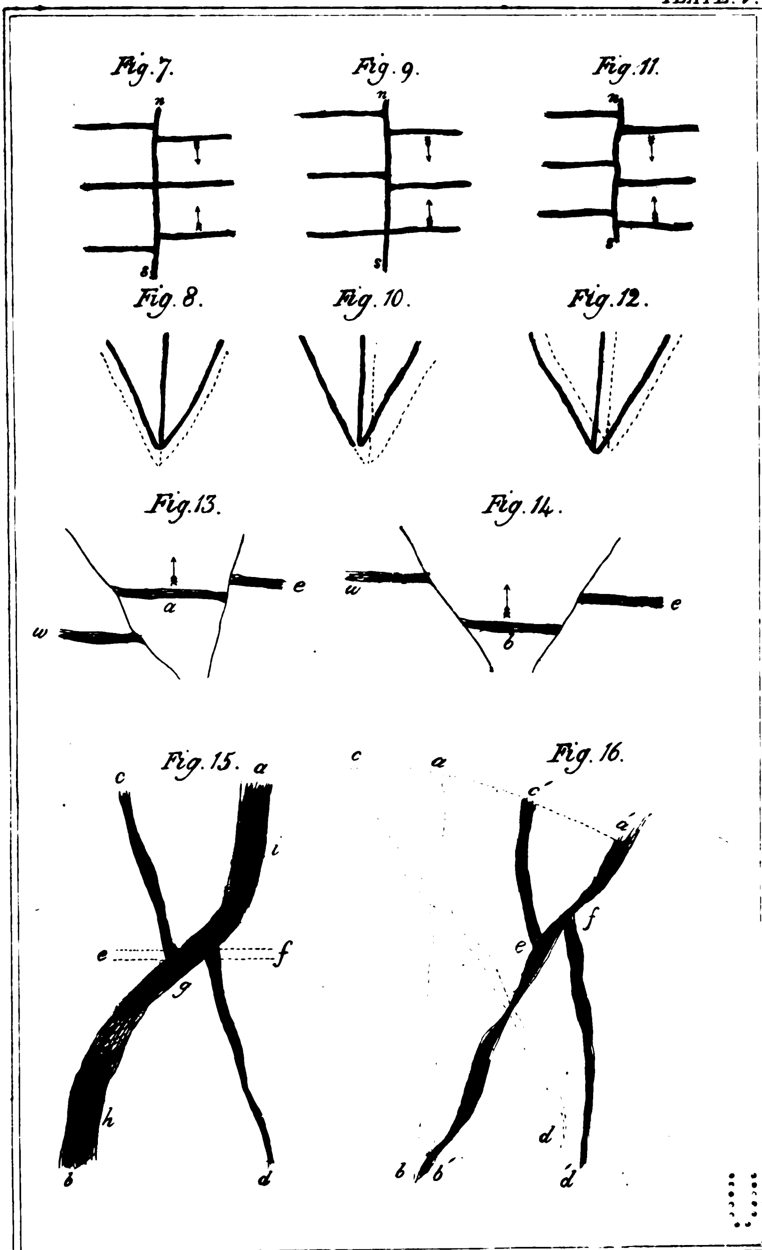
Note.—A Figure of the *Magnetic Balance* having been given in the Polytechnic Report in one of the plates which contains a representation of some of the mineral veins, &c., it has been considered best to add a description of the instrument to this paper.



J. Gann

Horizontal Plans

PLATE. V.



J. Genn.

Figs. 7. 9. 11. 13 & 14. Ground plans.
Figs. 8. 10. 12. 15. & 16. Sections.

Fig. 22.

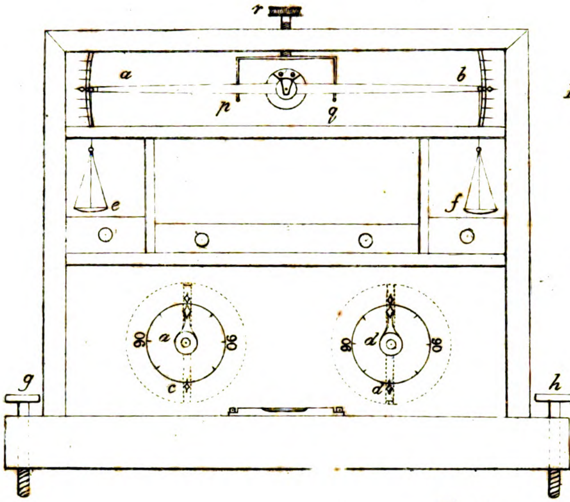


Fig. 23.

Fig. 17.

Section

Fig. 18.

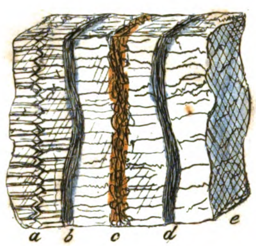


Fig. 19.

Fig. 20.

Fig. 21.

J. GANN.