

VIII.—*An account of the Discovery of some varieties of Tin-Ore in a Vein, which have been considered peculiar to Streams; with remarks on Diluvial Tin in general.*

By JOSEPH CARNE, Esq. F.R.S., &c.

TREASURER OF THE SOCIETY.

(Read October, 1820.)

THE origin of the tin-ore which, from the earliest periods of history or tradition, has been found in separate particles, or small pieces, in the lower part of the vallies, in the tin districts of Cornwall and Devon, is a subject which, whilst it excites considerable interest, is yet, like most other subjects of geological theory, exposed to several difficulties. The roundness of its particles,—their total want of connection,—the beds in which it is found,—the relation which these beds appear to bear both to the solid strata of the earth, and to the superincumbent matter,—and other circumstances, afford strong ground for supposing that the situation in which it is now found, is not that in which it was originally

placed ; and that it has been exposed to the violent action of water : whilst the non-existence of tin-ore in streams, in any countries which do not abound in tin veins ; and the stream tin-ore being, as well as what is usually found in veins, the oxide of tin, render it probable that, by the operation of a force out of the common course of nature, it has been separated from veins, or other depositories, in which it had originally existed, and been conveyed, with an immense mass of other substances, into the neighbouring vallies.

This theory is, perhaps, the only probable one which has ever been advanced ; and yet, on account of the difficulties with which it is attended, it has been seriously questioned whether the tin of the streams was ever connected with veins or floors, and whether it has not always existed in a separate and distinct state. One of the reasons commonly given (and, perhaps, more frequently than any other) for this supposition, is the fact that stream tin often occurs in certain forms and varieties in which it has never been discovered in veins. These are, 1st. the fibrous and veined oxide, commonly called wood-tin ; 2nd. the spherical or pear-form oxide, of which the fibres radiate from a centre, occurring either in separate minute masses, or in globular distinct concretions in the matrix, and when broken, forming the peculiar variety called the toad's-eye tin ; 3rd. the botryoidal oxide ; 4th. the spathose and resinous oxide. It has been not unreasonably argued that if these varieties have no existence in veins or floors,

(and that they have never been found there, has been considered almost a proof of this) we must look elsewhere for their origin; and in that case, we need not hesitate to look to the same source for the origin of the more common kinds of tin-ore which accompany them.

In the first volume of the Transactions of this society, Mr. Majendie mentions his having been informed that, several years before, wood-tin was found in a mine in St. Columb, not attached to the walls of the vein, but imbedded in the clay of which it was composed; but he had seen nothing of it himself.* With the exception of this circumstance, to which much uncertainty appears to be attached, I have never heard, until lately, of any of those varieties of tin-ore, except, perhaps, the last, having been found in a vein; but by the discovery, which I am about to mention, the question may be regarded as decided.

On the side of the hill which rises southward of Barius Bridge, about two miles from Penzance, on the Land's-end road, is a small tin-mine called the Garth, or, as it has lately been newly named, East Huel Cock. The slate country extends from Penzance to the foot of this hill: *there* the granite commences, and continues from thence all the way to the Land's-end. The lode of this mine is at present wholly in granite: in its course westward, it may, perhaps, intersect the slate, but it has never been seen in that connection: it varies very little

* Page 238.

from an east and west direction, and underlies southwards from one and half to two feet in a fathom, or in an angle of from 15°. to 22°. from the perpendicular: its width is very great; in the narrowest part it is nearly nine feet, and in the widest, upwards of fourteen. It cannot be doubted that the upper part of this lode was explored at a very remote period, as it bears marks of the earliest kind of mining: in one part of it there is one of those excavations (called by the miners *coffins*) so common in the most ancient mines, in which all the operations were open to the sun: the workmen could, in that way, proceed no deeper than they could draw the water with a hand pump. This circumstance makes it probable that tin* was found very near the surface. I have been informed that about sixty or seventy years ago, the heaps, which lay on the sides of the excavation, were found rich enough amply to remunerate those who *dressed* them.

Since that period, this lode has again been explored in the modern and regular way of mining: an *adit level* was brought from the valley, which when it came to the lode, was fourteen fathoms deep, and a shaft was sunk from the surface: the workmen almost immediately discovered tin in the shaft, and at the depth of five fathoms it became much more plentiful: the concern was continued to the depth of twenty-six fathoms, (or twelve fathoms below the adit) and was then abandoned, either on account of the poverty of the lode, or, what is more probable,

* By the word *tin* here, I always mean tin-ore.

for want of a better machine than a *whim* to drain the mine of water.

About three years ago, the Garth was again set at work, with an engine worked by a water wheel, for draining the water: the present workmen, on exploring the lode immediately below the *old workings*, found it productive of tin, and it has continued so to the present depth of thirty fathoms, although scarcely rich enough to pay the expences which attend the concern: the tin-ground in the lode is about six fathoms in length, and occurs directly westward of the intersection of the lode by a clay cross-course, on which the *adit* was driven: the lode has not been explored east of the cross-course.

Whether any of the peculiar varieties of stream-tin were found in this lode in the former periods of working, I cannot learn; but I have no doubt that they were, as some of them have occurred in great abundance in the small part which has lately been explored, viz. six fathoms in length, and nearly four fathoms in depth. In all this space, wood-tin, and toad's-eye tin, have been plentifully found: tin in globular distinct concretions, from the size of a pin's head to that of a pea, has occurred more sparingly; and of botryoidal tin, only a few specimens have been met with. Some parts of the lode have yielded a larger quantity than others; but in general these peculiar varieties have been most plentiful on the northern side of the lode.

Of the specimens which I have the pleasure to present to the society, Nos. 1-6, are of the lode itself:

it has in general a very granitic appearance, but it is not granite: its constituent parts (except the metallic ores) appear to be quartz, felspar, and chlorite, coarsely mingled together, the two former highly crystalline. The only metallic ores, which I have observed in it, are the carbonate of iron, and the oxide of tin: the tin is not generally scattered throughout the stone, but exists in singular forms, and in such modes as have been seldom, if ever, observed before. Where the felspar predominates, the tin occurs in small separate layers between the crystalline masses of felspar, possessing the fibrous texture and brown colour, peculiar to the wood-tin, as in the specimens Nos. 7-8. It occurs also in contemporaneous veins in the quartz, as in No. 9, and in similar veins between the quartz and another constituent part of the stone, as in No. 10, and investing the sides and summits of the quartz crystals, as in Nos. 11-12. No. 13 is a specimen of the globular distinct concretions: on breaking a stone, these concretions are often found bedded in one part, and capped by the other, as in No. 14; when broken, they commonly present the appearance of toad's-eye tin, as in Nos. 15-16. In some of the specimens two or more of these varieties may be observed in the same stone, as in Nos. 17-18. No. 19 presents the wood-tin with a rough botryoidal surface.

Here then we have what I may presume to call a decisive proof, that most of the varieties of the oxide of tin which have long been deemed peculiar to streams, exist also in veins, and have existed here

very near the surface, and in considerable quantity. With respect to the spathose and resinous oxide of tin, the quantity found in streams is very small; and although it may never have been found in small distinct masses in veins, as it is in streams, it is frequently met with, united with the common oxide, in the same crystal, one part of the crystal being black, and another of a greyish white or sparry colour, and sometimes having a yellowish or reddish tinge like rosin, from which the term resinous has been applied to it. I consider the small bits of this kind found in streams, to be broken parts of such crystals.

It may, perhaps, not be wholly useless to offer a few considerations with a view of obviating, or lessening, the other difficulties which are frequently urged against the theory of stream tin to which I have alluded.

I. "*If*," say some, "*the stream tin has been derived from the upper parts of the veins; tin would still be found at the very top of the veins, where they come out at the surface; but this is rarely, if ever, the case; and if tin does not now exist so high in the veins, it is not likely that it ever existed still higher.*"

In reply to this it may be stated, 1st. that although it is not common to find tin at or immediately under the surface, we may reasonably conclude from the numerous excavations on the course of veins, which still remain open to the day in old tin-mines, in several parts of Cornwall, especially in St. Just, St. Agnes, and Gwennap, that considerable quantities

of tin have in past times been found in veins, almost immediately below the surface of the solid strata of the earth, and even level with the clay which usually forms the uppermost coat. The Garth probably furnished an instance of this. Other instances have recently occurred. In Huel Diamond, in St. Just, tin of the first quality, in snow-white quartz, and unconnected with any other metal, has been plentifully found within a few feet of the surface. This was also the case in Kelynack in the same parish. In the valley between Nancothan and Drift, in Madron, the streamers in bringing up a channel for the river, met with two tin veins, in one of which they found a bunch of tin, which produced them upwards of fifty pounds: this was in the clay which there forms the upper part of the shelf or solid earth. In Carclase mine, near St. Austell, which nearly resembles what is termed by the Germans a *stock-work*, the tin also appears to have been discovered almost immediately under the surface. 2nd. The ochreous substance called the *Gossan* of copper lodes generally contains a small portion of tin, and it was common formerly to *dress* it for the sake of its tin: this substance occurs at the very top of the veins, and is often discovered in ploughing the fields. 3rd. That floors of tin have existed not only near the surface, but quite level with it, is as certain as tradition can make it—for there have been no recent discoveries of this kind: the spots where these have occurred are still indicated by the wide but shallow excavations which are found in some parts of the

west of Cornwall. The highest floor in the Bunny, in St. Just, is said to have been discovered by the appearance of the tin at the very surface; and a floor in a part of Botallack was nearly as shallow.

I presume these facts are sufficient to obviate this difficulty, and to shew that, in the violence of the deluge, or of any power capable of removing any part of the crust of the earth, not only the tin in the highest parts of the veins, but entire floors of tin, might have been displaced from their original situations, and deposited in the vallies.

II. "*Beds of arenaceous tin-ore have been discovered in several stream-works, under the shelf, or the solid strata: these beds, therefore, must have existed prior to the strata which cover them, and cannot consist of diluvial tin.*" This fact may be allowed without admitting the consequence, for unless it is clearly proved that the superincumbent *shelf* is united on every side to the neighbouring solid strata, and thus so completely covers the space which contains the tin, as to leave no inlet through which the tin could have been deposited underneath it, the inference drawn by the objector cannot be admitted. Now not only has no case occurred in which this has been proved; but after an extensive and particular investigation of the stream-works west of Penzance, I am convinced that the masses of *shelf*, wherever they occur over the tin, are either horizontal or slightly inclined ridges, extending from the sides of the basin or cavity in which the tin is found; or else small flat masses of slate or clay which,

although now wholly unconnected with the *shelf*, formerly formed a part of it; but were severed from the neighbouring mass by the same force which carried the tin into the valley, and at the same period. In Chyvenhall stream, in the parish of Paul, such ridges are not uncommon: the streamers give them the name of *cap-shelf*, or caps of shelf covering the tin: they are also met with in several other stream-works in this neighbourhood: the following rough section may convey some idea of them.



Suppose the space between the black lines to represent a valley in which there is a deposit of tin: the dotted part represents the tin-ground: where it is thickly dotted it is rich, and elsewhere poor. The workmen after removing the superincumbent beds of gravel, silt, &c. find a rich bed of tin at *a*, which they pursue as far as *b*, and find it become very poor: before they relinquish that part, they sink into the *shelf* below *a*, and find another bed of tin under it: should this bed not continue productive as far as the opening in the *shelf*, that part of the stream-work would, perhaps, be abandoned without discovering that the intermediate *shelf* was merely a ridge; but on taking away the tin-ground, supposing it to continue rich, the end of the ridge would appear.

Workmen not accustomed to these occurrences, would probably suppose, on coming upon one of these ridges or beds of *shelf*, that the tin-ground was terminated, and would, therefore, abandon that part of the concern: the western streamers, however, are so much accustomed to the *cap-shelf*, that they always penetrate a few feet into what appears to be the *shelf*, before they are satisfied that it is not *cap-shelf*. When they have met with tin in these situations, they have, on pursuing it, frequently discovered the termination of the ridges.

In the Carnon stream some beds of slate have been found reposing on the tin-ground, but entirely unconnected with the solid strata forming the bottom and sides of the excavation.

III. *If the stream tin has come from veins, we might expect the tin of every individual stream to bear a close resemblance to that of the nearest mines; but this is not the case.* It is allowed that this is not generally the case, although it is sometimes observable. The tin, for instance, of the Wendron mines, of Huel Trumpet, Trevenen, Huel Ann, Trenethick Wood, &c., is amongst the purest in Cornwall, and closely resembles the stream tin of the neighbouring vallies. The ore of Pentuan stream also, according to Mr. Smith's account,* bears a close resemblance to that of the veins of Hensborough hill and its vicinity: on the other hand, a considerable part of the tin of Carnon stream, which is near the Gwennap mines, is of inferior quality, and not considered as grain tin.

* Geol. Trans. Vol. 4, page 407.

But supposing such a similarity were never discoverable, can it be supposed that, in the violence of the inundation which swept the tin from the hills, it was carried only to the nearest vallies? It would rather be carried in the direction of the overpowering current. There is good reason to suppose that most of the tin, which was thus swept from the northern parts of Cornwall, was conveyed to the vallies on the southern side of the county: this point I shall endeavour to illustrate hereafter, as it will be again alluded to.

IV. *The tin-ore of the streams is in a state of far greater purity than that of the veins, and is almost wholly used for grain tin, for which scarcely any tin-ore from veins is fit: indeed grain tin cannot be made from the best tin-ore from veins, unless the latter is mixed with a large proportion of stream tin-ore.* This is perfectly correct; but what is the principal cause of the deterioration of the quality of the vein tin? Doubtless its connection with other metallic minerals, such as oxide of iron, pyrites, sulphuret of copper, galena, wolfram, &c. Now as the whole mass, in its removal from its primary situation, must have been particularly open to decomposition, is it unreasonable to suppose that the sulphurets, and other combinations which are most liable to decomposition, were thus separated from the tin, whilst the oxides, which are least liable to it, still remain? The oxide of tin, as now found in streams, is generally free from all other metallic ores except oxide of iron.

V. *If the stream tin-ore came from veins, how is*

it that the ores of other metals, especially those of copper, lead, and zinc, so common in the veins of Cornwall, are not also found in streams? The answer to the last objection may have some reference to this also, as these ores are generally sulphurets; and in addition, may be stated the well known fact, that copper-ore rarely occurs so near to the surface as tin-ore, but is found far deeper in the veins; and, therefore, not so liable to have been swept away with the surface of the earth. Of lead-ore there is very little in Cornwall; and with respect to zinc-ore (blende), it frequently occurs in the upper parts of copper veins; and it is singular enough that some small fragments of it have been found in the Carnon stream: these, however, are of little consequence, for had none ever been met with, we might still suppose that all the sulphurets, whether of copper, lead, or zinc, had been long since decomposed.

VI. *Tin is frequently found in veins in a different earthy or stony matrix from that in which it commonly occurs in streams.* This objection is scarcely worthy of notice. The principal vein-stone of tin is quartz, and with this stone, tin is generally connected in streams: stream tin (especially the toad's-eye tin) is also often found in shorl-rock, which is so common in the granite country, both in beds and in veins, that it has been considered by some as a variety of granite:* it is particularly common at, or near, the junctions of the granite and slate. In the parishes of St. Austell and Roach, there are large tracts of

* Vol. 2, page 249.

shorl-rock intersected by tin veins, and also veins of shorl-rock containing tin, intersecting the granite, as in Carclase mine. The principal vein-stone besides these is chlorite; but this earth being much more susceptible of decomposition than quartz or shorl-rock, it is not surprizing that so little of it has been found in streams.

VII. *Native gold is frequently found in streams; but has never occurred in veins.* This objection is frequently urged, but with less reason than some of the others: the intention of it seems to be to infer that because no veins of gold have ever been discovered, nor has it been found in the veins of any other metal, it must, therefore, exist independently of veins, and if so, tin may also exist in the same way; it is, however, so far from being certain that the gold found in Cornwall is not the product of veins, that the contrary is by far the most probable; for, in the first place, no gold worthy of notice has ever been found in the western part of Cornwall: there are tin-streams in the parishes of St. Paul, St. Buryan, Sancreet, St. Just, and Madron; but I have never seen a grain of gold from any of them, nor am I aware that any has ever been found, unless,* perhaps, a few minute particles unworthy of attention. In Carnon stream, which may be called, from its situation, one of the central stream-works, a small quantity has been found; but the principal part has been discovered in the eastern stream-works of

* I must except a traditional account of a stream in St. Just, in which a minute quantity is said to have been found.

the parishes of Ladock, St. Stephens, Luxullian, &c. ; we may, therefore, infer that the source of the gold is in the eastern part of the tin district of Cornwall. 2nd. Gold has been frequently found in streams *in*, and attached to, the matrix, generally quartz : I have seen several specimens of this kind : now in the case of any other metal common to Cornwall, the quartz would be without hesitation considered a vein-stone. 3rd. It has been stated, in a former communication to the society,* that in a stream-work, in the parish of Ladock, the gold is not found north of a certain line. All these circumstances render it probable, that a vein which contains gold exists somewhere in that vicinity, although it has never been discovered : this is now rendered more probable by the late discovery of so many varieties of stream tin in the vein of the Garth mine, which had never before occurred in veins.

I am not aware that any other facts or arguments, of any consequence, have been adduced against the probability of the stream tin having been derived from veins. A few facts may be mentioned which are strongly in favour of it, or which prove, at least, that the present situation of stream tin was not its original one. 1st. The situation of tin-ore in streams generally bears some relation to the width of the valley, and also to its rapid, or gentle, descent. In those parts of a valley which may be termed the *gorges*, where the hills, or the rocks, on each side, come so close as to leave but a narrow passage, there

* Vol. 1, page 236.

is seldom much tin-ore found: the currents were probably too violent to permit it to settle there. Where the descent of a valley is rapid, the whole of the tin-ore is usually found lying immediately on the *shelf*; but where it is gentle, the bed of the tin-ground is generally thicker, but not so good, as the ore is mixed up with diluvial matter; and where it is very small, the tin-ore has been found mingled with the whole diluvial mass, even within two or three feet of the surface. Chyvenhall stream-work, in St. Paul, furnishes an instance of the latter.

2nd. The spot which is esteemed most favourable to the existence of stream tin, is just at the point where one valley opens into another, at a pretty large angle: the probability is, that the progress of the currents coming down the vallies was rendered less rapid by their contact, and that, in consequence, a portion of the tin-ore settled at the point of contact.

3rd. Stream tin is often found connected with the matrix, or (as a miner would say, if he were shewn a specimen, without being aware that it came from a stream) with its vein-stone.

4th. There is a great dissimilarity in the stream tin of different districts, especially in the wood-tin: that of the St. Paul streams, for instance, bears little resemblance to that of the streams of St. Stephens or Luxullian: my inference is, that the ores came from different veins.

The peculiar situation in which nearly all the stream tin of Cornwall is found, compared with the localities of the most productive tin-veins, is highly illustrative of the direction in which the

current of the deluge swept over the surface. All the productive streams are in vallies, which open to the sea on the southern side of the Cornish peninsula; whilst most of the richest veins* are situated near the northern coast, where all the vallies open towards the north: most of those vallies have been explored; but, although small portions of tin have been found in many of them, no extensive beds have ever been discovered. The mines, for instance, of the parishes of Lelant, Gwinear, Camborne, Illogan, St. Agnes, and Perran-zabuloe, are all near the northern coast, but there are no productive streams in any of those parishes: on the southern side, however, are the streams of Perran-arworthal, Ladock, St. Stephens, Roach, St. Austell, Luxullian, &c. Now on looking at the direction which the streams bear from the mines, it will appear most probable that the course of the current, which swept the tin from its original situation, must have been from north to south, or rather from N.N.W. to S.S.E. The circumstance, already mentioned, of the gold in Ladock not being found north of a certain line, is also in favour of this fact. The same circumstance has occurred in Trethurgy moor, near St. Austell, with respect to wood-tin: it has been traced to a particular part of the moor, where it ceases to occur.† The Garth mine, which I have here described, and the stream-works in its vicinity, furnish a striking illustration of the same fact. About

* Those which are nearer the south coast, are, however, generally situated north of the streams.

† Vol. 1, page 239.

a mile north-west from the mine, and in the valley immediately below it, is the stream-work of Drift moor ; but neither there, nor in any stream-works further north, has any wood-tin been found, nor scarcely any tin-stones similar to those which have occurred in the mine ; but if we cross to the opposite side, we shall find, from one to two miles southward from the mine, the stream-works of Chyvenhall, Clija moor, and Kerris, in which we meet with the wood-tin, the contemporaneous tin veins, and the tin investing the quartz crystals. I possess specimens of each variety from Chyvenhall stream, which closely resemble those from the Garth mine.