II. *A Description of the Red Oxyd of Copper, the production of Cornwall, and of the Varieties in the form of its Crystal, with Observations on the Lodes which principally produced it; and on the Crystallization of the arseniated Iron.*

By William Phillips, Member of the Geological Society.

The Mine called Huel Gorland, in the parish of Gwennap and county of Cornwall, is in a hill whereon is situated the town of St. Day, to which it is immediately contiguous eastward. In this mine there are seven lodes; one of tin, the others of copper; but as only three of the latter have produced the red oxyd of copper, it will not be important further to notice the others. These three lodes are known by the names of the North Lode, the Great Gossan Lode, and the Muttrell Lode. The latter, is that noticed by the Count de Bournon, as having produced the arseniate of copper, in a paper published in the Transactions of the Royal Society, in which he has so ably and scientifically described that mineral.

In the North Lode which runs eighty fathoms north of the Great Gossan Lode, the red oxyd of copper was occasionally found with fluate of lime; though, compared with the quantities produced by the other two lodes, very sparingly.

The Great Gossan Lode averages about four feet in width; the Muttrell Lode about three feet. The former runs eight degrees from the north of the west, meeting the latter, which runs four degrees from
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the south of the west, at a certain point, whence they run together for about fifty fathoms. The united lode is about twelve feet wide, and takes a direction nearly east. The underlay* of these lodes is north; the Great Gossan Lode about two feet, the Muttrell Lode one foot ten inches, and the united lode one foot nine inches, in the fathom. The two lodes are about thirty-seven fathoms apart at fifty fathoms west of the point where they meet; from which place they have been worked, respectively, the Great Gossan Lode about two hundred and thirty fathoms, and the Muttrell Lode seventy fathoms, at the adit level.† They afterwards run on together about forty fathoms in Huel Gorland mine, and further east form a valuable part of the rich and extensive mine called Huel Unity. Huel Gorland is in granite.

In that part of the mine where the two lodes are separate, the adit is fifty fathoms from the surface, but after they have run together some distance, it is only forty fathoms, the descent of the hill being towards the east. The adit being nearer on a level than the surface of the country, it is, therefore, in noticing the depths of different parts of a mine, most correct to date from the adit level, as is the practice of miners. The depths hereafter given are so dated.

In the two lodes, the red oxyd of copper was found under very different circumstances. In the Great Gossan Lode it occurred

* The generality of the lodes in Cornwall run nearly east and west; their downward direction is not quite perpendicular, but generally more or less inclining to the north or south. This inclination is called the underlay of the lode.

† It is the first object of a miner, in the working of a mine, to drive a passage or adit from the nearest low ground or valley to meet the shaft, for the purpose of conveying off the water, which is raised to the adit level by the means of the steam engine. It will therefore be obvious that the depth of the adit from the surface of the mine, must depend on the height of the ground in which the mine is, and the depth of the neighbouring valley.
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principally between the sixty-six and eighty-six fathom levels, in considerable quantity, often in well-defined crystals, and occasionally intermingled with native copper. Above it, the lode abounded with fluuate of lime, frequently very solid, and so pure, that they, whose business it is to assay copper for the miner and the purchaser, preferred it as a flux to that of any other mine. Among this fluuate of lime, and sometimes intimately mingled with it, considerable quantities of the yellow copper ore were found, and some arsenical pyrites containing 4 or 5 per cent. of copper, though comparatively little of that gossan, which, as will presently be noted, constituted the greater part of the Muttrell Lode; nor was the arseniate of copper discovered in any part of this lode, west of the junction of it with the Muttrell Lode.

The Muttrell Lode is one, to which no other lode hitherto discovered in the County of Cornwall bears any analogy. Throughout almost the whole length of its working, but particularly in that part, above, below, and in which was discovered the great deposit of red oxyd of copper, with the beautiful varieties of which this mine has enriched the cabinet of the mineralogist, this lode abounded in an ochreous substance, frequently accompanied by quartz, which from its appearance may be termed an argillaceous oxyd of iron; and which, sometimes for a considerable length and depth, constituted alone the great body of the lode. This substance is always considered by the miner as an indication of neighbouring riches; it is technically called gossan, and is denominated kindly, or very kindly, in proportion to the darkness of its hue, and the looseness of its texture. Through this gossan they sunk in the Muttrell Lode forty-six fathoms, and almost as many above the adit, before they arrived at any considerable quantity of the red oxyd of copper, which afterwards continued through a space ten fathoms in depth,
and about six fathoms in length; being disposed in bunches, the largest and richest of which were about fifteen feet in length, by as many in depth.

In this lode, the red oxyd of copper was accompanied occasionally by vitreous copper ore, black oxyd of copper, arseniate of copper, arsenical pyrites, quartz, and fluate of lime. Native copper also occurred in considerable quantities, generally in contact with the red oxyd, and more or less intermingled with it. It was sometimes remarkably brilliant, and occasionally occurred regularly crystallized. There were however considerable masses of the red oxyd unaccompanied by any of the above substances, hollow within, and presenting, on being broken, perfect and varied crystallizations. From the depth of fifty-six fathoms, the search for this mineral was continued for forty fathoms lower, with but little success; bunches of a few tons in weight, and smaller quantities were occasionally discovered, but these became less frequent; so that, at ninety-six fathoms under the adit, the further working of this lode was abandoned. At this depth one part of the vein consisted only of gossan, and was six feet in width, forty fathoms from which it narrowed to three feet, and was there composed of yellow copper ore and quartz.

Further east than the principal body of the red oxyd of copper, and at different depths in the Muttrell Lode; that is, nearer the junction of it with the Great Gossan Lode, were found the interesting varieties of the arseniate of copper, and occasionally that substance which in the paper before alluded to has been described by the Count de Bourron, and by him called Cupreous Arseniate of Iron. These substances were also found in considerable abundance at the line of junction of the two lodes, and in its immediate neighbourhood eastward, at various depths, but with scarcely a trace of the red oxyd of copper until the depth of fifty-six fathoms, at which,
place this mineral also was found in the Gossan before described, occasionally intermingled with arseniate of copper. The latter occurred, besides, in great abundance in the same lode in Huel Unity; indeed, I believe it is to that part of the united lodes which passes through this mine, that mineralogists are chiefly indebted for the fine varieties of the arseniate of copper.

That beautiful mineral, the cubic arseniate of iron, was also found at and near the junction of the Great Gossan and Muttrell Lodes; but occurred in greatest quantity in the latter, thirty fathoms west of the junction, about the adit level; being forty-six fathoms higher, though perhaps not immediately above the part in which the first discovery of the red oxyd took place. The cubic arseniate of iron was also found in the Gossan before described.

Since the publication in the Philosophical Transactions of the paper by the Count de Bournon, containing a description of this mineral, I have obtained some varieties in the form of its crystal, not described in that paper. In addition to the perfect cube (fig. 1.) and that modification of it, by which four of its solid angles are replaced by an equal number of equilateral triangular planes (fig. 2.) as described by the Count de Bournon, I possess some in which each angle so modified has received an additional modification, by three triangular planes placed on the edges, and inclining to the axis of the crystal. This variety however rarely occurs in the perfection in which it is represented by fig. 3. for, generally, the two modifications are so blended together, as to give a roundness to the whole as in fig. 4: I possess also others in which the edges of the cube are replaced by planes (fig. 5.); others in which the modifications described in figs. 3 and 5 are combined, as in fig. 6: others again, where the same modifications occur, but in which each of those angles that are not replaced by the two modifications as in fig. 3.
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are replaced by three triangular planes as shown in fig. 7. I have also others which have the edges replaced, and in which each of the angles is also replaced by both modifications (fig. 8.) The crystals above described vary in colour from light and almost transparent green, to dark green, sometimes having a brownish tinge; others are of a resinous appearance and are almost transparent. It may be remarked that the crystals of this substance are generally more or less, though not regularly striated on the surface, and that the striæ constantly take the directions described in fig. 2: they do not however admit of a fracture in that direction, nor have I satisfactorily obtained it in the direction of the faces of the cube. Some crystals of a dull green colour, on being broken, have been found to enclose other cubes of a darker colour, and iridescent on the surface. I have to regret the impossibility of giving the admeasurements of the various angles formed by the modifications and varieties of the crystal of the arseniate of iron, on account of their minuteness.

Description of the red Oxyd of Copper.

This substance, which during the last ten years, has been found in Cornwall in great abundance, was previously of very sparing occurrence in that county. I am not aware of its having been mentioned as a production of that district, by any foreign mineralogist, until very lately: even the celebrated Haüy has not quoted it in his Traité de Minéralogie as a Cornish mineral. Many cabinets however now abound with it. Previously to the labours of Mr. Chenevix on this substance its composition was by no means well understood. From the analysis by that able chemist it appears to contain copper 88.5, oxygen 11.5, and is therefore a sub-oxide of copper, and "exists in a state hitherto unknown in nature." In reference, doubt-
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less, to that analysis, it has been called by Brongniart, Cuivre oxidulé.

The colour of this mineral varies from carmine red to metallic grey, occasionally inclining to black.

Its lustre is considerable—very considerable in the more translucent crystals.

It is not very brittle.
It easily cuts calcareous spar, but will not scratch fluor spar.
It gives, when rubbed on paper, a slight red streak.
It emits no smell when rubbed.
When powdered it is of a brick-red colour.
It emits in that state no light when thrown on a hot iron.
Its specific gravity is 5.6.
It is soluble with effervescence in nitric acid, to which it imparts a greenish tinge.

The fracture of the crystals, particularly of the more translucent ones, is very smooth and inclines to conchoidal; but is frequently uneven, and inclining to shattery, in those of a darker hue. I have met with some octohedrons that admitted a fracture in the direction of their faces, but have not found any of a cubical form in which a division parallel to the circumscribing planes was practicable.

The form of the primitive crystal, according to Haüy, is the regular octohedron (fig. 1.) and of the integrant molecule, the regular tetrahedron.

The crystals of this substance are mostly well defined, but do not in general exceed a line in length. The largest in my collection is nearly half an inch; I have seen others somewhat larger. They are however frequently so small, as to appear to the naked eye a mere point, but by the assistance of the lens, the perfection of their geometrical forms may easily be discovered: a perfection rarely
observable in the larger crystals. They are generally of a considerable external lustre, occasionally approaching to metallic; and are sometimes, though rarely, iridescent on the surface. In some of the most recent specimens afforded by Huel Gorland, the crystals exhibit a singular external brilliancy, occasioned, apparently, by a deposition, after the formation of the crystal, of small thin facets which cannot be detached by the knife, of the same form as the faces of the crystal itself. The crystals of this substance are mostly aggregated, and frequently confusedly grouped; it is by no means common to find one in which all the solid angles are disengaged. A singular variety was found in small quantities in Huel Jewell mine, of a dark red colour and remarkable lustre, in hollow octahedrons, formed by very minute crystals, each arranged in the same direction, and attached at the solid angle. This variety is sometimes accompanied by uranium in small tabular crystals of a light green colour.

The compact red oxyd of copper, usually denominated tile ore, which by Brongniart is called Cuivre oxidulé ferrifère, has been found in several mines in Cornwall. In Huel Gorland, this red oxyd often occurred massive, sometimes with portions of native copper passing through it; and in this state, as well as when crystallized, passing into black oxyd. Crystals were frequently found deposited on native copper, the irregular crystallizations of which formed, as it were, the nuclei of the superimposed crystals; and these were generally varieties, the primitive form being rarely found so circumstanced. Crystals also occasionally enclose minute portions of native copper.

Specimens of this substance occur, consisting almost wholly of a pure mass of aggregated crystals; it is however usually accompanied by quartz, and occasionally by a compact and very hard substance, apparently composed of quartz, in intimate mixture with the Gossan before described. It has also been found with fluor spar in Huel
Jewell; in chlorite, and in brown and almost pulverulent mica in Huel Gorland. The crystals enclosed in the latter substance, it may be observed, are always of remarkable brilliancy and in well defined varieties. In the latter mine it also occurred with blue and green carbonate of copper; with fibrous arseniate of copper; in cubes with the green cubic arseniate of iron; with mispickel and pyrites. I possess one specimen from Cornwall, but from what mine is uncertain, in which it is accompanied by vitreous and yellow copper. It has been found in capillary crystals in Huel Gorland, Carharack and Tol Carn mines; in the latter in recomposed granite though but very sparingly. I have one specimen from Tin Croft mine, in which the red oxyd is intermingled with native copper, and with jasper of a fine red colour.

There are perhaps but few minerals that exhibit so many beautiful and regular forms, although the modifications of its primitive crystal, hitherto noticed, are only six in number. Of these forms, four have been given by Haüy, which, with two or three delineated by Sowerby in his British Mineralogy, constitute the whole of what has been published relative to the crystallographical history of this interesting substance. My own attention has been particularly directed to this subject, by the possession of a large collection of specimens, chiefly from Huel Gorland mine; from which have been selected the principal varieties in the form of the crystal, which are here presented in a regular series. The number of these will doubtless be increased by future research. It does not seem requisite to offer detailed remarks on each individual crystal; it will suffice to make some occasional observations, and to note some peculiarities that might not be perfectly intelligible by the assistance of the figures alone.
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The primitive Crystal and its varieties.

Fig. 1 is the primitive crystal; the angle formed by the meeting of the two faces PP has been ascertained by Haüy to be 109d. 28' 16". Fig. 2 is the result of a * decrease on one face of the upper, and on the opposed face of the lower pyramid. This crystal has aptly been called the segment of the octahedron, as the explanatory fig. 3, will evince. Fig. 4 is the primitive crystal elongated; this elongation arises, as is obvious, from a regular increase of the crystalline laminae on one face of the upper pyramid, and on that face of the lower to which it is united at their common base. Fig. 5, is the same occurring in capillary crystals. Fig. 6 differs from fig. 4 in the upper pyramid only; on the already increased face of which, a still further increase of laminae has taken place, as well as a similar deposition on the opposite face of the same pyramid. Fig. 7 is produced by an increase on one face of the upper, and on one face of the lower pyramid of fig. 4, as will be obvious on consulting fig. 8. Fig. 9 is the consequence of an increase on two opposed faces of the upper, and on the other two opposed faces of the lower pyramid of the primitive crystal, as will be seen by fig. 10. Fig. 11 is the result.

* In the present imperfect state of mineralogical language, it is difficult on every occasion to find terms by which even facts can be accurately defined. For instance, in that modification of the octahedron, where the solid angle is wanting, and which though differing in form from the primitive Crystal, can scarcely be called an imperfection in crystallization, there is no term in use justly descriptive of the fact. The terms truncation and decrease are obviously inaccurate. I have used the latter as perhaps the least exceptionable. It is with deference to the opinions of the Count de Bournon, I venture to observe that the term retrogradation lately adopted by him seems equally objectionable with either of the preceding.
of an arrangement that may not be allowed strictly to come within
the meaning of the term *macle*, in the sense in which it is used by
Romé de l'Isle, being simply two crystals of the last variety, uniting
by one of the four hexagonal faces of each crystal, so as to form in
appearance but a single crystal. I possess also another, in which
two crystals of the succeeding variety are in like manner attached.

Fig. 12 is a highly interesting variety of the primitive crystal, as
it forms the passage of it, as fig. 13 will shew, into the acute rhom­
boid, fig. 15, of which fig. 14 is the intermediary stage. This
rhomboid, I have not, from the minuteness of the crystals, which,
though numerous, exceed not in size the extremity of the smallest
pin, been able to submit to the goniometer. This form also exists in
the Spinelle ruby and in the diamond; which, as well as the red
oxyd of copper, have for their primitive form, the regular octohedron,
and give an acute rhomboid of 60° and 120°.

THE FIRST MODIFICATION.

This modification consists in a decrease on the six solid angles of
the primitive crystal, so that each is replaced by an equilateral quad­
rangular plane, perpendicular to the axis that passes through the
angle, and forms the passage of the octohedron into the cube. The
angle caused by the meeting of the faces P and I, Fig. 16, is,
according to Haiiy, 125°, 15°, 52°. Fig. 24 shews the direction of
the laminæ of the cube. Fig. 25 may rather be considered an acci­
dental circumstance, than as forming an important part of this series.
That the triangular face formed by the decrease of crystalline lami­
æ on the solid angle of the cube (fig. 24;) corresponds with the face
P of the primitive crystal will be obvious. I could not therefore
hesitate to delineate this interesting combination, of which several
instances occurred on the same specimen. Fig. 29 represents the
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cube in capillary crystals, of which I possess a specimen from Tol Carn mine, in recomposed granite, and of the most lively carmine colour. Fig. 32 is an octohedron formed of minute cubes, of which there are several on the same specimen. Fig. 33 shews the passage of the cube into the rhomboidal dodecahedron by the deposition of the cubic facets, progressively diminishing in size, on each face of the cube. This interesting crystal at first excited the suspicion that the cube is the primitive form of the red oxyd, which abated on reflecting that the octohedron will admit a fracture in the direction of its faces, and that the cube will not, as has been already noticed: the direction of the laminæ in both cases is shewn by figs. 24 and 37. These circumstances indeed prove the octohedron to be the form of the primitive crystal.

Second Modification.

This modification arises from a decrease along the edges of the primitive crystal, which replaces each by a plane perpendicular to the axis that passes through the middle of the edges. It shews the passage of the primitive form into the rhomboidal dodecaedron. The angle formed by the meeting of the face P with the plane 2, Fig. 34, is 144d. 44', 8" as given by Haüy. The striæ on fig. 37, which shews the passage of the primitive form into the rhomboidal dodecaedron, denote the direction of the laminæ. In fig. 41, which resembles in its general form the crystallization of the oxyd of tin, the decrease on the edges formed by the meeting of the two pyramids is so considerable, as to give the shape of a parallelogram to the four planes which replace the four solid angles, also formed by the meeting of the two pyramids.
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THIRD MODIFICATION.

This modification is the result of a decrease on each of the solid angles of the octohedron, and on its edges, which replaces each of the solid angles by four planes inclined on the axis, and placed on the edges of the octohedron.

Fig. 61, which represents this modification uncombined with any other, is here delineated in order to shew it in that state, but I have not so seen it. It is however probable that it may hereafter be discovered.

This modification is extremely rare. The crystals on which I have hitherto observed it scarcely exceed half a line in length. It is perhaps, therefore, impossible to determine with accuracy the admeasurement of the angles.

FOURTH MODIFICATION.

This modification is the result of a decrease along the edges of the octohedron, as well as the second modification, but with this difference, that, in this, each edge is replaced by two planes inclined on the axis passing through the middle of the edge (fig. 64.)

The planes 4, 4, on fig. 67, may be considered as resulting from an after-deposition of those planes on a crystal formed as fig. 39. I possess a specimen on which there are many of these singular crystals. This species of deposition may frequently be observed. I have repeatedly noticed it on the plane 2 of fig. 39, not exceeding one half the length or breadth of the plane; and again, in distinct laminæ so disposed as to produce a triangular pyramid on each face of the primitive crystal, which respectively formed the base, as in the instance of fig. 70, but much more acute.
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Fifth Modification.

This interesting modification is found in combination with each of the preceding, but is rarely seen displayed by itself on the primitive crystal as in fig. 74. It arises from a decrease of the crystalline laminae on that part of each face forming the solid angle, by which each is replaced by an obtuse quadrilateral pyramid; the faces of which incline on the axis that passes through the angles. The angle formed by the meeting of P and S is about 160°, and of T on S about 144°.*

Fig. 78 seems to be the result of a partial after-deposition on the faces of the primitive crystal, by which each face of it (such parts of them excepted as contribute to form the solid angle,) is brought in form to resemble fig. 77, except only that in this the solid angles of the primitive crystal remain.

It may perhaps be imagined that some of the latter figures in the series of this modification, exhibiting its combination with some of the preceding modifications might have been omitted; but as the term variety is used to signify combination of two or more modifications, as well as those differences in crystals which arise from the various proportions of the faces to each other, by which variations in the form of the face are produced; and as each of these differs in one or more of these respects, and actually exists, it seemed proper not to omit them.

* There are other modifications, and their combinations delineated in the series of the crystallization of this substance, the angles of which it would have been desirable to have given; in most, if not all of which, it is, from their exceedingly small size, to be regretted that it would have been difficult, if not impossible, even for the most skilful and practised hand, to have subjected them to the goniometer.
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Sixth modification.

This modification is the result of a decrease, by which each solid angle is replaced by eight triangular planes, two on each face of the primitive crystal, and inclining on the axis that passes through the angles. Fig. 106; I have not seen this modification as thus described, but only, as in the following figures, in combination with other modifications. The crystal represented by fig. 108 contains all the modifications of the primitive crystal of this substance, which, I believe, have hitherto been noticed.
ARSENIADE OF IRON.
RED OXYD OF COPPER.

Primitive Crystal.

Fig. 1. Fig. 2. Fig. 3. Fig. 4. Fig. 5.

Fig. 6. Fig. 7. Fig. 8.

Fig. 9. Fig. 10. Fig. 11.

Fig. 12. Fig. 13. Fig. 14. Fig. 15.

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RED OXYD OF COPPER.

First Modification.
Fig. 28

Fig. 29

Fig. 30

Fig. 31

Fig. 32

Fig. 33

Second Modification.

Fig. 34

Fig. 35

Fig. 36

Fig. 37

Fig. 38

Fig. 39

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W. Lory, sculp.
Second Modification continued.
Fourth Modification.
RED OXYD OF COPPER.

Fifth Modification.
RED OXYD OF COPPER.

Fifth Modification continued.