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I.—*On some Cornish Tin-stones and Tin-capels.*

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First Paper.

THE tin ores ("cassiterite") for which Cornwall has so long been famous occur under the following conditions:—

1. As pebbles, rolled masses, or grains, in stanniferous gravels and sands (stream-tin.)

The detrital tin-ore of Cornwall may be grouped under the following heads:—

a. The tin pebbles and grains of the most ancient elevated quartz gravels, such as those of "Blue Pool," in Crowan, referred to by Mr. Tyack,* and of St Agnes Beacon, mentioned by Messrs. Kitto and Davies.†

b. The pebbles and grains of the "Head" of angular debris—the "overburden" of the china-clay districts. This is often found at elevations not only considerable in themselves, but relatively, as compared with the surrounding country. It differs as a whole from the quartz gravels just referred to, not only in being much less waterworn, but also in being generally much coarser, some of the fragments being very large. It occurs covering killas as well as granite. Grains of tin-ore are often found widely

* See *Trans. Roy. Geol. Soc. Corn.*, Vol. ix. p. 177.

† *Ibid.* p. 196.

distributed through the subsoil in the neighbourhood of tin veins, even where there is no "head" properly so-called. This may or may not be of the same age.

c. The ancient stanniferous valley gravels. These occur at all elevations up to nearly 700 feet, but always in situations which are relatively low, *i.e.*, in the immediate neighbourhood of ground at a greater elevation. These deposits are now almost entirely worked out,—they have often been described, most completely, however, by the late W. Jory Henwood.*

d. As a constituent of river-gravels and sea beaches now in process of formation. The tin-ore here referred to is generally in fine particles—often angular or sub-angular. Where it is the result of natural processes of denudation, and consequently produced with extreme slowness,—as on some of the isolated beaches near St. Agnes—it is very pure, but where it results from the more rapid operations of the miner, as in the bed and at the mouth of the noted "Red River" which divides the parish of Illogan from Camborne, it is extremely impure from the presence of pyrites, mispickel, wolfram, chalcopyrite, and other more or less readily decomposable minerals. These impurities no doubt existed to some extent in the veins from which all stream-tin appears to have been derived, but have been removed gradually by natural chemical as well as mechanical processes.

2. As the filling of definite fissures traversing granite, slate ("killas") porphyry ("elvan"), and other rocks; usually in a distinctly crystalline condition. The so-called "leaders" of most of the tin lodes of the county are such deposits.

The fissure-deposits properly so-called have been well described by Henwood, Foster, and others.†

3. As the filling of minor joints, fissures, and shrinkage cracks in such rocks, also generally in a crystalline condition. Minute fissures so filled are observable in almost all sections of tin-stones. When such tin-filled joints are numerous, we have the so-called "stockworks" of the county.§

The stockwork deposits are less known than the fissure deposits proper, but they occur in many localities both in granite and killas. *Fig.* 1, pl. 1 represents a fragment of killas from such a deposit at Minear Downs, near St. Austell.

4. As the cementing material of conglomerates and breccias

* "Observations on the detrital tin-ore of Cornwall." *Journ. Roy. Inst. Corn.*, No. xi., 1874.

† See *Trans. Roy. Geol. Soc. Corn.* Especially Vols. v., viii., and ix.

§ Some of these stockworks are described by Dr. C. Le Neve Foster in the *Quart. Jour. Geol. Soc.*, Aug. 1878, *p.* 654.

occupying fissures. Such deposits have been observed at Wheal Fortune, near Marazion; Perran Downs, near St. Hilary; Relistian in Gwinear; and more recently on what is believed to be the same lode as this latter at New Rosewarne Mine in the same parish.

At Relistian rounded pebbles of a dark green chloritic schist several inches across occurred, cemented together by a mixture of oxide of tin, chalcopyrite, and quartz sometimes amorphous, but usually more or less crystallized. A fine specimen of this conglomerate, now in the Museum of the Royal Institution of Cornwall, is represented in fig. 2, pl. 1.

At New Rosewarne Mine Dr. Foster* distinguishes six periods in the formation of the deposit as follows:—

I. Formation of an open crack or fissure into which fragments of the walls fell, and a few pebbles from above.

II. These fragments were cemented together forming a killas-breccia.

III. The crack re-opened; fragments of the already formed breccia fell in from the walls, together with very great quantities of killas and a number of rounded pebbles.

IV. This confused mass of fragments was cemented into a solid mass by having quartz, tin-stone, mispickel, and chlorite deposited around the pieces.

V. Crack re-opened on the south side.

VI. Copper ore was deposited and sent small veins into the already existing tin lode.

Dr. Foster considers that the cementing materials were introduced in the following order or nearly so.

1. Quartz
2. Tinstone
3. Mispickel
4. Chlorite
5. Pearl-spar, calc-spar, chalcedony, iron pyrites and copper ore.

5. As a constituent of ancient breccias occupying fissures, as at Prideaux Wood Mine.

6. As a minor constituent of granite, elvan, schorl-rock, tourmaline-schist, and "capel," mostly in tolerably distinct crystals.

* *Report Miner's Assoc. of Cornwall and Devon*, 1866, p. 26.

The remarkably rich deposits at East Wheal Lovell * and Rock Hill, † the celebrated "Carbonas" of the St. Ives district.‡ and the numerous apparently isolated nests of tin crystals met with in decomposed granite may be mentioned in this connexion.

7. As pseudomorphic replacements of felspar, schorl, quartz, and occasionally other minerals—in granite, elvan, or capel.

Many of these have been observed at Rock Hill,‖ Belowda Hill,§ and numerous other localities, the crystals being replaced sometimes by cassiterite alone, sometimes by a mixture of cassiterite and schorl.

8. As a pseudomorphic replacement of organic structures.

Fragments of deer's horns impregnated with oxide of tin from the Carnon Valley are now in the Museum of the Royal Geological Society of Cornwall, at Penzance, in the British Museum, and in a private collection at Lostwithiel. These horns will be further referred to hereafter.

Setting aside the stream-tin, which is of course derived from the degradation of pre-existent rocks, the fissure and joint deposits (2 to 5) and the pseudomorphic replacements (7 and 8) are evidently due to stanniferous solutions, and few will doubt that the tin which occurs as a minor rock-constituent (6) is also due to the passage of such solutions through the rock. On this point more will be said hereafter.

The "capel" above referred to is simply an altered band of country, whether granite or slate, occurring in the immediate neighbourhood of most of the fissures which contain oxide of tin. So long as it contains enough tin to pay for working it is regarded as part of the lode by the miners, when it ceases to contain tin or contains so little that it will not pay to work, it is called capel and regarded as "country." It is therefore impossible to separate tin ore from tin capel in any scientific sense.

The workable capel is often many times wider than the original fissure or lode proper. Fine examples of these tin-bearing capels occur at Dolcoath, Tincroft, and other mines near Camborne.¶

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* Foster, *Trans. Roy. Geol. Soc. Corn.* ix. p. 167.

† Collins. "Notes on the Rocks and Goonbarrow Mines." *Rep. Miner's Assoc. of Cornwall and Devon*, 1873, p. 66.

‡ Henwood. *Trans. Roy. Geol. Soc. Corn.*. Vol. v.

‖ Collins, "Notes on the Rocks and Goonbarrow Mines" cited above.

§ Foster, "Notes on Belowda Hill Mine," *Journ. Roy. Inst. Corn.*, xvii., 213.

¶ In a recent paper read to the Geological Society of London, our Foreign Secretary Dr. C. Le Neve Foster has described in considerable detail one of the most important lodes in Cornwall, the so-called "flat-lode" which lies on the south side of Carn Brea Hill, near Redruth. This lode has been worked to a great depth in a series of adjoining mines, and for a length of several miles. For a part of that distance it occurs between the granite and killas, but in some places it is bounded by granite, and in others by killas on both sides; the lode although variable in direction (bearing) and slope

Three distinct modifications of Cassiterite have long been known, and of each there are several varieties which have received distinct names. The three kinds are—

a. Crystallized (Diamond Tin, Sparable Tin, Rosin Tin.)

b. Fibrous and Radiated (Wood Tin, Toad's Eye Tin, Shot Tin.)

c. Pseudomorphous (after felspar, quartz, schorl.)

All three kinds occur in stream-tin, and in well known subterranean deposits.

The crystallization of Cassiterite was long ago worked out with great minuteness by Wm. Phillips, in a memoir presented to the Geological Society and illustrated by no fewer than 235 figures of crystals. Mr. Phillips calls attention to a very important fact which is still as suggestive and almost as puzzling as it was in his time, viz., that certain combinations of forms are characteristic of certain deposits, remarking that "entire veins seem to be productive principally of the same varieties; of this fact he gives several remarkable and striking examples."*

I would also mention an elaborate memoir on the crystallization of Cassiterite, by F. Becke, which appeared in 1877, in Tschermak's Mittheilungen, † in which the author endeavours to shew that three

(underlie) being more nearly in a plane than the actual junction of the two rocks. The actual fissure appears everywhere to have been small, rarely more than two feet wide and often only a few inches—or even a mere joint. The fissure must have been actually open for some time as it is more or less completely filled with a sort of breccia, formed of pieces of the containing rocks cemented together by quartz, oxide of iron, oxide of tin and other minerals. The country is highly silicified, sometimes on one side, but often on both sides of the fissure or lode proper, and thereby converted into what the miners term capel. In some parts, especially near the fissure proper—the capel contains enough tin to pay for working, when it is regarded by the miners as part of the lode and worked as such.

The capel, whether originally granite or killas has now pretty much the same appearance—indeed the only observable difference usually is that the altered killas retains some of its original lamination, while the altered granite has no such lamination. [See fig. 5 pl. iv. Tresavean, and fig. 3, pl. ii. Penhalls.

The following figures from Dr. Foster's paper will shew the importance of this lod from a miner's point of view.

	Tin Stuff. Tons.	Clean Tin Ore. Tons.
Wheal Uny, in 1876 produced ...	17702	349
South Carn Brea	2040	30
West Basset	29144	618
West Wheal Frances	6652	123
South Condurrow	19421	588
Wheal Grenville	8500	138
Total	83459	1846

The average produce was 2¼ per cent. of clean tin ore (black tin). The above was more than one-eighth of the total production of tin ore in Cornwall, in 1876. (See further, Foster on the Great Flat Lode, Quart. Journ. Geol. Soc., Aug. 1878.)

* *Trans. Geol. Soc.* Vol. 2.

† *Min. Mitt.* 1877, p. 244.

distinct types of form-combination characterise the crystals of Saxony and Bohemia, Cornwall, and Pitkaranda respectively. The author does not, however appear to have seen the elaborate memoir of W. Phillips referred to above.

Crystallized Tin proper is always more or less transparent, thin splinters invariably allowing a large proportion of light to pass. It is occasionally nearly colourless, but generally exhibits various shades of brown, from brownish-yellow to nearly black. Under the microscope in thin sections it always exhibits a peculiar granular appearance somewhat like that observable in olivine. The purest crystals are dark with polarized light and crossed prisms, but generally even well-formed crystals exhibit bright sparkling granules due to minute particles of entangled quartz.*

Cassiterite is distinctly dichroic, but usually very slightly so.†

Large crystals are occasionally found lying loose in the vein as in the case of the fine macles formerly found at Seal-Hole Mine, and the unique curved crystals found at Wheal Fanny; both figured by Phillips in the before-mentioned memoir.

A variety which occurred in the lode at St. Austell Consols a few years since, at a depth of 15 fathoms below the adit, consisted of a mass of amorphous cassiterite covered thickly with minute acicular crystals, the latter evidently a secondary formation.

Wood Tin. This is so called because of the resemblance of its fibrous-radiated structure to that of exogenous wood; it was long supposed to be peculiar to the stanniferous gravels (stream tin), but its occurrence in the lode at Wheal Providence, near St. Columb, in masses of about a pound weight, near the beginning of the present century, was reported to the Royal Geological Society of Cornwall, by Mr. Ashurst Majendie, in the year 1818,‡ since then it has been found at Polberrow Consols, Blue Hills,

* Analyses of crystals of Cassiterite almost invariably reveal the presence of small proportions of silica.

† "The optical properties of tin-stone do not appear to have been investigated since Brewster's time; at least Des Cloizeaux who places tin-stone among the uniaxial and positive substances refers to Brewster (*Ann. des Mines*, 1857, p. 300), as his authority. For investigating the optical properties, a section was used cut at right angles to the principal axis of one of the individuals of a twin crystal from Schlackenwald, whose intercalated twinned lamellæ also permitted an investigation as to dichroism. In the polarizing microscope by white light a dark washed-out cross was seen, without, however any indication of coloured rings, although the plate (or slice) was 1*mm* thick. By using a plate of biaxial mica the cross was resolved into two hyperbolas, the major axes of which were at right angles to the principal optical section of the mica plate.

The twin-lamellæ, which as might be expected (selbstverstandlich), shewed no cross in the polarizing microscope, were examined with Haidinger's dichroiscope and appeared very slightly dichroic. The two images shewed a difference of tint in the brown which was scarcely observable,—one was dark brown with a touch of reddish-brown, the other was slightly duller with a somewhat greenish sheen." F. Becke, in Tschermak's *Min. Mitt.*, 1877.

‡ Trans. Roy. Geol. Soc. Cornwall, Vol. 1, p. 237.

Penhalls, Wheal Coates, Wheal Coit, and Wheal Trevaunance, all in the parish of St. Agnes; at several mines in Gwinear and Sancreed parishes; and notably in the 162 fathom level at Wheal Vor, in the year 1866.* At this latter mine it occurred in large kidney-shaped masses, associated with crystallized cassiterite and quartz in a part of the Wheal Metal lode six feet wide and worth fully £600 per fathom. The wood-tin occurred mixed up with ordinary crystallized tin-stone together with much chlorite, chalcedony, dolomite, felspar, and pyrites.

A very remarkable occurrence of Wood Tin was met with at Prideaux Wood Mine, many years since in a kind of conglomerate of grains and crystals of quartz cemented together by yellow copper ore and oxide of iron. In this complex mass were embedded fractured segments of globular concretions of wood tin originally from one inch to four inches diameter. These shew a well-marked concentric and radiated structure, the former being indicated by bands of alternate dark and light brown tint. Altogether they much resemble the kind of limonite known as "wood iron." Fine specimens of this conglomerate may be seen in the British Museum.

At the Garth Mine (since known as East Wheal Cock) about two miles west of Penzance, about the year 1827, wood-tin in botryoidal masses and toads-eye tin occurred in great quantity—together with ordinary crystallized tin-stone, quartz, felspar, chlorite and carbonate of iron.†

Wood Tin is so nearly opaque, even when of light colour; and at the same time so brittle that it is extremely difficult to get it transparent enough for examination beneath the microscope. One of its most common modes of occurrence is as a thin opaque fibrous coating on the summits of quartz crystals. ‡ A section of this kind of formation sometimes exhibits a zigzag arrangement of lines somewhat resembling "fortification agate," and might be called "fortification tin." Other forms of Wood Tin are known as "toad's-eye" tin, "pea-tin," and "shot-tin." These consist of small brown spherical masses, in the first case imbedded in quartz or other material of a lighter hue than the oxide itself; and in the second aggregated together with little or no foreign intervening material. F. Becke regards Wood Tin as an extreme form of the well known acicular crystals sometimes spoken of as "Needle Tin." There are however, some rather important physical differences.

* G. M. Henty, Rep. Mincrs. Association of Cornwall and Devon, 1867, p. 55.

† Carne, *Trans. Roy. Geol. Soc., Corn.* Vol. iv. pp. 99-100.

‡ Occasionally these coatings form a kind of cap which may be lifted off at pleasure.

Pseudomorphous Tin Ore. This occurs at many localities in Cornwall, replacing Orthoclase, Quartz, Schorl, (?) Wood, (?) and Horn.

"Large pseudomorphous crystals of cassiterite after felspar occurred formerly in considerable abundance at Huel Coates, St. Agnes. . . . . Many of the larger crystals presented the curious circumstance of shewing the original felspar replaced by oxide of tin only about half across longitudinally. Similar pseudomorphs have been found at Carn Brecon, St. Mewan, near St. Austell; and also, about ten years ago at Balleswidden, St. Just, by Mr. Rd. Pearce.

The silicate of tin described by Mr. G. Garby is perhaps a pseudomorph after quartz. Some occurred about 1820 (at Wheal Primrose) as an impalpable powder, or compact; yellowish-grey in colour and composed of 53·0 p.c. of oxide of tin, and 46 per cent. of silica. According to Mr. J. Michell, some of the silicate of tin was in hexagonal prisms, much like quartz, but with the summits always wanting."* The writer has one of these prisms in his collection which will be further referred to hereafter.

I have lately been studying the microscopic characters of a considerable number of Cornish tin-stones, and I now propose to bring the results before the Mineralogical Society.

CRYSTALLIZED TIN-STONES.

a. Tin in Elvan.

Tin Ore from Budnick Mine, St. Agnes. This is a compact dark greyish-brown material occurring in irregular veins in a light grey elvan, and also as the cementing substance of brecciated portions of the same elvan; the elvan traverses killas. Under the microscope with half-inch objective, ($\times \frac{66}{1}$,) it appears as in fig. 4, Plate II, and is seen to be composed of cassiterite, quartz, and a fibrous green chloritic mineral. The cassiterite consists generally of well defined yellowish to brownish crystals, often very simple in form, many of them shewing distinct "lines of growth" marked by layers of a darker brown tint, and all possessing the peculiar granular appearance already mentioned as characteristic of cassiterite. A few of the crystals are black with crossed prisms, but most of them are brightly coloured from the presence of minute granules of quartz.

The interspaces between the crystals are mostly filled with quartz, more or less powdered with a greyish to black dusty material, a few fine needles of schorl, and many minute fluid cavities. In places, however, there are patches of the green chloritic mineral, partly fibrous and radiating, partly distinctly crystallized in the form of felspar, of which mineral they are I believe pseudomorphs. This green material is scarcely if at all dichroic. I regard it as one stage in the transformation of felspar into acicular tourmaline.

* Collins, *Handbook to the Mineralogy of Cornwall and Devon*, part ii. p. 25.

Belowda Hill. This also is an elvan deposit, the tin occurring in nests and veins. The specimens examined show a great deal of tourmaline in large radiated masses. Many of these exhibit bright blue and green tints, with ordinary (unpolarized) light. There are also numerous fine colourless or very pale blue needles of the same mineral, and some radiated groups of a colourless or pale-greenish yellow, flaky or semi-fibrous mineral, which is no doubt Gilbertite.

Two felspars are discoverable, one however being mostly changed into Gilbertite, while the other occurs in moderately large, much-fissured, and only slightly changed crystals.

The cassiterite is mostly present in highly modified "massular"* crystals, but it presents nothing special in its optical characters. A portion of one of the slides is represented in fig. 3, pl. iii, under the one inch power ($\times \frac{28}{1}$)

Parbola. The specimens examined were cut from a dark vein traversing a grey elvan. The sections shew a mass of large crystals of cassiterite closely compacted together. Many of these enclose long slender needles of what appears to be tourmaline, and the few interspaces are filled with a dark brown ferruginous substance. The whole is much fissured, and stained reddish-brown in the neighbourhood of the fissures.

New Rosewarne. In this also the tin occurs as dark veins in a light-coloured elvan. With the one-inch power, the veins are seen to be composed of needles and brush-like groups of tourmalinemingled with large macled crystals of cassiterite.

Tresowes. The specimens examined were cut from a large pebble of "stream tin," found at Tresowes clay works, in Breage. It consists of a mass of large macled "massular" crystals, shewing distinct "lines of growth,"—not unlike the Budnick crystals, but larger and less simple in form. They were probably derived from a vein traversing elvan at Tregoning Hill, on the side of which Tresowes is situated.

Terras, (St. Stephens). This elvan has been rather extensively worked for tin. It is a grayish stone with numerous dark-brown and nearly black patches, which are evidently pseudomorphous fillings of cavities from which felspar has been removed. Most of these are filled with interlacing crystals, or amorphous grains of schorl—some contain both

*Lat. *Massula*,—a little lump. A word seems to be required to denote crystals which are approximately of equal dimensions in all directions. *Massular* will then be analogous to *acicular* and *tabular* as under.

Massular, pretty equal in dimensions.
Acicular, much extended in one direction.
Tabular, much extended in two directions.

"Acicular" crystals are called Prismatic, when the needles are tolerably thick.

schorl and cassiterite, and a few are wholly filled with crystals and crystalline grains of this latter mineral, mostly "massular".

A piece of this elvan is represented in fig. 3, pl. XI.

A great many other elvans have yielded tin ore in quantity from time to time in Cornwall, as at Castle-an-Dinas, Wheal Jennings,* &c. In all these the cassiterite either occurs as the filling of fissures and veins, or as a replacement of felspar, and always more or less associated with schorl.

At Wheal Jennings sometimes as many as 30 separate "strings" could be counted in the space of one inch.

b. Tin in Granite.

East Wheal Lovell. The slides prepared and examined were from the remarkable tin deposit described by our foreign secretary, Dr. C. Le Neve Foster.† Originally a granite, much of the felspar is changed to a gray, dusty looking material, not dark with crossed prisms, which with a high power ($\times\frac{225}{1}$), seems to consist of minute and imperfectly-formed crystals of Gilbertite, and perhaps a little tourmaline. In places in the neighbourhood of these grayish spots there are very distinct needles of tourmaline, and radiated flakes of Gilbertite. The quartz contains many fluid cavities, and includes a little black opaque mica, together with some irregular crystals and granules of cassiterite, which are of a somewhat darker colour than usual.

Balmynheer. This also is from partially decomposed (kaolinized) granite. It has a basis of quartz which encloses and surrounds bands and nests of small irregular crystals and grains of cassiterite, mingled with minute crystals, grains, and feathery groups of blue and brown tourmaline. Using the half-inch power ($\times\frac{66}{1}$), the quartz appears powdered with grayish dust, but with the one-fifth ($\times\frac{225}{1}$), most of this is resolved into minute needles of tourmaline.

Fleddry (near Bugle, St. Austell). The specimens examined were from a great stanniferous band of only slightly altered granite, which crosses the decomposed granite (Caclazyte or china clay) of the neighbourhood. At Rocks and Great Rocks Mines this is known as the Fleddry lode. The stone is grey in colour, and has a granitic appearance. Under the microscope it is seen to consist chiefly of quartz, having a dusty appearance from the presence of innumerable minute cavities; mingled

* See an excellent description of the mode of occurrence of the cassiterite at Wheal Jennings, from the pen of Mr. Geo. Seymour, Jun. *Trans. Roy. Geol. Soc. Cornwall* IX, 185.

† *Trans. Roy. Geol. Soc., Cornwall*, Vol. IX, p. 167.

with the quartz, are a little Gilbertite, many dark patches of tourmaline fringed with bluish needles of the same mineral, a few bright yellow and blue patches of tourmaline, and certain dark-gray granular looking masses which appear to replace felspar crystals; with the half-inch power, these latter are seen to be composed of little crystals of cassiterite—mostly rectangular, or nearly so in section. An average sample of the stone taken from the band—which is about 20 ft. wide, and contains very little tin visible to the naked eye—yielded, on analysis, 3½ per cent. of metallic tin.

Wheal Bunny, St. Austell. This is very similar to the stone from the Fleddry lode just described, and it occurs in a lode or band which is probably continuous with it. The bulk of the stone is quartz, in which are many beautiful branches and radiating groups of green tourmaline needles —sometimes surrounding crystals of a yellow, blue, or brown colour, as a fringe. The cassiterite occurs apparently replacing felspar, as in the last example, but is much brighter in colour, and separate crystals are even smaller. No prismatic or acicular crystalsof cassiterite are visible in either of these instances.

West Basset, flat lode. The specimen illustrated in fig. 2, pl. iv. may be taken as a type of the "blue peach" tin-stones of the lodes in the Carn Brea district. Occasionally the tin appears somewhat in the form of broken felspar crystals—in some instances exhibiting a cleavage-structure and form resembling orthoclase. In the section illustrated the cassiterite appears as an irregular band filling a fissure which crosses still older fissures filled with quartz—these latter traversing a matted mass of acicular crystals of tourmaline.

Dolcoath, 314 *fathom level.* This stone is very similar to the last. Here again the veins of quartz cut through the acicular mass of blue tourmaline and are themselves traversed by veins of cassiterite. Fig. 4 pl. iv shews part of one of these veins under the half-inch power, and fig. 3 is intended to illustrate the minute structure of "the blue peach" basis under the one-fifth power ($\frac{225}{1}$). In the fissures there is much acicular schorl. Some of the tin veins are in places as little as $\frac{1}{500}$th of an inch in thickness. Separate grains and crystals are sometimes only $\frac{1}{1000}$th of an inch.

Dolcoath. 324 *fathoms level.* Blue peach tin-stone. This is very similar to the stone just described.

Dolcoath. Sump below the 314 *fathoms level,* 1878. This stone is evidently a breccia, it consists of angular patches of a fine-grained green or bluish material, which is apparently composed in the main of a net-work of fine needles, imbedded in a crystalline mass of cassiterite, which

exhibits distinct crystals in a few places. A little quartz occupies the interspaces, which are very few—and this encloses many fine needles of tourmaline.

Dolcoath. Very rich stone from about the 260 *fathoms level.* 60 *p. c. metallic tin.* This is a mass of rather large grey crystals—mostly massular, some have a yellowish or brownish centre—there are also frequent yellow stains near the lines of cleavage. Some of the crystals shew very numerous cleavages—mostly however parallel to the principal axis of the crystals. "Lines of growth" are scarcely to be seen in either of my sections (5) of tinstones from this part of the mine. With the cassiterite in all the sections is a little quartz and some fringed crystals of tourmaline. Some of the crystals contain imbedded needles which are probably schorl.

East Caradon, stone raised in 1866. This is a very beautiful stone consisting chiefly of large and rather simple prisms of cassiterite, intermingled with a little quartz and some beautiful dark green hexagonal crystals of a mineral which appears to be tourmaline. Fig. 2, pl. V. represents a portion of one of the slides as seen with the $2\frac{1}{2}$ in. objective ($\times\frac{12}{1}$.)

North Treskerby. This consists of a dark reddish-brown stone, sections of which under the microscope sre seen to consist of light-coloured crystals, mostly prisms, embedded in a deep red, nearly opaque substance, which is mainly, if not exclusively oxide of iron. A few of the prisms are stained with red in spots and patches. The appearance presented when viewed with the one-inch power($\times\frac{28}{1}$) is as shewn in fig. 4, pl. V.

c. Tin in Schorl-rock.

Boscaswell. This is a schorl rock "tinstone," it consists almost entirely of highly modified "massular" crystals of cassiterite mingled with schorl, and forming a firmly compacted mass. It contains, however, many small cavities or "vughs," and these are generally crossed by slender needles of tourmaline as shewn in fig. 5, pl. ii. One slide in my possession has a little striped felspar shewing between the cassiterite crystals; a few minute red garnets are also visible.

Boscaswell Downs. This very beautiful tin-stone is also from schorl rock. It consists of a basis of clear quartz, in which are enclosed many large brilliantly coloured tourmaline crystals, with fringed edges like those described as occurring in the black quartz crystals of Boscaswell Downs.* There are also numerous fine separate needles or small groups of needles of the same mineral sprinkled through the quartz. The quartz basis also encloses some rather large "massular" macles and irregular grains of cassiterite.

* See "On certain Black Quartz Crystals," by J. H. Collins, *Min. Mag.*, Vol. I, p. 115.

Rock Hill. This stone is from the remarkable mass of stanniferous schorl rock described by me in the Mineralogical Magazine, in 1876.* In some parts the rock is composed largely of quartz, in others it chiefly consists of schorl, but everywhere there is a little tin. Fig. 1, pl. iv. represents a thin section of a dark bluish mass from this deposit, under the half-inch power ($\times\frac{66}{1}$). When thus examined it is seen to be composed in the main of an agglomerated net-work of very fine acicular crystals of blue tourmaline, in which are imbedded radiated groups of much larger crystals of brown tourmaline, and a few small crystals of cassiterite exhibiting the characteristic granular appearance.

d. Tin in Killas.

Wheal Vor, 160 *fathom level.* This is a killas "tin-stone," it is, however, very similar to the Budnick specimen, but the crystals of cassiterite are less distinctly prismatic, generally somewhat more highly modified, frequently fractured, and often macled. Fig. 1, pl. iii. shews one of these macles drawn with the camera lucida under the half-inch power ($\times\frac{66}{1}$).

The quartz of this stone contains many minute fluid cavities and a green fibrous chloritic mineral, similar to that occurring in the Budnick specimens.

Tretoil. This is also a killas tin-stone. It consists of a *melange* of crystals of cassiterite, mostly short prisms, with a very little of a dark interstitial mineral—probably oxide of iron—and a few cavities which seem to have been originally felspar crystals, but are now occupied by a semi-fibrous greenish, grayish, or yellowish mineral. Fig. 4, pl. V, represents part of a slide of this stone as seen with the one-inch objective.

With polarized light these crystals shew brighter colours than usual. No quartz is visible in the stone.

Part of the specimen was analysed and yielded 92 p.c. of oxide of tin.

Wheal Vor, 140 *fathom level.* This is a specimen of a kind of ore which was worked very largely at Wheal Vor, a few years since. It consists of alternate bands of dark grey slate, and of quartz filled with crystals of cassiterite. Fig. 2, pl. iii. represents part of a thin section magnified, shewing the dark slaty bands alternating with the lighter bands of quartz, and these latter interlaminated with oxide of tin, sometimes in irregular forms, but mostly in crystals more or less highly modified. Fig. 4, pl. iii, represents a part of the same section more highly magnified ($\frac{150}{1}$.). The quartz seems to have crystallized between

* On the occurrence of Achroite at Rock Hill. *Min. Mag.*, Vol. I., p. 55

the laminæ of the slate so as to extend them, and the tin oxide has then been deposited in its cracks and cavities.

With the one-fifth objective ($\times\frac{225}{1}$), many fine needles of tourmaline are visible, which seem to lie mostly with their long axes in the directions of the laminæ, and to follow them in their bends around certain dark shapeless opaque knots, which are probably amorphous tourmaline. An attempt to represent this appearance is made in fig. 5, pl. iii.

New Fowey. These specimens are from a lode traversing killas and situated a little to the north of the great Fowey Consols lodes; it has only been worked a few fathoms deep. In this specimen with the quarter-inch power ($\times\frac{150}{1}$), the cassiterite is seen to consist of small highly-modified crystals mingled with chlorite, some of which occurs in beautiful rams-horn groups; the whole imbedded in a basis of quartz as shewn in fig. 2, pl. ii.

Part of this specimen was analysed and yielded 22 p.c. of oxide of tin.

Penhalls. The specimens examined consisted of a dark grey very siliceous killas. Under the microscope the appearance did not materially differ from the Penhalls capel, hereafter to be described, except that there were veins and patches of tin visible.

Penhalls "Toad's eye" Tin. Much of the toad's eye tin observed in different mines—as at the Garth Mine near Penzance, consists of wood-tin, and will be described in a future paper. Much wood-tin occurs too at Penhalls Mine, but the specimen of "toads eye" examined from here, which was kindly furnished by Dr. Le Neve Foster, consists chiefly of ordinary crystallized tin, arranged in a somewhat peculiar manner.

To the unaided eye the specimen presents the appearance represented in the fig. 1, pl. V. A thin cross-section under the two inch power ($\times\frac{16}{1}$) shows a group of cross-sections of rectangular prisms, imbedded in and surrounded by quartz. This group is surrounded at a little distance by an incomplete circle of crystals having a slightly radiating structure, and exhibiting nearly concentric lines of growth as shewn in fig. 3, pl. V. A few angular dark patches which also have a somewhat circular arrangement are apparently interspaces between quartz crystals; some of them are seen to contain many minute needles of tourmaline when viewed with high powers. Others look like very dark wood tin.

The whole arrangement looks as if it had arisen as follows:—

a. Formation of bundles of prisms of cassiterite in a quartz magma.

b. Deposition of quartz in more or less distinct prisms around the centres so formed.

c. Deposition of cassiterite and tourmaline irregularly on the outside of the quartz groups, part only being crystallized.

d. Deposition of quartz around the whole compound mass.

Wheal Fortune, Breage. The specimen examined consisted of a dark greyish-brown killas spotted and banded with white quartz, and having light yellowish-gray macled crystals of cassiterite in its joints varying from $\frac{1}{4}$th to $\frac{1}{12}$th of an inch across, and mingled with a little Gilbertite.

Thin sections of the killas near the joints were made, and in these the quartz was seen to be as usual full of minute cavities, giving it a gray dusty appearance. It also contained very large numbers of tourmaline needles, blue near the tin crystals of the joint, but elsewhere brown, and arranged in a somewhat banded manner, the joints cutting the bands nearly at right angles. The whole may be regarded as a stanniferous tourmaline-schist.

Roche Consols. This also is a highly stanniferous tourmaline-schist, the basis of which is mainly cassiterite instead of quartz as is usual.

It is much more stanniferous than the last as the tin seems to permeate the whole rock, instead of being mainly confined to the joints.

Wheal Primrose, St. Agnes. The specimen from which my sections were cut was an old one, the mine having been closed for many years.

It is a compact grayish stone to the naked eye, not unlike a stanniferous sandstone. In a thin section it is seen to consist of a mass of light-colored quartz full of minute needles of dark-brown cassiterite, often pointed at each end. A good many brown patches and grains of oxide of iron are visible, and also some patches of what looks like tourmaline

e. Tin Breccias

Reference has already been made to the occurrence of cassiterite as the material filling fissures, &c., in various kinds of rock. The specimens now to be described probably differ nothing in principle from these, but being on a much larger scale, it may be convenient to place them here under a separate heading.

Relistian and New Rosewarne. The tin conglomerates of these mines have already been described (page 3).

Wheal Lucy. This mine was worked a few years since to a very moderate depth. The tin deposits were very irregular, much of the tinstone consisted of a breccia composed of a peculiar soft brownish material, which looked like decomposed greenstone, cemented together

with cassiterite, often in large crystals, and a little quartz. A specimen of this breccia is represented in fig. 3, pl. i, drawn to the natural size.

In thin sections under the microscope some of the included fragments exhibit a structure which might very well belong to a basaltic rock which had undergone much decomposition.

Wheal Uny. Compact Tin-stone. This is a very peculiar tin-stone. Viewed in the mass it looks like an alternation of bands of dark "blue-peach," and of a paler grayish-brown material, both extremely fine-grained and very hard. Under the microscope, in thin slices. it looks like a breccia, in which ordinary "blue-peach" plays the part of the cementing material, and encloses angular fragments of a peculiar brownish-gray granular material, which certainly contains tin, from the known richness of the stone, but is optically quite unlike ordinary crystallized cassiterite. The whole mass has been fissured across, and the fissures filled up subsequently with quartz,and, in one specimen, some very light coloured crystals of cassiterite of the ordinary kind. In the neighbourhood of this there are distinct needles of schorl; elsewhere these are almost entirely absent, the blue-peach being mostly made up of the greenish or bluish chloritic material.

Needles of the tourmaline project into some of the quartz masses, and these latter as well as the quartz of the veins are full of minute fluid cavities.

TIN CAPELS.

As already stated, there is no real geological or petrological distinction between *tin-stones* and *tin-capels*—a capel being merely a tin-stone which does not contain enough tin to pay for working. As the average produce of the Cornish tin-stones is but little over 2 per cent. of tin-oxide, and as many are worked with less than 1 per cent., it will be seen that the distinction made by practical men rests entirely upon considerations of economical working, which vary with the locality and the surrounding conditions. Thus the 'capel' of one mine may be the 'tin-stone' of another.

To the unaided eye capels appear in three principal forms, which may be termed *granitic, schistose,* and *compact* respectively. The latter is essentially a deposit of amorphous or crypto-crystalline quartz, which may or may not enclose particles of foreign bodies; it is not usually of much importance, nor does it occur to any very great extent in connexion with the Cornish tin ores.

The granitic and schistose capels on the contrary are of the highest importance, and are usually readily enough distinguishable from each other, although they no doubt pass into each other at times. Both are very highly altered rocks, which have been altered by precisely the same chemical agencies. Both are characterised in general by the presence of much tourmaline in some form or other, and the types of their extreme modifications are 'schorl-rock' or 'schorlyte,' and 'tourmaline schist.' Each consists essentially of quartz and tourmaline, in the first arranged irregularly as in granite, in the second in approximately parallel bands, due no doubt to the original lamination of the schist from which it has been derived. Occasionally both may be seen in one stone as in the specimen from Wheal Burn, illustrated in Plate VI.

Both these important rocks are found in great abundance near the junctions of granite and killas—and I believe nowhere else; rarely indeed are they found more than a mile from the actual junction except of course as surface or subsoil fragments, or as transported materials in valley gravels, and occasionally in so-called raised beaches.*

a. Granitic Capels.

South Condurrow, flat lode, "grey back," or "black-granite." In mass this is very dark bluish gray, evidently an altered granite, the felspar changed to quartz, and the mica to the mixture of chloritic mineral and tourmaline already so often referred to. There are many tourmaline needles in the fissures, and a few irregular grains of tin—some not more than $\frac{1}{2000}$th of an inch across. With the one-fifth objective and a good light, many little yellow grains appear, which may perhaps be tin. Some of these are scarcely more than $\frac{1}{20000}$th of an inch across.

Tresavean. This is a good example of the "blue peach" slightly stanniferous capels, its shadowy granitic structure is shewn in fig. 5, pl. iv. under the half-inch power ($\frac{66}{1}$). Some of the patches of quartz have much the form of felspar crystals, and I believe they were once felspar.

* The quartz of veinstones is usually more or less crystalline, contains numerous gas and fluid cavities, and encloses ores of tin, copper, zinc, and other metals. Capels are most frequently composed of a quartzose base through which crystals of schorl are very thickly disseminated, either in the form of spheroidal aggregations radiating from various centres or as acicular crystals crossing one another in all directions. Sometimes, particularly when they occur in slates, capels are mixtures of quartz and chlorite; in others both chlorite and tourmaline are present. They also often contain innumerable small fragments of the country rock, and are traversed by narrow strings of quartz into which project hair-like crystals of schorl, which are generally attached to the sides of the enclosing fissure. Phillips, *Quart. Journ. Geol. Soc.*, Aug. 1875, p. 341.

West Basset flat lode, 114 fathom level. This is a good deal like the Tresavean stone; the "blue-peach" basis is mostly, however, grayish when viewed with a high power, and it seems to consist chiefly of a flaky mineral penetrated in all directions with minute needles of blue tourmaline. A few pale green patches are present, which are perhaps chlorite. No tin is visible in this stone, except perhaps in patches, in one little vein less than $\frac{1}{500}$th of an inch in thickness, which small as it is, is in one place distinctly "heaved" at an oblique angle by a still finer one not more than one-tenth its breadth. The brown patches look somewhat like wood tin, and are distinctly fibrous under high powers; they are however still more like a brown tourmaline.

Another specimen from this locality shews a little tin and a few brown spots, which are probably peroxide of iron.

Carn Brea. This also is a 'blue-peach' capel. Under the microscope it is seen to be composed mainly of quartz, together with patches of the bluish felted material, a few distinct blue and yellow crystals of tourmaline, and a few grains of tin, the whole exhibiting a shadowy granitic structure

There can be little doubt that the four specimens last described, which are types of at least one half of the tin stones at present worked in Cornwall, represent granite rock altered *en-masse*, the felspar mostly changed to quartz, the mica to chlorite and schorl; the whole much fissured and filled up at different periods with quartz and cassiterite. The matted mass of "blue peach" frequently encloses irregular angular portions of quartz, the remains of the quartz of the original granite, together with other quartz masses of a more regular form, and apparently pseudomorphous after felspar.

b. Schistose Capels.

Penhalls. This is a good example of an altered killas capel—really a variety of tourmaline schist—in which the alteration has not proceeded so far as to obliterate the original laminated structure. Fig. 3, pl. ii. is drawn as seen under the two-inch objective ($\times \frac{16}{1}$). The rock consists mainly of quartz, but is rendered somewhat laminated by a series of fine bands of amorphous tourmaline. It has been fissured and repaired in several directions and at several distinct times. The whole is crossed by a fissure which is mainly filled with quartz, but carries on its walls an irregular band of a green chloritic mineral, resembling that already described as occurring in the specimens from Budnick and Wheal Vor. A small

nest of cassiterite is shewn at one place. With the one-fifth power ($\times \frac{225}{1}$,) as in fig. 1, pl. ii. the green mineral is seen to be chlorite, sometimes in approximately hexagonal crystals, but more usually in irregularly radiated bundles of plates presenting a fibrous appearance and in the form of felspar crystals. In one or two places the rams-horn groups so common in the New Fowey tin-stone may be seen. The fibrous chloritic substance and the amorphous bands of tourmaline appear everywhere to be passing into acicular needles of tourmaline, which seems to be the final product of the cycle of changes.

Wheal Vor. This is a very hard capel, very similar to the last, only the needles of tourmaline are larger. There are a few small crystals and grains which look like cassiterite, but I am not certain about them.

New Consols Mine. The general structure of this capel is like that of Penhalls, but it contains no chloritic mineral. Instead of this there are many opaque patches and grains of a grey mineral, which shines with a greyish metallic lustre when viewed as an opaque object. As the stone contains arsenic, this substance is probably mispickel.

In the fissures there are a good many acicular crystals of tourmaline, but no tin is visible in the sections examined, although the capel yielded a little tin by treatment on a large scale.

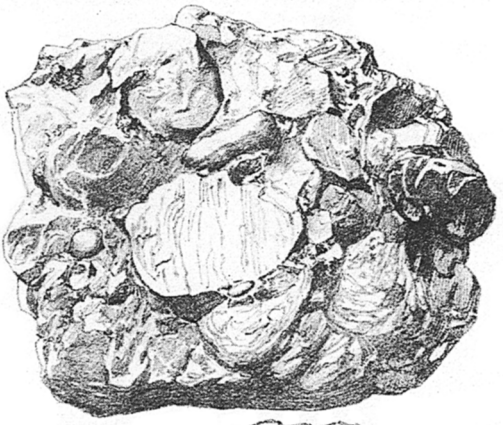
Cusgarne Downs (*Tourmaline Schist.*) This is part of one of the striped surface stones from the junction of the granite and killas which are so abundant in most of the tin producing districts of Cornwall. Like the Penhalls specimens it consists of alternate layers or bands of quartz and tourmaline. The tourmaline here is mostly brown, and occurs in short, rather broad prisms, formed around some opaque substance, which has probably supplied the ferruginous constituent of the tourmaline. The quartz encloses many minute prisms and grains of the same mineral, and a few approximately rectangular brown crystals which may be cassiterite. This may be regarded as a typical specimen of the Cornish tourmaline schist. It contains about 150 distinct bands or layers to the inch.

Park of Mines. (Fig. 4, pl. VI.) This is an example of tourmaline schist, from the immediate neighbourhood of one of the richest deposits of tin ever discovered in Cornwall,* but it has many characters in common with the capel just described and also with one of the Wheal Vor stones. As indicated by the figure it is composed of alternate layers of schist, many hundreds to the inch—the dark layers chiefly tourmaline and the

* See "A Deposit of tin in the Park of Mines," by Dr. C. Le Neve Foster.

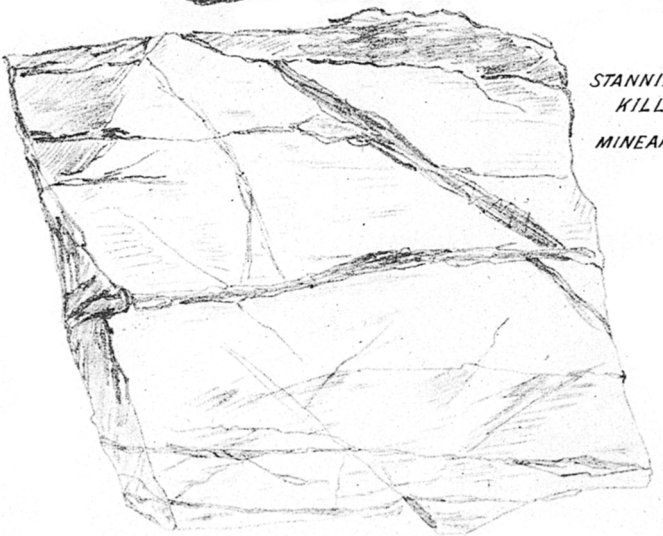
light ones chiefly quartz. Most of the tourmaline here is dark-grey to nearly black and opaque, and in irregular masses, but a few fine needles project into the quartz and here and there a minute grain of tin oxide is discernible.

The foregoing descriptions relate to examples of most of the ordinary tin-stones of Cornwall which contain crystallized cassiterite. In a future paper I propose to deal with the numerous varieties of wood-tin, and to discuss the origin of the Cornish tin-pseudomorphs and tin deposits generally.



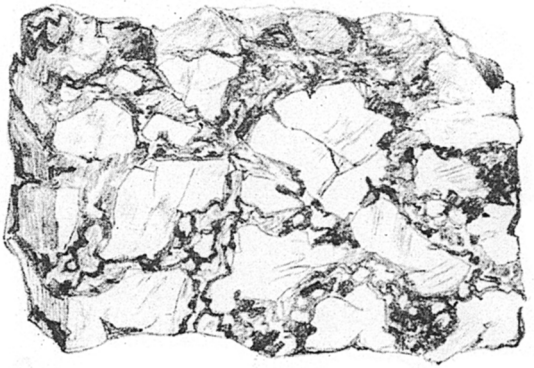
STANNIFEROUS CONGLOMERATE.

RELISTIAN MINE.



STANNIFEROUS KILLAS.

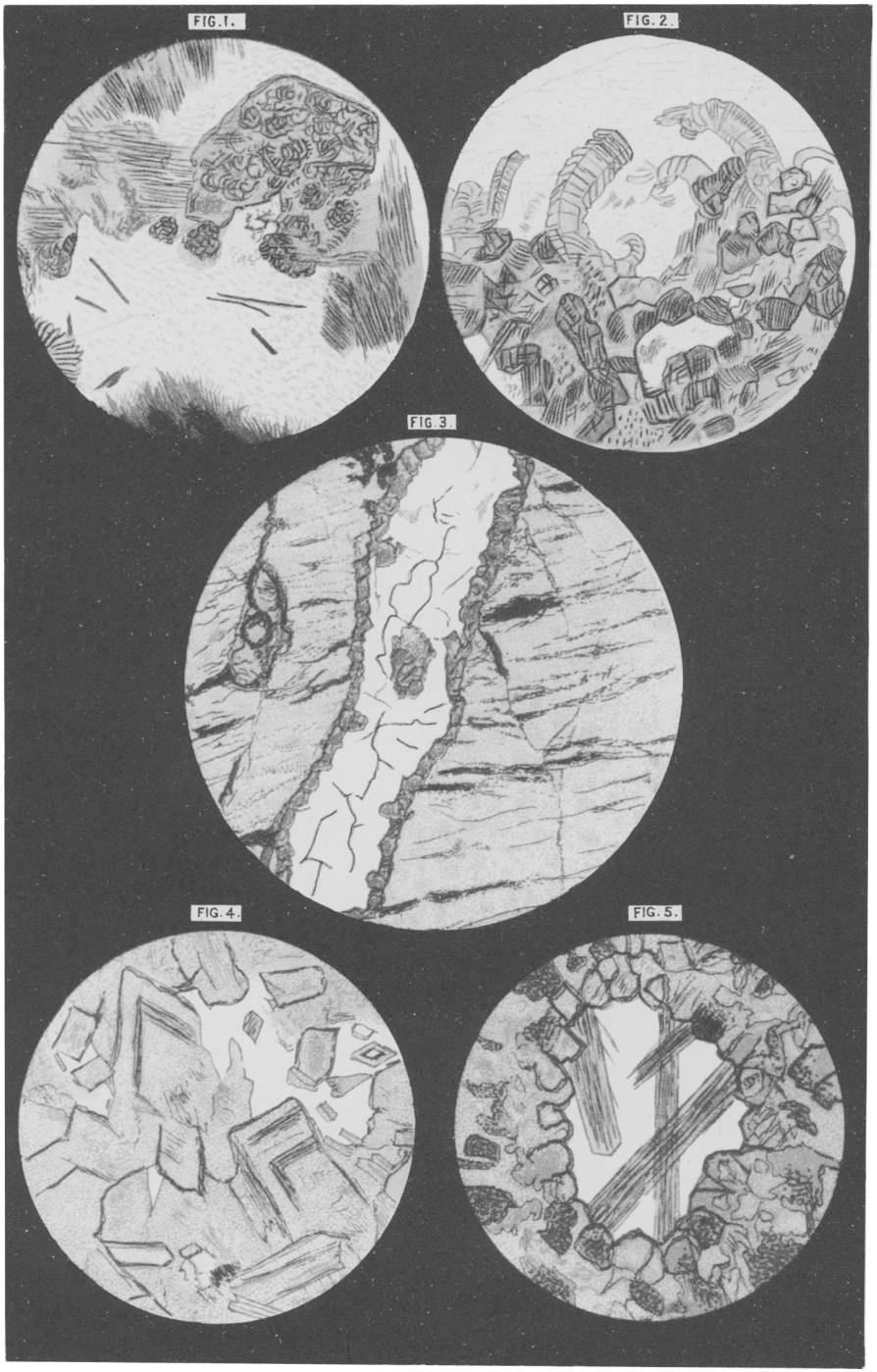
MINEAR DOWNS.



STANNIFEROUS CONGLOMERATE.

WHEAL LUCY.

J.H.C. Del.



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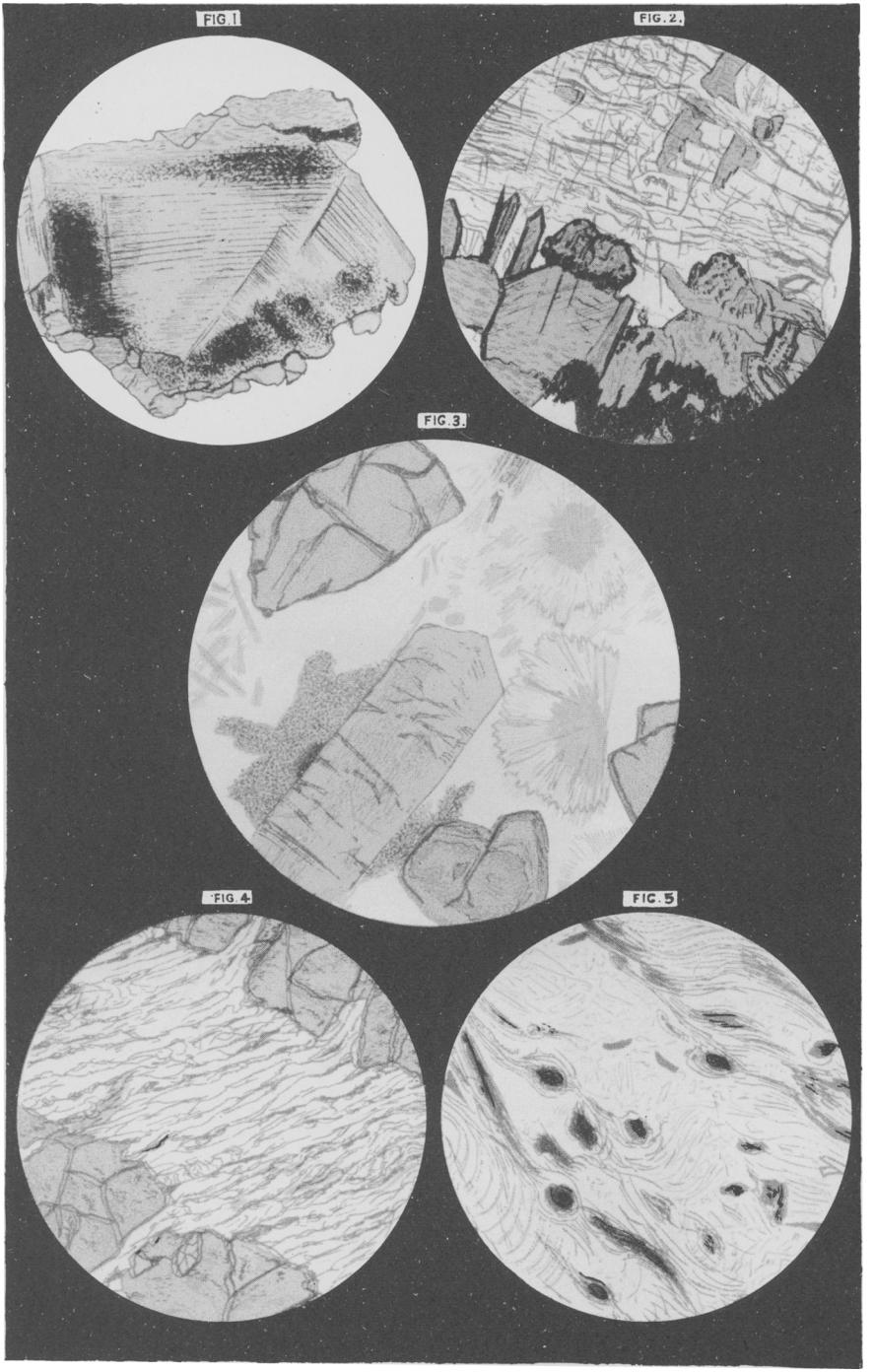

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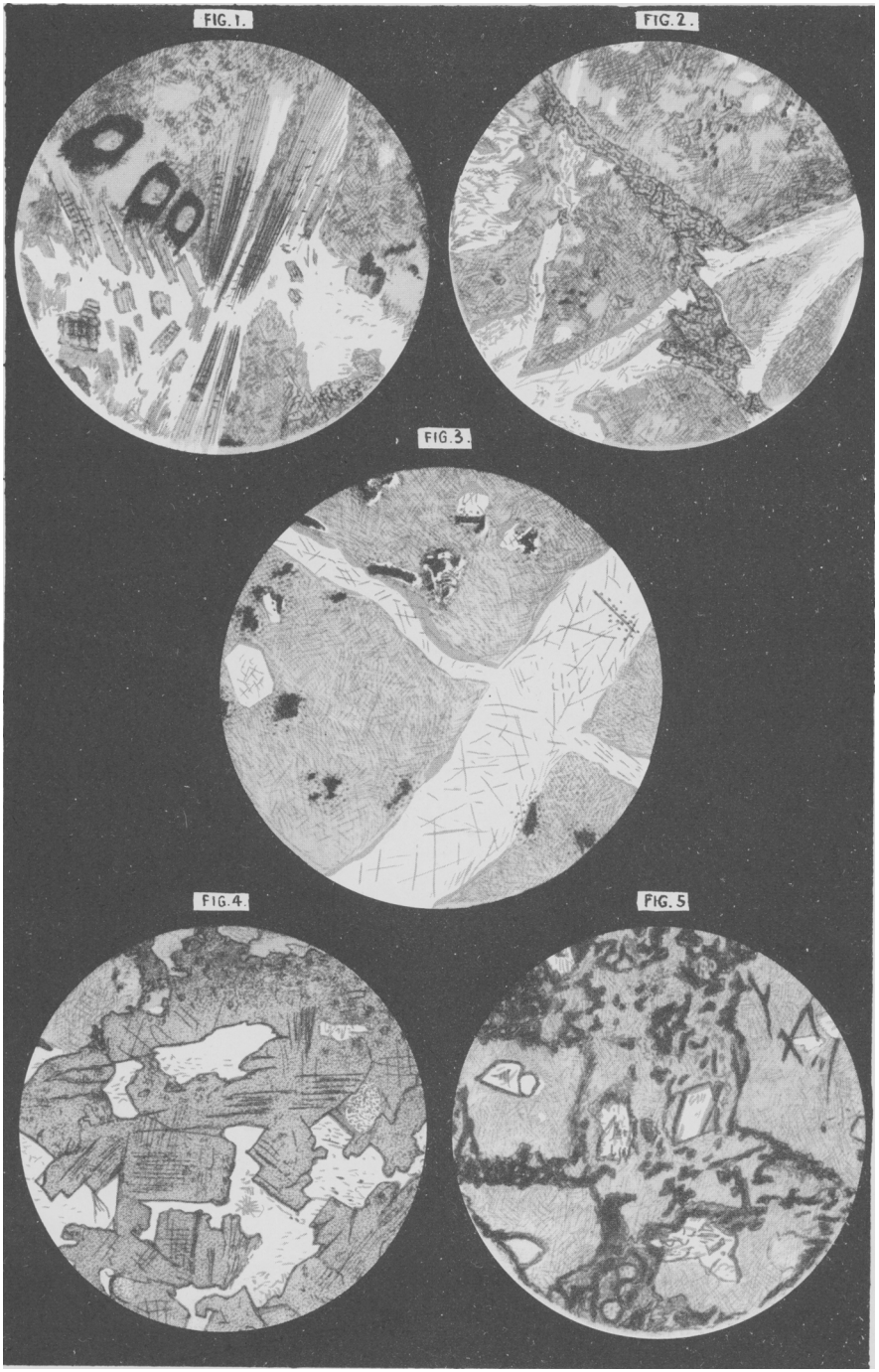

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CORNISH TIN-STONES.

FIG. 1.

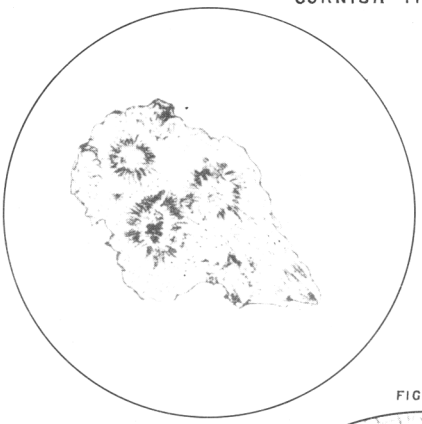


FIG. 2.

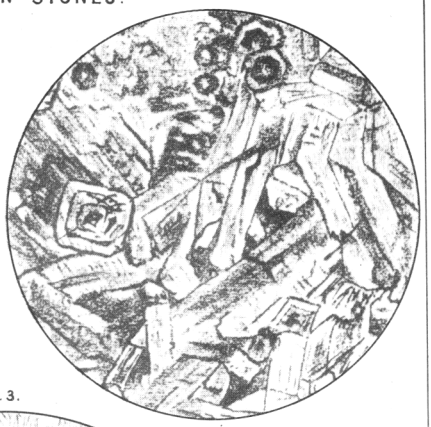


FIG. 3.

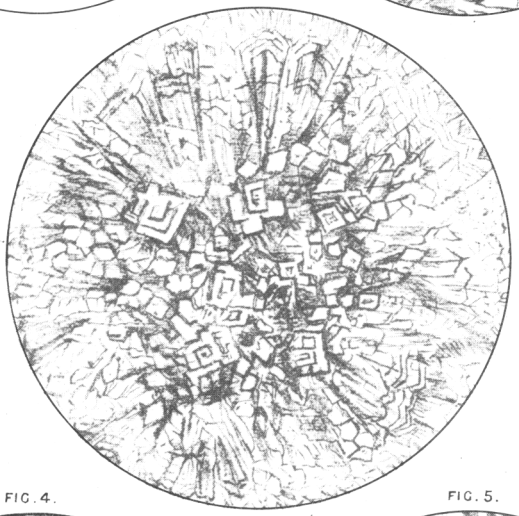
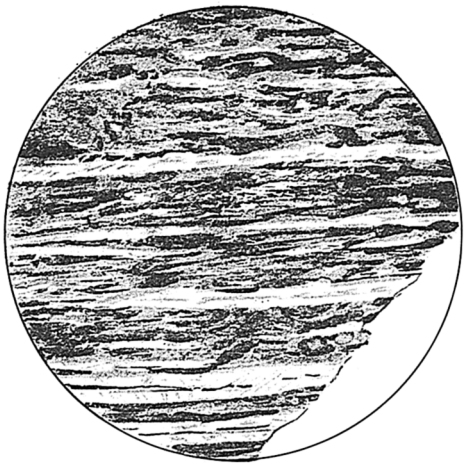


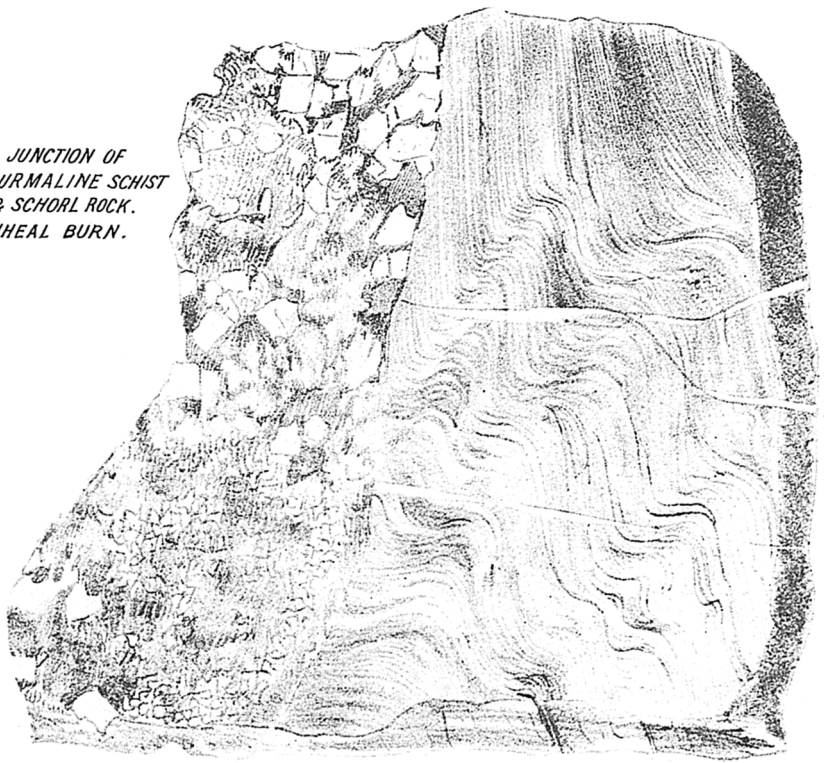
FIG. 4.

FIG. 5.

CORNISH TIN STONES.



TOURMALINE SCHIST.
PARK OF MINES.



JUNCTION OF
TOURMALINE SCHIST
& SCHORL ROCK.
WHEAL BURN.

J.H.C. Del.