GEOLOGY OF CORNWALL

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A SKETCH

OF THE

GEOLOGY OF CORNWALL,

INCLUDING A BRIEF

DESCRIPTION OF THE MINING DISTRICTS,

AND THE ORES PRODUCED IN THEM.

BY

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With Geological Map of Cornwall,

AND

Numerous Steel Plates, illustrative of influence of Rock Formations on Scenery.

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PREFACE.

During my present visit to England, my father, Mr. Robert Symons of Truro, pressed me to write a condensed account of the Geology of Cornwall, to accompany his forthcoming Gazetteer of Cornwall. This, owing to the limited leisure at my command, has been hastily written, and some of the matter may express my views imperfectly. Mindful of the diversity of opinion amongst the highest authorities, respecting the formation of veins, the author puts forward his ideas tentatively with a vivid consciousness of the difficulties which beset the elucidation of their genesis.

This reprint from the Gazetteer of Cornwall, has been made at the solicitation of many of the authors friends, who considered it desirable that the geological sketch should be published in a more readable form than that afforded by a large book of reference. Though a revision would have been most desirable, it was rendered impracticable because of the departure of the author from England.

In the method of treating so extensive a subject as the geology of a county endowed with such vast mineral riches as Cornwall, the author's object has been to avoid as much as possible, confusion of arrangement, and the use of technical language, and each subject will be found

as much isolated as the plan of the work would admit. The author has desired especially to show that the mineral wealth of the county is very remote from exhaustion, that, on the contrary, capital intelligently and honestly applied to the development of ground, skilfully chosen, would result in an increase of prosperity for Cornwall and a fair return to investors.

To illustrate the effect that the secular denudation of the diverse geological formations has impressed on the physical character of the scenery, eight steel plate engravings have been kindly furnished by Messrs. Besley & Sons, of Exeter. The geological map has been reduced from the old Ordnance Survey, and the vein systems obtained from the plans published at various times by Messrs. Robert Symons & Son; whilst, for the colouring of the Silurian strata, the author is indebted to the courtesy of Mr. J. H. Collins, F.G.S.

In the preparation of this Geological Sketch, the following works have been consulted: De la Bĕche's Geology of Cornwall; Trans: of the Geological Society of Cornwall; Moissonet's Rich Parts of Lodes; and Collins' Minerals of Cornwall. Nearly the whole of the statistical matter has been derived from the publications of the Mining Record office.

Scottish Club, W.

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ILLUSTRATIONS.

ERRATA.

Page 12, *for* archœan *read* archæan.

„ 20, *for* plentomaria *read* pleutomaria.

„ 23, *for* and the few beds termed greenstone *read* and some of the beds.

„ 67, *for* and the reverse of the dip *read* and the reversal of the dip.

„ 90, *for* sholes *read* shales.

„ 99, *for* tungstate of iron converted *read* was converted.

„ 104, *for* multation *read* mutation.

„ 174, *for* from the Saxon lodes *read* from the lodes in Saxony.

„ 178, *for* slime separations *read* slime separators.

GEOLOGY OF CORNWALL.

Chapter I.

HISTORICAL.

Cornwall is probably the most ancient mining country in Europe, if not in the world, and without doubt the Danmonians who worked the detrital deposits of tin on the granite bosses of Dartmoor and Bodmin Moor, during pre-Phœnician times, with which to fashion their domestic utensils, were the earliest tin miners. During pre-historic British ages the Phœnicians—the most enterprising merchants the world ever produced—crossing the Oceanus Britannicus were rewarded by the discovery of the stanniferous peninsula, which they called Belerion. A very important trade in tin, and perhaps lead, was developed, and for a long period Cornwall supplied the east with this valuable metal in exchange for brass, earthenware, and other articles, and consequently attained a civilization infinitely superior to the other provinces of Britain.

TOPOGRAPHICAL.

The peninsula of Cornwall is roughly shaped like a sea boot. It extends from the county of Devon, 80 miles in a south-westerly direction, to the Land's End, 30 miles

to the south-west of which are the Scilly Isles; the width varies from about 6 miles at Hayle, to 45 at the Tamar, a large river which separates it from Devonshire. The area has been computed at 1400 square miles, equal to 896,000 statute acres. A glance at the map will show that the county is nearly surrounded by the waters of the Atlantic Ocean, whose waves, born far out in its bosom, lashed into fury by the violence of the prevailing westerly gales, break with irresistible power on its shores. The existing configuration of the Cornish coasts is indeed the result of ages of marine erosion, evinced by the deep bays and estuaries which have been hollowed out of softer strata, whilst the compact rocks protrude as high craggy headlands, whose obstinate resistance to the tidal surf is clearly indicated by islets or chains of rugged reefs, the most dangerous of which are marked by bells or are surmounted by tall lighthouses, in which the keepers are isolated for months by the unceasing roll of the Atlantic billows.

Although the capes on the north coast are not so prominent as those in the English Channel, the coast line, owing to the exposure of the edges of alternating dark and white schist of unequal hardness to the nor-westers, are much more indented, and numerous bold promontories, bare and serrated, lend a character of grandeur and sublimity to the whole line of coast, unequalled by any other portion of the English shore. The cliffs are everywhere so magnificent in diversity of contour, changefulness of the hues of its red brown, yellow, and blue rocks, and in its variform steeps and precipices, that it becomes difficult to localize the best points, but a pre-eminence *has often been* claimed for the perpendicular columnar

granite of the Land's End, and the jagged slate rocks dominating the narrow porths in the neighbourhood of Tintagel.

Some of the islands, separated by oceanic action from the mainland, possess considerable historic interest. St. Michael's Mount must especially be noticed, on account of its admitted association with the ancient tin trade between Cornwall and Phœnicia. It is a granite cone rising about 240 feet above the sea, situate in front of the town of Marazion, from which it is separated by a shingle beach dry at half-tide.

Cornwall is surrounded by a shallow sea seldom reaching 40 fathoms, and this depth is only found near the principal headlands, where the tides rushing around them at a speed of four or five miles per hour, has swept out a clear channel for itself. The bottom slopes westward at so slight an angle to the edge of "soundings" that it would resemble, if raised to the surface, a boundless plain. The tidal wave arriving from the Atlantic flows up this slope, until striking the Land's End, one part expands itself in the broad waters of the English Channel, whilst the other, running with tumultuous rapidity into the Bristol Channel, becomes pent up, and by its reflex action causes an abnormal rise in the tide along the northern shores, the waters along which have thus a mean height somewhat in excess of that found to obtain on the southern coast.

The deep bays from the Land's End to the Rame head, and the less embayed shores on the north, are fringed by exquisite beaches of golden sands commonly made up of small comminuted shells, whose low specific gravity suffers the frequent gales which blow from the north-west, to

carry the sand up the cliffs, where its fall over the fields spreads desolation. These sand dunes advance into the interior until stopped by a small stream or a public road. They are very extensive at Whitesand Bay, Heyl-mouth, Perran, Newquay, and in the vicinity of Padstow. In modern times the advance of the sand dunes has been effectually prevented by the growth of the reed called Arundo arenaria. The numerous coves between St. Agnes and Bude terminate in picturesque and romantic strands, which are almost hidden beneath the high precipices that render them more or less difficult of access. In the western coves quite a number of species of microscopic shells have been described and figured; indeed, the beach consists mostly of these, mingled with innumerable larger shells and some quartz sand.

The force of the waves breaking against the shore, causes a slow though continuous travel of the beach in their direction, which is accelerated by the prevailing current. Owing to the prevalent winds from the west, the Cornish shingles move eastward, and this has led to the formation of lakes at Helston and Swanpool, because the volume of the fluvial waters became insufficient to remove the accumulating sand and pebbles, so that the final result is a wide bar which effectually separates the sea from the fresh water surface behind it.

The heights of the county which form the water shed are nearest the north coast, principally owing to the larger river basins of the Tamar and Fowey. The narrowness of the county precluding the existence of long river courses, very many of the so called rivers are really mere streamlets. The secular exfoliation of the granitic domes, *left divisional* planes more or less open to atmospheric

action, which, softening particular bands, determined in numerous instances the direction of the rivulets that took their rise on the eruptive rock of the highlands. In the clay slates, the courses of the rivers appear to follow in many cases the junction of different strata, and this is more especially observable where formations of different ages are contiguous, Excepting the Camel, the rivers falling into the British Channel are insignificant, and no harbours of refuge for distressed ships are to be found ; but on the south littoral, the larger rivers expanding into estuaries, have given existence to commodious harbours and secure anchorage. Whilst all the southern creeks can be entered at any time, those debouching into the Bristol Channel, can only be made on the flood tide.

The peninsula of Cornwall, jutting far into the Atlantic, occupies a position extremely favorable to the fishing industry, and the waters of both channels are frequented during the season appropriate to the species, by immense shoals of mackerel, pilchards, and sardines, whilst hake, conger-eels, and pullock, swarm along the coasts. The headquarters of the pilchard fisheries is at Penzance, though St. Ives and Mevagissey are also important. Besides the fresh pilchards consumed in the county, from twenty to twenty-five thousand hogsheads of pressed fish are annually exported to the Mediterranean. The mackerel are sent principally to London, comparatively small quantities being sold in the county.

At Mevagissey, the young fry of the pilchard is canned and sold as Cornish Sardines. The oyster fisheries are nearly exhausted, though a certain quantity is still dredged at Falmouth and Helford. All the estuaries are frequented by salmon, and their peel are found far up the

rivers, which are consequently much visited by anglers.

The heights of Cornwall do not extend in an unbroken ridge, but form a chain of elevated domes between which is low ground, though most of the north-eastern portion is raised considerably above the rest of the county. The physical appearance of a country depends very much indeed on the strata of which it is formed, and particularly when—as in the present case—eruptive and metamorphic rocks of diverse epochs are predominant. The central portion of the county is elevated from four hundred to a thousand feet, and is of a pre-eminently bleak and dreary character, especially during winter, when every object is shrouded in fog. The granite ranges, which are numerous and extensive, possess few dwellings to relieve the savage grandeur of its wild rocky carns and tors, nor are there any paths or tracks, by which a stranger could extricate himself from the deep and dangerous bogs which contour the hills and treacherously conceal their horrors beneath a smiling garb of verdant and luxuriant moss. The interior can only be trodden by the herdsman, who during the summer months leads his cattle to feed on the coarse grass and exuberant heath, whose purple hues clothe the hillside and invest the fantastic piles of granite rocks, which crown every summit with a splendour not all their own. The highlands where clay slate prevails are of a very much softer character, though sufficiently sterile. In place of tors and swamps, undulating and solitary plains, diversified in the north-east by hills of soft outline extend monotonously for many leagues. These hills, and frequently the downs, are disfigured by a layer of quartz or fieldspar, which imparts to them a dreary sterility *much aggravated* by the paucity of prominent objects to

relieve the uniformity. In summer these downs are bedecked with tufts of variegated heaths, which in autumn is succeeded by a gorgeous outburst of the furze blossom that embues the gentle slopes with golden hues. Half a century since, these downs or commons were far more extensive and desolate, but thousands of acres have been brought into cultivation by the miners and small farmers with incredible labour, worthy of more generous leases.

Anciently these downs are said to have possessed a sylvan character, and in many places remains of charcoal pits have been ploughed up, and decayed tree stumps exposed in localities where no trees have been known to flourish by the oldest farmers. In the mining districts which usually occupy these commons, the barreness is intensified by unsightly burrows of mine rubbish, which, intermingled with rough and rickety wooden structures carrying tramways, flat rods, and hauling chains, with ragged sheds, and the varied unclean appliances which the dressing of the metallic ores necessitate, combine to form a scene, the dismal wretchedness of which remains unequalled. Many square miles of country are thus laid waste and rendered worthless for agricultural purposes, though the industrious miner, who is usually the proprietor of a house and plot of ground, labours with infinite toil and commendable perseverance to level the burrows in order to obtain pasturage for his cow.

The more or less circularly shaped granite bosses that extend in a linear direction from Dartmoor to Land's End, lose elevation towards the west, thus, the highest tors of Dartmoor attain a height of 2000 feet, which diminishes to 1368 at Brownwilley on Bodmin Moor,

1034 at Hensbarrow tumulus, 850 at Crowan Beacon, and 800 feet at Carminnis, until at the Scilly Isles (Hesperides of Herodotus) the highest granitic peaks are but 220 feet high at St. Martin's obelisk, the rock finally vanishing beneath the ocean in an extensive reef. The trunks of forest trees, often found in the detrital accumulations resting in the depression of the eruptive bosses, seem to imply that at a remote period the heights were clothed —partially at least—in forest growth, however this may be, the present violence of the winter storms scarcely permits the growth of trees on the highlands of the western part of the county, where they are exposed to the full force of the Atlantic gales.

The few stunted trees and straggling bushes striving to vegetate, indicate unerringly the direction of the prevailing winds by the growth of their branches eastward. This deficiency of forest land, has developed a large timber trade with the Scandinavians to supply the pine wood required to keep open the shafts and levels of the numerous mines.

The **Scilly Islands** are composed wholly of ordinary granite, and consist of six large islands and a multitude of islets and rocky masses to the number of a hundred and forty-five. Numerous rock basins, many of large size and by some believed to be Druidical, which crowd the surfaces of large blocks, are hollowed out by the action of rain water. The scenery amongst the islands is romantic, though the want of trees much impairs its beauty ; they are adorned by bushy heaths which the semi-tropical character of the climate has caused to cluster luxuriantly amongst the surface rocks. Palms may be seen flourishing *at Tresco,* and the geranium flower ornaments with a

flood of crimson the fronts of the cottages and the garden fences. Fish multiply amid the lovely rocky isles in security, and the western reef literally swarm with gigantic seals, while during the mating season myriads of sea-fowl flock around the rocks above, or cover acres of the surface of the adjacent sea. Coral grows abundantly not only here, but in the vicinity of Falmouth.

If the scenery amongst the downs and moors fails to excite the softer emotions of the heart, this cannot be said of the beauteous and fertile valleys, which, taking their rise amongst the tors, course southward through charming dells, woods, and flowering prairies, to the English Channel. No description would do justice to the varied and delightful landscapes which abound on the southern slopes.

In the time of the Romans two **Roads** were made, one on the north through Stratton, Bodmin and Redruth, to St. Ives; and the celebrated Watling street extending from Saltash through Liskeard, Truro, and Helston to Penzance. These roads are still the chief thoroughfares, and whilst the latter passes through the most picturesque scenes of the south, the former traverses the grander regions of the Cornish heights.

The **Climate** of Cornwall is varied and uncertain; on the north coast the atmosphere during summer is bracing without being cold, whilst on the south it is humid and relaxing, and westward, at Mount's Bay, the summer is very hot, and at Scilly becomes even sub-tropical. The winter is nowhere severe, snow seldom falling, but the continuous rains and mists make the climate during this part of the year very trying to all but those of robust constitutions. The mildness of the climate compared with

that of eastern and central England is due to its more pronounced insular character, and to the heated waters of the Gulf Stream. This maritime situation ensures an equable temperature, and the meteorological register shows but a small range.

The population is variable on account of the irregular state of the metal markets, because during times of depression the miners wander abroad in search of employment. Just at present the county is suffering severely from the low prices which prevail for metallic products. In 1871 the total population amounted to 362,098 and this compared with the last census shows a decrease of inhabitants of 32,614.

The Land's End.

SEQUENCE OF GEOLOGICAL FORMATIONS.

Rarely does such a small tract of country as Cornwall, possess such advantages and incentives to the study of vein systems associated with primary schists that have been mineralized by the upheaval and intrusion of eruptive rock. For the scientific classification of the strata, and the minerals they enclose, the Geological Society of Penzance was originated in 1818, since which time many eminent geognosts have, with unselfish zeal, laboured to adjust the chronological position of the Palæozoic beds of the west, and to elucidate the genesis of the innumerable fissures, by which they are disrupted. Glancing over the map issued by the Geological Survey, the colouring represents a chain of granite islands rising above a sea of slates. This simplicity of geologic structure is, however, only apparent, the rocks when studied minutely presenting complications which the scanty opportunities for investigation afforded by a cultivated country, render difficult of solution. The similarity of the Cornish killas, aggravated by metamorphism, cleavage, and contortions, together with the consequent broken condition of the often scarce fossils, adds to the difficulty of clearly determining the relative age, or defining with anything like accuracy, the precise superficial extension of these ancient formations; indeed, but for the length of the coast line, with its lofty precipices and deep inlets, the sequence of the clay slates west of Liskeard would be still more ambiguous than is at present the case. Allowing for the irregularities produced by upheaval and denudation, the clay slates become gradually older from the carboniferous beds of Launceston

and Bude, to strata below Silurian in the west. The formations in this series are shown to be distinct by their unconformability, and by the dissimilar strike of the bedding, but whatever position they may hold in order of time, they alike exhibit plenteous evidence of contortion and denudation, each having furnished the materials for the building up of its successor; moreover, each has been disturbed by the intrusion of igneous rocks before the upheaval which produced the granitic domes.

According to Mr. J. H. Collins and others, who have devoted themselves untiringly to remove the obscurity which has so long enveloped the age of these primary schists, the following table represents very nearly the stratagraphical order of the Palæozoic strata.

Formations.	*Rocks.*	*Strike of Strata.*	*Dip of Strata.*	*Thickness of Strata.*
				Feet.
Archœan?	Mica slate, &c., of Lizard ..			
Cambrian? ..	Ponsanooth Beds	N.W.	N.E.	12,000
Lower Silurian ..	Veryan Beds ..	S.W.	S.E.	23,000
Upper Silurian?	Fowey Beds ..	S.S.E.	E.N.E.	10,000
Lower Devonian	Liskeard Rocks	E.	S.	
Lower Devonian	Plymouth Rocks	E.	S.	
Upper Devonian	Petherwin Beds	E.S.E.	N.N.E.	
Carboniferous ..	Launceston Beds	E.	S.	

ARCHŒAN. The Lizard Head is composed of micaceous and talcose slates, &c., similar in character to those on which the Eddystone lighthouse is built, and to *the* large extent of mica schist forming the southern ex-

tremity of Devonshire between Bolt Tail and the Start Point. These rocks form portions of a metamorphic series bearing little relation to the Cornish strata, which were subsequently deposited. Around the serpentine of the Lizard promontory are some highly crystalline metamorphic rocks, which are considered by some to be of pre-Cambrian or Archœan age. They consist of gneissose rocks, hornblende schist and rock, gneiss, gabbro, and diabase, in nearly all of which the hornblende has a distinctiveness and brilliancy rarely observable elsewhere. The constituents of these varieties are hornblende and felspar, generally in about equal quantities. They appear to dip under the mass of serpentine, though this is not satisfactorily determined, because on the north in certain localities they dip from it. The junction of the clay slate with the hornblende schist is signalized by the presence of a conglomerate, which is sometimes besprinkled with native copper and some mundic.

CAMBRIAN. Excluding the metamorphic zones of slate mantling around the eruptive bosses, and those portions cut up by numerous granitic dykes and lodes, the clay slates lying at a distance from the granite are not much altered from their original condition after consolidation.

The oldest slates sweep around the Carnmenellis granite from Godolphin through Crowan, Gwinear, Camborne, and Redruth, to Perranwharf and old Kea, extending also northwards to the Illogan and St. Agnes cliffs. On consulting the ordnance map, this formation is found to embrace the richest and oldest tin mining districts in Cornwall. There seems little doubt that these beds are pre-Silurian, on account of their ancient appearance and

rough foliated and siliceous character, and Mr. Collins has classed them provisionally as Cambrian. They enclose neither sandstone nor limestone, and no fossils have ever been found in them. Throughout the whole formation the basset edges of the beds have a north-westerly strike, with a dip at Ponsanooth close to the granite of 45° to the north-east, though on following the strata eastwards this angle becomes reduced to twenty degrees. The total thickness of the formation may reach 12,000 feet. Similar rocks rise from beneath the Lower Silurian near Cargoll and come out at Penhale Point; hard silicious rocks are also visible on the coast south of Pentewan, the strata in both cases having a direction similar to that of the principal mass.

The rocks of the **LOWER SILURIAN** occupy a much larger area than those of the Cambrian, and the included fossils leave no doubt as to their geologic age. This formation is much intermingled with that of the Devonian, the upheaval and denudation of the latter having exposed in an irregular manner the Silurian strata. They surround in a broad belt the Hensbarrow granite, extending northwards through St. Wenn and St. Breock to Wadebridge and enclose the mines of St. Austell and St. Enoder. There is also a patch covering parts of the parishes of Perran, Cubert, and Newlyn. The whole of the Gwennap and Chacewater mines are encased in Silurian strata. They also stretch from Mevagissey and Ladock along the south coast to Helford, occupying both sides of Carrick Road. All the clay slates between the serpentine of the Lizard and the granite of Carnmenellis and Tregoning, and the whole of the schists west of Cam*borne* to Penzance and St. Just, are considered to be of

Lower Silurian age. The mining fields of Wheal Vor, Marazion, Hayle, St. Ives, and St. Just, find themselves in this formation. A very large proportion of the slates consists of rather hard thin bedded rocks usually grey or blue in colour, which sometimes assume a roofing slate texture, or deteriorate into tender arenaceous shales. Amongst these are numerous beds of highly siliceous rock that bear a considerable resemblance to intrusive greenstone, some thick bands of quartzite, and many siliceous conglomerates.

The strike of the strata is very constantly to the south-west, with a dip towards the south-east. Mr. Collins assigns a thickness of 23,000 feet to the rocks of the Lower Silurian.

The **UPPER SILURIAN** rocks usually spoken of as the Fowey beds, occupy a limited area between the Cornwall railway and the coast, along which they prevail from St. Austell Bay to the waters of the Hamoaze. Fossils, especially icthyolites, are plentifully found along the littoral in the arenaceous beds, and fix with some certainty their stratigraphical position. The prevalent colour of the slates is a dull grey or brown, which shades off into yellow and lake.

The beds are but little disturbed, and there is a characteristic absence of greenstone, with the presence of some beds of limestone. Although Restormel iron mine and the Herodsfoot lead mine have been worked in these rocks, they cannot be esteemed as highly metalliferous. The strata have a regular strike to the south-south-east, with a east-north-east dip of 26° for several miles, and this has enabled Mr. Collins to assign to the Fowey beds a depth of deposition equal to 10,000 feet.

The Devonian rocks, which rest unconformably on the Silurian, spread over all the eastern part of the county as far north as Launceston, where they descend beneath the carboniferous formation.

The **LOWER DEVONIAN** is well developed in the parishes of St. Austell, Ladock, and St. Allen, extending along the shore from the Gannel to the farther side of the Padstow estuary. The Ladock beds consist of alternations of hard dark grey and bluish schists, with soft reddish or yellow slates, and with some conglomerates and sand stones that course with remarkable persistency and regularity from Mevagissey to Perran. Notwithstanding that these beds are much disturbed by intrusive rocks, and are folded into anticlinals, they have a regular east and west strike and a general southern inclination. In the Ladock beds, throughout the whole thickness of 1500 feet, neither limestone nor fossils have yet been observed.

To the south of Bodmin Moor in the neighbourhood of Liskeard, are Devonian rocks that are believed to be the lowest of the series. They extend eastwards across the higher tidal waters of the Tamar, and the largest part of the Caradon and Tavistock mining districts are found in them. The Plymouth red sandstone and slates overlie the Liskeard beds. Both these sub-formations have a regular east and west strike, and, though there is some crumpling of the strata there is a prevailing dip to the south.

The **UPPER DEVONIAN** rocks, termed also the Petherwin beds, which border the Carboniferous formation, reach to the foot of the granite ranges of Bodmin Moor and Hingston Down. They enclose throughout large bands of greenstone or altered siliceous slate, intercalated in hard fine argillaceous beds, which, curving around with

the granite, become so highly crystalline to the north and west of Camelford, that excellent roofing slate is obtained from them. The strike of the beds seem to be influenced by the contour of the granite, from which they incline, and distinctly dip under the shales of the next formation. The Upper Devonian rocks of Cornwall are but little metalifferous, only a few superficial deposits of manganese having been worked.

Only an unimportant area of the extreme north-east of the county is occupied by the grits and shales of the **CARBONIFEROUS** system, which repose with considerable lack of conformity on the slates of the last formation. They have been much disturbed by igneous action, though no ores of metals other than a few manganiferous deposits of little magnitude have been discovered. The general strike of the beds is east and west, and they frequently have a southern inclination.

Although there are no rocks of the **CRETACEOUS** epoch nearer than the east of Devonshire, a considerable quantity of chalk flints and fragments of the Greensand lie scattered over West Cornwall. They are especially noticeable on the eruptive rocks of the Lizard and Land's End, and even on the granite of the Scilly Isles. No satisfactory explanation of their presence has yet been suggested, but it has been imagined that the formations containing these flints may have extended farther west than they now do.

The whole of the county is very destitute of limestone, none existing west of Truro, and the few limestones occuring to the east being scarcely fit to burn; consequently the lime used in Cornwall is quarried in the extensive and excellent calcareous strata on which

Plymouth is built. Such beds as exist, usually crop out from the argillaceous slates in thin and irregular beds of very inferior quality, having little extension either superficially or in depth. They enclose numerous fragments of fossils, which on account of the altered character of the lime rocks, are only visible in thin sections when examined through the microscope. Calcareous beds occur in patches along the south coast from Helford to the Hamoaze in Silurian strata, and on the north coast from the Gannel to Padstow estuary, and also in the neighbourhood of Petherwin, where it is intercalated with Devonian beds.

The conditions under which the Palæozoic slates of Cornwall were accumulated, were little favourable to the existence of those organisms on which the deposition of calcareous matters is dependable. All the Cornish strata are more or less fossilliferous as far west as Truro, after which they become involved with the granite dykes, and so disrupted by fissures, that metamorphism has probably destroyed any fossils which may have previously existed. The Cambrian has been found very barren of fossils, for though much search has been made in them, only rare fragments of tabulate corals have been discovered. The Lower Silurian beds are more productive, and many of the fossils, especially **Orthidæ**, are in a better state of preservation. In the neighbourhood of Bodmin are **Trilobrites** and crinoidal remains. The quartzites of Gorran and Veryan are sometimes very prolific, particularly at the Nare Head, where **Orthidæ** abound, and **Terebratulæ** and **Trilobites** are found. West of Truro fucoidal impressions have been noticed.

Though the superficial extent of the Upper Silurian

beds compared to that of the older subformations is but small, yet it is distinguished by a large number of interesting fossils, representative of many of the Palæozoic marine groups.

The petrified organisms are found most numerously along the littoral from Whitsand Bay by Polruan, Fowey, and Par, to Pentewan. At the Black Head near the last named place, the discovery of **Graptolites** have definitively fixed the Silurian age of those rocks. From the Rame Head to St. Austell Bay, corals have been abundantly discovered, and in many places as at Crennis, at Fowey, and in the limestone of the Black Head, are numerous remains of corals and encrinal stems, together with traces of other organisms. **Trilobites** are found also at various points, as well as **Brachiopodæ.**

The Fish beds that prevail from Polruan to Whitesand Bay are indicative of Upper Silurian age, though eastward they are said to approximate to the Lower Devonian group; the species however being peculiar to the former. The fragmentary state of these fish bones render somewhat doubtful the genus **Onchus**, which has been based on the variety of defensive spines found.

The beds of the Lower Devonian enclose many fossils, particularly in the vicinity of Liskeard, and between Newquay and Padstow, where corallines, encrinites, and similar genus abound in the beds containing calciferous matter, that prevails between the Hensbarrow granite and the Bristol Channel.

Trilobites, numerous in Roseland valley east of Liskeard, are rarer on the north coast; they are much broken and often even comminuted.

The large Sub-Kingdom **Mollusca** has one or more

genus in every class represented by fossils. Thus, amongst the Brachiopoda, **Terebratulæ**, and **Spirifers** are not uncommon on the north, and these, together with **Producta, Cirrus,** &c. are often gathered from the Plymouth beds, the fossils of which are believed to be mostly referable to the Mountain Limestone.

In the Lamellibranchiata, **Bellerophon** is met with in the Liskeard beds and elsewhere; and among the Gasteropoda, **Buccinum** and **Plentomaria** are not uncommon, whilst **Orthoceratites** and **Goniatites** stand for the Cephalpoda. It is to be regretted that only a small proportion of these fossils are well preserved.

The beds of the Upper Devonian are so much metamorphosed by the proximity of the Bodmin granite, and by the numerous and broad bands of greenstone, that the fossils found are far from numerous, and usually in a state very ungrateful to a collector. They prevail, however, throughout all the beds which curve around the highlands from Tintagel through Petherwin to the Tamar north of Hingston Downs. The fossils found, omitting the **Trilobites,** are much the same as those in the Lower Devonian, and therefore need no recapitulation, but they represent more nearly the character of the Mountain Limestone, and vegetal impressions are common.

In the roofing district in the vicinity of Tintagel, the fossils have a defined outline, and are encrusted with gleaming green plates. Fragments of **Spirifers** are frequent in the quarries of roofing slate, and many of the fossils are singularly distorted through the elongation caused by the cleavage pressure that gave to the fine argillaceous slates their crystalline character.

GREENSTONE. The Devonian schists in the

north-eastern part of the county, and the slates between Hayle and Mount's Bay are associated with numerous groups of hard green rocks, which have been indiscriminately termed greenstones. They have not, however, the same origin, but owe their existence both to intrusion and metamorphism. By much the larger proportion of these igneous looking rocks are found interbedded with the slates, from whence, owing to their indurated character, they often rise in low rounded knolls, or run into stony eminences. The contemporaneous formation of these beds appear clearly indicated by the coincidence of their direction with the strike of the strata, whether that be S.W. as in the Lower Silurian, east and west as in the lower Devonian, or S.E. in following the superior beds of the Old Red Sandstone. There is however an important distinction to be made in considering these rocks, for while most can without hesitation be referred to intrusion, many of the hard siliceous beds found in the metalliferious districts, many owe their durability and appearance to metamorphism. It is not always easy to distinguish these two classes when they are proximate to the granite, around which, on account possibly of the upheaval of the whole mass of strata, and the subsequent exposure of their basset edges by denudation, they sometimes seem to contour. Though the bulk of the **TRAPPEAN ROCKS,** especially those skirting the granite, remain hard, they are by no means always so, but often assume an amygdaloidal, vesicular, pumiceous, cindery, or even earthy form, where decomposition has loosened the structure. All these beds of greenstone, whether felspathic or siliceous, must have been existant prior to the granite upheaval.

Greenstone is rarely visible amongst the Cambrian beds, though some intensely hard siliceous rocks are found above the edge of the Gwennap and Penryn granite. Similar bands, though more quartzose and thinner, are seen north of Redruth. In the vicinity of Penzance there is a large development of altered slates and contemporaneous trap rock, which is very interesting because of their intimate alternation with argillaceous slates, and the conformity of the strike of the bedding with the contour of the deep indentation of the granite. Hard greenstone rock fringe the granite from St. Just to St. Ives, imparting to the western cliffs the ruggedness and romantic grandeur which attracts so many tourists. In some of these rocks, as at Botallack, Lariggan, and other localities, actynolite and axinite in beautiful crystals replace the hornblende, and also occur in veins. Numerous beautiful greenstones are interbedded with argillaceous slates east of St. Michael's Mount, and can be well studied along the Perranuthnoe cliffs; also in the Silurian slates near Helston, and at Roskreage Beacon on the borders of the hornblende schist of the Lizard.

The bands of Irestone, which appearing in St. Erth, cross the parishes of Gwinear and Camborne to the Roskear mines, have long been known; they are harder than any other beds in Cornwall. They are composed of minute granular hornblende, compact felspar, and quartz. Few greenstones have been observed in the central part of the county between the granitic domes of Carnmenellis and Hensbarrow, and from the latter westward to the coast, and northward to Padstow inlet. The *Upper* Silurian strata from Fowey eastward are equally

undisturbed by intrusive rocks, and the few beds termed greenstone in St. Stephens are merely altered slates. At St. Breock Downs is a remarkable group of quartzose bands, narrow, but well defined, whose strike and dip seem parallel to those of the accompanying slates for several miles. On the north of the tidal portion of the Camel are numerous contemporaneous greenstones, often vesicular, and similar rocks of Lower Devonian age east of Liskeard, have an east and west direction. The trappean rocks near the latter town exfoliate and leave hard nuclei like the greenstones of Saltash. The greenstone rocks of the Upper Devonian have a more important development than those of the more ancient formations, and appear to have been far more displaced by the granitic upheaval. The trappean rocks intercalated with the argillaceous slates, which have a strike a few degrees west of north in the parish of St. Teath, appear to take a bend around to the N.E. by Delabole and Tintagel, and continuing the curve arrive at the opposite side of the Bodmin moor, where their course is parallel to that of the eruptive rock, which has a S.E. bearing. The bands are broad and continuous for a long distance, and consist of every variety of greenstone, from the dark foliated hornblende rock found near the granite, to pumiceous and earthy beds stained with iron.

Besides the greenstone beds and contemporaneous trappean rocks, there is another class whose formative epoch is not so evident, as it cuts through the slates in irregular veins resembling the intrusions of granitic matter at the junction of that rock with the clay slates. Most of these are doubtless of pre-granitic age, though some may been injected during the cumulation of the

Lizard serpentine. The small and numerous trap veins that find themselves near Newquay, Saltash, St. Cleer, Helford, and at other places, which are filled sometimes with vesicular matter, but generally with green or greenish brown compact and homogenous rock, capable of receiving a high polish, scarcely merit the title of **TRAP DYKES.** The comparatively low temperature which existed in the veins at the time of their intrusion would be little likely to cause any considerable metamorphic effects on the enclosing rocks, and therefore, though the slates in their immediate neighbourhood are often displaced and even contorted, yet only the walls of the larger fissures, with some included fragments, have been here and there altered by heat, and by subsequent decomposition.

The siliceous greenstones and trappean beds and dykes, though occurring through the whole Palœozoic series of Cornwall, have not perhaps been observed with the intentness that their intimate association with the best metalliferious regions requires.

SERPENTINE. Though many parts of the county are noted for the production of rare minerals, no district possesses such geological interest as the Lizard, where a group of crystalline rocks, consisting of serpentine, diallage, and allied species exhibit a complexity of detail, and an association of beautiful earthy minerals rarely observed. The whole mass occupies the southern portion of the promontory, and is nearly surrounded by a broad interrupted border of hornblendic schists, that appears to form a sort of basin enclosing the serpentine plateau, whose limits are defined with sufficient exactness by the beautiful Cornish heath,

Serpentine Rocks. —— KYNANCE COVE.

called **Erica vagans,** which enlivening with its hues the sombre solitudes of the spacious downs, is found nowhere else except on magnesian rocks of analagous character, near Menheniot railway station. The eruptive period of the Lizard rocks is not yet conclusively determined; indeed, the present extent is due to more than one bursting forth of igneous matter. De la Bêche imagines that they may have appeared during the deposition of some of the Cornish Killas, though no traces of serpentinous rocks have been discovered in the conglomerates associated with those slates. Its pre-granitic age admits of little doubt, as it rests apparently on granite, veins of which are found penetrating it at many places along the encircling shores. The serpentine itself acts very much like granite, for though it seems to have little disturbed the southern dip of the Helford slates, there is, in some localities a kind of passage between the hornblende schists and serpentine, with an outward dip, and it has even broken through the slates at Pencarrack, and cut through the hornblende schists at Porthalla. These junction rocks are accompanied by a development of a limy substance, and much red colour in the serpentine. The Lizard rocks have a composition of remarkable variety, accompanied by a rich diversity of colours, that on polishing discloses a wealth of brilliant shades of red, brown, green, and grey, whose silky and pearly lustres are worthy of all the commendations which its manufacture into artistic ornaments has elicited.

DIALLAGE ROCK. The diallage rock which covers four or five square miles between St. Keverne and Coverack, is due to an eruption posterior to the consoli-

dation of the serpentine, because many veins of diallage containing fine crystals of saussurite traverse it at Coverack Cove. At Porthoustack and at Ruten Point, it has cut through greenstone and greenstone porphyry. The rock is composed of felspar, hornblende, and diallage, so that while it is often true diallage rock, it sometimes resembles a coarse mixture of hornblende and felspar; diabase is found and gabbro also. After consolidation, fissures were formed in both serpentine and diallage rock; a large course of diallage runs from Carakclews through Gwinter like an elvan, and similarly a dyke of trappean porphyry fissures the serpentine from Bochin southward to Penhale, whilst bands of trap rock prevail at Coverack Cove. Veins of steatite are numerous, and were formerly quarried for the manufacture of porcelain. Unimportant veins, at the contact of diverse rocks, yield specimens of native copper, one of which, weighing a hundredweight, was sent to the exhibition of 1851. Nowithstanding the extent of the magnesian rocks, chrome ore has only been noticed in minute quantities.

Serpentine in areas of small extent has been found in other parts of the county, as at Nare Head in Veryan Bay, where there is a group of rocks precisely like those of the Lizard. There is also a small outbreak through the clay slates at Duporth, and a fine dyke at Clicker Tor exposing variegated shattered rocks, with steatite or asbestos in the joints.

THE GRANITE ROCKS.

It has been shown that the clays, sandstones, conglomerates, and limestones which surround the eruptive

highlands of Cornwall, though all included in the Palæozoic or Primary group of formations, have yet been deposited at periods so immensely removed one from the other, that there was time sufficient for a specific and even generic mutation of marine life, and for a change in the deep seated axes of upheaval, by which some of the clay slates were folded into ridges, from which the strata inclined both ways. Thus the portion of Britain, now called Cornwall, was sea and land alternately before the upheaval of granite, which was to transform a mass of barren schist into rocks teeming with metalliferous wealth. Some physicists are of opinion that the granite range, stretching from Scilly to Dartmoor, is the result of upward thrusts given at distant epochs by forces acting in diverse directions; but geologists who have devoted their time and abilities to the study of the Cornish strata, consider them as formed during the same geological period, and place the epoch after the deposition of the Upper Devonian. From the constitution of the granite, it is inferred that it was cooled under a pressure, whose equivalent has been calculated at five miles of depth.

The general direction of this granite ridge is east-north-east, and though no doubt the original thickness of the slates brought up on the granite was very great, during and since emergence from the ocean, denudation has exposed a chain of granite domes of various extent, and reduced the thickness of the surrounding slates so considerably, that over most of the county the backs of the elvans and lodes have been brought within workable distance of the miner. So much appears to have been swept off some of the granite ranges, that the nucleus is approached, and the manner in which they were built up is

thus rendered to some extent obscure, but close observation of the numerous masses and broad bands of rock differently aggregated, supplies strong evidence that the earlier consolidations were subject to numerous disruptions, which not only elevated the mass, but extended it laterally. The granite produced by secondary eruptions, may perhaps be recognized by the corrugated surface of the granite from Carnbrea underground to East Pool, by similar ridges north of Hensbarrow, by the heterogenous aggregation of the composing mineral, and variety of texture assumed by broad bands of rock. Most of the subordinate intrusions have a direction more or less co-incident with the general trend of the range, but frequently they are small, curved, and irregular. The smaller tracts are fine grained, though often coarse when of great width, but both are distinguished by a finer and harder texture along the margin. Veins of greisen are not rare, especially in decomposed granite, though many of them may be considered lodes. Hensbarrow granite, which has possibly suffered less denudation, has a texture and composition of remarkable inconstancy, and is traversed by veins of finer or coarser texture, which in rare instances are nearly "giant granite."

The granite protrudes above the slates in masses of rounded form, and the exfoliation produced by the reaction of external influences, has given rise to a massive lamellar structure which is very conformable to the surface and dips at gentle angles under the clayslate. This, combined with the fissures due to the divisional planes, has caused the granite to assume the columnar and tabular appearance so characteristic of this rock. It will have been perceived from the above remarks that the reiterated

fractures sustained by the consolidating granite crust, could only have resulted in a very considerable diversity of the proximate constitution, as well as the texture of the erupted masses. The more closely the rocks are observed, the clearer becomes the evidence of the extreme incongruity of the granite. Generally the rock has a coarse granular appearance, which is most pronounced in the Land's End district, and is of the finest grain on Dartmoor. The composition, though subject to endless minor deviations, is usually a mixture of felspar, quartz, and mica, with some schörl; the latter, though scarce in the central positions, often assumes much importance towards the confines of the granite. This is especially the case around the Hensbarrow boss, where even the rocks of the interior abound in schörlaceous veins. Large areas are rendered porphyritic by the occurrence of big crystals of felspar, sometimes white, but beautifully tinted in the vicinity of the metalliferous deposits by incipient decom position. As a rule it may be said, that the crystals forming the aggregate, are individually imperfect, or have their edges not sharply defined.

The granite is also drier, more compact, and of a more homogenous texture when far from its junction with other rocks. There are limited areas where, as at Godolphin Hill, the component crystals are embedded thickly in a felspathic base. In some districts, notably in the neighbourhood of St. Austell, the granite consists of felspar and quartz, in which the former, under the influence of schörlaceous veins, has become so soft as to admit of its being washed for china clay. The granite is so variable that it is quite impossible to give its chemical composition with anything approaching to accuracy.

If we take an ordinary porphyritic kind, in which the proportion of felspar, quartz and mica are respectively equal to about one-half, one-third, and one-sixth, there would be about 73 % of silica, 19 % alumina, and 8 % of potassa, besides fractional percentages of iron oxides, magnesia, lime, soda, manganese, and fluoric acid, and where schörl abounds, boracic acid. Other common varieties do not contain so much silicic acid.

As granite owes half its bulk, and nearly all its mobility to **FELSPAR**, its character and resistance to decomposing influences is very dependent on that mineral. When the felspar weathers, the rock separates into its component parts, and the surface is strewed with growan. The felspar crystals bestow on the rock its ensemble, thus in the finer grained and non-metalliferous portions, the confused aggregation with felspar, gives the granite a dull grey colour, whilst in those places mostly approximate to the mining fields, where the felspar crystals are as a rule ill defined, and where incipient oxidation has altered their colour, variegated shades of brown, red, crimson, green, &c., impart to the rock characteristic hues that please the eye, and guide the miner in his search after subterrene ores. The large felspar crystals are sometimes removed by solution and re-filled with binoxide of tin as at St. Agnes Beacon, or adorned by radiate schörl as at St. Ives. The felspar of Cornwall (orthoclase) is a silicate of alumina and potash, containing about two-thirds silica, one-fifth alumina, and one-eighth potassa, with a small admixture of peroxide of iron, lime, and soda.

The decomposition of the felspar in some of the granulitic portions of the granite, changing the latter to a soft

crumbling mass, renders the potash and part of the silica soluble, and thus leaves the hydrous silicate of alumina, which is washed out and sold as china clay. Small tortuous veins of felspar frequently traverse the granite.

After felspar **QUARTZ** is the most important ingredient of granite. It is amorphous and seems to have been to some extent plastic, when the mica and felspar had assumed more or less their forms. It is generally pellucid, has a pearly white lustre, and often appears to have a smoky interior. In the midst of the granite ranges, the quartz is distributed with considerable evenness, but where disturbed, or when near the junction with other rocks, it is more variable, and contemporaneous veins of quartz, or quarts mingled with felspar, are frequently to be observed dividing the granite for quite a distance.

The **MICA** though usually small in quantity, has numerous, black, brown, and silvery white colours that give a pleasing brilliancy of appearance and diversity of character in the mineral districts, although more dull and monotone elsewhere. Short veins of mica are in some localities numerous, but are rarely of magnitude; half-an-inch in width or less being the common size. The following analysis of Cornish varieties will give a general idea of its composition.

	Grey Mica.	Brown Mica.
Silica	50·82	40·06
Alumina	21·33	22·90
Ferric Protoxide ...	9·08	27·06
Oxide of Manganese		1·79
Fluoric Acid ...	4·81	2·71
Potassa	9·86	4·30
Lithia	4·05	2·00
	99·95	100·82

Schörl is widely diffused through the Cornish granites, but is generally in small proportion in the main masses, except in the bosses of Land's End and Hensbarrow. In the latter it plays a most important part, as also along the junction of the slates with the eruptive rock. The following is a proximate analysis of the black variety so common in the Cornish granites.

Silica	36·10
Alumina	34·29
Oxides of iron	16·69
Boracic acid	5·88
Manganese	·22
Magnesia	1·64
Lime	·54
Soda	1·74
Potash	·34
Fluoric acid	·74
	98·18

Neither **HORNBLENDE** nor **TALC** are abundant in ordinary granite, though chlorite and talc replace to a small extent the mica in varieties; **PINITE** is however rather common in the Tregoning and Land's End district. At rare places, as in the Carn Marth rocks, fluor spar is found as a constituent.

Tin ore or cassiterite is found disseminated in patches of granite in St. Just, and on the eastern side of Tregoning Hill, but it can scarcely be said to be a constituent of the granite.

GRANITE VEINS. The eruptive matter which rushed into the earthquake chasms formed in the earliest consolidated granitic crust, was probably injected at the same epoch as the granite veins which rent asunder the adjacent sedimentary strata whenever the requisite pres-

sure became developed by the upheaval of the granite. As granite veins are seen cutting the clay slates in small tortuous veins, or penetrating between the beds wherever a junction is exposed, either amongst the rugged cliffs or in the mines, it is rational to infer that they occur along the whole line of juxtaposition. The character of these veins, which have no definite direction, is the same as the granite from which they were derived. The veins are usually of no great length, but since at Porthleven Cove and other places, they may be seen less than an inch thick, though of considerable length, the eruptive matter must have possessed a considerable amount of fluidity. From the numerous fragments torn from the slate and isolated in the veins, the force of the eruption must have been immense; in some places the molten rock has forced itself through strata which have closed behind it and left isolated masses of granite. Granite veins gradually fine out, have no distinct walls like elvans and indifferently intercalate with the strata or run athwart them. Owing to some difference in the rate of cooling, the smaller veins have more quartz and less mica with a finer grain; and the larger, though crystalline and even porphyritic in the middle, are compact along the sides. All the veins and isolated masses of granite are recognised, after due examination, to proceed from the main mass, and like it are non-metalliferous. If one may judge from the numerous granite veins visible about the beach and cliffs of the Lizard, penetrating serpentine and diallage rock; the inference that the magnesian rocks of that promontory have also suffered from the same upheaval, and now overlie granite is difficult to resist. The localities where the veins occur are much too numerous

to mention, but they can be best studied at Trewavas, near Helston, Polmear in Zennor, Porthleven in St. Just, and underground in the mines which are opened along the junction at the northern foot of Carnbrea Hill.

SCHORL ROCK. This rock is so intimately associated with the granitic rocks of Cornwall, that although many dyke like masses of schörl rock are found along the junction and running into the slate, and numerous schorlaceous bands and veins traverse the granite itself, it is quite impracticable to colour it on the map apart from the eruptive rock. The schörlaceous granite occurring in bands amid the ordinary granite, it may be that they were formed after the first consolidation of the erupted granite, though many alterations must have since taken place, owing to the facile manner in which schörl changes its locale; thus, it has been noticed that when schörl has penetrated into the cavities left vacant by the disappearance of the felspar, the enclosing rock in the immediate vicinity possesses little or none of that mineral. Many of the schörl rocks have a beautiful appearance; they are white when very quartzose; mottled, grey, and black in Luxulyan valley, where pinkish orthoclase and black schörl are embedded porphyritically in a grey crystalline quartz; whilst in another variety small prisms and groups of stellate schörl are thickly sprinkled through similar rock. The varying proportions of schörl to quartz are infinite, and while sometimes schörl is predominant, at others the quartz rock may contain scarcely any. Thus some species are even harder than the granite, and resist atmospheric influence far more successfully. This resistance is very pronounced in the western portion of Hensbarrow, where the Calliquoiter cairn, and the celebrated

Roche Rocks, break the monotony of the Moors, and invest them with sombre grandeur. Beside forming rugged ridges of schörl rock, this mineral is found abundantly amongst the altered rocks which so constantly accompany the junction of the clay slates with the granitic masses. The transition from granite to clay schists is remarkably interesting in many places, but perhaps nowhere is it so instructive as at Carclaze, where the lamellar varieties of schörl rock are exposed in a vast hollow that has been excavated across the junction, for the purpose of extracting the tin ore and the china clay accompanying the schörlaceous schists. As far as observation has gone, schörl is characteristically associated with tin ore amongst the altered slaty felspar beds along the margin of the granite in the famous mines of Tincroft, Cook's Kitchen, and Dolcoath. The unstable character of schörl, and its power of altering the appearance and character of both granite and slate, is shewn by its frequently occupying the joints in granite lodes, and by the occurrence of the tourmaline schists that gradually blends the granite into slates. But in addition to the prevalence of schorl in the positions above indicated, it plays also an important rôle throughout the entire mass of some granitic bosses, and this is most especially the case in the St. Austell hills, where schörlaceous veins are very numerous, and generally connected with the presence of both tin ore and kaolin. From the variety in composition and appearance of these veins, and the irregular manner of their occurrence, it is not an easy task to give an intelligible and concise description of them,* but the facility with which schörl

* Vide pamphlet published by Mr. J. H. Collins, F.G.S., on the Hensbarrow granite, where will be found a full and excellent account of these rocks.

rock passes into granite, gives colour to the suspicion that a large portion may be simply altered granite, due to the replacing of felspar by schörl; even brecciated masses have been found re-cemented by it. Although in the other eruptive bosses of Cornwall, schörl is not so prevalent, yet it may be said that schörlaceous veins—sometimes with felspar, sometimes with quartz—usually associated with cassiterite, are found in the granite of every mining district in Cornwall and Devon. Besides those in the Roche district, large masses of schörl rock are prominent at Wheal Trannack near Helston, Porthleden in St. Just, and at Tresavean in Gwennap.

CONCEALED GRANITE. Nearly all mining districts are clearly recognised to bear a close and intimate connection with the metamorphosed rocks, which the upheaval of the granite through the argillaceous schist has produced. Though from a cursory examination of a geological map of the county, the numerous lodes and cross courses found far from the confines of the granitic bosses, would appear to controvert this statement, a little reflection will lead to the conviction that the mineralized strata are almost without exception closely approximate to the eruptive rock, if verticality be regarded. Taking such districts as Marazion and Chiverton, both distant some miles from the junction of the crystalline with the schistose rock, we may feel assured from the numerous elvans which traverse the slates, that the main mass of granite is not distant. Though the varying size and dip of these elvans modifies to a considerable extent their porphyritic character, still from their appearance and mechanical composition, the relative remoteness of the nuclei from whence they proceeded can be roughly estimated.

Taking for examples the thinning out of the Gwennap group in the neighbourhood of Truro, where the porphyritic structure is almost lost, and elvan acquires the texture of sandstone, and the Chiverton group, where, but for their occuring in slates they might easily be taken for sandstones, one need not hesitate to affirm, that where these granitic dykes are wanting, the argillaceous slates become barren when distant from the eruptive domes. In the mining districts rarely found on the granite, the proximity of the slates seems also to have been essential, and though it would be rash to attempt to judge the amount of denudation which the granite has suffered from the metalliferous character of the existing surface, still there is a blank barrenness of mineral in some bosses when compared to others, which taken together with the rich stanniferous gravels that once filled the moors, would lead to the conclusion, that the more or less want of metalliferous wealth may be in relation to the depth of crystalline rock removed by the agency of water.

It was formerly considered that the granite inclined under the clay slate at about an angle of 45°. This has since been found in several instances not to be the case, the most important exception, and the one best known, is that seen in the mines lying on the northern slope of Carnbrea Hill; here, the granite after reaching a depth or 115 fathoms commenced to rise again until the top of a ridge was attained, and although it renewed its northerly dip, it rose into another ridge at East Pool. There can be little doubt that this character is prevalent going north, for, on the coast of St. Agnes, and Perran, the granite again comes to the surface at Beacon Hill and Cligga Head. Notwithstanding that the observations of geolo-

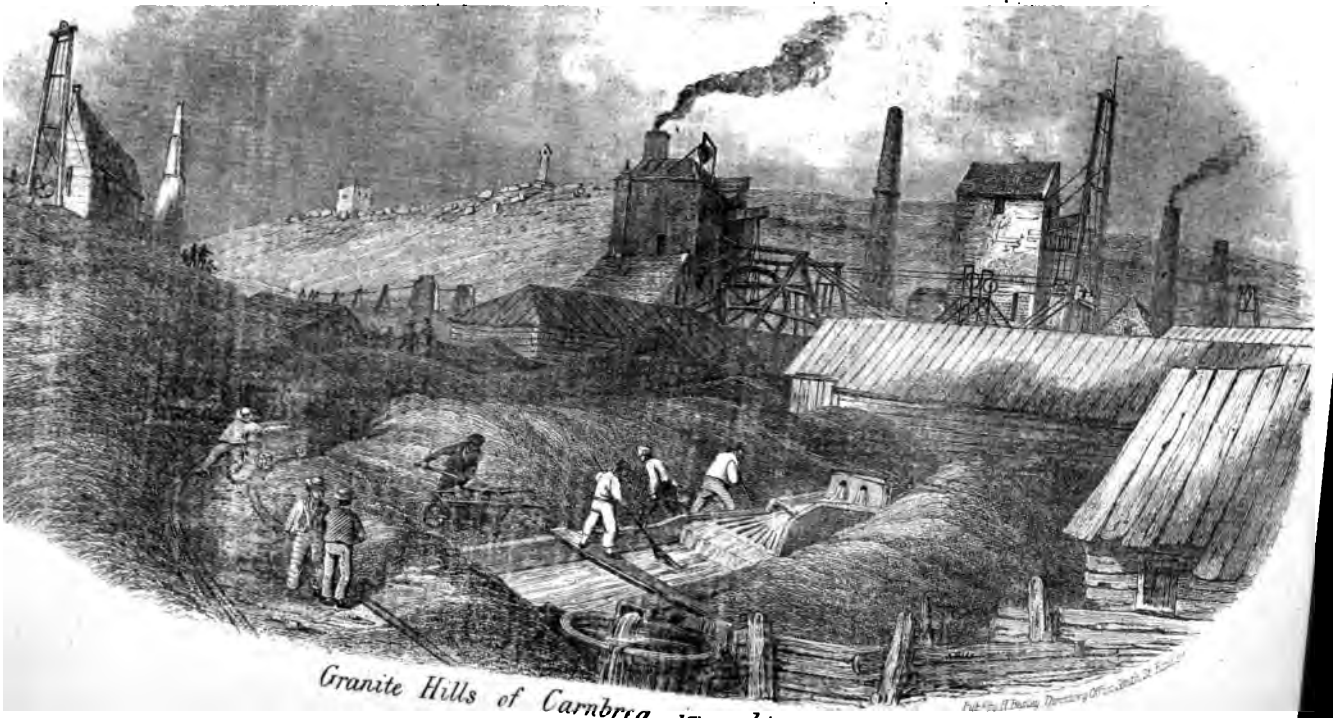
gists have shown conclusively, that the Cambrian and Silurian strata suffered from disturbance and contortion before the granitic upheaval, there are many tracts in the clay slate, where a quaquaversal dip of the beds, and a domelike contour, suggests the existence of eruptive bosses hidden beneath strata of moderate thickness. Thus the elevated ridge of St. Breock Downs—with its dyke-like courses of quartzose rock—consists of slates which conform with much accuracy to the swell of the hill. At Camelford, where the visible granite ceases, the seaward curve of the greenstones and their anticlinal dip, seem to indicate that the granite would be found at no great distance from the surface on the high ground between Roughtor and Cadon Hill near Tintagel. The fundamental axis of the eruptive rock is plainly detectable at the surface through most of the county, by the groups of elvans that run out in the direction of the succeeding boss. This can be clearly recognized between the mountains of Bodmin Moor and Dartmoor, where the elvan dykes stretching across the fruitful valley of the Tamar expand into the two small granitic eminences of Kit Hill and Hingston Downs, midway between the mountains. Though no main mass of granite comes to the surface in the Lizard promontory, the appearance of small elvan dykes, and the occurrence of numerous granite veins around it, leave no doubt on the mind of the observer that the granite supports the mass of serpentine.

KILLAS or CLAY SLATE. It has already been observed that the slates of Cornwall belong to geological formations deposited during most, if not the whole, of the time assigned to Palæozoic times, and that the strata composing them had been so disturbed, that in many

localities the beds were folded into anticlinals, and that the whole series of slates, limestones, sandstones, and conglomerates were consolidated, and had acquired to a considerable extent their present structure and appearance ages before the upheaval of the granite. The lentiles, veins, and splashes of quartz found everywhere associated with the schists, but most prevalent and contorted amongst the older strata, show that silica in solution prior to the granitic upheaval was not rare. Though these veins are termed contemporaneous, because of their being confined to a sequence of beds geologically limited, the silicious matter has been deposited within them by percolation in the same manner as at present, and consequently in the older and more disturbed beds, foliations and masses of quartz are predominant. These veins are short, irregular, and without walls; they have no persistent strike, dip, or size, nor do they enclose any mineral. The strata throughout the county vary in thickness from that of a sheet of paper, to several feet, and though usually clayey or fine grained, are often mixed with arenaceous strata as in the Ladock beds, or with conglomerate made up of moderately sized fragments, but occasionally—as at the Nare Head—of larger pieces, some of which reach the weight of several hundred pounds. The beds lie parallel to each other, and though sometimes uniform, are distinguishable by difference in structure, colour, and texture. Exfoliation of the slates along the joints and cleavage planes has much broken them up near the surface, but below the influence of atmospheric causes, they are sufficiently compact, and the strata generally clearly defined. It must, however, be admitted that the strike and dip of the clay schists are

often recognised with difficulty—especially in mineralized strata—because they are so much obscured by the planes of lamination, which are often the same as those of the bedding, and sometimes much more prominent. The disturbance consequent on the upheaval of the eruptive rock did not extend far from its borders; on the contrary, the distant beds—excluding the contortions due to plutonic action before the granitic intrusion—in spite of numerous changes of bearing and dip are but little deranged.

The activity of the plutonic forces, which awakened after the consolidation of the Silurian and Devonian formations, carried up the strata and left them arching over the numerous domes which form the Cornish and Devonian mountains. It has been estimated that these schists have had a minimum thickness of forty thousand feet, and this thick mass must have been denuded from the granite hills during its gradual rise and emergence from the sea. The clay slates like the granite fail in height from east to west; they mantle high around the Devonshire tors, whilst at the Land's End they are seen only in patches which disappear beneath the sea. The crystalline schists now seen mantling immediately around the bosses, are the denuded basset edges of the strata uplifted by the granite, and must therefore form a portion of the lowest beds of the formation to which they belong. These, metamorphosed by contact with the igneous rocks, have assumed that compact crystalline, but thick lamellar structure, which is so eminently characteristic of the metalliferous rocks, when in the immediate vicinage of the granite. The strata in the mineral districts incline at easy angles ranging between 20° and 30° from the granite; and this feature combined with



A TIN MINE

the similarity possessed by the altered slates, make it appear as if the same beds curved around with the granite, when really they often thin out, and are replaced by others almost identical in character.

The inclination of the slates is only high, when the line of juncture between the igneous and sedimentary rock happens to coincide with the strike of the killas, but though the mechanical effects produced, may seem to have been comparatively slight, the chemical alterations—to an important extent dependent on the original structure—are of the greatest magnitude, and have in an infinitude of ways transformed the contact rocks, and by replacement of one mineral for another, rendered it a matter of considerable difficulty to recognise their pristine character. It will not be deemed strange, that as the strata owe their changed condition to heat, their metamorphic character should be in direct relation with remoteness from the eruptive rock; and accordingly it is found, that whether these be slaty greenstone, hornblendic, chloritic, micaceous, or compact felspar slates, at a distance from the junction comparatively small, a schistose clay slate diminishing in metalliferous value invariably succeeds. The contact rocks, both granite and slate, are usually hard and compact, though in some districts where schörl prevails, decomposition has softened them, and a sub-crystalline texture, with a massive structure distinguishes the slate beds. Their character is so diverse around the different granitic tracts, that only the principal varieties can be enumerated in this place, whilst any rock peculiar to a district, will be referred to farther on. The prevalence of schörl in the granite, and of mica in the slates is of general occurrence, and often

it is quite impossible to detect the true line of separation. When schörl is not present in quantity, the transition is often imperceptible, the granite becoming more and more quartzose, and the slate more micaceous as they approach, though an absolute line of juncture cannot always be recognised. It is not rare for the contact to be sharp, slate resting directly on granite, and this species of junction is most common in the non-mineralised rocks. The conduction of the granitic heat has been the cause of some curious and interesting transformation of strata; thus, slates of fine texture have been changed to felspathic rock, sandy micaceous slate to mica slate, and even to a rock resembling gneiss, whilst some hard slates have become garnet bearing, and enclose patches of actynolite and axinite. Tourmaline schist is very common along the junction of the Hensbarrow, Tregoning, and other bosses, but it is difficult to say how much of these transformations may not have been effected by substitution since the consolidation of the granite.

Though the dykes of granitic matter called by Cornishmen elvans, have not mass sufficient to produce marked metamorphic changes on the slates which they traverse, yet in some places—where by some current, fresh igneous matter was perhaps passing—the elvan has pushed out veins into the contiguous strata, as at Poldory and Trevellas. At the United Mines there is an elvan which shows gradual transition to massive slate.

DIVISIONAL PLANES. The whole of the slate formations, together with the granite, greenstones, elvans, and even the veins themselves, are divided into innumerable rhomboidal and triagonal figures by a jointy

structure, the origin and age of which are as diverse as the rocks they traverse. The manner in which these lines of least resistance were first developed, has not yet been satisfactorily shown, but as they are common to all rocks,—whether subjected to plutonic action or not—and acquire their fullest development when nearest the surface, it may be due principally to a balance of the inherent forces which constrain every mineral to assume the crystalline shape appropriate to its elementary composition, and to the exfoliation of the rock which takes place when relieved from pressure, and exposed to aqueous action. It is then evident that the Cambrian acquired most of its jointy structure long before the Silurian strata were deposited, and that an immensity of time elapsed before the Devonian and Carboniferous series were built up and similarly affected. Thus each formation became penetrated by planes of division peculiar to itself, besides some created subsequently, which might be common to rocks of widely different ages. It is in this way that the oldest sedimentary rocks of Cornwall are usually those the most split up by planes of separation. The metamorphic action which accompanied the upheaval of the eruptive rock, though it obliterated in its immediate neighbourhood the ancient joints, gave after consolidation existence to a new series, which are now seen to traverse indifferently granite, granite veins, elvans, greenstones, and transition slates. The prolongation of joints from one rock to another, which is so noticeable along the junction of granite and slate, cannot therefore be considered as a proof of contemporaneous origin. Where great pressure prevails, or when the rock is of a nature little acted on by decomposing influences, the

joints though so prominent in the exfoliating rocks, are in depth so close as to be often invisible, though their existence is made evident when they are cleaved by the quarrymen, to whom these planes of division are of the utmost value and economy, the grain, as they term it, enabling them to shape their blocks symetrically. The divisional planes traverse the county at angles nearly vertical, but are so much more prominent in some localities, that they seem to affect a sort of grouping arrangement. They are most persistent in two directions, one oscillating principally between N.N.W. and N., whilst the other crosses them at right angles or nearly so; a third group less conspicuous prevails capriciously in some districts, and divides the rhomboids into rudely triangular forms. There are other groups having directions somewhat different, which appear to be affected by the character of the rock which they traverse, as in the serpentine of the Lizard, where they have a N. by W. bearing. A most interesting feature associated with the direction of the joints, is their general parallelism to the east and west lodes, elvans, and caunters, and the north and south cross courses. This connection is so obvious, as to leave an impression, that the fissure systems are but the final development of forces which originated the divisional planes. Like veins, they are not continuous, are subject to minor variations of division and dip, and have a parallelism which displays itself in groupings. Elvans and lodes, and even different portions of the same, have sets of these parallel planes, which are often filled out with quartz and tin ore.

In mineral districts the planes are more numerous and definite, sometimes one series prevailing to the more or

less partial exclusion of the others, and they also run into each other both in strike and dip. They vary from an inch to several feet apart, have usually the thickness of a line, but are more open in favoured situations, and are then generally filled with clayey matter or quartz in slate, and with felspath and mica in granite rock. It is then apparent that the jointy structure associated with rocks and veins is of no particular age, but is a necessity to rocky matter, whether accumulated as strata, or segregated as metalliferous veinstuff. This inherent interstitial structure permits the circulation of currents of water through both sedimentary and plutonic rocks, as well as within the different vein systems.

CLEAVAGE. Neither jointy structure nor lamination of the slate beds have anything in common with cleavage planes, which though often imperceptible, and their existence only recognised by the facility with which the rocks split in their direction, pass through everything regardless of the undulations, foliations, or contortions of the disturbed strata. They pervade also the numerous fossils of the Tintagel neighbourhood, distorting them by elongation along the lines of lamination. The dip and direction of the cleavage is constant, and though sometimes nearly coincident with those of the bedding, crosses them at every conceivable angle. It is then evident that this property has been developed since the disturbance of the strata by plutonic force. Usually the slates effected have a grain so fine as to be indistinguishable, and some of them have such a perfectly fissile structure, as to be quarried for roofing slate; this is especially the case in the Delabole district, where numerous quarries have been opened.

Notwithstanding that the cleavage permeates the whole district, its fissility is, to a marked extent, dependant on the rocks encountered; for when the slates are not of a slaty texture, but become siliceous, gritty, or of a loose nature, the cleavage becomes less pronounced, and in quartzose rock disappears entirely. Again, when passing from one rock to another—for instance greenstone to slate—cleavage is not indifferent to the sudden change of texture, which gives rise to hesitating wavy lines.

On the outskirts of the Delabole district, where the laminating force has been weaker, fine homogenous grained slates may possess a fair amount of fissility when the intercalated beds of sandstone may show but slight traces. The colour may be grey, green, or reddish, without the slates being necessarily different in constitution or less obtuse to weathering. The roofing slates are principally confined to the north of Cornwall, though some are found in the vicinity of Saltash, and near Padstow. The slates of the Delabole quarries dip westward at angles a few degrees removed from verticality, and are divided at intervals by east and west joints. The slates produced are of good quality, and, besides supplying the county of Cornwall and Devon, are largely exported.

Chapter II.

ELVAN COURSES. Having touched on the jointy and laminated structure inseparable from rocks that have been subjected to pressure, when brought near the surface by upheaval and denudation, the description of the many diverse systems of veins subsequently developed follows naturally. To one accustomed to wander in the underground workings of the mines, the priority of the porphyritic dykes, which are known to all classes in Cornwall by the name of elvans, is manifested in various ways. That the range of granite hills through the two western counties are all connected by ridges now concealed under clay slate of varying but comparatively of moderate thickness, is made evident by a glance at the Geological Map, where the elvan dykes may be seen extending with scarcely a break of continuity from one eruptive boss to the other. Their formation during the consolidation of the superior crust of the granite, admits of small doubt, and though they may be considered geologically of the same age, the absolute distance in time between the genesis of the different groups must have been, humanly speaking, infinite. Their relative age may often be distinguished, the earlier elvans being recognized by their more granitic structure, and by their frequently acquiring a greater width as they approach the granitic nucleus.

The porphyritic elvans, which are much the most numerous, fill fissures made probably through a much thicker crust, at a period when the superincumbent strata were less heated and allowed a quicker cooling, so that the crystallization of the felspathic matter was more or less impeded; consequently, these dykes are continuous through granite and slate, and can be traced with facility near the junction of those rocks, but with more difficulty as the interior of the erupted rock is approached. Elvan has the same chemical composition as the granite from which it proceeds, but its aggregation and structure, though probably identical at the bottom of the fissure, becomes less and less granitic *pari passu* with remoteness from the nucleus. The size of the dyke and the quantity of molten matter poured through it, effects materially the rate of refrigeration, and consequent constitution of the rock consolidated. The effects of cooling are most conspicuous at the sides of large elvan courses, or throughout them when their size is diminutive. Thus they change quickly in breadth but more slowly in length, for, however granitic they may be at first, they become highly porphyritic on entering sedimentary strata, though, during a course of some miles through them, they gradually lose this character, until at last, assuming a fine granular aggregation they have much the appearance of sandstones, from which however they are easily distinguished by their colour and characteristic jointy structure. They seem to effect a grouping arrangement, which may perhaps be due to their occurring on hidden ridges of granite along which the subterrene pressure has been more strongly directed. However this may be, the greatest development of these groups of elvan dykes is to be found running from one

granite boss to another, or taking a direction roughly parallel to the line of general upheaval. There are some localities which seem to confirm this idea, one for instance in Gwennap, where a network of elvans has the appearance of forming the spine of a spur of eruptive rock not far beneath. The Cornish elvans occur in the same manner as trap dykes, from which they differ chiefly in mineral aggregation, but are more plutonic in character. They fissure granite and slate indifferently, and run for many miles intersecting the beds at all angles, but preferably follow the lines of divisional planes, to which circumstance Mr. W. J. Henwood attributes their usually smooth and well defined walls. They are easily found by the numerous quarries opened along the outcrops, and are conspicuous underground by the crystals which they enclose, and by the contrast of colour and structure with the rocks in juxtaposition. In the granite their distinctness is not so apparent, but they nevertheless show a porphyritic character for long distances, and in one instance very nearly crosses the widest part of the Carnmenellis boss. Elvans rarely preserve straight courses either in strike or dip, but seize on the places of least resistance, and it is owing to this that they have a general wavy course that becomes abrupt when meeting with obstinate strata. Though these dykes keep as a rule a firm decided course, even those the most prominent are liable to split, a noticeable example of this occurs at Cayle near Hayle, where the Marazion elvan divides, one portion continuing to Pool village one side of a course of irestone—which may have given rise to the split—whilst the other to the north of it becomes the Roskear elvan.

If the fissures now filled with granitic matter, were

formed by fractures in the comparitively thin crust first consolidated over the molten rock, these elvans must of necessity become patchy and finally cease altogether in depth; and there are symptoms at the bottom of the deepest mines in the Dolcoath district, that their termination will be found at a moderate depth. It is seldom that the laminæ of the slates assimilate in parallelism to the dykes of elvan, but where they do so, fragments of the rock traversed are sometimes found near the walls along which the current seems to have carried them. An instructive example is afforded by the Pentewan elvan course, where, although they are very numerous at the sides, none of the shattered pieces ever reach the central portion.

The general directions of elvan courses varies but little from those common to the divisional planes. The Land's End tract seems singularly destitute of well characterised examples, the patches observed usually appearing to belong—like many of those of Hensbarrow granite—to a period anterior to the formation of true elvans. In the neighbourhood of Penzance commence the most considerable elvan courses in Cornwall; they have a remarkable diversity of bearing near Marazion, where one runs N.E. through Carn Brea district, while another extends eastwards to Godolphin Hill, and a third takes a southeasterly direction to Trewavas cliffs near the Looe Pool. A most interesting group of elvans cross the county from the Lizard through the East Wheal Rose Mines to Newquay, and their diverse aggregation of minerals seem to proclaim them of different epochs. Many of them appear to curve away from the Gwennap dykes, to which they bear a resemblance, others, such as the Trelissick

elvan, may possibly owe their origin to convulsions which heralded the approach of the granitic upheaval. The important groups of elvan courses that ushered in the formation of the St. Austell vein system, possesses a W.N.W. bearing, which is that of no other group in the county. The numerous elvans between Saint Columb and St. Wenn, indicate that the granite may be existant at no great depth, and their continuity and parallelism is indeed worthy of especial notice. These, like those associated with the granite hills of Bodmin and Dartmoor, run persistently from east to west. There is an extraordinary white elvan, composed of felspar and quartz, that runs from the neighbourhood of Camelford, several miles to Padstow, unaccompanied by a pronounced system of veins.

The dip of elvans is more regular than that of lodes, and though some of them have a flat underlie, yet very frequently their angles of inclination are less removed from the perpendicular. A great number incline at angles ranging between 50° and 60°, or from 3½ to 5 feet in a fathom. Usually, and especially in the Camborne and Redruth neighbourhood, they incline from the granite.

The breadth of elvans are subject to such frequent and great variation, as to induce considerable suspicion that the hanging wall has slipped downwards during cooling. The width ranges from a foot to sixty fathoms, but the general size lies between two and twelve fathoms. They increase in average width from Marazion, where they are from one to eleven fathoms wide, to Gwennap, where their breadth is from three to thirty fathoms—but are again much smaller in the St. Austell group, in which

district they vary from two to eight fathoms. The excessive variation in the width of even the same dyke is well exemplified at Wheal Unity in Gwennap, where the elvan—which was extensively excavated for the tin ore it contained—was in some places only six feet wide, whilst at others it swelled out to sixty fathoms.

The structure of elvan courses throughout all the metalliferous slates, bears a distinct relation to their remoteness from the parent rock, and the consequent more rapid cooling of the injected granitic matter. Their ultimate chemical composition may be everywhere much the same as the granite itself, but the aggregation of the minerals to which they owe their pronounced porphyritic character is dependant somewhat on the size of the dykes, but chiefly on the distance they have flowed through unheated strata. This is abundantly evident when the dull, hard, fine grained, and sometimes laminoid borders in contact with the walls of clayslate, are compared to the middle of the elvan, where the numerous brilliant crystals, sprinkled through a coloured granular base, produce a vivid contrast. This selvage, if it may be so called, is very prominent when the slates are of a loose schistose character, but is less marked when the walls are compact and crystalline. In the granite, the elvans having had their source from the mass below, are very similar in appearance and aggregation, but may be traced by their general finer grain, and by the compacter portions against the walls, whose texture resists weathering and remains hard even when the interior has been softened.

Some elvans, for instance those of Cubert, Padstow, and Blisland, have a very granitic base, but are rendered

porphyritic by disseminated crystals of felspar, which are more numerous adjacent the sides. Throughout the schistose strata of the county, the elvans have usually a fine grained basis of felspar and quartz, though in Gwennap it is more than ordinarily felspathic and compact, whilst in many localities it is confusedly crystalline. This base is rendered more or less porphyritic, by crystals of felspar often large, and by translucent crystals of quartz —which in the Gwennap group of elvans, assume the form of sharply defined dodecahedrons—interspersed with less numerous spiculae of schorl, sometimes pinite, rarely chlorite or hornblende, but nearly always some mica, whilst in the Trelissick elvan course a mineral like bronzite prevails to the exclusion of other crystals. Remote from granite, the felspar crystals gradually disappear, and after them the quartz crystals, until the elvan has an even texture and granular appearance, like yellow sandstone, though still recognisable by the jointy structure it owes to lateral cooling. This change of character is so distinct, that one is tempted to judge the relative depth of the underlying granite, by the intensity of the porphyritic character exhibited by the elvan. The diffused crystals are sometimes so numerous and pronounced, that they give a distinctive colouring to the mass; thus the black elvan of Chacewater owes its dark tint to the unusual development of schorl and chlorite, the blue elvan of Wheal Ann to hornblende and chlorite, and the white dyke near Camelford to the absence of these minerals, and the prevalence of white felspar.

The colour of the compact granular base is generally of a light yellowish brown, but changing capriciously and without apparent cause, it may be green and roseate, or

grey and drab, within a few feet, or even each side of a line. The more felspathic an elvan, the more prone it is to soften when exposed to the action of water, but this decomposition is erratic; for the rock may be hard at one place, whilst in another not far away it may be worked for fire clay. In porphyritic elvans the felspar has sometimes disappeared, and the cavities are beautified by acicular crystals of various minerals growing from the sides, or are completely filled with tin oxide. More rarely—as near Terras—the base suffers decomposition, and the crystals remain intact. Very seldom, as on the cliff near Wheal Golding, an incipient concretionary arrangement has become developed at the surface of some elvans. As a rule, concentric lamination is not natural to Cornish elvans, which affect a jointy structure that divides the dyke into rude triangular masses. The joints when open are filled with ochreous matter, often with tin ore, and more rarely with native copper. Although elvan courses have little in common with lodes, yet they are often so called by miners, on account of their enclosing reticulated veins of tin ore when in slate, which mineral is also often disseminated in the elvans traversing granite; accidentally other minerals are found disseminated in the rock, amongst which, crystals of mundic, nodules of graphite, and galena may be mentioned.

In Cornwall elvans have such a well recognised influence on the segregation of ores, that no group of productive veins in the clayslate has ever been discovered unaccompanied by dykes of porphyry or courses of greenstone, and even in the granite, their influence is clearly discernable. Tin ore is associated in the closest intimacy

with granitic rock, and is seldom, if ever, found far away from it. Lodes when intersecting a compact felspathic elvan, or following one of its walls, are, almost without exception, found to contain large courses of tin or copper ores, and sometimes the latter grows richer in the elvan than in the granite or slate; but should the porphyry be jointy, the lode may, owing to its broken condition, be unproductive. Elvans which permit free aqueous circulation, have had, especially in the killas, an important influence on the enrichment of the "bunches" of mineral in connection with them, but those hard, fine grained, quartzose varieties, in mining parlance known as "dry elvans," assist but little the deposition of metallic ores. Elvan courses are not heaved to the same extent as the lodes, with which they are so closely intermingled, and this may perhaps be on account of their width, hard crystalline and unyielding nature, and to their greater verticality.

There is another kind of dyke, called, by Camborne miners, Irestone which, though less plutonic and but slightly porphyritic, has just as favourable an influence on lodes as true elvans. They consist principally of chlorite, quartz, and hornblende, are of remarkable compactness and induration, and are found running for long distances with an average width inferior to that of elvans. They seem older than the elvans, though the latter rarely intersect them, prefering to take a parallel course. They have the same bearing as lodes and elvans, and are at Roskear and Tincroft, about twenty fathoms wide. An eminent mining authority in the Camborne district has remarked, that in the killas, no mineral of value has been discovered apart from courses of elvan and greenstone.

VEIN SYSTEMS. The instability of the terrestrial surface, which a study of the rocks of Cornwall reveals, gives a considerable shock to one's ideas of the solidity of the earth; and the ocean, the archetype of changefulness, is found to have had an eternal existence compared to the time during which a series of strata became deposited, and by denudation restored to the ocean. Doubtless the granite was denuded on emerging from the ocean, but its true crystalline texture proclaims the vast depth of sedimentary strata with which it was covered at the period of consolidation. Though it is difficult, with our imperfect knowledge of what may happen some miles below the surface, to designate a theory which would be capable of explaining the origin of the diverse fissure systems, which have, time and again, ruptured the clay slates, we may conjecture that they were formed immediately after the elvan courses, when the granitic crust had acquired an increased thickness. The fissures were possibly the result of earthquake shocks, widened by shrinkage and general upheaval of the slates; but in whatever way they may have originated, they permitted freer access of water to the heated rocks, and introduced conditions eminently conducive to the segregation of both earthy and metallic minerals, and to their deposition in favourable cavities at a distance appropriate to their several affinities. The immensity of time demanded for consolidation, allowed ample opportunity for the formation of fissure groups, for the dislocations and faultings which developed the hollows, and for the gradual filling of these by mechanical or thermo-electric deposition. The minerals would appear to have been deposited according to the resistance they have offered to heat and pressure;

'Junction of Killas and Granite.
S^t MICHAEL'S MOUNT

in this way can be perhaps partially elucidated the association of the richest deposits of tin ore with depth, and the occurrence of galena at a distance from the intensest thermal action, whilst cupreous deposits seem to occupy an intermediate position. The association of tin and copper in the same vein. may be partially explained by the re-opening of the tin lode, and subsequent deposition of cupreous ores between it and the dislocated hanging wall. The two parts of the lode are usually separated by a "parting" of clay or quartz. The whole county having been subjected to fissure systems produced at numerous epochs, during which the existing veins were many times opened, faulted, and the resulting cavations again filled with lode stuff; the elucidation of all the phenomena of heaves, and of the occurrence of metallic mineral, is attended by insuperable difficulties. Notwithstanding that in some instances, the so-called heaves may have been small in amount, it is certain that the vertical or very slightly oblique downward movements caused by the cross courses, is of much greater magnitude than the earlier geologists of Cornwall conceived. Though the surface is now so level, a study of the heaves in the St. Agnes and Perran districts, discloses an aggregate downthrow to the south, caused by the east and west lodes of more than a thousand feet; while the cumulative slip east, due to the cross courses, has been estimated by Mr. J. H. Collins, F.G.S., at many thousands of feet. In the face of such enormous dislocations, together with the probability that slips of strata have taken place between the cross veins, unaccompanied by much movement of the latter, the recognition of the ends of a heaved lode must be of extreme rarity.

The definition of true fissure veins is not altogether so easy as might appear; broadly stated, they may be said to be clefts of varying width, extending from the surface to such deeper portions of the earth's crust, as have a temperature and pressure sufficient to cause such hydro-thermal circulation through them, as will lead to their being filled with minerals of a character different from the strata which they have cut through. It would be well to mention here that beside the true fissures which traverse granite, slate, and elvan indifferently; there are numerous non-persistent veins, which, as they are confined to rocks of a definite epoch, are usually spoken of as contemporaneous. These veins are not metalliferous, but contain only earthy minerals; they are found all over the county and are filled with felspar, mica, schörl, quartz, chlorite, actynolite, thallite, axinite, prehnite, garnet, serpentine, asbestos, agate, jasper, opal, &c.

RELATIVE AGE OF VEINS.

Few places in the world can compare with Cornwall in the number and diversity of veins, and the anomalous phenomena which have accompanied their formation during a long continued succession of disruptions. For the sake of perspicuity the lodes and cross courses have been arranged in groups, and a relative age assigned them dependant on the intersection of one vein by another; and, though there may be a few cases where a vein crossed by another may yet be the youngest, there is no better test of relative age, than the matter of one vein passing through that of another. Mr. Carne, at an early period

in the geologic history of the county, devoted himself to the study of its vein systems and their priority of formation. The attempt to separate such a complicated series of fissures, with an approach to correctness, into definite systems possessing the same age, would be impracticable, on account of the numerous movements which older veins unquestionably suffered, when reiterated convulsions gave rise to new fissures. As however some sort of provisional classification, though to some extent erroneous, is indispensable in order to describe intelligibly the occurrence of lodes and cross courses, they may—if we trust to the evidence of intersections—be distributed in seven groups as follows, viz. :

1. Older stanniferous lodes.
2. Newer stanniferous lodes.
3. Older east and west cupreous lodes.
4. Caunter lodes.
5. Cross courses and Flucans.
6. Recent lodes.
7. Slides.

Although the cross courses and flucans are placed in the same group as if they were of similar age, there are many examples of their crossing and heaving each other ; and had their intersections been exposed to the same amount of observation as those of lodes, it is possible that considerable diversity of relative age would be apparent in them.

The development of parallel groups of productive veins, is influenced to a marked extent by the general character and texture of the geological formations disturbed by the eruptive rock. If, for instance, the Cornish strata had been of homogenous character, or composed

of ancient rocks already highly metamorphosed, instead of alternations of clay slates and sandstones of diverse grain, whose separate homogeneity, induced a wavy direction of the fissures due to the refraction of the subterrene shocks; the vast metallic wealth stored in the cavations resulting from the downthrow of the hanging walls, might have had no existence, or at least the deposits would have been comparatively insignificant. It is undeniable that veins are the largest and most persistent in compact and thick lamellar strata of diverse grain and density, particularly when strata incline gently outward from the granite, with a strike parallel to its flanks and to the line of general upheaval. Supposing indeed that the whole of the clay slates were nearly of a similar texture, density, and composition, the fissures finding nothing to refract them, would make an almost plane fracture, whose faulting would unfold hollows of insufficient importance to allow of that energetic hydro-thermal circulation, to which deposits of the useful metals are generally believed to owe their origin.

It has been remarked by the earlier investigators of the fissure systems of Cornwall, that the cumulative thickness of all the lodes known and undiscovered, would amount to an incredible proportion of the rocks; but it must be remembered that the fractures were formed successively by long continued upheaval, during which the clay slates lost much of their bulk by shrinkage, and the fissures acquired access of width by abrasion, aided by intense thermal action, which dissolved much of the wall matter that subsequently subsided in those portions of the veins, where a lower temperature prevailed. Though some groups of veins (especially those to the south of St.

Austell, and St. Just) have a widely different bearing, yet the general strike of the lodes—which coincides so singularly with the great lines of granitic eruption which run from the Scilly Islands to Exeter—seems to demonstrate that though intermittently formed, they, together with the cross veins, are nearly all the result of the same general epoch of upheaval. The fissuring extends throughout the county, but lodes become more numerous as the eruptive rock is approached, and are best developed in the slates which repose immediately on the granite. The influence that the mechanical condition and dip of the strata exercises on the development of veins, is made manifest by their absence where shelfy strata predominate, or where the strike of the beds is not concurrent with the contour of the granite; and, by their number and size, where the strata possessing the necessary favourable characters prevail. Viewed comprehensively, both lodes and cross courses thin out after running for some distance, but the fissuring continues in the same direction. It is not at all certain that the same vein extends without a break more than a couple of miles in length, but it is generally believed that the County Cross-course has fractured the rock from sea to sea. Although the lodes extend so considerably in length and depth, and are so important in regard to their metallic produce, yet they would resemble, even at a large scale, only a sheet of paper in size.

Every considerable system of fractures has its appropriate set of cross veins which have a relatively rectangular direction. The slate beds resting on the granite adjacent the junction, though so completely shattered by fissures of diverse direction, have been subjected to less downward movement of the hanging walls of lodes and

cross courses than those at a distance. The amount of dislocation is in evident relation with remoteness, for while the apparent faulting of veins near the granite is seldom extreme, at a few thousand feet the downthrows become very considerable. Observation has been little directed to the very difficult study of downthrows, but in St. Agnes—where the frequent intersection of two series of lodes with opposite dips, has revealed the important movements to which veins are liable—the evidence seems to suggest that the granitic cones may have received some part of their elevation because they were forced up along these fissures by the upheaval which produced them. In some districts where strata of contrasted character prevail, the extent of faulting is made visible, but in Cornwall the clay slates are so similar, that the slip of the hanging wall can seldom be measured. The faulting, caused both by veins and cross veins, generally appear cumulative in a direction from the granite; and the downthrow, especially of the crossveins, is not often the result of one fissure, but is made up of a number of parallel veins, which often compose what is called a cross course. Even the east and west lodes loose their mineralized character when they are distant from the granite, and become faults filled only with clay or quartz.

The grouping of joints and of elvans has not escaped observation, and the lodes and cross veins which follow nearly their direction affect a similar parallelism. There need be no hesitation in believing that these groups are due to distinct shocks affecting a certain assemblage of slates by which they are often limited. When such a collection of contemporaneous lodes occur in favourable strata, they are—being subject to the same conditions—

commonly productive across a zone that coincides approximately with the bearing of the associated cross courses; an occurrence which the miner expresses by "ore against ore." At whatever time, during the elaboration of the metalliferous deposits as now seen, veins may have been formed and filled; subsequent shocks not only formed new groups but opened again the older fissures. The lines of fracture did not necessarily take the plane of the wall, but frequently crossed the vein irregularly giving rise to "partings" in the gangue. In this way the size of lodes was considerably augmented; and this mode of increase is remarkably developed in Crowan and Gwinear, where the "comby" quartzose lodes supply the most conclusive evidence of repeated enlargment. In whatever way the downthrows may have been produced the result in every case is to lower the hanging wall, which sliding down on the waving unequalities accompanying every fissure, occasioned a succession of cavations that became filled with the valuable metalliferous products, alternating with barren "bars of ground" at those points where, the two walls being in close contact, the deposition of mineral was obstructed. The deposits in lodes, whether of earthy or metallic minerals, are due to the choking up of the ancient water channels by precipitation.

Lodes have been spoken of as very absolute in their course, but though they may be ever so persistent, the miner could "a tale unfold" of the troubles experienced in following veins through the "nips" where the opposing walls meet and leave only a line as indistinct as a divisional plane by which to trace them, when the lode is said to be "lost." This difficulty is greatly aggravated by the

shattered nature of the lode, which is rarely if ever simple, but splits off into parallel **branches** that may rejoin the same or another lode, or may dissipate itself in the slate, and sometimes an insignificant string may leave the lode and become the productive part. That most of these branches and splits are contemporaneous, may be inferred from observing those portions of rock known as "horses," which are often included in large lodes, especially where strata of diverse appearance are crossed, when the surface of parting will be discovered in the opposing walls. Sometimes lodes split and diverge considerably from each other, as in the Marazion and St. Just districts, and occasionally in connection with cross veins, as at Great Devon Consols and Polgooth. There are numberless examples of "blind leads," or veins that do not reach the surface, but they may be placed in the same category as "**droppers,**" which fall away from the lodes. Branches and veinlets are known to the miners as "droppers" when they leave a lode; when they dissipate themselves in the "country" they are usually considered to "bleed" the lode, but "**feeders,**" the lateral branches which fall into a lode, are believed to have an enriching influence when the angle of incidence is small. Joints are even supposed to have a similar effect when they fall into the lode. By these innumerable fissures, the mining districts have been shattered into huge lentiles of rock, more or less cemented by the mineral deposited, which owing to the jointy structure, are subdivided into small fragments of triagonal shape.

The **strike** of the vein systems of Cornwall is in remarkable accordance with that of the true elvan groups, even when these are discordant—as at St. Austell and

Marazion—with the general trend of the granitic upheaval. The lodes subordinate to each eruptive boss, have a direction appropriate to it, though this *per se* seems to have exercised little modifying power on their character, as caunter lodes bear no distinctive impress apart from that of "bearing." The important groups of meridional elvan courses that cross the county at Truro, separate vein systems of very different strike; for while those to the east have an oriental bearing, others between Truro and Penzance run with great persistency to the north-east. In the district of St. Austell the average bearing is north-east by east, in that of St. Just north-west by north, the latter bearing agreeing very nearly with that of the caunters. In the district lying around Godolphin Hill, the lodes assume indifferently all three directions. In every district the lodes are subject to warpings, that have a very decided influence on their metalliferous contents, and observation has brought out the fact, that the bearing of rich parts of lode are as a general rule nearest to the average direction of the enclosing vein, especially when it coincides with the general line of upheaval.

The great bulk of the copper and tin ores raised, has been obtained—according to Capt. Charles Thomas—from deposits that affect a magnetic bearing (1860) ranging between five degrees north, and twenty-five south of east. To give the average bearing of the lodes in each district would serve no purpose, and might indeed lead to erroneous ideas, because the average bearing of one series of veins, would be confounded with that of another whose formation in time would be different. Lodes of diverse bearing are chiefly confined to the extreme west of Cornwall, where two, and often three sets of lodes are preva-

lent; eastward it is seldom that the lodes are intersected by caunters. It is not probable that lodes ever cross large tracts of granite, because they are naturally restricted to that portion of the eruptive rock which was consolidated at the time of their formation; but that they cut through smaller bosses, is evinced by one or more of the Polladras tin veins, which, fissuring Godolphin Hill are worked on the southern slope at Wheal Grey. This phenomenon is interesting as tending to confirm the theory, that the formation of Cornish veins is due to forces acting on a comprehensive scale, far outside any influence exerted by isolated hills of granite.

INCLINATION OF VEINS.

The dip of lodes, owing to varying direction of the plutonic action during upheaval and consolidation, is very irregular, yet there is some coincidence between the inclination of the veins and that of the lines of pressure caused by the elevation of the granitic masses. Comprehensively speaking, it may be said that in the central portion of granitic tracts, the lodes have scarcely any distinctive hade, that on their flanks, in the majority of cases, the dip is towards the granite, whilst the rest incline from it, and these latter increase in number and verticality, until in the killas remote from the intruding mass, they become again nearly perpendicular. There is a considerable variation in the amount of dip, the few called "flat lodes" falling only thirty degrees from horizontal, but the mean inclination of lodes from Dartmoor to the Land's End, is—according to Mr. W. J. Henwood

—about seventy degrees, and the same authority states, that nearly two-thirds of the veins hade to the north. However much the inclination of any portion of a lode may vary, it returns towards the mean plane, and the reverse of the dip is of rare occurrence, except in the case of a perpendicular lode. The different angles which a vein pursues in depth, is mainly due to the refraction of the initial blow by alternating strata of diverse texture or density. The range of angular inflexion in the same lode, is from 10° to 25°, and in exceptional examples even 35°. Thus, wavy planes are produced, and any movement of the strata occasions a fall of the hanging wall; this will leave hollows that must of necessity be the most vertical portions of the lodes, and of course those which must be the receptacles of mineral deposits. Therefore the richest deposits are found enclosed in the compactest rock, in those portions of the lode nearest to verticality, and a change to a flatter dip would naturally be indicative of approaching poverty. Flat lodes yield copper or tin ores of inferior quality, but they nevertheless are submissive to the above rule. Though veins of little inclination may be comparatively poor, it is impracticable to fix a hard and fast line for the most productive dip.

Size of Veins. From what has been said above, it may readily be recognised that width is the most uncertain property of a lode. Its variability is such, that from a line with difficulty distinguishable, it may swell out to a valuable deposit; this does not happen suddenly, but the breadth increases gradually, the metalliferous portions proclaiming their advent by the admixture of stones of pyrites or blende, and of the metal which is the chief product of the lode. The greatest width of a Cornish

lode is sixty feet, but such magnitude is rare. Beside the difference in size produced by faulting, in passing from one rock to another the softer portions of the walls of a vein may be crushed together by pressure. Fissures when first formed were mere lines and their enlargment was due principally to the faulting occasioned by reiterated shocks. Lodes in granite are somewhat smaller than those in clay slate, the average width in the former (Mr. W. J. Henwood) being 38, and in the latter 45 inches. In mining parlance, a lode is a rock from which metalliferous ores are extracted, and in this sense many lodes have a much greater width than that of the associated fissures. This is owing to the brecciated condition of the "walls," and to their impregnation by the percolation of mineral waters, which not only fill the interstices, but may dissolve the rock and substitute in its place the mineral in solution. The size of lodes appears to have a close connection with the priority of their formation, if we take the mean width as deduced from the careful and laborious measurements of Mr. W. J. Henwood, viz.:

Tin and copper lodes	...	feet	4·70
Tin lodes	...	„	3·06
Copper lodes	...	„	2·93
Lead lodes	...	„	2·00

This is in accordance with the theory of the re-opening and faulting of veins, because the oldest would naturally be subjected to the greatest number of movements. The extra size of the tin and copper lodes may be attributable to re-opening, or to the junction in strike and dip which would cause them to run on together.

BACKS OF LODES.

We can only conjecture whether or not the veins systems of Cornwall at the time of their formation ever reached the surface; but as the large granitic veins, by their arenaceous structure and dissipation amongst the slaty beds when remote from the eruptive rock, seem to be confined within a limited zone; it is logical to infer that vein fractures would not have a more penetrative power. As a consequence veins may perhaps exist whose "backs" do not reach the surface. With few exceptions the "backs," or basset edges of the lodes near the surface, to a depth that does not often reach much below the level of the vallies, have been much transformed by oxidation; a result which the miner calls "bleeding of the lode." The extent of this change depends on the depth to which rains containing carbonic acid and oxygen can penetrate. Owing to this chemical reaction the gangues have become "Gossans" to a limited depth irrespective of the surface undulations, and in exceptional cases have been seen 50 fathoms from "grass." The alteration is perhaps most profound in granite, because of its superior elevation, and the facility of circulation afforded by cross courses. It must not be imagined that gossan is always concurrent with the "backs," on the contrary, it is, except in some very favoured districts, oftener absent. Its presence is dependant first, on the character of the contents of the vein which is not always metalliferous, and again on the proximity of the enclosing walls, whose opposing undulations create such a difference, that though a lode may have a fair average width, it is often so squeezed as to be untraceable at the surface.

The composition of gossans is of course entirely subordinate to that possessed by the original matter, they are therefore chiefly quartzose and ferriferous. The very hard, siliceous, and non-metalliferous portions of the backs, are obtuse to oxidation and have suffered little change. As a similar character distinguishes true tin lodes, their backs show gossan only imperfectly, but sometimes have been worked for the tin disseminated through them. Those on the backs of copper lodes are irony, less quartzose, have a decided vesicular structure, and are more friable than tin gossans. The minerals contained in the drusy quartz nearest the surface, are earthy brown iron, black copper ores, green and blue carbonates of copper, blende, galena, and occasionally spangles of native copper and cupreous arseniates; indeed, the greater number of curious and rare minerals have been obtained from the shallow portions of lodes, and are seldom found in connection with productive bodies of ores. The transition from the gossans to the courses of ore which they conceal is not abrupt, but the ferruginous and quartzy substances are gradually replaced by mundic, yellow copper ores, zinc blende, and other sulphides, until no traces of oxidised metals remaining, the productive deposits are reached. In not a few instances a gossan may be the back of a deposit of sulphide of iron or arsenic, but as mundic "rides a good horse" a cupreous deposit may be expected at an increased depth. Notwithstanding that gossans may occasionally be deceptive, one that the miner would recognize as a true ferruginous gossan, has never failed to cover rich deposits either in Devon or Cornwall. The finest lodes around the Carnbrea Hills, and the celebrated lode of Devon Great Consols were all concealed

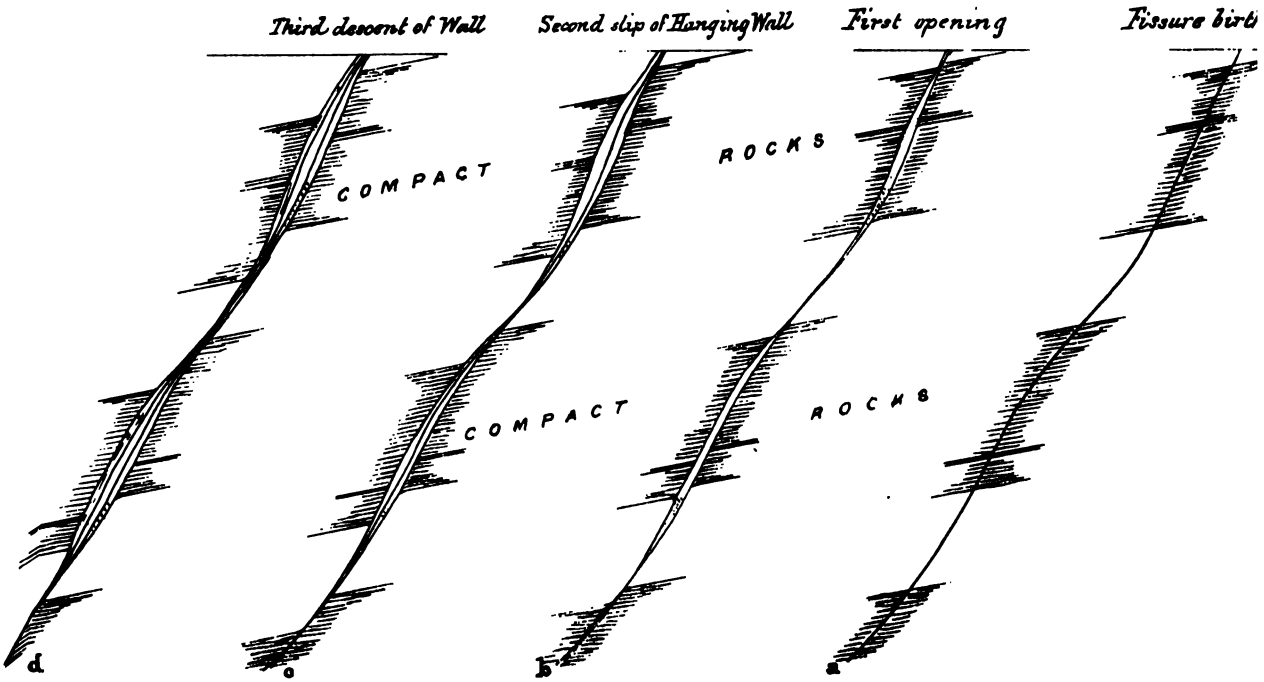
under masses of splendid gossan. Miners have predilections for gossans of a certain colour and hardness, which are not always the same in different districts. The usual colour of a good gossan should be brownish red of various tints, but a poor gossan is generally composed of a milky white quartz often mingled with slaty rock, more or less destitute of ferruginous hues. As a rule the backs of tin lodes are much harder than those of copper or lead lodes. Gossans though not of themselves valuable, often become so through admixture of gold and silver, which is sometimes present in quantity sufficient to be successfully worked. The want of gossan does not necessarily stamp a lode as unproductive, though it is considered by miners as an unfavourable indication.

The mechanical **Structure of Lodes** is simple, and their planes, joints, and interstices, are evidently due to the same inherent causes which have produced those seen in any consolidated rock. They were developed during the formation of the vein, but subsequently to the deposition of any separate portion of it. The quartzose parts of veins ore often "comby"—and singularly so in the parishes of Gwinear and Crowan, being made up of a number of thin lentiles of quartz with definite walls, which owing to the movement of the walls at diverse epochs, are deficient in continuity. In poor lodes, these lentiles are composed of white crystalline quartz whose opposing serrated surfaces create drusy cavities which are sometimes of considerable size. In more mineralized strata, the lentiform masses are extensive and compact, and are so similar to the "country" that even the miner may be deceived, and follow a plane that is not the true wall of the lode, to discover which "crosscuts" are

driven across the walls. The general displacement to which the encasing rocks have been subjected even in recent times, is made apparent by the planes of moist plastic clay which are found along the wall of the lode, and between partings of the same lode. Even a compact mass of "lodestuff" often confirms by a conchoidal structure with polished striated faces called "slickensides," the movements to which the filling matter itself is liable. The substance of the lodes is also divided by joints which are often a continuation of those from the enclosing rock, and at times a horizontal lamellar structure exists across the vein.

Walls of Lodes. This is a subject which has been much discussed by people, who, from the similarity often existing between the walls and veinstuff, have supposed that much of the contents of lodes may have been segregated from the "country" rock and some have even believed in their congenation; but, notwithstanding that originally a minute fraction of the more soluble ores may have been enclosed at the time of the deposition of the strata, it is more in harmony with the conditions that regulate the segregation of mineral matter, to suppose that the metalliferous character of the adjacent rock, is attributable to infiltration and substitution during the filling of the veins themselves. That smoothness of wall which is so important a characteristic in productive courses of ore, may be the result of an initial fracture in a compact lamellar rock, or to the fissure being concurrent with the previously existing jointy structure. Where these conditions are absent, the walls are liable to be rough and even jagged, and not likely to enclose large bunches of ore. The opposing sides of valuable lodes,

DIAGRAMS TO ILLUSTRATE GROWTH OF VEINS



could never be adjusted, on account of the change of position, and the frictional abrasion produced by the descent of the hanging walls, whose protrusions must have crushed large fragments off the walls which fell either to the bottom of the hollows, or became a breccia in the side of the lode.

Walls have, accordingly, a very varied structure, and may possess a sharp line of division, a brecciated character, or may pass into the contiguous rocks by such insensible gradations, that it would be difficult to point out where the gangue terminates and the "country" begins. In granite where the vein matter derived from the contiguous country retains its appearance with greater obstinacy than in clay slate, the transition, though also gradual, is accomplished in less distance. In schörlaceous lodes the layers of schörl and felspar change so gradually, that no definite stratum can be safely selected as the true wall. Slabs of contiguous rock split off along a joint, become by the removal of the soluble parts and the infiltration of quartz or metallic minerals, true portions of a lode. The wall of a lode is often clearly defined, and especially so when the gangue is quartzose. In some lodes—particularly interesting in the parish of Gwinear—boulders, like concretionary lumps, were found in the walls, and were possibly the first filling of a fissure caused by friction, which, in the absence of mineral in solution was consolidated by earthy matter. But in numerous other instances in that and in other districts, this debris, cemented by spar and sulphuretted ores, or by tin oxide, formed the lode, and proved the presence of fertilizing solutions. The brecciated character of the fissure walls, is, as might naturally be anticipated, very prevalent in all districts,

whatever metal the lodes may produce. As the separated pieces are forced off the points where the hanging wall crushes on to the foot wall, and the fragments fall into the bottom of the hollows, this brecciated structure is most conspicuous where the lodes become flattened. They occur both in granite and slate, are generally termed the "capels" of the lode, and in many instances they pass into "country" without any plane of separation. These capels much increase the size of the lodes, and often contain a workable percentage of cassiterite. The useful parts of lodes also become larger than the original fissures, both in granite and slate, by the infiltration of mineral matter into the interstices of a shaken portion of the wall, or into the rock itself by substitution. This mode of lode creation is exemplified in an interesting manner in schorlaceous granite, where rich bunches of ore often accumulate on one or both sides of a slender veinlet.

In cross courses the walls are often still less discernable, on account of the number of fractures, and the occurrence of lateral quartzose veins and strings, which also make their appearance in the cross course. In the granite the filling bears even more resemblance to the encasing rock, and a true wall is frequently undiscoverable. It is owing to this incorporation of the rocks in juxtaposition, assisted by the freer percolation of pluvial waters in them, that the mineral character of the strata indicates by a peculiar softening change in them, the proximity of a lode. The "Keenly ground" is of course due to the presence of the fissures, the walls of which—especially in the deeper veins—may have been subject to a mild metamorphic action, which predisposed the rock

to change when subject to the percolation of waters containing carbonic or other acids in solution. In some districts, notably at St. Austell, the lodes stand out like stone walls, owing to the decomposition of the felspathic granite which they traversed. It should be added, that to imagine all metalliferous gangues to have originated in the same manner would be erroneous; on the contrary, the method of vein formation and the segregations of their contents differ according to the characters of the rocks disrupted, the way in which the dislocations have occurred, and to the geological age of the formation which the veins have fissured.

Lodestuff or Gangues. From what has previously been said, respecting the alternating hollows and pinches which the descent of the upper wall must of necessity occasion in an undulating fissure, it will be manifest that the matrices which enclose the metallic ores must have a distinct reference to the mineral character of the contiguous strata. The change in the rock traversed is therefore immediately followed by a corresponding alteration in the earthy, and frequently even in the metallic, filling of the lode. Though the filling of the hollows by vein stuff has been due to various causes acting at divers periods, silica is associated with the matrix in every kind of rock, and is usually the most prominent ingredient. In clay schists, the gangue is composed of quartz and slaty matter; and in granite, of quartz and decomposed granitic debris. A careful investigation of the contents of veins, gives striking evidence of the complication of causes which has determined their segregation, and of the mode in which the lodes acquired their size by successive movements and refillings. (*Vide* PLATE I).

As the percolation of water would naturally descend through the interstices towards the heated zone lying between the unconsolidated granite and the clay slates, the fissures were probably filled at first with water at high heat and pressure, and therefore in a suitable condition to hold in solution both earthy and metallic minerals, and the aqueous circulation set up by the cooling of the superior stratum, would conduct them to fitting localities in which they would be deposited by subsidence, or by precipitation amongst rocks having the requisite thermo-electrical affinities. In dessicated strata undergoing metamorphic action, metallic minerals may have passed through in a state of sublimation, and been deposited in veins amid colder rocks. The perplexing manner in which ores of different metals are found intermingled, may be due to some change in the character and strength of the ascending currents; because, it is well known, that a trifling alteration in the condition of a solvent will retard or induce precipitation. Besides the slaty and quartzose matter which go to make up the bulk of the gangues, there are other earthy minerals met with but in far smaller quantities, such as calcite in the northern part of the county, fluor spar, &c.

In the granite districts the earthy minerals are in different proportions, for though quartz is still the prevailing mineral, felspar, schörl, and mica are more or less prominent, which give the gangue a somewhat granitic aspect. A faint distinction can be recognised between the lode stuff of veins of different formative eras, the tin veins having a more compact crystalline texture, whilst the filling of the copper lodes is more open and often separated from the walls by flucany selvages, that become

still more pronounced in the cross courses. Flucan receives its full development in the cross flucans and slides, which are admittedly among the youngest dislocations, and are exclusively composed of clayey substances. There is but little evidence of particular arrangement in these earthy gangues, for although there is often a "leader" which runs for some distance both in length and depth, it is perhaps more customary to find an irregularly mixed gangue.

The heterogenous character of the veinstuff is more than reflected by the eccentric mode in which metallic minerals are distributed in it. Unquestionably the most abundant are sulphides of iron and arsenic, better known to Cornishmen as mundic and mispickel; then comes blende or black jack, and wolfram. The most abundant of the useful ores is copper pyrites, tin ore, galena, and manganite. These ores occur in veins occasionally associated with others less common, such as barytes, antimony, silver, uranium, bismuth, and molybdenum. Tin is the only oxide existing in depth, the metals being nearly always mineralised by sulphur and arsenic. Though the mixture is irregular, the passage from earthy to metallic minerals is never abrupt, but a "course of ore" is gradually developed by the appearance in the matrix of what the miners call "stones of ore." The useful ores, with mundic and arsenic, occur in the lodes in the form of strings, bunches, and courses of ore, sometimes "clean" but generally contaminated with a changeable proportion of the earthy minerals above noticed, quartz being always predominant. This matrix containing no mineral of value is called "deads," and is either put to "stull," that is thrown in the "gunnies"

or cavites left by previous excavations—or hauled to the surface and trammed over the "burrow tip." None of the lodes produce ores throughout their length, but chiefly in those hollows caused by the flexures of the fallen hanging wall where the sides—especially the foot wall—are defined and compact, with a bearing approaching the mean direction of the lode. Therefore courses of ore necessarily occupy the most perpendicular, and broadest portions of the lode, and it follows that when these productive channels dwindle and the lode becomes pinched, a corresponding "bar" or alternation of barren ground must be anticipated. As the courses of ores, whether tin, copper, or lead, fill hollows which are usually confined to the compactest alternations of the clayslates, and as the latter slope away at gentle angles from the granite, it would be expected that the rich parts of the lodes would incline from the eruptive bosses. This is found with very few exceptions to be the fact, and not only in the slate but even the granite, the deposits affect a dip, having a relative coincidence with the outward inclination of the granitic grain, due to conditions developed by its junction with the sedimentary strata. There are exceptions to this peculiar, and to miners, very important circumstance; for instance, where the clay schists have a bearing nearly parallel to that of the lodes, when faulting produces hollows with little obliquity, and the deposits may then often approach a columnar outline; and where the horizontality of the slates having remained undisturbed, the courses of ore might have little dip in any direction. It will thus be comprehended why, if one of a group of veins in strata of alternating compactness possesses rich courses of ore, the corresponding parts of the

parallel lodes may be expected to yield results equally good. The prevailing dip of the productive portions of a lode, or of a group of lodes, is an object of much interest to the pratical miner, as much capital may be expended in a wrong direction, when the dip of the "country" is not recognised; and therefore by careful observation of the diverse density of the strata, and their relations to the strike and dip of the veins, he strives to attain the requisite knowledge.

Lodes are called productive in the sense of paying, but they may be rich in ores for which there happens to be no demand. Formerly many ~~sulphides~~ ores, such as arsenic and blende were treated as "deads" that are now remunerating the miner for his labour. A good course of ore should be massive, compact, with an indefinite structure; but comby quartz, with a pronounced jointy and horizontal bedding having defined partings and drusy cavities, are unequivocal symbols of poverty. Veins which cross groups of productive lodes are almost without exception poor, nor are crooked lodes very favourable to deposition of mineral.

True courses of ore, which are generally persistent in length and dip, may be more easily found than other deposits in veins, many of which have had their genesis at subsequent periods, and which on that account have been designated by M. Moissonet "accessory" or "accidental riches." There can be no doubt that after the formation of much of the veinstuff, reactions of an interesting character happened. These abnormal changes are most clearly exemplified in the remarkable accumulation of ores in the carbonas, pipe veins, and amorphous unconnected masses of mineralised granite in the Land's

End district, and in the changes affected where schörl abounds. Even in the most recent epoch, the frequent occurence of pseudomorphs, clearly shows that the gangues and ores of lodes are exposed to incessant alterations; whilst there is reason to suspect that movements of the walls still take place, and may in the present, as they have in the proximate past, given rise to those eccentric bunches and strings of ore whose mode of segregation is so obscure. Carbonas appear to owe their presence in the granite, to the infiltration of metals in solution along some irregular vein or joint, near which the surrounding mass becomes impregnated by precipitation and substitution. The rich floors, bunches, and veins of tin ore in the schörlaceous granite of Hensbarrow, are due to precisely similar action. Important **Stockwerks** have been opened where these impregnations abound at Carclaze, Beam, Minear, and others in the granite; and at various places in the clayslates near Bodmin, from all of which much cassiterite has been obtained. Copper ores have also been raised from **Stockwerks** in the schistose rocks at the Bunny mine in St. Agnes.

CROSSCOURSES and FLUCANS.—These veins cross the county with a mean direction approximately the same as the faults which traverse the Palæozoic rocks of Wales and England. They are variously known amongst Cornish miners by names having reference to their contents or other peculiarities; thus they are termed in the vicinity of Camborne and Tavistock, crosscourses if they contain quartz, and flucans when they are filled with clay. In the west they are called cross gossans when enclosing ferrugiuous quartz,

"trawns," and "guides" because they lead to productive lodes. In the Saint Austell district they are distinguished as iron lodes, because many of them have been worked for iron ores. So vague is the signification of crosscourses, that in a lead district the east and west quartzose veins, which intersect the productive lodes are also known under that name. Their unmineralised character has afforded no incentive to exploration, and they have on that account not attracted the same investigation as metalliferous veins; consequently, the dislocations to which they may have been subjected, are inadequately appreciated. For this reason an estimation of the age of cross veins, in relation to that of the diverse origin of lodes cannot be made. Although it is a generally accepted fact that meridional veins are the result of the last upheaval shocks, it is not improbable, that many of them were produced during the re-opening of the older, and formation of some of the younger veins; convincing proof of this is wanting, owing to the downthrows of the cross veins, and the tendency of the last faulting to obliterate the effects of previous slips. But in some instances near the granite—where the fall of the hanging wall is always less in amount—evidence of contemporaneity is palpable. In many cases the filling matter of the crosscourse between the heaves, partakes of the mineral character of the lode, and even in some examples, the metallic minerals are carried along the whole extent of the heave, and the course of ore made continuous through lode and crosscourse. At Wheal Friendship and at Ting Tang mine, this occurred in a most marked and highly interesting manner; a course of vitreous copper ore, two feet wide, extended from the end

of the lode through the crosscourse to the heaved portion of the lode, in such a way as to demonstrate that the dislocation took place after the north and south vein had been filled with earthy minerals. If it were certain that none were in existence until after the formation of the various east and west systems of dislocations, it would still be true that the different groups of crosscourses themselves are of many epochs, because they are often found intersecting each other. These meridional veins are less undulating than lodes, and seemingly have also less persistence of character, splitting up into branches, and dwindling both horizontally and vertically more than lodes. For this reason though a crosscourse may fissure an extensive district, its absolutc continuity may well be doubted. There are numerous examples of their not reaching the surface, and sometimes they are peculiar to the lode, or even the portion of the lode they intersect. They are rather less frequent in granite than in slate.

The heaves occasioned by these transverse fissures harass the miner, and discourages the adventurer, by cutting off the lode—which is often difficult and expensive to re-discover,—and by dividing rich courses of ore, the part disrupted being seldom met with again. Though perhaps the faulting along the line of cross fissures are individually of comparatively small extent if separately considered, yet as they occur with downthrows mostly in the same direction, the magnitude of the cumulative result is sufficiently important. Taking for example, the series of faultings—which have been so well observed by Mr. J. H. Collins, F. G. S.—along the littoral from the Saint Agnes Beacon to Padstow, eastern downthrows are frequently met, some of which disclose slips of more

than five hundred feet, so that the total amount of the dislocation must exceed 10,000 feet. The downthrow does not often take place along a simple fracture, but numerous lateral veins, enclosing slender plates of rock, continue the displacement in the same direction. Owing probably to the thickness of the superincumbent strata and compactness of the rock, the short fragments of the lodes are often surprisingly perfect. The general eastern dip and downthrow of the faults seem to indicate that the Beacon Hill has attained some of its relative altitude by being forced up along their walls. It is then evident that the slates composing the Beacon Hill must be the oldest of the series disrupted, an opinion that receives some confirmation by the proximity of the subjacent granite, which in Cornwall often carries up the slates bodily.

There is a remarkable tendency in the crosscourses, to assume a rectangular position with regard to the group of lodes they intersect. Their strike oscillates between N.W. and N. by E., which is a much smaller range of direction than is occupied by the east and west veins. The variation of crosscourses and flucans from the perpendicular is much less than that of lodes, and their irregularities are not of so pronounced a character. Their dip, equally east or west, is rarely if ever reversed, and the average hade is about 80°. Change from one rock to another does not seem to be attended with such deep inflections as those to which lodes have been subjected—though this may be due to their crossing the strike of the strata—nor, from their lack of metalliferous ores, does it produce any notable change in their contents. As the cross veins are more vertical, and their flexures

assimilate more to the mean planes of the fissures than those of lodes, their size is somewhat more constant. The width varies from one foot to five fathoms, and is perhaps a little greater in granite than in slate. The mean width of the crosscourses of the county—quoting Mr. W. J. Henwood—is four feet.

The structure of crosscourses is much more open and jointy than that of lodes, the principal joints usually taking the direction of the divisional planes. There is consequently a very "comby" appearance in the veins of quartz, that go to make up a crosscourse, and their walls are often accompanied by numerous lateral joints or veins filled with quartz, which constantly slipping downwards, developes what miners call "disordered ground." There are two other series of joints that are displayed in the gangue where it is compact, or when it approaches to the character of the contiguous "country;" in the latter case these joints often take the direction of those in the country, but when the filling matter is of a different nature, they are confined to the vein.

The characteristic absence of metallic ores in cross courses, has been generally considered by geologists to be owing to their formation during the comparative tranquility that followed the intense thermal action which bestowed on the veins due to upheaval their metallic richness. But if this view be accepted, it will render the barreness of these east and west veins associated with meridional veins rich in lead rather anomalous. If it be conceded that vast periods of time, according to finite computation, elapsed between the creation of the diverse groups of fissures, intense vulcanic action might be going on in one place whilst dormant in another; and

in this way cross veins associated with any particular group may have been filled with a siliceous gaugue, whilst at some distance a series of east and west veins may have been filled with metallic minerals. The alternations in the lodes themselves from earthy to metallic minerals, render it evident enough that there were periods of quiesence when ores of the useful metals were not in solution, or at least when the conditions admitted of no precipitation.

There appears to be no appreciable difference in the mode by which the **gangues** of lodes and crosscourses have been accumulated, either chemically or mechanically; and the filling matter bears much the same relation to the encasing rock, being clayey or quartzose in slate, and granitic in eruptive rocks. It also changes with the character of the latter, being schörlaceous or felspathic according to the predominancy of these ingredients in the granite traversed. They often contain fragments broken off the walls, and acquire a slaty texture where the latter are so large as to extend some distance along the fracture. That crosscourses have been exposed to the same depositing conditions as existed in lodes, is exemplified in many districts, and when metallic ores occur, they are exclosed or dispersed through a matrix of earthy minerals just in the same manner as in lodes. There are few metallic ores occuring in lodes that are not represented in the north and south veins, though tin ore is rare, and where observed found only in small quantities. Cupreous and ferruginous sulphides have, however, been worked in the crosscourses at Ting Tang and Consolidated mines, and in the flucans at Herland. Iron oxides are common in Saint Just, and from the crosscourses in

the granite and slate of the Hensbarrow district, most of the iron ore exported to Wales was raised. Zinc blende, silver, cobalt, antimony, and others, have also been met with. When at a distance from granite rocks, they have yielded abundance of galena, and some of the richest mines in the county have been worked on these cross lodes. The production does not seem however to be persistent in depth, and lead mines have, compared with those of copper or tin, a very ephemeral though prosperous existence.

It has been generally considered, that the facility of aqueous circulation afforded by the porosity of the cross veins, has had a most fertilising influence on the lodes which they intersect. From their non-metallic character, they are supposed by many to be of later date, but in this case, it is rather difficult to understand in what way they could have had any influence on lodes existing at the time of their formation. It is more consonant with ones perceptions of the mechanical effects of the movements, which have so repeatedly changed the relative positions of such a hetrogenous mass of dislocated strata; to believe that the influence of cross veins has, by severing the rigid longitudinal strips of rock, permitted descent of the "hanging walls" of lodes, and thus enlarged or given existence to cavations, the opening of which was before, more or less resisted by the inequalities of the flexures along their walls. Deposits of rich ore previously existing have often been divided by a crosscourse, and the manner in which rich bunches of ore are found in parallel lodes between two crosscourses, scarcely supports the assumption that deposits owe their richness to the circulation set up by

their advent. It may be doubted whether at great depths cross veins have much influence on the rich parts of lodes, but near the surface many deposits that may —for want of a better term—be called accidental, owe perhaps their segregation to the freer circulation in the lodes, consequent on the opening of the meridional veins.

Slides. These fissures are without doubt the latest formed, as they intersect the systems already noticed, and only contain the flucany—that is the clayey matter produced by their motion. Nevertheless, though of such recent period, they were certainly formed long previous to the present configuration of the surface, because they cause no more break in the general contour than do the lodes. The number of slides known is not great, and they can only be traced on the cliffs or seen in the mines. They have not been noticed in granite, or metamorphosed strata, but are confined to schistose clayslates, and appear to fall away from the ranges of granite at a flat angle. They have an east and west bearing, and though usually only a few inches wide, attain at Herodsfoot, a size of three feet; but even when of this size, their contents are derived solely from the abrasion of their walls. It may be remarked, that almost without exception flucany veins —be they lodes, cross courses, or slides—are indicative of motion along their planes, because the flucan is the result of abrasion. The dislocation caused may be very great, so much indeed, that it has often been impossible to find the heaved part of a lode.

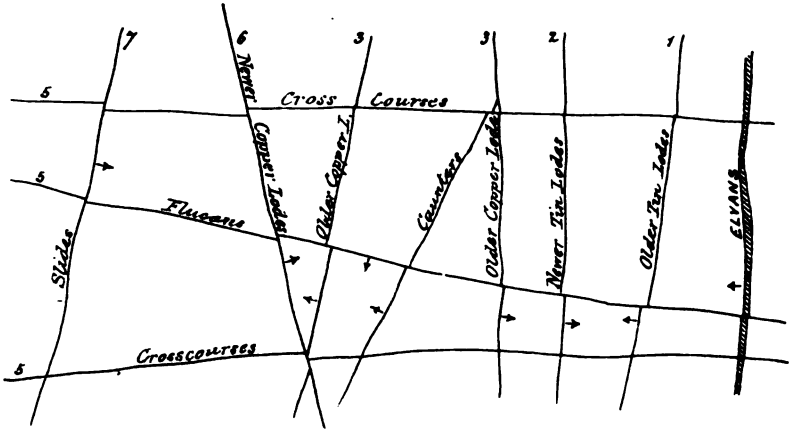
Intersections. To the miner the intersections of the lodes with each other is a subject of the greatest interest and importance; for often on the result of an anticipated junction, depends the working or stopping of a mine.

The conditions under which veins meet are so complicated, that it is scarcely possible to foretell whether the junction will be favourable or the reverse. In many instances the apparent junction of two or three veins may be due to contemporaneous fissuring, and when the rock is not too much shattered, a good deposit often collects there, should the lodes be of nearly similar dip. Frequently the intersection of lodes is simple, no dislocation taking place, and no doubt numbers of these have been met with in the mines, but have received no notice. Simple junctions are most agreeable to the miner, because the size of the lode is usually augmented. When two lodes intersect in depth at an acute angle, a course of ore may be awaited, and the smaller the angle included the better; should the angle be large, or the rock be much disordered, ore in large quantity must not be expected.

If such lodes were previously well defined, with one or both productive, a rich deposit may be relied on, and even when lodes, previously unproductive, possess a similarity of dip and gangue, the junction generally yields ore. Sometime lodes not merely meet, but coalesce without intersecting, and continue together both in strike and dip, and instances have been observed where two lodes of opposite dip run down together. Such junctions, are with rare exceptions, eminently productive, and by doubling the width of the lode lessen the expense of extraction. Occasionally three lodes coalesce as at South Roskear mine, where the main lode, the Caunter, and Roberts lode, formed a junction, and continuing together for 300 fathoms, produced the immense cupreous wealth for which Old Roskear was famous. (*Vide* PLATE II).

The intersection and junction of the east and west

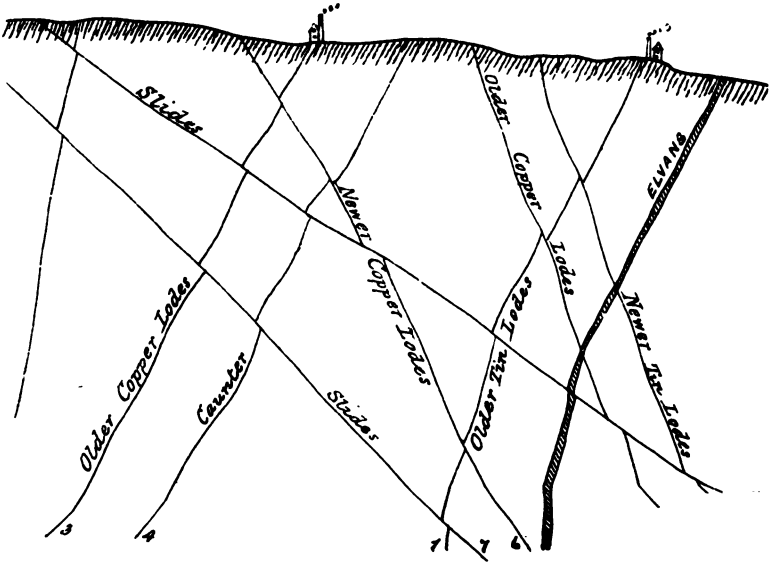
DIAGRAM SHEWING HEAVES DUE TO INTERSECTIONS OF VEINS OF DIFFERENT RELATIVE AGE



PLAN

The figures show sequence of vein systems

SECTION



veins, whether in strike or dip, display phenomena similar in degree though not in direction, to those of the lodes and cross veins. In some localities the intersection of lodes of opposite dips has given rise to displacements which are called "upthrows." In Saint Agnes where these dislocations have been developed to a remarkable extent, the lodes dipping south have thrown up the older tin veins, to distances varying from a foot to over twenty fathoms. Wheal Pink lode has in a short horizontal distance been thrice thrown up, so that the same level has passed through it three times, and it appears on the surface as three distinct lodes. These dislocations, as well as the slip of the hanging walls of lodes, seemingly increase in amount with remoteness from granite. Mr. W. J. Henwood mentions that lodes have been heaved by each other as much as forty feet, and mostly to the smaller angle.

There are some examples of the cross veins being intersected and heaved by the later east and west copper lodes; they are rare, but where occurring give rise to heaves which are sometimes so considerable as five fathoms. The throw of an elvan-course by a lode is of extreme rarity, but an instance occurs in the cliffs between Saint Agnes and Perran.

Heaves. The faulting caused by the crosscourses are called by Cornish miners "heaves," because they imagined that the separation of the ends of a lode was due to horizontal movement. It may be truthfully said, that notwithstanding the attempts of Mr. W. J. Henwood and others by tabulated observations to attain some general laws that would aid the miner in his search after the heaved end of a lode, the data arrived at are but

meagre, and the results of the intersections of lodes with crosscourses not very intelligible. All heaves are, without doubt, due to subsidence of one side of a vein, and the inexplicable discordance attending Cornish veins, may be attributed to their number and to the numerous epochs of disturbance. Though near the granitic domes, some amount of lateral movement down their slopes probably occurred, the extent of nearly all heaves is due to the same vertical movements that originated the faults in the coal fields, which, owing to the distinctive character of the alternations of sandstone, sholes, and coal, can be accurately measured. The similarity of the slates of Cornwall does not give the same facility for realising the extent of faulting, though on the bold cliffs facing the Bristol Channel, a vast amount of vertical movement can be verified, and it may be inferred that the same discordance extends inland. The granite has been also displaced by the heaves seventy or eighty fathoms, as by the County and the Great Crinnis cross-courses, both of which are right hand heaves. Elvan dykes are unaccountably obtuse to heaves by cross veins, though there are many examples; perhaps their size, compactness and rigidity may oppose an amount of obstruction to movement, that the more yielding slates do not possess. Some heaves may not be due to motion, but either to contemporaneous shattering—which can be well studied in the vicinity of Saint Agnes—or to the initial blow developing along the line of least resistance. The plastic nature of some slates is well illustrated by the small fractures—many probably of the same age as the lodes—which by local movements have caused heaves at one level, contrary to that seen at a lower level on the

same lode. Even in crosscourses of importance, local subsidences of yielding strata must often superinduce contradictory heaves; and these movements may still be going on slowly. That such local disturbances have been the cause of much complication, will readily be admitted by those who have observed the dislocations which have taken place along joints, even when they are so fine that their existence is only suspected by the diverse character of the rocks in juxtaposition.

The faulting of crosscourses is less near the granite, and generally increases in amount in proportion to the thickness of the sedimentary strata resting on it. Heaves are not always as simple as they appear on plans, but are often complex, and associated with subordinate fractures connected with the lode intersected. The end of the heaved lode, as Mr. W. J. Henwood admits, having little in common either in size, or contents, must owe their dissimilarity, as near the granite, to frequent re-opening and filling since the formation of the cross vein, or to the extent of the downthrow. This difficulty of recognizing ends of heaved lodes is further increased by the flucany matter along the walls, and the varying obliquity of the lode and the intersecting vein, both in strike and dip. How great this difficulty is, may be conceived when Mr. Henwood states, that he sees no difference that the dip of a lode makes on the heave. Although the extent of the faulting in the clayslates was mostly greater than Mr. Henwood conceived, yet, as the great bulk of his observations was collected near the junction of the clayslate with the eruptive rocks, where the dislocations were at a minimum, his conclusions with respect to length of heave, and its intimate connection with the size of the veins, may still be quoted.

The movement taken by the faulted portions of the strata is similar in direction to those of the coal fields, that is the hanging wall slips down the plane of the fissure towards the greater angle. From a miner's point of view, most of the heaves are to the "right hand" along the crosscourse, those to the "left hand" being to a less distance; and though—following Mr. W. J. Henwood—there are three per cent of exceptions, the general rule is, that the same crosscourse heaves all the lodes in the same direction. The preponderance of heaves to the greater angle is stated by the same authority to be as five to one, and the mean distance of dislocation to be fifteen feet. The proportion heaved towards the greater angle bears a relation to the angle of intersection; for while they are variable when the angle is acute, they are almost all heaved to the greater angle when the veins are nearly perpendicular to each other. Neither the kind of rock nor the metalliferous contents of lodes affect the amount of heaves, as they are due to mechanical motion, but the extent of the heave is as might be expected, considerably influenced by the size of the crosscourse or lode, as it is in consequence of repeated slips of the hanging wall, that veins acquire their magnitude. Accordingly, the researches of Mr. Henwood have conclusively shown, that the larger the crosscourse the greater is the dislocation of lodes, and that if the lodes are also large the heaves attain their maximum distance. Thus the mean heave when the vein and lodes are small, is only four feet, whilst the intersection of large crosscourses by large veins, raises the average heave to about thirty feet. But the angle of incidence also modifies the length of the heave, thus both a small angle and a right

angle are less favourable than an open angle, the greatest heaves occuring when the angles of intersection lie between 30° and 60°, the maximum average heave being found at an angle of 45°. Yet though the most extensive heaves are at this angle, they are most numerous at right angle, and when the angle is very acute heaves are unfrequent. The amount of heave varies much at different levels, owing perhaps to local movements and to the flexure of the lodes crossed, whilst the amount of dislocation caused by a crosscourse is increased, when by containing clayey matter it becomes a flucan. Even such a large compact lode as Dolcoath is slightly affected by veins of flucany matter.

Elvans, though resisting successfully the movements caused by crosscourses, have been frequently slightly heaved, and at some intersections the heave has been important; for instance, at Trevellas Porth, Gover elvan, and near Marazion. Elvans have in rare instances appeared to heave lodes, as at Polgooth and at Boskilling; it may well be, however, that the initial blow was not strong enough to fracture the elvan.

It would then appear, that the productions of any vein systems depend on reiterated dislocation, and these having been most prevalent near the junction of the granite with the slate, the best deposits have naturally become segregated there. The above epitome of intersections will not be very intelligible to the general reader, nor could any description well be, for it possesses even for the miner much of obscurity.

Chapter III.

Distribution and Paragenesis of Minerals.

The earthy minerals yielded by the veins of Cornwall have much in common, as quartz in various forms occur in all the systems of fissures. The non-metalliferous portions of crosscourses and lodes are generally made up of quartz more or less crystalline, which in granite becomes mixed with felspar, schörl, and mica. In some places where the slates have been highly metamorphosed, beautiful and rare crystals of siliceous minerals—axinite, garnet, &c.—are found, but nowhere in such profusion as in the siliceous greenstone rocks which skirt the coast in the Parish of Saint Just. Topaz and beryl have been seen at St. Michael's Mount, and numerous scarce earthy minerals have occasionally been found in the neighbourhood of Penzance, such as actinolite, thallite, &c.

Cassiterite, or tin ore is scarcely ever totally absent where metamorphic rocks prevail, and it is consequently seldom discovered far distant from the granite. Tin ore has been extensively mined in Saint Just, Saint Ives, and Lelant. The mines around Tregoning Hill have been very productive, as also those in Wendron, but the deepest, richest and most extensive deposits of cassiterite, exist along the northern slope of the granitic hills of Carn Brea and Carnmarth. An important belt of tin producing strata, *extends* through the parish of Saint Agnes to the south

of the granitic ridge lying between the Beacon Hill and Cligga Head. Much tin ore is found in the lodes scattered about the western moiety of the Hensbarrow granite, and there is also a tin district skirting the south flank of the Bodmin range, between Caradon and Warleggan. The cone like granite hills of Hingston Downs and Kit Hill are very productive of tin ore. It is somewhat peculiar that tin oxide is associated with minerals that, like schörl contain a notable per centage of fluoric acid, which is so constantly present, as to suggest that the deposition of stannic ores have been thereby influenced. Although rich mines of tin ore have been known in slate, when elvans are in proximity, it is a mineral which affects crystalline rocks, and has probably been deposited during abnormal temperature and under high pressure. It is always found in east and west lodes, and is not found in cross veins, indeed it is only in rare cases that veins crossing a productive lode rectangularly contain any metallic minerals, but such phenomena have occurred, as at Redmoor near Callington.

Chalcopyrite, or yellow copper ore, is more widely distributed even than cassiterite, but although equally dependant on metamorphic action, it has been deposited in the massive slates which repose on the granite. Like the granite loving tin, copper ores are occasionally deposited outside the strata it most affects, but though rich bunches have been, as at Tresavean and Penstruthal, worked in the granite, yet a copper lode entering that rock generally changes to tin, nor do cupreous ores ever reach the depths attained by stannic oxide. The sub-sulphurretted ores of copper are found in connection with

altered rocks, and prevail in the greenstone near the junction, notably in Carn Brea and Gwennap districts, and in the greenstone skirting the western coast of the Land's End district, whilst the yellow ores occur mostly in slates more distant. It is therefore not surprising, that the mines of Camborne and Illogan which formerly produced copper should now be worked for tin. The mines of Cornwall on this account yield at present no great aggregate of copper ores, but formerly it was raised from nearly all the mines, and most largely in Gwennap, Camborne, Redruth, Gwinear, Caradon, Tavistock, and Saint Austell. Wood tin has been obtained from Penberth, Garth in Illogan, and near Saint Blazey, but only as specimens.

Cornwall formerly produced large quantities of **Galena,** but latterly the mines have become exhausted, and the low price induced by the vast quantities of bullion obtained from the Nevada mines have so depressed the market, that there is but little encouragement to develope new mines. Lead ores were formerly supposed to be confined to veins having a meridional direction, but the discovery of the Chiverton lodes, which had an east and west bearing, corrected this assumption. The associations of plumbiferous veins with slates, still further removed than those of copper from granite, is unquestionable; but that a considerable amount of metaphorism is necessary to insure productiveness, is shown by the meagre and barren lead veins in slates that are comparatively unaltered. Small quantities of lead ores have been obtained from Saint Erth, Phillack, and Gwinear, but lead lodes are of no value west of the Carn Menellis range. The principal deposits of lead were discovered at

Wheal Golden and Penhale in the Parish of Perranzabuloe, at Wheal Rose on the coast south of Helston, in the East Wheal Rose district near Truro, at Trelawney and Mary Ann mines in the parish of Menheniot, at Herodsfoot in Duloe, and more lately in the mines worked on the celebrated Chiverton lode. Galena has also been raised in many parishes in the vicinity of Padstow. The Cornish lead ores are much esteemed for the large proportion of silver they enclose. The most argentiferous galena has been raised from the Chiverton, Trelawney, and Herodsfoot mines, and also from some lodes in the north of Cornwall. Very rich silver lead ores have been obtained in large quantities from the Tamar lead mines in the parish of Beerferris.

Silver.—Beside the silver diffused through the sulphuret of lead, large quantities of the pure metal have been found in arborescent and reticulated forms. Much native silver was obtained from the Druid's lode in Dolcoath, splendid and large specimens from Wheal Ludcott near Liskeard, at Wheal Brothers near Calstock, and in other localities. Silver has been found in nearly every mining district in Cornwall, though generally in small quantities. Outside of these sources of silver, it is widely distributed in the gossans and lodestuff of many groups of lodes, and the importance of these ores—which are often thrown over the burrows—is very insufficiently recognised. The present generation of miners read with surprise, that our foretinners threw away as worthless many rich ores of copper, but it is possible that posterity will be still more astonished at our neglect of the argentiferous wealth concealed in the backs of the lodes, and pitched over the "tip" as "deads." In the Callington

and Calstock districts especially, immense burrows containing several ounces of silver to the ton which have been extracted from almost inexhaustible lodes, lie scattered over the downs. At New Great Consols near Callington these argentiferous ores were successfully treated some years since.

Iron.—The ores of this metal, either in the condition of oxide or sulphide, are always associated with Cornish ores, and probably no vein is destitute of ferruginous substances. Its sulphuret is in frequent association with the principal metallic ores produced, but it possess no value in this state; when however the ferric sulphide is unmixed with other ores—as is generally the case in the crosscourses—they have acquired a value by oxidation, the sulphur having been carried away by the carbonic acid contained in the pluvial waters, and replaced by the proper oxygenic equivalent to form **Hematite,** or when hydrated, **Limonite.** Of course these iron ores can only be formed near the surface where atmospheric influence can have free action, but the accidental character of the country where they prevail has greatly tended to develope oxidation, and to afford facilities for the cheap extraction of the mineral. Iron lodes have been thus produced in great number and importance in the Hensbarrow granite, more especially in the contiguous clay slates. Many mines have been opened in the parishes of Saint Enoder, and Saint Stephens, and along the flank of the granite range to Lostwithiel, where the vast excavations made on the Restormel iron lode are indicative of a large and profitable production. This lode has been thrown down to *the east* several hundred feet, hence the size of the vein.

Hematite has been also quarried in the parishes of Saint Wenn and Boscastle, whilst Limonite has been found at Constantine and Lanivet. Carbonate of iron, or Spathic ore, exists in immense masses in the Perran iron lode at a depth of about fifty fathoms, but the backs have been oxidised into hematite and limonite and are worked extensively. **Chrome Iron** has never been found except in very small amount in the serpentine of the Lizard. Phosphate of Iron has been seen in the mines of Wheal Owles, in Saint Agnes, and in some of the mines of the Wheal Jane district near Truro. **Vivianite,** in beautiful indigo crystals two inches long, was found on magnetic pyrites, and earthy phosphate was often met with in some of the Saint Just lodes. **Graphite** has scarcely ever been seen, but is said to occur in an elvan at Restronguet Creek. **Wolfram,** though only existing in masses in a few places, is somewhat generally distributed, and where found is always associated with tin ore, from which, on account of its nearly equal specific gravity, its separation is almost impracticable. It occurs in profusion in the granitic rocks of Cligga Head, and contaminates the ores of East Pool and Drake Walls mine. At the latter place the ores were difficultly saleable until Dr. Oxland installed a process by which tungstate of iron converted into a marketable product as tungstate of soda. Wolfram is also found in many of the tin mines of Hensbarrow, and less conspicuously in some of the mines to the north and east of Carnmarth Hill, and in many others situate at the northern part of Carn Brea. The titanate of iron called Ilmenite is found as a black sand in Manaccan, and massive at Porthalla, and also at Buckland *monachorum in Devonshire.*

Many rarer minerals are sparsely scattered through the lodes of the county, amongst which may be mentioned an ore of Uranium called pitchblende found in St. Ives, Saint Just, Illogan, and Saint Austell. **Bismuth** has been remarked in Saint Ives Consols, Dolcoath, and a few other mines. Molybdenite in Saint Ives and Gwennap. **Barytes** in Consolidated and Wheal Friendship mines Gwennap, in Saint Austell in the lead mine of Mary Ann, and in the Restormel iron mine. **Cobalt** ores have been noticed at Pengreep, Wheal Sparnon, and Polgooth mines. There are many other rare and beautiful minerals occurring with the useful ores, which, being too numerous to mention, the reader is referred to the comprehensive handbook of Mineralogy, compiled by Mr. J. H. Collins, F.G.S.*

Pyrites, Mispickel, and **Zinckblende,** are found associated with each other, and with the ores of copper, tin, and lead, throughout the mining districts; it would therefore serve no useful purpose to give the localities in which they occur. Mispickel and "black jack" are especially associated with tin lodes, and less persistently with those of copper. Mundic is often present with tin ores, but is seldom absent from copper lodes, and yellow copper ores are always found chemically combined with a large proportion of the ferric sulphide. Zinc blende is scattered indifferently in lodes, whether of tin copper, or lead, and often all three of the above mentioned minerals are found associated in the same deposit.

Productiveness of Strata.—At the risk of some repetition, it will be desirable to epitomise the lead-

* This valuable and portable book of reference can be obtained of Lake and Lake of Truro.

ing circumstances affecting the association of metallic ores with particular groupings of strata; for, a very superficial acquaintance with the rocks of the County is sufficient to show the intimate connection which exists between them. The fossils found at Crinnis beach and other places in rock fissured by lodes, afford direct evidence that animal life flourished ages before their formation. Although the dependance of good initial fissures on the original mechanical structure of the slates, and on the texture imparted by metamorphism is so absolute as to render hazardous the assertion that the vein systems richest in metallic minerals were formed under the greatest thickness of sedimentary rock, yet, it is nevertheless worth remembering, that those beds believed to be relatively the oldest, have furnished the largest supply of metalliferous products. A reference to the coloring of the geological map which accompanies this article, will render the association clearer to the reader; there, pre-Silurian strata—probably Cambrian—are seen to spread over the area in which the famous tin mines of Camborne, Illogan, and Saint Agnes have been worked, while the richest copper mines are excavated in the clayslates of the Lower Silurian. But notwithstanding this coincidence the best veins are dependant to an important extent on the original structure of the slates, and especially to the crystalline and compact character they have acquired by metamorphic action during the epoch of the granitic upheaval. In consequence of this action, which, owing to the weak conduction of schistose slates, did not penetrate to a very great distance, the rocks productive of the useful ores are not found distant from granite. If one could discern the underlying

eruptive rock, the revelation would possibly confirm the assumption of the non-existence of large deposits more than a few thousand feet from the granite. At least the old theory of congenation is shown to be untenable by the absence of ores in clayslate remote from crystalline rocks. In plombiferous districts remote from them, as for example that of Chiverton, which is situate mid-way between the ranges of Carnmarth and Hensbarrow, granitic dykes come to the surface, and afford positive proof of the proximity of the granite beneath.

The chief effect of metamorphism on the structure of the slates, has been to render them crystalline, and to harden them into thick alternations of beds different in density. These characters aided by the enormous pressure, developed conditions highly favourable to the formation of fissures persistent in length and dip. There is reason for conceiving, that the strait smooth foot wall of strong lodes, is due to the fissure taking the path of least resistance offered by the divisional planes. There are other conditions which contribute to the making of beneficial vein groups; for instance, the position and inclination of the strata resting on the granite is all important. In the richest districts, the slates are regularly and moderately inclined, their strike parallel to the eruptive range and approximately so to the lodes themselves. This is not the place to speak of those strata which influence most favourably the productive character of a lode, as there are very considerable local differences, but comprehensively, it may be remarked that rocks should not be of such excessive hardness as to cause a splintery fracture, nor so soft that the walls would be liable to contraction by pressure. The connection

between substantial strata and productive lodes, is sustained by the occurrence of ores in connection with ranges of greenstone. A dry shelfy rock, thin soft shales, greatly curved or contorted strata, or slates abutting against the granite at a high angle, are unfavourable to the developement of persistent fissures. It has already been noticed, that the opening of fissures in this alternation of different rocks, has been owing to the action of gravitation impelling the hanging wall to slide down at each repetition of subterrene shocks.

The metamorphism of rocks is not peculiar to the slates, for during consolidation, the latter reacting on the granite produced transition rocks which have a structure and composition different from either the crystalline or sedimentary strata. Schörl gives active assistance in this alteration. As in the slate so in the granite, good fissures and large metalliferous deposits, are seldom, if indeed ever, found outside the metamorphic zone; as distance increases, so lodes disappear, until in the interior of the granitic bosses, the slates remote from granite are not more barren. The metamorphic granite rocks favourable to productive deposits are, like those of slate, variable when one district is compared with another, but generally miners seem to prefer a rock to which a certain amount of decomposition has given a distinctive haziness to the outline of the felspar with a "plumb" texture; whilst a very hard fine grained rock with defined porphyritic character is not regarded with favour. The examples of a lode becoming poor or rich, and altering its metalliferous character, on encountering a distinct change of strata, especially when the change is from granite to slate, are numerous and striking, but the

multation may possibly be due to different epochs of deposition. Tin lodes and basic cupreous ores, exist in harder and more siliceous rock than copper pyrites or galena. Thus the testimony of the rocks is in accord with experience in regard to the general distribution of ores, viz.: that copper cannot be expected to occur largely in a tin country, and that lead must not be sought for in a rock congenial to copper, and the converse of this holds good. When one reviews the numerous chain of favourable circumstances neccessary for the origin, development, and filling of productive veins, no surprise need be expressed, that the difficulty of discovering rich deposits in them, demands such patient perseverance, and so much expenditure of capital. First the original composition and structure of the slates, and their metamorphosis into the thick lamellar masses of alternating density requisite for the formation of true fissures; the resting of these more or less crystalline beds on the granite at angles favourable to the development of cavations, with a strike approximately coincident with the trend of granite, and the direction of the line of volcanic upheaval. The continuance of shocks to reopen the fissures, in order to allow faulting between the walls, without which thermal circulation would be languid, and no lodes of any size could develope; and finally the formation of crosscourses to tolerate freer movements of the hanging walls of lodes between them.

Denudation.—The sedimentary beds which rested on the granite at the time of its consolidation, were lifted up by the upheaval, and subsequently abraded and washed away by the ocean, or denuded by atmospheric influences. The metamorphic rocks, which doubtless covered the eruptive

Schorl Rock.— ROCHE ROCKS.

Tabular Granite.— CHEESEWRING.

domes, have also, together with any metallic deposits with which they were associated, been denuded by the waves of the ocean and now form beds of shingle and sand in the English and Bristol Channels. Owing to the disappearance of such a thickness of crystalline rock, the central portions of the granitic bosses have been stripped of much of their metallic wealth by the unbottoming of the elvans and veins. There are however some patches of metamorphic rock still remaining, as in the mining districts of Wendron and Roche; they are of a rather sporadic character, and the larger and more elevated tracts of Bodmin and Dartmoor are entirely barren of the useful minerals, and the only evidence of former fertility—the superficial deposits of stream tin—have long since vanished in ministering to the wants of earlier civilizazations. Formerly, when much of the county was protected by primeval forest, the disintegration caused by the exposure of the rocks to alternate rains and sunshine was less than at present, though now the cultivated portions resist with much pertinacity the degrading influence of the weather. Torrential rains are rare in Cornwall, as the rainfall is distributed over about seven months of the year. The results of the decomposition initiated by aqueous causes is very apparent in the hilly lands, where large blocks of granite have weathered into tabular forms. Many of these old cairns and tors have assumed the most grotesque outlines, for the fashioning of which the Druids have been partly accredited. The high ridge of Carn Brea is one of the localties where the mode in which granite degradates may be best observed. The exfoliation of rocks commences along the jointy structure, down which permeating waters attack the

felspathic constituent, and gradually enlarge the veinletts *pari passu* with the denudation of the surface. By this means the most resistant rocks became gradually prominent and their angles rounded off, until in the course of ages the blocks acquired a flattened spheroidal exterior, and were piled one over the other like cheeses.

Lanyon Cromlech.

In some districts the granite is found decomposed to great depths and over extensive areas, and some large tracts of the surface are covered with growan. Where schörl is present the softening of the felspar is very complete.

In the clay slates, the same yielding of the softer rocks to denuding action is apparent where vallies have been eroded around harder strata. Miners have observed that when a ravine or depression runs across lodes, they are often found productive on one side only; and this sterility seems in most cases to be due to change in the

structure or induration of the rock, the river scouring its passage through the rock most easily abraded. The annual rainfall in Cornwall varies from about 35 inches in the west to 60 inches in the north.

Raised Beaches.—The uplifting of the rocks of Cornwall was so slow, as to allow of enormous erosion by the beating of the waves against the coast. There is no evidence of any paroxysmal event, and nature appears to have enjoyed a tranquility that permitted an exuberance of animal life and vegetation, equal to that now existing. Though it is seldom that a casual observer would be able to find positive proof of the gradual rising of the granite from the ocean, owing to the many causes which combine to degrade rising cliffs along the coast line; yet there are numerous places, where, owing to favoured situations, fragments of sea beaches raised from 10 to 60 feet above sea level have so far resisted obliteration. These beaches—geologically recent, but of great antiquity—prove by their general appearance and contents, that the land continued to gain elevation down to a period when the species of marine life had assumed their present forms. The action of the weather, and the accumulation of detritus, causes a talus that sometimes reaches the summit, which has concealed many of the ancient beaches, so that in some thousands of years they may be unrecognisable. The raised beaches are composed of layers of boulders, pebbles, gravel, and sand, analagous to those which now so beautifully adorn the crescent shaped margins of the bays that engirdle the coast. They are also bestrewed with white limestone and basalt, and with flints similar to those found on the downs of the Land's End. They extend down nearly to

the present beaches along the shores of Mousehole and Saint Just, where there is an immense thickness of granite boulders. Bordering the south western flank of the Bodmin granite near Saint Neot, and on towards Warleggan, there are somewhat similar accumulations of granite boulders, amongst the lower stratum of which cassiterite has been extracted. Where the miners have not made excavations, this detritus is so completely concealed all along by a talus of debris, that the extent of the remains of this ancient beach cannot be ascertained. It is not often that the granitic islands would be able to show such evidence of the sojourn of the Atlantic waves around their bases, because the denudation of perhaps a thousand centuries could scarcely be expected to leave, except by a succession of very favourable circumstances, any vestiges of sea shore. As these raised beaches are found numerously along the coast, both in the granite and clay slate formations, it is needless to enumerate them.

Submarine Forests.—The long continued elevation of Cornwall, which the boulder and gravel deposits inland at Saint Neot, and along the coasts, show to have happened, has in the newest recent epoch, given place to a movement of subsidence. Submarine deposits of tree stumps, vegetal remains, bones, stanniferous gravels, &c., have been found at the mouths of nearly all the creeks, both on the north and south coast, at a depth which has been shown to reach thirty feet at Pentuan and other places. The filling up of the creeks with mud, and the general shallowing up of the English and Bristol channels, also point to the cessation of upheaval movements. Within the past half century, the debris sent down the

streams from the tin mines and china clay works, have filled up many important creeks, such as Tregony, Gweek, Devoran and others, and the lapse of another century may find many Cornish estuaries changed to verdant pasturage.

CHAPTER IV.

THE MINING DISTRICTS.

The general dispositions of the vein systems of Cornwall, and the occurrence in them of useful metalliferous products having been noticed, a clearer conception of the *tout ensemble* may be acquired by the reader if a few sentences be devoted to describe the prominent points of the groups of mines lying around each granite boss.

THE SCILLY ISLES.

Though the character of the rock between Scilly and the Land's End is concealed by the ocean, one can without hesitation believe that like the eruptive bosses of the main land, the numerous isles and rocklets are simply the tors of a submerged tract of granite which has a quaquaversal dip beneath clay slates similar to those reposing in the other granitic ranges. Although the rocks of Scilly appear to possess the cubical and columnar structure of the Land's End district, it is, as far as known, unproductive of metallic minerals. Possibly previous to denudation, clay slates may have covered the plutonic rock, and a zone productive of minerals may have been existent; if this were so, the scarce patches of elvans, and the occurrence of some small veins, in which were occasionally discovered traces of

tin, copper, and lead, may represent the rocks which at the time of the vein formations were in a state of viscidity that rendered the retention of the useful ores improbable. The few veins that can now be seen, have no importance and produce no metallic minerals.

ST. JUST DISTRICT.

There is no group of mines in the whole of Cornwall and Devon which presents such varied interest as that of St. Just, whether one considers the opportunities afforded for rock study by the deep zawns which so frequently penetrate to the junction of the granite with the sedimentary strata, the remarkable systems of fractures, the development of curious and rare metalloid minerals, or the distance to which the miner has burrowed beneath the sea under the shadow of the wild, rugged headlands, amongst which the houses and engines of many of the mines are so dangerously and singularly perched. The sea having worn its way through nearly to the eruptive rock, has left but a fringe of highly siliceous slates resting on it, and along this narrow band the copper and tin mines have been worked. The true crosscourses, which are but few, have a bearing approaching that of lodes in other localities.

Fine crystals of orthoclase and white mica near the junction, and large patches of black tourmaline are frequent. Pinite is also prevalent at Nangisel Cove in Sennen, Tol-pedn-Penwith near the Logan Rock, and at Lamorna and Mulvra Hill. Axinite has been found at various spots around the Land's End, but is best displayed

in the bold rocky cliffs of St. Just, amid which at Huel Cock a vein of violet crystals was formerly worked for specimens. At "The Bunny" are some peculiar floors of cockle or schörl. The metamorphic rocks which lie on the granite along the St. Just and Zennor shores are very complicated, and will well repay study. They consist of slaty micaceous felspar rock, usually found next the granite, granular felspar rock, a hard siliceous green rock, and hornblende rock. These rocks are generally very characteristic, and sometimes reciprocate with each other; they are well developed at many places, but probably they can be best observed at the Gurnards Head. The altered slates, which are very hard and weather well, incline northwards from 25° to 45,° rarely the dip of the junction is reversed over small spaces where the metamorphic strata seem to support the granite.

The occurrence of clayslates along this coast, or even anywhere near the margin of the Land's End boss is infrequent. The St. Just veins pursue very abnormal bearings; the principal lodes approach north-east, a direction nearly parallel to the fissure systems of Germoe, others are more nearly east and west. A peculiar group of lodes, locally called guides, which have some characters common to cross courses and the same bearing as the cross veins of the Caradon district, often curve away westward and run along with the lode, and at these junctions rich courses of ore have been successfully worked. The lodes cross the border of the granite at right angles, and appear to lose their productiveness for tin towards the interior, consequently the junction rocks which are the most productive, have been followed several hundred fathoms westward under the sea.

The lodes have not been so rich as those of some other parishes, but they have been fairly productive. Although Levant returns 1000 tons of copper ore yearly, most of the mines are worked for tin ore, which being found in the granite near the junctions, the deep workings are moving slowly westward. The richest tin mines are in the Botallack group, and here the veins cross and coalesce with each other in a way quite unique. The richest copper ores found in the county were raised at Levant, Botallack, and other mines, in the metamorphic rocks along the junction, but the lodes changed to tin on penetrating the granite. The ores were vitreous, native, with copper pyrites, and some salts of copper, the ores sold averaged over twelve produce.

Balleswidden is a mine in the granite, which has been worked on a course resembling an elvan more than a lode. The matrix is composed of felspar, quartz, white mica, and schörl, amongst which cassiterite is distributed irregularly in large quantities. In the junction slates, the gangue of the lodes is quartzose with some ferruginous matter, and occasionally some felspar clay and lime; in the eruptive rock the vein stuff is also quartzose, but a granitic character predominates. Schörl, chlorite, and brown iron, are met with in most of the lodes, and sometimes fluor, mundic, and ologiste iron. In the guides and scorrans, quartz and ferruginous oxides prevail. Mispickle or blende is but little associated with the ores in the matrices of the St. Just lodes. Several of the rarer ores of iron are found in small quantities at Levant and Botallack in the form of arseniates and phosphates. Native bismuth and its oxide and sulphide are found in the same mines, and at Balleswidden, together with apa-

tite, fahlerz, and ores of cobalt, nickel and uranium. Some carbonate of bismuth raised at Wheal Owles was sold at the rate of £130 per ton. The lodes in Morvah and Zennor were in similar rocks and produced much the same minerals. The cobalt ores of Wheal Owles were sold for £40, whilst small quantities of the ores of uranium (pitch blende) fetched over £100 per ton. The situation of the richest and most extensive mines being on the brink of the lofty accidented cliffs, much of the machinery, engines, whims, and roads, are built on overhanging rocks, or on the summits of vast cliffy precipices rising from the ocean, and communicating with the shore by frail wooden stagings. At the Botallack mines, the difficulty of transporting the ores from the ends of the deep levels extending a thousand yards under the sea, compelled the adventurers to construct a diagonal shaft seaward in order to afford a more direct communication with the bottom of the mine. Down this incline Queen Victoria descended about the year 1860, and only a short time subsequent to her visit, the rope attached to the wagon snapped, and several miners were hurled down 200 fathoms and killed. At Levant Mine they have a steam engine at work, 1250 feet under the surface, situated 600 yards from the coast, under the Atlantic billows.

ST. IVES DISTRICT.

The geological character of the rocks are nearly the same as in the parishes just noticed, the same bands of felspar and hornblende rocks, skirt the granite to St. Ives *town*, and thence eastward to the Wheal Providence

mines. The mines usually produce tin along the littoral from Boscaswell to St. Ives Consols, but they have, with few exceptions, been unsuccessful. The country is wild and sparsely inhabited, but the uplands are rendered romantic by numerous cairns of great elevation that rise from the heath-clad downs, the side of which are bestrewed with enormous granite boulders. The transition of the granite to slate is not abrupt; the former grows fine-grained and quartzose with schorly spots, graduating into a rock composed of schörl and quartz, which is succeeded by felspathic rocks similar to those of the coast to the south. The crystals of felspar are large, and often manifest a remarkable coincidence of direction.

The lodes bear east-by-north, and the trawns—as the cross courses are called in this district—are nearly perpendicular to them. The matrix of the ores and the ores themselves, are much the same as in St. Just, rich copper ores being found along the junction in the greenstone rocks and cassiterite in the granite. The walls of the trawns are argillaceous and smooth, and their principal contents are quartz, schörl, and earthy iron. In the parish of St. Ives occur the remarkable deposits known as "carbonas," large masses of stanniferous granite that assume a sort of linear direction and are obscurely connected by the jointy structure of the rock with lodes. One of the carbonas in the St. Ives Consols mines was 250 yards long with a diamater of about 20. It had only a very partial attachment to any lodes, but appeared to be a portion of granite into which the tin ore had been gradually accumulated, filling up the joints and veins, and substituting itself for some of the constituent parts of the rock, which consisted of the usual granitic minerals,

felspar, quartz, and schörl. The deposit shaded off into the granite, becoming gradually less and less stanniferous. Enormous quantities of tin were raised from these carbonas, which are not developed in any other part of the county. They do not appear at the surface, but some very similar deposits in Towednack and Zennor have been worked at "grass." The copper ore raised from Huel Trenwith and Providence mines, was contaminated by the oxides and phosphate of uranium. Specimens of bismuth have been picked from the ores of St. Ives Consols, and cobalt bloom has been seen in Huel Trenwith. Although the population of St. Ives was two decades ago actively engaged in the flourishing mines, there is now not a single mine at work, excepting a few tinners who are employed in St. Ives Consols above the adit.

LELANT MINING DISTRICT.

The lodes of Towednack and Lelant are parallel to those of St. Ives, as are also the cross courses. Outside of those worked in the greenstone of St. Ives, all the mines are tin producing. The Huel Margaret group is situated on the junction of the granite and slate, and some years ago great profits were made, but the mines are now only tin producing, and pay no dividends. The Huel Reeth mines, wholly in granite and remote from the clayslates, were formerly very productive, but failed in depth. The gangues are granitic in the eruptive rock, consisting principally of quartz, chlorite, brown iron ore and sometimes mundic. The trawns are composed of *schörlaceous* granite, and some of the cross courses are

made up of combs of crystalline quartz. The gangues besides tin and copper, enclose sometimes in small quantities blende, mispickle, and calamine; of the rarer metals, molybdenite has been observed in the ores of Huel Mary. Mining is at a very low ebb in this district, and the three or four mines returning tin are making no profit.

MARAZION DISTRICT.

No mining of any importance has taken place in the interesting alternations of slates and greenstones, which occupy the deep bay in the granite immediately west of Penzance. Several fine elvans traverse these strata, and enter the granite. In the southernmost of these, generally called the Penzance elvan, which crops out of the sand about a hundred fathoms in front of the Esplanade, the jointy structure is filled with tin ore for a width of twenty feet. It was worked by a miner a century ago, who with that boldness and practical skill characteristic of the Cornish miner in all the mining fields of the world, built a shaft in the midst of the sea, which he connected with the shore by means of a wooden staging. The shaft was sunk several fathoms below the bottom of the sea, from which the water was pumped out by flat rods attached to a steam engine on the Green. Nearly £100,000 worth of tin ore was raised, and the adventure was exceedingly prosperous until the staging was demolished by a large ship driving across it during a violent storm. The mine was re-opened at a great expense thirty years ago, but was unsuccessful. Some rare minerals were obtained, amongst them tin white cobalt.

THE most delightful spot in Cornwall, whether for the tourist or artist, the mineralogist or geologist, is the St. Michael's Mount. This conical island, 500 yards in diameter and 200 feet high, is made up half of sedimentary strata and half of granite. It is full of interest to the geologist because of the phenomena associated with the transition rocks, and here the mineral collector can fill his bag with specimens of rare and beautiful minerals, viz.: apatite, beryl, pinite, topaz, garnet, tourmaline, and others, together with bell metal ore, tin ore, and wolfram.

In the parish of Ludgvan, between the towns of Penzance and Marazion, the Huel Darlington group of mines were extensively worked a quarter of a century since. The lodes traversed deep blue slates, sometimes with greenstone and actynolite rock. The principal lodes were highly mineralized, producing both tin ore and copper pyrites in a gangue of quartz, slaty matter, mundic, with occasionally some arseniate of iron. At West Darlington some argentiferous lead, silver glance, and native silver were found.

In the parishes of Marazion, St. Hilary, and Perranuthnoe, the slate in the vicinity of the lodes is grey to dark blue, and is crossed by highly porphyritic dykes which are signalised by the presence of pinite. The gangue of the veins is quartz, slate, felspar, clay, earthy iron

ore, and mundic, accompanied by melanterite and copper pyrites in the slate, which is replaced by vitreous copper ore when the lode comes into contact with the elvan course. The influence of the strata on the deposition of copper ore seems well displayed where a lode happens to follow the wall of the elvan, as the vitreous ore is next it whilst the yellow ore is towards the slate. In most of the lodes considerable quantities of tin oxide exist, and formerly black tin was sold in some quantity, though at present, except at Penberthy Crofts and at Tregurtha and Owen Vean, scarcely any mining is being done. Many copper mines were worked in the clay slates of Perranuthnoe; Wheal Speedwell, Wheal Neptune, and Halamanning mine were among the richest.

GODOLPHIN & WHEAL VOR DISTRICT.

The granite boss stretching across the parishes of Godolphin and Breage rises into two eminences, the beautiful cone of Godolphin 532 feet, and Tregoning ridge 635 feet above the sea that washes its southern flank. The junction around the hills is studded with mines, many of them celebrated for their productiveness. The transition rocks are extremely interesting, and very similar to the alternating strata of granite and slate seen in Dolcoath and Cooks Kitchen underground, but which owing to the ravages of the sea, can be seen open to the day in the celebrated Trewavas cliffs. Many of the junction rocks are interesting, because they demonstrate how gradual the change from slate to granite may be; at Carleen, the lamellar dark blue slate, slowly becomes a

crystalline quartzose rock, which, developing into porphyritic felspar rock, shades off into the usual kind of altered granite seen near the sedimentary rocks. The Tregonning Hill is micaceous, and resembles in that of Hensbarrow, is prone to decompose and produces china clay.

The lodes are very numerous on the western side, and some of them have produced much tin. The celebrated Great Work mine in the hollow between the two hills, was worked 150 years ago, and sold considerable quantities of black tin, though little is being done there now. The lode is rich in granite, contained no tin of value when it entered the clay slates. There is a very regular group of veins extending from Tregonning Hill across the slate basin to the Western granite, which was celebrated half a century ago for the extraordinary riches yielded by the Great Wheal Vor lode. It was re-started 30 years ago, and a hundred inch cylinder and other pumping engines were erected to drain the mine to the bottom, which however was not found to be so stanniferous as the reports led the adventurers to expect. Many other parallel lodes were rich, particularly Wheal Metal and Wheal Sozen. It is a most productive locality for tin, and considering that the mines around Wheal Vor have paid more than £1,000,000 in dividends, has been strangely neglected. The rich old copper lode of Godolphin was in slate, and the grey ore cropped out at surface. It produced various cupreous ores and some stannic oxide, which were enclosed in a gangue of quartz, brown iron ore, chlorite, slaty matter, and mundic. The Great Work mine is in granite, its lodes are granitic with brown iron ore and mundic, in which were distributed large quanti-

Columnar Granite. — TOL-PEDEN

ties of tin ore. The rich tin mines of the Great Vor district were in slate, and the gangues consisted chiefly of quartz, slate, chlorite and iron pyrites, which became arsenical at increased depth. Of the scarcer minerals, tungstate of lime is found at Penberthy Crofts, fahlerz at Great Work and Wheal Prosper, mimetite or arseniate of lead at Wheal Prosper, apatite and topaz at Tremearne, whilst pinite is prevalent in the granite of Tregoning hill.

In the clay slate west of the Looe Pool, is a group of meridional lead lodes which produced argentiferous galena in large quantity, half a century since. About the same time the old Trewavas mine in granite was a rich copper mine, and as at the St. Just mine, the engines were erected on frowning granite crags, and the ore was followed under the sea. At present the waves wash into the workings, which are full of sea water and cannot be drained.

The face of the country from Helston south to the serpentine of the Lizard, and along the banks of the Helford creek, is a succession of hill and dale, picturesquely diversified by wood and water. The tabular appearance of the serpentine which forms the Lizard, invests it with rather a monotonous aspect, though many romantic, but short valleys and ravines, have eroded passages through the lofty and majestic coast line, which the Lizard opposes on all sides to the ocean. The numerous deep indentations in the variegated rock, leading to lovely beaches embosomed in rugged cliffs, attract numerous visitors. Very little has been done on the southern slope of Carn Menellis, the only mine of importance which yielded tin being Wheal Vivian. At Gweek some elvan courses cross the creek in a north-east direction, but no lodes have been observed. At Swanpool, near Falmouth, much

lead was raised, and an arsenic refinery erected some thirty years since, but the operations were unsuccessful.

Several beautiful and remarkable minerals are found about the serpentine of the Lizard, viz.: steatite, asbestos, diallage, actinolite, and schillerspar. Some copper ores occurred at Polurian cove, Huel Unity, and Huel Downas; magnetite at the Lizard Head and Gwinter; ilmenite at Porthalla; chromite at Cadgwith; and menaccanite at several places in the parish of St. Keverne.

WENDRON MINING DISTRICT.

The rounded eminences of Carn Menellis present a dreary expanse of furze-clad summits, whose partially cultivated slopes shade off into dreary moorlands, whilst the valley bottoms are disfigured by the unsightly stream works of the ancient and modern tinners. The Wendron tin mines are situated mostly in the granite, the mineralized belt extending to Stithians. The principal mines are grouped around Porkellis Moor which is traversed by numerous lodes, but although much tin ore was in the aggregate extracted, the district was not very successful. This was in some measure due to the immense body of water held by the Porkellis Moor compelling the erection of large pumping engines, though it must be admitted that there is a tendency in the lodes to dwindle in size and productiveness in depth. A short distance south of Porkellis Moor, is the Wheal Lovell group of tin mines, long famous for the rich courses—or rather columns—of cassiterite that bestowed a short though dazzling existence to the mines in which they occurred. The deposits of

East Lovell were very peculiar, they were not formed in the veins, which are usually small, but apparently by the infiltration of the tin oxide into the walls, which, spreading to a distance of some feet replaced the granite. But in accordance with the general law, that the hollows produced by movement are the depositaries of metal, these carbona-like masses have developed where the vein is largest, and these spaces having but a small angle from the perpendicular, the aggregations bear a considerable resemblance to pipe veins. The gangues of the lodes in Wendron are pronouncedly granitic, and the indications seem to point to impoverishment increasing with depth. The only mines returning tin just now are Basset and Grylls, East Lovell, New Lovell, and New Trumpet Consols, but the aggregate quantity produced by them is less than a hundred tons.

Among the lead ores raised from the lode of the Huel Penrose group were mingled some arseniate, sulphates, carbonate and phosphate of lead. Cerussite was also found at Huel Unity in Sithney and at Huel Ann in Wendron, and wolfram in the tin ores of Prospidnick.

GWINEAR AND CROWAN DISTRICT.

Includes the mines between the granite bosses of Land's End, Godolphin and Carn Menellis. The upland plains present in a milder form the usual barrenness and disfigurement of a mining field, but the low undulating surface, slopes northward through a well cultivated country to the lowlands, around the muddy creeks of the Hayle estuary. The elvan courses and greenstone dykes are

very numerous and their direction various. The diverse bearing of the lodes, and the general dip of the lodes to the south, tend to make the district remarkable. Through St. Erth and Phillack the slates are soft in character and of a deep blue colour, the lodes in which have been productive of copper. Mellanear, which sells about 7000 tons of copper pyrites a year is now the only mine of importance. The lodes yield beside copper, blende, and some plombiferous ores in a gangue similar to that filling the lodes in Ludgvan and Marazion. The rich copper lode of Huel Alfred produced very fine specimens of plombic phosphate and other rarer compounds of copper, lead and silver.

In Gwinear the slates are rather fissile and flaggy, they have various tints of blue in some parts, at others reddish brown, and the parish is essentially cupriferous. Though several important mines existed a quarter of a century or more ago, there is at present not a single copper mine at work. Huel Tremayne was extensively worked for tin, but the only tin mine now at work is Wheal Jennings, which returned in 1882, only 26½ tons of black tin. The gangues are more quartzose than those previously noted. The district is nowhere deeply mined, the shafts seldom reaching much over a hundred fathoms in depth, the sinking being stopped whenever unproductive ground was touched. Tin ore has been raised in small quantities in most of the mines and was abundant in Trevaskis, Carzise, and Rosewarne. The historical mines of Herland and Huel Unity, have yielded a number of rare and curious minerals in a gangue which is very quartzose and slaty. These comprise horn silver, argentite, red silver ore and native silver, bismuth ores, and ores of uranium,

as well as arseniate of cobalt; whilst at Relistian and Trevaskus tennantite, and at Huel Unity and Trevaskus molybdenite, earthy cobalt and bitumen were found. Huel Unity was also remarkable for the variety of cupriferous ores yielded by the lodes. Relistian mine was first worked as a quarry, which is still open for a length of nearly a hundred yards and a depth of seventy feet.

The characteristics of the parish of Crowan are much the same as the adjoining parish of Gwinear, the mines producing chiefly copper pyrites. Formerly those most famous for their metallic wealth were Wheal Strawberry, Huel Treasury, Binner Downs, Wheal Abraham, and Crenver mines; but for many years last past very few mining works have been carried on in the parish. Some years ago the old mines of Crenver and Abraham were drained to work the tin stuff supposed to have been put away to "stull," but no success rewarded the expenditure of the £150,000 required to open them. The mines are all comparatively shallow, and spirited sinking would probably be attended with great success.

CAMBORNE AND ILLOGAN MINES.

The country in these parishes amongst the mines is rendered dreary and wretched by the countless heaps of mine rubbish, the large areas covered by unclean and delapidated dressing sheds, and by numerous mine streams, foul with slime which meander across roads and fields with aimless persistency. The Carnbrea Hill, crowned with magnificent rocks and a tall monument, is the highest land in the vicinity, having an elevation of 740 feet.

At the northern foot of Carnbrea Hill, a few parallel lodes—extending less than two miles in length—have been worked for hundreds of years, and have yielded an aggregate of millions of pounds sterling worth of black tin. Though not so profitable as some few years since, when labour was cheaper and the price of metal higher, the aggregate production of Dolcoath, Cooks Kitchen, Tincroft, and Carnbrea is nearly 4000 tons per annum. The southern foot of this narrow granitic ridge has been also rich, and sells at present more than 2000 tons of tin. Thus a third of the tin produced in the county, is raised from the parallel groups of lodes which follow the direction of Carnbrea ridge. Most of these mines produced copper pyrites and vitreous ores until three decades since, when, after passing through some unproductive ground, the copper was unbottomed, and rich courses of cassiterite were everywhere discovered. A group of lodes a short distance north, worked at East Pool and Wheal Agar bid fair to be very productive, as the former mine sells about 1500 tons of black tin yearly, and is in the dividend list. There is also a group of rich lodes associated with greenstone dykes, which at Roskear and the Setons have sold enormous quantities of rich copper ores. It is impracticable to give here the names of the rich mines which have been worked in these parishes, but speaking broadly, the whole ground is rich in metallic minerals, and wherever a good lode has been perseveringly followed non-success has been rare. The alternations of granite and slate at the junction are most peculiar, the latter having been metamorphosed into thick lamellar dark blue or purple slates, crystalline in character and felspathic in composition. The lodes on entering the granite soon

change to tin and usually increase in size, and a very successful future may safely be predicted for many of the mines in the stanniferous zone. The mines are becoming very deep, Dolcoath having reached a distance of 400 fathoms from the surface. The immense gunnies in this mine give cause for anxiety, as in 1828 an immense subsidence took place, and there is at present a slow movement downwards as is evidenced by occasional slips of ground.*

The lodes have an average direction of about 30° south of west, they incline north and south, and being in transition rocks are both productive. The caunters have a bearing about 20° north of west, and have yielded some galena and blende, though chiefly copper pyrites. The gangues of the lodes throughout are much the same, viz.: quartz, brown iron ore, chlorite, and sometimes fluor and lithomarge, which, where greenstone prevails, is mingled with quartzose slate, in the blue silky slates with slaty matter, and in the eruptive rock with granitic matter. In the metalliferous portions of the lode, mundic, blende, and galena are often present. Besides copper pyrites, vitreous copper and purple ore, there are found occasionally native copper, red and black oxides, green and blue carbonates, with specimens of fahlerz, hydrous and anhydrous sulphates and phosphate of copper. The only ore of tin is the binoxide, but small quantities of wood tin were found in the Garth mine and tin pyrites at Carnbrea. Silver or its ores have been found in Huel Basset, East Pool, West Dolcoath, and North Dolcoath. It was also formerly largely raised from Carn Entral mine near Tuck-

* In 1687 a superficies of nine acres subsided into the old mine workings at Fahlun in Sweden, and left a chasm 260 feet deep.

ingmill, in which mine it was found native, as sulphide, and combined with antimony. Cobalt and nickel have been raised from East Pool and sold for £40 per ton, they occur also at Dolcoath. Various ores of Uranium —pitchblende, torberite, antunite and johannite—are found in South Basset, Tincroft, Dolcoath, and East Pool; in the latter mine some tons have been sold at prices varying from £70 to as high as £200 per ton. Wolfram occurs with tin ores at East Pool, Carnbrea and Dolcoath; a considerable amount is sold at East Pool at about £12 per ton. Bitumen has been seen in East Crofty, Cook's Kitchen, and Tincroft. Bismuth and bismuth glance have been sold at Dolcoath and East Pool for £50 a ton. Beautiful specimens of the ores produced by the deposits around Carnbrea and Carnmarth, may be studied in the collection at the Jermyn Street Museum, London.

REDRUTH AND GWENNAP DISTRICT.

The mines worked around the circular boss of granite called Carnmarth, although of comparatively shallow depth, have been amongst the richest in the county, second only to those associated with Carn Brea, and it is possible that with pluck and perseverance—similar to that exhibited by Capt. Charles Thomas in 1850, when insisting on sinking the shaft through poor ground during the transition from copper to tin—many of the rich copper lodes might in depth be found to enclose rich courses of cassiterite. But for Captain C. Thomas the mines working in the Dolcoath lodes might to-day be *as idle* as those of Gwennap. From the summit of the

Carnmarth cone—771 feet above the sea—the mining tracts are seen sloping away to the Truro river eastward, to the coast northward, and to Hayle westward. This magnificent prospect includes the oldest, richest, and most extensive tract of mineral ground in the county, and, on account of the unfruitful character of the soil, and the myriads of burrows of various shades of blue, yellow, and brown, is the most barren in aspect. The surface of the downs is covered with a white layer of quartz fragments, the debris of ages of denudation.

To the south of Redruth Town is a group of copper mines, of which Tresavean and Wheal Buller form the centre, that has been exceedingly productive of copper, both in the slate and in the transition rocks accompanying the junction. Most of these have been exhausted and are now idle; the only mines now working are West Poldice, Tresavean and North Penstruthal. Wheal Gorland has produced much fluor spar, which formerly sold for 22/- a ton, but is now worth only 10/-. To the north of Redruth, the Wheal Peevor cluster of lodes yielded excellent returns of tin for many years, but they have fallen off very considerably lately. The Redruth lodes which bear about 24° N. of East, being a continuation of the Illogan district, are filled with the same gangues, and produce the same common and rare minerals.

The quantity of tin returned from the Camborne and Redruth mines during 1882, the slimes from the dressing floors of which, find their way through the Portreath and Red rivers to the sea, is about 7900 tons of black tin, and a further quantity of about 1520 tons (£65000 worth) is obtained from the slimes dressed by the

streamers on those rivers. More than 75 % of the tin produced by the county, is obtained within the upper watershed of these two little valleys. Allowing five per cent for the tin ore finally lost in the Bristol Channel, the miners lose from their dressing floors, more than a fifth part of the tin raised from the mines. This seems an exceedingly large proportion, but when one learns that no less than forty-four companies are employed in incessantly re-washing the slimes along the river beds, the difficulty of devising any means to check this waste at the mines will be readily acknowledged.

The **Gwennap Mines**, though some tin was obtained from them, must be considered as forming a copper district, since all its lodes have yielded that metal in large quantity. Unfortunately from want of a good system of mining, and of combination between the numerous companies, the mines were worked a good deal on the hand to mouth system, and no provision made for the future by keeping the shafts well ahead of the stopes; this system led to mines being abandoned after the shallower courses of copper were exhausted, and the water became too fast for the remaining mines to work, except at a loss, though some of the lodes were rich when the last suspension of Clifford Amalgamated took place. At this mine no less than nine pumping engines, averaging 76 inch cylinders, besides nine other engines, were employed. To re-open the mines would require a large capital and years of time to reach the deeper courses of ore, which analogy would lead one to believe must exist.

The County crosscourse traverses the parish of Gwennap, and is said to be traced from Tywarnhaile on the north coast into the Carn Menellis granite, a distance

of eight miles. Some of the lodes running eastwards are said to continue to the Wheal Jane group of mines, which is not less than seven miles. It may be questioned if the identical fissures are so persistent, though the system of fractures is indubitably the same. The famous copper mines of Gwennap have been the richest in the county, and the immense dividends declared during the first half of the present century, imparted such confidence to the public, that it has taken a quarter of a century of share jobbing and "calls" to quench the spirit of speculation. The mines that produced the largest masses of copper ore were worked in the group of lodes running through Cosgarne Manor. Unfortunately the statistics of sales are not accurately known, but the aggregate value would not be less than £10,000,000, whilst the profits made amounted to more than £2,500,000. In this district—which employed 5000 persons thirty years ago—the only mine of any importance in operation is West Poldice, which returned in 1882, 143 tons of black tin.

The slates are thick lamellar, of a pale to a deep blue colour, and often silky in texture. The gangues are composed of quartz, red and brown iron ores, chlorite, and some fluer, which are associated with argillaceous matter in the slates, and with granitic substances when the lodes traverse granite or elvan courses. The ores produced are chalcocite and copper pyrites, mundic and blende, and near the surface native copper, cuprite, and black copper ore. The mines on the Poldice group of veins produce much tin, especially in the deeper levels, accompanied sometimes by wolfram; in Huel Unity Wood were collected the finest crystals of cassiterite ever

seen in Cornwall. Of the rarer ores, tin pyrites were found in the Barrier mine, barytes in the United and Consolidated mines, molybdenite in Huel Friendship, cobalt and uranium in Huel Gorland, Huel Jewell, and Ting Tang, vivianite in Huel Gorland, and bitumen in Poldice.

The Gwennap elvans and lodes prolong themselves into the parishes of Kenwyn and Kea, where they produce tin with large quantities of iron and arsenic pyrites. Wheal Jane, which is the only considerable mine in operation, sold 117 tons of black tin in 1882.

SAINT AGNES DISTRICT.

With but a small break, the mineralised slates of Gwennap extend to the Saint Agnes coast, along which from the Beacon—621 feet high—to Cligga Head, there is evidently a subterrene ridge of eruptive rock, that may perhaps extend itself under the slates of the Perranzabuloe district. Although the absolute height of Saint Agnes Beacon is not great, yet as the plateau like moors, and sub-arid downs which surround it, are relatively much lower, it is a very conspicous object for miles around; the cone also possesses much geological interest on account of a belt of peculiar fossilless sand and clay which encircles its base. The granite of the beacon has a character intermediate between that rock and elvan, and is traversed by numerous veins of tin oxide. At Huel Coates the large orthoclase crystals have been often decomposed, and by substitution made pseudomorphic after cassiterite. The Cligga Head mass

has also many features possessed by elvans, and is made up of many dykes which differ in texture and components, so that in one the rock may be porphyritic and in another resemble greisen. Numerous veins of tin oxide with schörl and wolfram give the whole rock a dark and mottled appearance, and, owing to the burrowings of the tinners, the face of the inaccessible cliffs is maculated with innumerable cavities which penetrate far into the headland. Molybdenite occurs at the junction of the granite with the slate.

The lodes in the neighbourhood of the beacon have been long worked for tin ore, amongst the most celebrated are the old mines of Polberrow and Huel Kitty. There are many tin mines still at work, the most prominent being those of West Kitty, Huel Kitty, and Penhalls. Saint Agnes produces about 700 tons of black tin per annum. This district is remarkable for the disturbances in the relative situation of the rocks, which the intersection of lodes of opposite inclination has caused to take place, and for the dissemination of tin ore through the innumerable small fractures which the rock has suffered. From the exposure of the veins along the cliffs and in elvans, tin ore has been worked from time immemorial. The numerous bold capes which jut out from the coast at right angles to the direction of the groups of lodes and elvans, allow great facilities for the study of their basset edges, and of the heaves occasioned by the crosscourses. The lodes are rather small and quartzose, and slaty matter often predominates. Wood tin was found in the Pye lode at Polberrow, bismuth at Huel Coates, Huel Rock, and West Kitty, and stannite in the latter; at Huel Kind, vivianite and topaz occur.

The tin of Saint Agnes was once supposed to "make" shallow, but the rich tin found in Huel Kitty at 150 fathoms deep has tended to dispel this surmise.

In the sienna and blue slates to the south-west of the beacon, are situated the copper mines of the Huel Towan group; though now idle, 30 years ago they were very productive. There was nothing peculiar in the vein filling, or in the occurence of the ores. Some ores of uranium were met with at Huel Basset, and bitumen at South Huel Towan.

PERRAN MINES.

This parish is distinguished by the varied nature of its mineral productions; its lodes gave existence to the copper mines of Perran Saint George, the rich lead mines of Wheal Golding, the lead and blende mines of the Chivertons, the tin mines of Huels Budnick and Vlow, the iron mines of Duchy Peru, and the silver mine of Huel Mexico. The slates enclosing the copper lodes of Wheal Prudence, Perran Saint George and Wheal Leisure, &c. is usually pale blue, soft and prone to decompose. The copper mines of this group yielded a profit of £250,000. The lead lodes of Penhale and Huel Golding are seen crossing the indentations along the cliffs on which the machinery was perched; they were productive, but have been temporarily abandoned. The tin mines of the Huel Budnick district were not very rich. The Budnick lode, which is associated with an elvan, is remarkable for the heaves which it causes in the cross veins of Penhale and Huel Golding. The lead

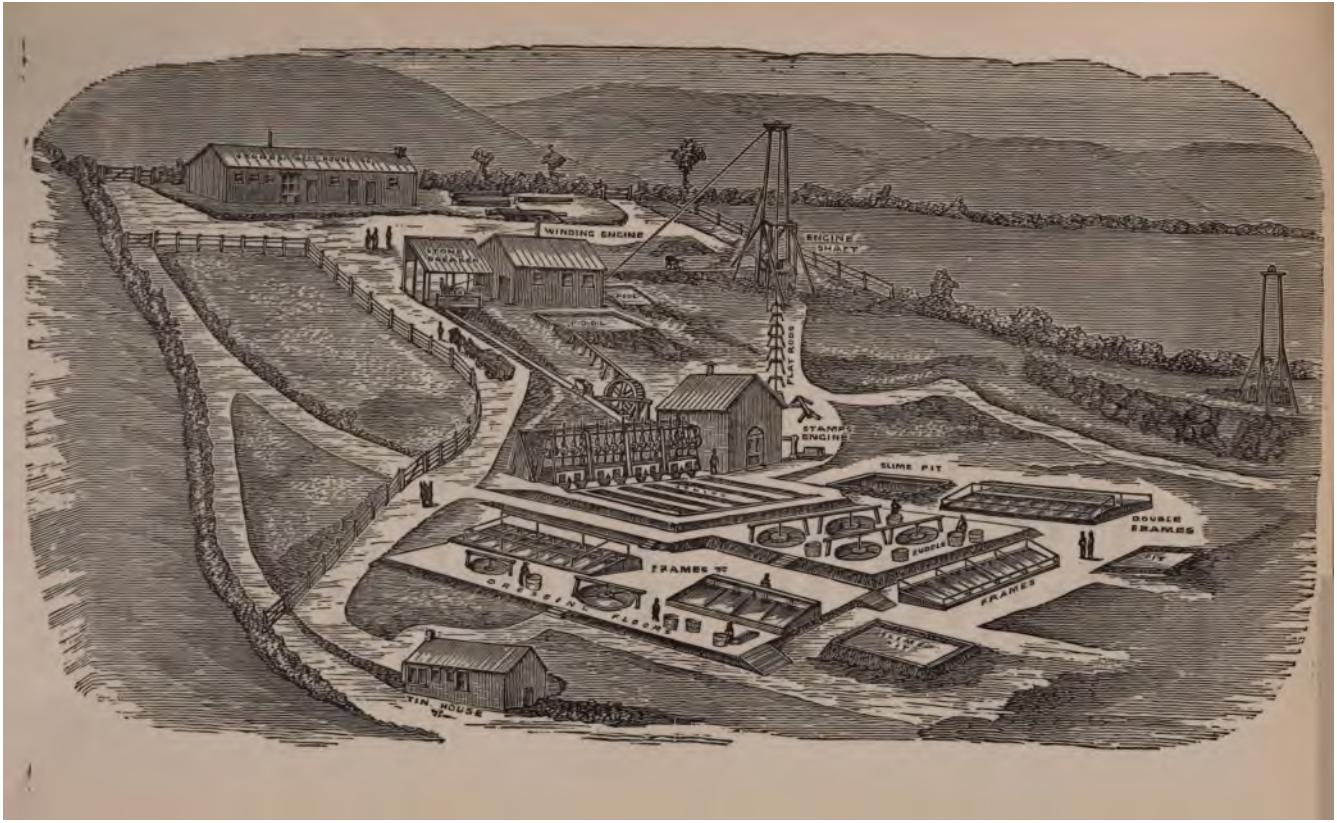
lodes of the Chiverton district possess a peculiarity nowhere else remarked in Cornwall, they have a bearing approaching that of the tin lodes. Wheal Chiverton and West Chiverton yielded enormous masses of galena for many years, but became exhausted about 10 years ago after dividing about £230,000. Much fine blende of good percentage was raised, and at Great South Chiverton some blende of a beautiful amber hue was found in sinking the engine shaft. The two Chivertons, like all lead mines in the county, became unproductive before reaching the 200 fathom level, a depth comparatively shallow. At Huel Mexico much silver ore was raised half a century since, in the state of chloride and sulphide, together with capillary and arborescent silver.

EAST HUEL ROSE DISTRICT.

The east and west lead lodes of the Chiverton mines prolong themselves eastward into Newlyn, where the lodes of the Shepherds group were cut in 1816 by some labourers engaged in draining a marsh. They were worked with much profit 40 years ago, and lately have again been opened. Besides these lodes, there is a group of north and south lodes accompanying the Saint Columb elvan course. The lode worked under the name of East Huel Rose was extremely rich thirty years ago, and gave the adventurers over a quarter of a million profit. This mine has, within the last three years, been re-started and very fine pumping machinery has been erected to drain the workings, which on account of the loose decomposed character of the slates of this district are wet and difficult to keep open.

SAINT AUSTELL DISTRICT.

The tract of country in which the copper, tin, and iron mines are situated, lies on the beautifully diversified and wooded slopes that fall from the Hensbarrow granite southward to the sea. The once celebrated Crennis and Pembroke group of copper mines was situated along the cliffs from Par to Charlestown. The lodes produced the usual ores of copper associated with mundic, blende, and spathose iron, and were encased in a thick lamellar rock, pale to deep blue in colour, and often inclined to disintegration. Par Consols was worked to a depth of 250 fathoms, the deeper portion of the mine yielding tin, the profit on working both the copper and tin was £250,000. The lodes of Great Hewas and Polgooth, that accompany the well characterised group of elvan courses that run parallel with the southern edge of the granite, are principally tin producing, although rich courses of copper pyrites have occured occasionally, as at the 90 fathoms level in Polgooth, where the lode was six fathoms wide. In the latter mine, tin was found in the cross-course as well as in the lode. The tin lodes continue westward through Dowgas to the Terras mines. Here to develope a group of tin lodes, efficient stamping machinery has been recently started; as this is the pioneer mine of the district, the result will be awaited with interest. The gangue is generally composed of quartzose slate or quartz, but with felspar, clay, and schörl when near elvan. The tin lodes of the Huel Eliza group have been rich, and that mine has divided £60,000 on an outlay of £20,000; the tin sale in 1882 amounted to nearly 500 tons of black tin.


WINDING ENGINE
ENGINE SHAFT
FLAT RODS
STAMPS ENGINE
SLIME PIT
DOUBLE FRAMES
FRAMES
FRAMES
TIN HOUSE

The Fowey Consols copper lodes traverse blue slates often micaceous, or compact felspar rock, which perhaps owe their texture to an underground spur of the granite protruding from the Hensbarrow mass. The gangue consisting chiefly of quartz, slate, chlorite, and spathose iron, encloses mundic, iron, and copper pyrites, vitreous ores, and native copper. The working of the copper lodes gave a profit of £220,000; they then changed to tin, but the adventurers not having the patience to sink, the mines were stopped about 20 years since. There is in this mine a perpendicular shaft 300 fathoms deep. The Restormel iron mines to the east of Fowey Consols have sold large quantities of iron ores.*

TIN MINES OF HENSBARROW.

The average height of the granite plateau is about 650 feet. The bleak, ill-cultivated moors, are separated by shallow valleys into rounded elevations which are often crowned by cairns or craggy heights, whilst the slopes are strewed with huge schörlaceous masses *in situ* and with granite boulders and quartz. A dreary, swampy moor, with innumerable excavations and unsightly burrows made in search of stream tin, stretches for miles northward to the isolated granite cones of Belowda and Castle-an-Dinas. The surface over a large extent is much decomposed, and a layer of detritus fills the valley bottoms, rendering them soft and treacherous to the pedestrian. The tin ore in this boss is associated with

* The Eselschacht at Küttenberg, Bohemia, is nearly 4000 feet from the surface.

schörl in regular veins, as at the Bunny, Beam, Rocks, and other mines. The veins were usually small, especially when the tin ore was rich, but they seldom continued to any great depth, except at the Beam mine, where one was followed to a depth of ninety fathoms. Much of the tin ground accompanying the veins, owes its stanniferous value to the infiltration of the tin oxide into one or both sides of the lode, which is often small; a good example of this class of deposit is exhibited in the Rocks mine, where rich bunches of cassiterite were found so pure that they required scarcely any dressing. At Beam occurs ferric phosphate and wolfram.

These mines were anciently worked as open casts, and some of them were commenced centuries since. The lodes are nearly always in "pot" granite, and the ground has often been worked alternately for tin ore and china clay, so that they better merit the title of stockworks than mines. Not only the schörlaceous veins, but the bands of schörl rock, whose resistance to disintegration has rendered them prominent, enclose a small proportion of tin oxide. Courses of greisen, which are frequent in some localities, also enclose minute quantities. Although tin oxide is so much disseminated throughout the western moiety of Hensbarrow granite, the difficulty of mining operations, and the gradual empoverishment of the lodes in depth, tends to somewhat discourage deep mining. To the east of the Luxulyan gorge, the granite changes its character, becoming dry and hard.

The largest and most interesting stockwork in Cornwall is Carclaze, situated about two miles north of St. Austell. It has the credit of being the oldest excavation in Cornwall, and is said to have been intermittently worked for

500 years. The longest diameter is nearly half-a-mile, the area of the excavation thirteen acres, and the depth 132 feet. Though now worked principally for china clay, the numerous interlacing tin veins of opposite dip enclosed in a schörlaceous granite, were formerly stoped and stamped, and the tin ore separated by washing. At this time there were eight little stamping mills engaged in pulverising the tin stuff, the water and slimes being discharged through a tunnel about 500 yards long, that was also used as a canal, to transport the tin and tin ore to the works on the outside. Only four stamps now exist, and but little black tin is returned, but china clay is collected to the amount of about 5000 tons per annum. The amount of black tin then sold was about 10 tons yearly. The transition rocks are very interesting, and being laid open, can be studied with a facility unparalleled in the county. The granite acquires a stratified structure by the appearance of small schörl veins dipping towards the slate; these grow thicker, and getting mixed with veins of quartz or quartz and felspar, changes to tourmaline schist, which gradually shades off into brownish beds of clayslate.

The Gossmoor is limited on the north by the granitic range of Belowda and Castle-an-Dinas, 765 feet high. Parallel to the range on both sides is a remarkable group of elvan courses running with much persistency east and west. On the south many mines have been opened on a large light brown elvan of which the joints were full of cassiterite, but though Castle-an-Dinas mine was profitable, as a whole the district has not been very productive. To the south-west the copper and tin mines of St. Enoder parish, much worked some forty years since, are now idle,

they were never very rich, but East Basset is said to have declared some dividends.

Some very peculiar deposits of tin ore in the clayslates at Lanivet near Bodmin are worked quarry wise. Mulberry mine is by far the largest excavation, being as deep and nearly as large as Carclaze; the returns in 1882 reached sixty tons of black tin, and Wheal Prosper sold during the same year over twenty tons. The tin ore occurs in the joints and small fissures of the slate like a stockworks, and thus the whole hill has to be trammed away to the stamps and reduced. Reperry mine, besides tin, has many curious antimonial ores. The old Mandlin mine, situate near the eastern border of the Hensbarrow granite, was remarkable for the massive garnet rock which formed the matrix of the lode, and also for the occurrence of the minerals tungstate of lime, magnetic pyrites, wolfram and others.

To the north of St. Breock Downs, in the vicinity of Padstow, are a few north and south lead lodes which up to the present have led to no great mining operations. In the Delabole district are a few unimportant veins which enclose galena in small quantity. At Trugoe in St. Columb parish some copper ore, bismuth, and cobalt blume have been met with, and bournonite in St. Merryn.

CARADON DISTRICT.

The barren aspect of the Bodmin Moor is reflected by its rocks, which are very destitute of metallic ores, and it is only on the southern fringe of the granite that copper *and tin ores* abound. At Roughtor, east of Camelford,

a large sum was expended to discover whether the tin veins in granite improved with depth, but the failure was complete. At Blisland where there is a well marked, though very granitic group of elvans, no lodes of any promise have yet been noticed, but no explorations of importance have been made.

The mines around the Caradon Hill—1208 feet high—were originated by some miners driving an adit in 1836, but though comparatively modern, after a brilliant existence the first fruits of the district have been gathered, and the mines once so numerous and prosperous are now mostly stopped. South Caradon, the first mine opened, yielded 9% ore, and gave for many years handsome dividends, the total profit having been £380,000. The copper group extends eastward through East Caradon to Glasgow Caradon both very profitable mines. To the north is the Phœnix group of tin veins, where owing to the projection of granite ridges, and the faulting of the lodes, the hanging wall is slate, whilst the foot wall is often granite. The matrix of the tin ore is composed of quartz, chlorite and earthy iron ore. Adjacent the surface, copper pyrites, and malachite are found. Nearly all the lodes dip steeply towards the granite, and have an average width of rather more than three feet. At Gonamena tin ore is found in a manner somewhat resembling Carclaze, the excavation is a third of a mile long, and occupies a dozen acres, but the depth is only fifty feet.

To the west, the lodes are principally tin producing, and continue with a group of elvans through St. Neot to Warleggan. Though the mines have only been worked in a partial and desultory way, there is ample evidence that good tin lodes, which merit exploration, exist. At

a mine called Tin Hill a large quantity of stream tin was obtained from a remarkable deposit of gravel and boulders deposited beneath cliffy granite. Some elvan courses have been worked for tin with moderate success in this district.

TRELAWNY LEAD DISTRICT.

Three miles south of Caradon Hill is an interesting group of mines that have produced very large quantities of argentiferous galena. Wheal Ludcott created great excitement in the mining world in 1861, on account of the discovery of native silver, both capillary and arboriform, in an east and west cross course. The principal mines were on the Trelawny lode, and they all returned large profits on the capital employed. The lode was accompanied by a capel of brecciated structure, and the galena —which contained about fifty ounces of silver to the ton —was enclosed in a gangue of quartz, with some fluor, blende, copper and iron pyrites.

South of St. Neot, close to the road from Bodmin to Liskeard, is the East Jane group of lead lodes. In the clay slates of Lanreath and Duloe, five miles south-west of Liskeard, the Herodsfoot mine has yielded much silver lead ore, and beautiful specimens of bournonite (sulphide of lead, copper and antimony), and sulphuret of antimony which is found in quantity in no other Cornish mine. The veinstuff is quartz, fluor and calcspath. The lode does not now produce so much lead, in 1882 only 362 tons of galena containing 8130 ounces of silver were sold. At North Herodsfoot during the same year 63 tons of *silver lead* were sold.

CALLINGTON MINING DISTRICT.

The mines included under this name are those encircling the granite domes of Kit Hill and Kingston Downs west of the Tamar. Just north of Callington is the copper, tin and lead mine of Redmoor, situate on the western flank of Kit Hill, in a thick lamellar blue slate of silky lustre. The copper and tin are found in east and west lodes, and the lead in the crosscourse; this is the only mine in the county where veins crossing each other have both been productive of metallic mineral in quantity. The gangue of the former was quartz, slaty clay, and where near the elvan felspar clay; in the latter quartz, slaty clay, iron pyrites, and some ferric carbonate formed the matrix. Redmoor mine sold in 1878 cupreous precipitate, worth 114 ounces of silver to the ton. Ores of silver were found in Wheal Dudley and Wheal Vincent. The cone of Kit Hill, through which pass numerous small veins, is being cross-cutted by a deep adit level from the north side. The tin ore is associated with wolfram.

The granitic mass of Gunnislake, though scarcely two miles long, is lofty and the declivities singularly abrupt. The beautiful valley of the Tamar, with its orchards and gardens, winds around the eastern margin through a deep and romantic gorge. Hingston Down mine is situate near the summit, and at the foot of the northern slope are the tin and copper mines of New Great Consols, Lamerhoo, Devon Great Consols and others, whilst the silver mines, Prince of Wales, Huel Brothers, Harrowbarrow and Wheal Newton, together with the tin mines of Drakewalls, dot the wooded foot hills of the southern slope. Several mines in the Callington district produce

argentiferous copper ores in a quartzose gangue with mundic and mispickel. The ores of New Great Consols contain much arsenic, silver, copper, and tin, and from these were reduced arsenic, argentiferous precipitate, and black tin. The precipitate sold in 1875 fetched £3000. The Cornwall Chemical Company erected large arsenic and precipitating works at Greenhill, in Calstock, to treat the ores from their mines at Holmbush, Kelly Bray, Wheal Newton, and Greenhill. They put a splendid reduction plant that would have ensured success, if capital had not suddenly fallen short, and led to an abrupt suspension. From these mines large quantities of pyrites were sold, and the silver ore produced at Wheal Newton contained 26,800 ounces of silver. The only copper mine in operation on the Cornish side is Gunnislake (Clitters), which returned in 1882 copper ore to the value of £14,000. The group of stanniferous lodes at Drakewalls were worked anciently, though at present less than 50 tons annually are returned. It was at this mine that the wolfram which contaminated the black tin, was converted into a marketable commodity as tungslate of soda. Molybdenite occurs in this mine. The Huel Brothers parallel group of veins yielded much silver, and the gangues raised from the various mines—Harrowbarrrow, Silver Hill, Prince of Wales and others—are considered to possess an average value of several ounces of silver to the ton. The Huel Brothers lode which traversed a decomposed pale blue slate, produced red, vitreous, and black silver ores with native silver, associated with galena, spathose iron, blende, iron and copper pyrites, enclosed in quartz, slaty and felspar clay.

TAVISTOCK MINES.

The river Tamar, which separates the counties of Devon and Cornwall, has its source within three miles of the north coast, in the neighbourhood of Morwinstow. The country from Tavistock southward is much diversified by the meanderings of the Tamar with its multitudinous tributaries, and the deep valleys separated by narrow ridges, picturesquely variegated by woods, orchards, and gardens and sheets of water, shut in by softly outlined hills, afford an alternation of landscape and marine scenery delightful to the eye and pleasing to the imagination. Notwithstanding that the mines of this district are in the county of Devon, they are so closely connected mineralogically as well as geologically, that the description of the mining fields of East Cornwall would be incomplete without some notice of the rich copper and lead mines grouped around the prettily situated town of Tavistock.

A group of rich copper lodes extend from Gunnislake granite across the thick lamellar blue slates of the Tamar valley eastward to the Dartmoor range, but are most productive near the former. A little to the north of the eruptive boss on the same group of veins as New Great Consols, is the celebrated Devon Great Consols, the richest copper mine in the two counties, which in twenty years declared more than a million sterling in dividends. Eastward from the great crosscourse, the lode becomes poorer, and consequently, to treat the ores successfully, dressing machinery had to be erected. The company possess the most complete separating plant in the west. In spite of the low produce of the copper ore raised, the sales of copper ore in 1882 aggregated 12,000 tons, besides

2760 tons of refined arsenic. Bedford United returned £54,000 in dividends during the earlier working for copper, and has lately again become profitable. Wheal Crebor, another copper mine, opened on the lodes of the same group, sold £10,000 of copper ore in 1882. To the north of Tavistock are the Wheal Friendship copper mines, commenced in 1798, which gave a profit of £300,000; a small quantity of tin was also obtained.

The crosscourses running north from the Friendship group were worked at Huel Betsy, and near Lidford for galena. To the south of Drakewalls mine are the meridional lodes of Beerferris and Beer Alston, which crossing the Tamar twice, were worked under the bed of that river. The mines were lost, in consequence of the lode having been stoped up close to the bed of the river, which broke into the workings suddenly on a Sunday morning; had the accident happened on a working day 300 miners would have lost their lives. These mines were remarkably profitable, the galena produced being highly argentiferous. Several rare and beautiful phosphates, sulphates and carbonates of lead, and carbonates of copper were taken from the lodes. The company smelted the lead, and extracted the silver at their works on the Tamar at Ware Quay.

In the Devonian rocks which rest on the granite from Horrabridge around to Buckfastleigh are some copper and tin mines. At Bottle Hill tin has been largely raised, and the copper mines near Ashburton yielded very rich ores. The carboniferous slates which skirt the northern margin of the Dartmoor granite are non-productive unless in highly metamorphic rocks at the junction. Thus *at Belstone*, where garnet rock and greenstone are inter-

colated with slates, some copper ore has been obtained, and in 1882 a few hundred pounds worth were sold. Numerous mines of manganese are found in the carboniferous beds to the north of Launceston, and a considerable tonnage sold. Manganese was also raised in Calstock—near the Tamar.

CONCLUDING REMARKS.

No one who has studied attentively the metalliferous strata of Cornwall, and the mode in which the metallic ores occur in the fissures associated with them, can feel convinced that the rich tin and copper lodes, which at comparatively shallow depths, have been "worked poor" are exhausted, or that the analagous rocks mantling around the granite bosses may not enclose undiscovered lodes, maugre the thorough rummaging of the old tinners. The Caradon group of copper lodes discovered in the middle of the present century, is a remarkable instance of unsuspected mineral wealth, and one which finally dispelled the conviction of "Cousin Jack" that no copper could exist east of Truro Bridge. The richest mines must come to an end when the courses of ore are stoped away and no provision is made to pierce the poor bar of ground which the theory of vein formation makes manifest, must as a general rule intervene between two deposits.

A knowledge of where *not* to explore is important, and —speaking for Cornwall—great expenditure would be injudicious, whenever there is an absence of metamorphosed rock and massive felspathic or thick lamellar strata of variable density. Lodes found in such rocks,

carrying true gossany backs, may be followed with confidence, though the presence of oxidised iron is not absolutely indispensable to the occurrence of rich courses of ore. A chain of favourable events are requisite for the development of ore bearing lodes, and as these cannot be supposed to have happened everywhere, there are many wide tracts where the metamorphic rocks do not possess all the characteristics which are distinctive of good metalliferous districts.

Careful examination of the transition rocks around the granite by intelligent miners, with some capital discreetly applied to drive crosscut adits where auspicious conditions prevail, might, and very probably would, lead to discoveries equalling that of South Caradon, because many of the richest copper mines in the county have been discovered by accident. Less than half a century since, before promoters and mine brokers existed, small proprietors, farmers, and even artisans would combine to cut some lodes by an adit or shaft, and these ventures often led to important results. Nowithstanding that the lodes in abandoned districts such as Gwennap would at greater depth dislose rich masses of ore, the expense of re-opening and sinking through long bars of poor ground in search of them opposes almost insuperable obstacles while metals remain in the present depressed condition, but the future, possibly not so very remote, may yet see these mines working and producing large quantities of tin.

The great fall in the value of the metals produced by Cornwall during the last few years, has led to such a serious decline in the mining industry, that thousands of Cornishmen, have been compelled to leave the county, and may now be met with in all the mining fields of

the world. In 1836 no less than 30,000 persons were engaged in Cornish mines, it is doubtful if half that number find employment in that pursuit to-day.

To alleviate to some extent the present dangerous state of mining industry, *en attendant* a rise in prices, the introduction of machinery to expedite operations is of much importance. The loss in dressing tin ores is believed to be about one fifth of the tin extracted from the stopes, and if some means could be devised to stop even a third of this loss it would take mines off the calling list. Dolcoath and other mines are fast approaching a depth of half a mile, so that first class machinery for hauling the ores to surface, and convenience for the circulation of the mines has grown absolutely indispensable. To meet successfully the present crisis, it is essential to alter the mining customs, and to introduce a proper mining code assimilating as near as possible to those of Continental countries, whose governments have been watchful in byegone times to prevent the owners of the soil from usurping the national treasures buried beneath the soil.

The dependance of the west on the industries associated with mining, is a subject too well known and appreciated by landowners, farmers, and workmen, to require any observation here, but it may be remarked that the stoppage of the mines, would result in the semi-depopulation of the western towns, and a return of the inhabitants to their ancient condition of agriculturists and fishermen.

CHAPTER V.

GEOLOGICAL ECONOMICS.

A bare description of the rocks and minerals of Cornwall, and the localities in which they occur, would be perhaps unsatisfactory to the reader unaccompanied by some particulars of the processes by which the useful products are prepared for the market, and the uses to which they are applied in manufactures. The space alloted to this geological sketch, will allow of only a rapid review of the subjects of interest connected with each metal; but the preparation of porcelain clay, on account of its interest and importance (400,000 tons being annually exported), and its fabrication into such numerous articles of domestic utility, will be treated with a considerable amount of detail.

THE CHINA CLAY AND CHINA STONE PRODUCTS.

The Granite Rocks of the West of England have long yielded materials for the use of the potter. These consist chiefly of a fine white refractory clay, called indifferently kaolin, porcelain clay, china clay, or Cornish

clay; and a white vitrifiable variety of partially decomposed granite, known as porcelain stone, china stone,* or Cornish stone.

The rise, progress, and present condition of so important an industry cannot fail to be interesting to many. No very complete account of this industry was ever published before the year 1881, when Mr. David Cock, of Roche, published "A Treatise, Technical and Pratical, on the nature, production, and uses of China Clay." Mr. J. H. Collins, F.G.S, in his able and interesting treatise on the Hensbarrow Granite District, says that the earliest direct mention of the clay-works is that by Dr. Pryce, who stated that china clay, was in 1778, prepared for the potters in the parishes of Breage and St. Stephens, and packed in casks for exportation. The trade was, however, many years old when Pryce wrote, as Mr. William Cookworthy, in Devon, had established its value more than 20 years before, and had used it under a patent in his own pottery which was established in Plymouth in 1733. It is not clear whence he obtained his first clays, but in a pamphlet published in 1853, a letter from Cookworthy to a friend is inserted, which states that an American brought him specimens of **Kaolin** found in Virginia, and also specimens of porcelain made therefrom. This material, be observed, could be imported for £13 per ton.

The American and his specimens set Mr. Cookworthy on the *qui vive* and very soon he found a stone resembling

*No doubt the name of "china" clay and stone is derived from the fact that the porcelain goods were first made in china; and which, 60 years ago, were sold at very high prices.

that shewn him, in St. Stephens, probably about the year 1755. Three years later he found a similar material in the parish of Breage.

It is probable that the Cornish clay was known to him, and that he had already used it to some extent, keeping the fact secret, after the manner of the times. At any rate he patented the use of these materials in conjunction with Lord Camelford, in 1768. Dr. Borlase, who wrote in 1758, does not say that Cornish clay was then employed, but he states that many suitable clays may be found in Cornwall, and especially mentions those in Towednack, Tregoning Hill, and St. Enoder. He also states that he had himself made experiments with the clay of Towednack, and that Mr. Cookworthy had tried that of Tregoning Hill. This latter locality, therefore, was probably the birthplace of the Cornish china clay trade, as St. Stephens was of the trade in china stone.

Dr. Thomson, who visited Cornwall in 1813, briefly referred to the condition of the china clay districts as he saw them, in the "Annals of Philosophy" for that year. Dr. Fitton, in an admirable paper which he contributed to the same journal a few months later, describes what he saw when he visited Cornwall 6 years previous to Dr. Thompson's visit. He stated that were then seven works in operation in the parishes of St. Dennis and St. Stephens, the largest of which produced 300 tons per annum.

The next notice with which I am acquainted, says Mr. Collins, occurs in a short paper contributed to the Royal Geological Society of Cornwall, and printed in the year 1818. The writer, Dr. Paris, gives the quantities of

china clay and stone shipped from the port of Charlestown in 1816—1817; and he remarks that the amount of royalty, or dues, paid to Lord Grenville was £700 per annum! The West of England Company alone now pay to his representative a minimum rent of £7000 per annum. The total quantity shipped at Charlestown was under 4000 tons, and it is not likely that more than a few hundred tons were shipped from any other port at that time.

MODE OF OCCURRENCE.

In all the masses of eruptive rock dotting the county, some portions are productive of a fine refractory clay which is used in the highest branches of ceramic art. The bulk of the clays and china stone produced, comes from the granite lying to the south and west of Hensbarrow Beacon, only small quantities being furnished by Tregoning Hill, and some small works in Towednack, and Blisland.

Mr. J. H. Collins, who has closely observed the decomposed granite north of St. Austell, considers china clay in its natural state to be simply a granite of white or pale smoky quartz, white mica, and white felspar, in which the latter is partly or completely changed to kaolin. This rock is constantly associated with parallel groups of quartzose or schörlaceous veins which include also tin oxide; indeed, many of the kaolin deposits continue in the direction of veins for as much as a mile in length, while their breadth may be but a few feet. A very fine vein may be sufficient to influence the softening of the granite to a great width and depth. The decomposition of the felspar,

which is a silicate of alumina and potash, permitting the latter to be carried off in solution, leaves a hydrous silicate of alumina called kaolin or china clay. China stone is a mixture of quartz and more or less softened felspar which is quarried and exported to the potteries without praparation. Lately the West of England Company have had mills erected near St. Blazey to grind the stone to powder.

The natural clay rock is always covered with a thick layer of stones, sand, or impure and discoloured clay, known as "overburden." It varies from three to forty feet in thickness; and it must, of course, be removed before the clay can be wrought. The decomposed granite is found at all elevations except the very highest points of the districts, which are always composed of hard rocks—and its situation is usually indicated to the practised eye by a depression of the surface. These depressions are not observed in the case of china stone. The natural clay rock, being a decomposed granite, consists of kaolin, irregular crystals of quartz, and flakes of mica, with sometimes a little schörl.

MODE OF WORKING.

At the time of Dr. Fitton's visit, 70 years ago, Trethosa was one of the largest works, but it produced only about 300 tons per annum; now there are many works producing twenty times as much. The old fashioned system, somewhat modified in detail, but the same in principle, still survives in a few places. The following descriptions apply with more or less accuracy to a majority of the larger works of the present day, turning out from

2500 to 8000 tons of clay each, yearly. Two somewhat different methods are employed, according to the situation of the "bed" of clay, in relation to the surface contour of the immediate neighbourhood. The most general case is that in which the clay has to be raised from a veritable pit, the bottom of which is lower than the ground in the immediate neighbourhood on all sides.

The exact situation of the clay is first determined by systematic "pitting" to a depth of several feet or fathoms, or occasionally by boring. A shaft is then sunk either in the clay itself or preferably in the granite close to the clay. From the bottom of this shaft a level is driven out under that part of the clay which it is intended to work first, and a "rise" is put up to the surface, which should by this time be partially cleared of its overburden. The common depth for such a shaft is about 10 or 12 fathoms. As soon as the rise is completed to surface, a "button hole" launder is placed in it, and the remainder of the rise is filled up with clay. In the meantime a column of pumps has been placed in the shaft—say from 10 inches to 12 inches in diameter, and an engine erected to work them, unless water power is attainable. Owing to the low prices obtained for some of the clays, steam power in many cases is too expensive; but it will do in such a clay work as Rosemellyn, near Bugle, which yielded clay of superior quality.

For water, many works are almost entirely dependent upon that met with in sinking the shaft and driving levels; but of course this may be, and is, increased in some places by storing rain water in reservoirs, and by making use of such small streams as may be available. A small constant supply is sufficient even for a large work,

as it is used over and over again ; the clay in suspension being pumped up by the engine into reservoirs where the clay is deposited and the water becomes almost clear. The work commences around the upper end of the "button hole" launder, by running a stream of water over the exposed clay and breaking up the "stope," with picks. A large quantity of sand is constantly produced, and as constantly shovelled out of the way into wagons and removed ; while the water, holding the clay and fine impurities in suspension, runs down the launder, along the level, and into the bottom of the shaft, whence it is pumped up by the engine.

As the excavation becomes larger and deeper, more overburden is removed, and the upper portions of the launder are taken away, until at last the stopes reach the level, when the launder is, of course, no longer required.

At first the sand is thrown out by one or two "throws" but very soon it becomes necessary to put in an inclined tramway for raising the sand in wagons, and this is worked by a horse-whim, or by winding gear attached to the engine or water-wheel. As there are from 3 to 8 tons of sand produced in getting each ton of clay, of course its removal in the cheapest possible manner is a matter of great importance. Any veins or lodes of stone, or dislocated portions of clay, are raised from the "bottoms" in the same way as the sand.

The stream of water holding clay, fine sand, and mica, in suspension, is, in well-arranged works, lifted at once high enough to allow of all subsequent operations being carried out by the aid of gravity. The stream is first led into one or two long channels, the sides of which are *built* of rough stone. In these channels, called "drags,"

the current suffers a partial check, and the fine sand, and rougher particles of mica are deposited. From these drags the stream passes into other channels much resembling them, but of greater number, so as to divide the stream still further. The second series of channels, known as "micas," is often built of wood, but sometimes of stone. They differ in no respect, essentially, from the "drag," but are more carefully constructed, and better looked after; and as the stream is greatly divided, and is very gentle, the fine mica is deposited in them. The "micas" are often about eleven inches wide, ten or dozen in number, and one hundred feet or more in length. Provision is made, by the underground channels and plug holes, for the periodical cleansing of the drags and micas. This may have to be done twice a day, but generally only once. The deposit of the drags is worthless at present, and is always thrown away, but that from the "micas" is often saved, and sold as inferior or "mica" clay. The refined stream of clay then passes on to the "pits," which are often made circular, 30 to 40 feet diameter, and 7 to 10 feet deep.

These pits are built of rough masonry, and they have an outlet at the bottom opposite the point at which the stream of clay water is admitted. This outlet is stopped by a "hatch," or else by a plug, which is kept closed until the pit is full of clay. In each outlet, however, is fixed an upright launder about 4 or 5 inches square, provided with "pin holes" and wooden pins set close together, or near each other. As the stream of clay enters on one side it is continually depositing its burden, and the water runs off, nearly clear, from the pin holes higher and higher as the clay rises in the pit.

The affluent water is conducted directly to small storage reservoirs, and thence over the clay stopes, whence it does its work over again. It may here be mentioned, that when the stream of clay water enters the pits, it contains from 1½ to 3 per cent of clay, and what is called a good washing stream will carry about 1 ton of clay per hour.

When the pit is full the "hatch" is drawn, and the clay is "landed" into the tank. The upper portion is sufficiently fluid to run in of itself, but that near the bottom has to be helped out by men using "shivers" of wood or iron, which resemble large hoes, and by a small stream of water. The tanks are commonly, but not always, rectangular, built of stone, and paved with stone at bottom, often 60′ by 30′ by 6,′ or even larger. Once in the tank, the clay is left to settle until it has the consistency of cream cheese, the water being drawn off from time to time, when it is ready to be trammed into the dry.

The "dry" is a large building erected contiguous to the tanks. It is always composed of two parts, the dry proper and the "linhay" or shed. The floor, or "pan," of the dry is composed of fire-clay tiles, 18 inches square, 5 or 6 inches thick at the fire end, and gradually thinning off to 2 or 2½ at the stack end. The flues are built of fire brick about 14 inches wide, 2 feet deep at the fire end, and 9 inches deep at the stack end. Each flue should be supplied with a damper. The furnaces are built in and arched over with the best fire brick; the fire bars run longitudinally, and are about 6 feet long. The grate surface is about 2 feet 6 inches wide in front, and 4 feet 6 inches to 6 feet at back, according as each furnace supplies *three* or four flues.

The clay is brought in from the tanks in tram wagons, holding about half a ton, tipped on to the tiles, and spread in a layer from 9 inches thick at the flue end to 6 inches thick at the stack end. The fire end is loaded and cleared every day; the other end perhaps twice or thrice a week, according to the length of the dry, thickness of tiles, perfection of draught, &c. An average size for a first-class dry is about 15 feet wide, and 120 feet long, but some have been constructed considerably larger than this.

The pan of the dry should be 6 or 8 feet above the linhay whenever possible, so as to afford storage space for the dry clay without expending labour in piling. The tiles should be as porous as possible, for very much more water passes through the tiles and into the flues than is driven upwards in the state of steam.

When the clay in the dry is nearly free from moisture, it is cut into squares of about 9 inches; and when it is perfectly free from moisture it is removed and placed in the linhay ready for transit to the railway station or ship. In some cases it has to be carted to the station at a cost of about 2/6 per ton. This is a charge which seriously diminishes the producers' profit. In several places the dries are close by the Minerals railway as is the case at Fal Valley, Bugle, Burngullow, Rosemellyn, &c.

USES OF CHINA CLAY.

The first use to which china clay was applied as already stated, was the manufacture of porcelain, and this is still popularly believed to be its sole use. This, however, is

by no means the case—probably little more than one-third of the produce is so applied. Large quantities are used by bleachers for filling up the pores of calicoes as a dressing; and still larger quantities are used by paper makers to give "body" and weight to their paper, especially printing papers. The manufacture of alum, sulphate of alumina, and ultramarine uses up large quantities annually. Small quantities are used by photographers, manufacturing chemists, and colour makers, for a great variety of purposes; and, if reports are to be believed, it has been used in the adulteration of flour, and of artificial manures.

COST OF PRODUCTION.

A work capable of producing say 4000 tons of china clay yearly will cost from £2500 to £5000. To get the clay in the shed ready for the market, will cost about 9/- per ton, of which 2/6 must be expended in fuel for pumping and drying, 1/- in removing over burden, 1/- in removing sand, and 1/- for management and office expenses, leaving 3/6 as the net labour cost of washing and drying a ton of clay.

To the 9/- net cost of clay, must be added 3/- for royalties, 4/- for transit and shipment and 1/- for commission, bad debts, and sundries; making the average actual cost amount to 17/-. Some favourably situated works can, no doubt, save two, or even 3/- of this amount; in others the cost may amount to 20/- or even 22/-.

As to the selling price; this varies more widely than the cost of production; at present, prices are very low;

ranging from 14/- to 35/- f.o.b. Clays sold at the lower rates must be unremunerative.

In the year 1809, the produce of Cornwall and Devon was 1757 tons of china clay, and 1162 of china stone; in 1882 the produce was 270,910 tons of clay, and of stone 35,737 tons, showing an enormous increase of production, but owing to the competition amongst the producers, the average price per ton was ruinously low, being only 15/- per ton. Since 1853 more than five million tons of china clay and stone have been exported.

Ochre.—Some small quantities of ochre and umber have been produced. In the year 1857 twenty-five tons of umber were sold from a small excavation near Indian Queens. In the Terras mining district some adits which drain the mines, become partially choked by the oxide of iron deposited from the super saturated waters. Workmen go in and agitate the bottom with rakes, and the ochre is carried out in suspension and deposited in "catch pits; where, after the moisture has evaporated, it is sent away to be used in the preparation of iron paints. The low price—ten shillings per ton—of the ochre discourages the production, and the sales are insignificant; some years not a hundred tons are sold, but when the adits require clearing, the sales increase to many hundreds of tons. During the past ten years about 700 tons have been sold.

Fluor Spar.—This mineral was raised in some quantity from Huel Gorland, where it formed the vein-stone in a lode, and was sent to the Swansea copper smelters as a flux. It was sold on the mine at 20/- to 10/- per ton. Very little is now found.

Saint Agnes Clay.—The remarkable deposit of sand and clay near the foot of St. Agnes Beacon is

worked for economic purposes. The light siliceous sand of great purity is used to mix with china clay in the manufacture of Cornish crucibles, and the soft plastic clay is sold to the miners for the purpose of sticking the candles to their hatcaps, and some is exported to Wales for furnace linings.

The clay sold in 1882 amounted to 3400 tons, and realised a mean price of 9/6 per ton.

The following table, gives the number of tons of china clay, china stone, and St. Agnes clay sold from 1853 to the present.

Statistical Table.

	China Clay.	China Stone.	St. Agnes Clay.
1838	20,784	7344	
1853	17,000	9000	
1854	18,742	8246	
1855	60,188	19,961	
1856	65,510	7800	
1857			
1858	65,600	21,983	2052
1859	61,470	20,750	
1860	63,250	21,500	1748
1861	60,750	19,700	1894
1862	61,550	19,250	2208
1863	92,500	23,750	1900
1864	95,730	21,570	1450
1865	97,750	25,500	2016
1866	105,000	35,000	2024
1867	127,000	33,500	1816
1868	100,000	29,000	1479
1869	105,000	28,500	1375
1870	110,520	32,500	1189
1871	125,000	33,000	1601
1872	141,000	48,000	2022

Statistical Table—*continued.*

	China Clay.	China Stone.	St. Agnes Clay.
1873	153,000	45,000	2233
1874	150,500	42,500	1818
1875	108,250	38,000	1975
1876	105,275	34,500	390
1877	200,345	39,500	905
1878	185,203	41,250	1169
1879	273,862	38,142	682
1880	278,572	34,870	735
1881	241,658	30,479	825
1882	270,910	35,737	3400

CHAPTER VI.

TIN.

History.—This metal is believed to have been discovered originally by the inhabitants digging for peat. The time when tin was first worked is lost in obscurity, but during all historic ages, Cornwall has been famed for its stanniferous wealth. Before the recent discovery of cassiterite in Australia, the only places from which tin was obtained in quantity was from the mines in Germany—said to have been discovered by a Cornishman in 1240, and from the tin islands in the Java sea, where alluvial tin ore was first collected about the year 1710. Thirty centuries ago Phœnician vessels sailed through the Pillars of Hercules in search of the then rare metal, tin, which the mines of Spain had failed to produce in quantity sufficient to satisfy the demands of an expanding civilization. The commerce for tin between the ancient inhabitants of Cornwall and the Phœnicians is so old, that it was in active existence during, and even before the epoch of the Grecian Myths. The secret of the Cassiterides was so well kept, that it was not until 400 B.C. that some Greeks who had settled at Marseilles sent an expedition in search of them, they were discovered; *and* the great Mediterranean port shared with the

Phœnicians the advantages of the traffic at Iktis. The demand of the eastern nations must have had an exhausting effect on the deposits of alluvial tin, as we learn that in the time of Diodorus Siculus, the tinners had commenced to barrow in the backs of the lodes.

Many interesting remains of the Phœnician era have from time to time been found, some of which may be studied at the Truro Museum. Double pigs of tin, cast for transportation on mule back, have been picked out of the sea in Carrick Road; golden cups and collars, made out of the gold obtained from the stream works, with Greek and Roman coins, have frequently been discovered. After the destruction of Carthage, the tin trade fell into the hands of the Romans; and they seem also to have worked the tin mines, as their coins have been found in and near them. It is not probable that the Latins had a great ascendancy in Cornwall, though they may have founded a trading port at Tregony; in those days the nearest tidal port to the great tin streams of the Hensbarrow granite.

Tin Streams.—The tin layers which rested in the depressions of the granite hills, and the tin ore carried down into the valleys below, were the result of ages of denuding action. In the St. Austell district, the lodes containing tin being harder, stand out of the ground like stone walls. It is not improbable, that the granite was so much higher than at present, on its emergence from the sea, as to allow of a grade steep enough for the torrents to bear along the tin stone deposited at Carnon, Pentewan, and other places far from the tin bearing rocks. During thousands of years the "old men" were engaged in washing the tin ore which the degradation of

the mountains of granite had freed, and the labour lavished is strongly attested by the countless burrows and pits which still disfigure the "bottoms" of the streams flowing from the granite domes towards the sea.

About the time of the Christian era, vein mining was carried on all through the county, and that the industry was well sustained, and the mines worked as far as the appliances of the age would admit, will be readily credited by those whose avocations have enabled them to learn that scarcely a tin lode exists in Cornwall which has not been opened by the pits and adits of the ubiquitous tinner. In the reign of King John the production of tin in Cornwall was so small that the Bishop of Exeter received in lieu of his tithe only £6 : 13 : 4. Tin mining was much favoured by Richard, Duke of Cornwall, who, in the 16th century granted the tinners a charter which has since developed into the Stannaries. The method of washing the tin streams was simple, and the rude utensils employed were usually fashioned out of hard wood. It is also recorded that in Carew's time, tinstuff from the veins was washed on turf, on the same principle as gold ore is washed on blankets in Brazil. Tin Bounds have been worked within the present century, but they are now obsolete, nor are many stream works in active existence; as they have been streamed again and again, they are now almost exhausted. The largest deposits of stream tin were found in the Goss (Tregoss) moor, a marshy tract containing about 10 square miles, situate between Belovely and St. Dennis beacons. The stanniferous deposit is not completely exhausted in this tract, but it can only be profitably worked when the price of tin is *exceptionally* high.

The stream tin generally reposes directly on the rock, and is often in a remarkably clean state, with but little admixture of gravel. To account for this fact, some geologists have even imagined that a vast rush of water passed southward over the granite hills. Most of the best streams run to the south; but this is owing to the rivers that fall into the English Channel taking their rise north of the principal ranges of granite. The tin *debris* resting on the granite is usually concealed under peat, sand, or mud, with or without stones and shells; and underlaid by wood, leaves, and vegetable matter; the whole varying from five to twenty-five feet in depth. Near the sea at Pentuan and Carnon, this is mingled with miner's tools, oyster shells, animal remains, and even human skulls. The tin stratum at the Happy Union stream works, covered by 40 feet of gravel, ferruginous clay, black peat, sea sand, and shelly mud, consisted of fragments of clay slate, quartz, iron ore, &c., but no granite. The tin having been washed and rolled along the river bed for ages, has acquired a rounded form, and that degree of purity which gives stream tin so high a value in the market. The size of the tin stone varies from pieces a few pounds in weight to sand, and associated with it in all the large works were nuggets and prills of gold. The tin stratum in Carnon valley continued into the Restronguet creek, and was worked in 1700, at low water, by hundreds of men, women, and children. About 1865 the creek was worked opposite Devoran by means of a shaft surrounded by a mound. Wheal Caudle in the Helston Looe Pool was worked 30 years ago beneath about 30 feet of sand and mud. It is believed that Hensbarrow granite has yielded more

stream tin than the aggregated produce of all the other granite elevations.

Tin Dressing.—The ore from some lodes (as at Wheal Lovell) is so rich as to require little preparation for the smelter; but practically all the tinstone has to be stamped and dressed. The tinstuff is broken in the levels and from the stopes in the mines, and put into the kibble or skip without any sorting whatever, is hauled to grass, discharged into the waggon by the "lander," and trammed into the hoppers whence it is fed automatically through the "pass" into the stamps "cofer." Here the tinstuff is reduced to a fine grain, the size of which, depending on the class of tin, is regulated by the stamps grates fixed around the cofer-box. Should some of the tin ore vary widely in quality, or contain much copper pyrites, wolfram, &c., it is dressed apart.

In front of the stamps are the various strips, tyes, and buddles, by which the black tin is separated from the sand. The slimes carried away in suspension by the water are caught in special pits, trunked and framed. The last impurities are eliminated by "tossing." Ores containing arsenic are roasted after concentration, and re-washed. Although the intricate maze of tin dressing apparatus, often jumbled together with scant order, may appear to a visitor a puzzle not be unravelled, in reality the truly different operations are very few, and most of the work is a repetition, having for object the rejection of all foreign matter, so that the tin ore may be sold as free as possible from any substances which would lower its price at the smelters. The view of New Terras mine, near St. Austell, will give the reader some idea of the arrangement of the dressing machinery. As many mines

produce tinstuff containing only one or two per cent of tin, the numerous washings which it undergoes result in a considerable loss of fine tin ore, which certainly equals, if it does not exceed, a fifth of the tin that the vein stone originally enclosed. This loss is due in some measure to the difficulty of getting that portion of the ores already stamped to the size required through the gratings, which is thus reduced to slimes that carry away with them the floured tin oxide. Possibly for many ores, a change to dry grinding, and jigging, somewhat similiar to the method of treating copper ores, would result in an improved yield. The slimes retain the tin so tenaciously that the tailings from the mines in Camborne pass over many hundreds of buddles and frames in its course of several miles to the sea, which it enters still charged with an important proportion.

Smelting.—The cassiterite, freed as much as possible from foreign matter, is transported to the smelting-works, and sold at the standard which the smelters themselves fix. Here, if the ores are contaminated by iron or copper they are digested in acid. Anciently the tin ore was smelted in furnaces scoped out of the ground, by mixing it with charcoal, and using as blast a rude bellows. In the last century smelting took place in blast furnaces, which were called blowing-houses; these have all disappeared, but the name in some places still remains. The tin ore as delivered at the smelting-house contains from 60 to 75 per cent of white tin, the operations to extract which are conducted in reverberatory furnaces.

A charge of about 3000 lbs. is mixed with culm sufficient for deoxidation, and with lime or fluor spar to slag off the

silica. These must be thoroughly mixed with water sufficient to prevent the draught from entangling the fine tin. Immediately after charging, the door is closed and a strong fire maintained until the whole mass runs down, when the charge is well raked up, and the heat raised to complete the smelting. This operation occupies about 10 hours. The scoria, cooled by some damp smalls, is then removed, the slags last raked off being reserved for further treatment, because small shots of metal are entangled in them. The white tin is then run into iron pans and ladled into 3 cwt. moulds for liquation. The blocks of tin are arranged in the same furnace, and a moderate heat being applied, the tin melts slowly and runs into the heated pan at the side of the furnace. As the pile crumbles, so additional blocks are added, until 5 tons of tin have been collected. The residue is then fused at a high temperature, and run into the other pan to undergo another liquation; it contains nearly all the lead and iron which contaminated the liquated blocks. When the tin is tolerably pure this "sweating" process is unnecessary, and is now seldom resorted to in Cornwall. The tin, which has been kept molten by an auxillary fire, is now refined by forcing bunches of green wood into the bath; the ebullition that immediately follows produces a drossy froth which is composed of stannic oxide, with the oxides of the lead and iron that the liquation failed to extract. After the removal of the wood, the bath is allowed to settle an hour or so, during which it has separated into zones of different quality, the purest resting nearest the surface, and the second quality, or common tin, occupying an intermediate position. The *tin* remaining at the bottom contains about 5 per cent

of copper and lead, and has therefore, to be submitted to re-treatment. Refined tin contains about a quarter, and common tin nearly a half, per cent of metallic impurities. To smelt a ton of tin about 2 tons of coal are requisite. The loss in reducing the ore is often as high as a twentieth of the metal contained.

The uses of tin are manifold. It is largely employed in the tin-plate trade; is mixed with lead to form pewter; with copper to make bronze; and with copper and zinc to make brass and bell-metal. Tinfoil is made from it, and domestic utensils; and much is used by dyers in mordants, and by plumbers to compose solder. The importance of the tin-plate trade may be judged from the fact that 200 mills have been erected for their manufacture; but owing to the depressed state of the market for those goods, only 117 were in operation in 1882. During this year the aggregate production was 2,300,000 boxes weighing nearly 114,000 tons. Beside 12,189 tons obtained from the mines of Cornwall, and 50 tons from those of Devon, open quarries in the Roche district yielded 150, and streamworks 1655 tons of black tin; or a total of 14,045 tons for the two counties.

Tin mining in Cornwall has been injuriously affected by the discovery in Australia and Tasmania of vast deposits of alluvial tin, and the yield from them has so lowered the value of the metal, that few home mines can produce it at the ruling market price. In 1874 there were 230 mines in the two western counties returning tin, whilst in 1882 this number was reduced to a hundred. As the total weight of tin sold is about the same for both years, it follows that while the weaker companies have become defunct, the more important mines have greatly

increased their returns. The scant geological knowledge we possess of the Australian tin fields scarcely permits the formation of a definite opinion as to their continual productiveness, though several papers read at the Mining Institute seem to indicate that the alluvial tin has accumulated during the secular degradation of the granite. If this be so, it is by no means probable that many tin veins of value will be discovered, and though some years will pass before the deposits will be exhausted, Cornishmen may look with some confidence to a prosperous future. Meanwhile, the present regretable depression has stimulated the energies of "One and All" to obtain more efficient machinery, to more careful economy in all operations, and to a steady resolve to have the grasping cupidity of landowners checked by a fair system of mining laws.

COPPER.

The tin industry, originated by the Phœnicians, continued through the time of the Roman Empire to the present day; though the production of that metal fluctuated greatly. Copper does not possess the same historic interest as tin, because its ores lying concealed in veins usually under the tin, would attract less attention; and consequently the copper ore trade is of comparatively modern growth. Early in the 17th century, copper—which had been quarried in the celebrated mines of Anglesea, and raised from the Saxon lodes as early as the *tenth* century—began to be extracted from the Cornish

deposits. At this time the ores of copper were so little understood by the tin miners, that black and yellow ores were thrown away as "deads," with the mundic. In the middle of the 18th century, some of the Gwennap lodes yielded very rich work, *e.g* in 1757, copper ore, to the value of £15,000 was raised in five weeks, from Wheal Virgin, in Gwennap, at an expense of £300 only! The first sales of which any record remains, took place in 1726, when 2216 tons of copper ores appear to have been sold. In 1856 the amount raised had increased to 206,177 tons of six and nine-sixteenths produce, the highest quantity ever produced. The per centage of the ores, which during the early decades of copper mining was as high as 12, became reduced in 1850 to 7½; and during the last thirty years has varied from 6⅛ to 7⅛. Fron 1726 to 1855, inclusive, the ore produced in Cornwall and Devon realised over £50,000,000.

From 1855, owing to the exhaustion of the shallow deposits, and the transition of the lodes from copper to tin-bearing, there has been a gradual, but constant decrease in the production; so that in 1882, the copper ore sold amounted to only 26,641 tons, which contained an average of 6¼ per cent of pure metal. With so small an output, Cornwall has lost its reputation as a copper producing county.

Some of the adits, ramifying through the mining districts to drain off the surface water which percolates through the rocks, are of great length, and when driven through copper-bearing strata, the waters discharged therefrom are more or less cupreous. The most important one, running under the Parishes of Gwennap, Kenwyn, St. Agnes, and Redruth, has—inclusive of its

branches—a total length of thirty-three miles.* The percolation of the pluvial waters through such a number of veins, has collected in solution such a proportion of the sulphates of copper and iron, that the former can be profitably precipitated in "streaks" by the aid of scrap iron. Copper was first obtained by this method as early as 1750, in St. Just; but cupreous waters rushed in great volume from the Gwennap adit a century before any means were adopted to check this waste (in 1824). At Nangiles, where water retained so much sulphate in solution that the pumps had to be lined with wood; precipitating works were attempted in 1830, but as the produce sold for only £9 per ton, the mode adopted to gather the copper must have been very faulty. Precipitating works now occupy numerous sites in the Carnon Valley, and return copper dust worth 40 per cent. The waste of iron is considerable, as two tons of it are used up to throw down a ton of copper. The re-action by which the metal is obtained, is, of course, well known, the sulphuric acid of the cupric sulphate combining with the metallic iron to form sulphate of iron, which is carried away in solution. Mr. W. J. Henwood estimated that the water—1600 cubic feet per minute in 1850—issuing from the Gwennap adit held in solution one part in 600,000; if so, this quantity was sufficient to have produced forty tons of copper annually, if all could have been precipitated. Since the stoppage of the Gwennap mines, the cupreous value has been much lessened.

* The crosscut adit which unwaters the lodes of the Schemnitz mines to a depth of about 300 fathoms, is eleven miles long.

COPPER ORE DRESSING.

As in tin mines, so in those of copper, a large proportion of the lode stuff raised is "deads," that is to say, the proportion of metal included being too small to be profitably separated, they are trammed away to the waste heap. As the ores are rarely so regularly disseminated throughout the matrix as to require fine pulverisation, the dressing operations are simple, and the machinery not nearly so complex and costly as those in tin mines.

The gangue from the cupreous portions of the lode receives small attention in the "stopes" where it is "broken," but usually reaches the dressing floors unsorted. The methods in vogue for raising the produce of the gangue have a generic similitude throughout the county, but they are varied to suit the different species of ore. The first operation—except in case of oxidised ores, the comparative quantity of which is insignificant—is to reduce the larger fragments of rock by passing them through a Blakes crusher, or by breaking them up by a sledge hammer, and rejecting the poorer veinstone; this is termed "ragging." After this preliminary dressing, if the ore is moderately rich, a pile will be left fit for sale, and the rest goes through the Cornish crusher between the rolls of which it is broken down to the size of hazel nuts. Should there be no such machinery on the mine the "ragged" ore is "spalled," "cobbed," and "bucked" by the "bal maidens" to the requisite size. The ore is then "jigged" on an oblong sieve which is jerked up and down in a wooden case full of water, when the fines fall into the hutch below, the roughs remain on the sieve,

near Callington, where about the year 1874 considerable works were installed to treat the ores proceeding from the pyritous lodes worked on the slopes surrounding the granite boss dominating the Tamar river between Callington and Tavistock. These ores exist in quantities almost inexhaustible, and are rich in arsenic and silver; are cupreous, and often stanniferous. At NewGreat Consols during 1874, and following years, the wet reduction of such ores was in successful operation, but through injudicious interference with the management on the part of the London officials, this promising attempt to utilise poor mixed ores collapsed. The same fate overtook the Cornwall Chemical Company, whose works at Greenhill, and other places, though well conceived and arranged, were erected on a scale for which the capital subscribed was utterly inadequate.

It may be admitted frankly that the changeable character of Cornish ores, and their siliceous gangue, which prevents the sale of residues to the iron makers, militates against the process; still the Spanish pyrites, whose great merit is in the constancy of its composition, contains only two ounces of silver to the ton, and has to be freighted to England. The value of the arsenic in the ores of the Callington mines may be considered to counterbalance the disadvantages acknowledged. It is unquestionable that—as the mining and treatment of the arseno-argentiferous ores would exceed little, if at all, a cost of twenty shillings a ton—wet process reduction intelligently and honestly conducted, would open an excellent channel for the investment of capital, and for employment of numbers of the non-employed mining population. The process of reduction adopted at New

Great Consols was simple, and involved no complicated chemical reactions. The crushed ores were introduced into calciners, and the sublimed arsenic collected in long flues and refined; the ores were then roasted with salt and lixiviated, after which the chlorides of copper and silver were precipitated together in a tank containing scrap iron; and finally, the residues were dressed in the usual manner to separate the tin oxide. This process would have been much improved if the silver had been separated from the copper.

The use of copper, pure or alloyed, is so universal that it would occupy an inconvenient amount of space to enumerate them all. It is employed extensively for bolts, sheating, and nails, for vessels; for wire, silver, tubes, coins, and domestic utensils; and for bearings, pipes, and boilers, in factories, distilleries, and steamships.

LEAD.

Possibly the Phœnicians obtained from the Damnonians lead as well as tin, and the Latins, who wrought lead mines in Derby and Cardigan, may have encouraged its production in the western counties. Lead mining in Cornwall has never attained to any great importance, and has been somewhat spasmodic, owing to the sporadic discoveries, both in space and time, of rich deposits, and the celerity with which galena can be extracted. Lead is often associated with limestone, but in Cornwall the connection does not exist, for although some mines have been worked in the slightly calciferous Devonian slates in

the vicinage of Padstow, the most important lodes occur in clay-slates, which are distinctly subordinate to the granite, and are productive indifferently whatever their direction. Thus the Trelawny great lode had a north-by-north-east bearing, whilst the celebrated West Chiverton lode bore south-west.

Penrose Lead Mine, near Helston, which was working in the 17th century, and Old Garras in 1720, and again about the year 1820, yielded galena, containing a hundred ounces of silver to the ton of lead. In the present century the most prominent mines have been Shepherds, Wheal Golding, Penhale, East Wheal Rose, Trelawny, and West Chiverton. In 1845 Cornwall produced 6,063 tons of lead, but in 1853 the total had fallen below 5,000, from 1867 to 1871 the large sales of galena at West Chiverton brought the total up to about 6,500 ; since then the returns have generally fallen off, until in 1882 the sales amounted to only 454 tons of lead worth £10 per ton. From 1853 to 1882 inclusive, the 118,000 tons of lead produced from the galena sold, contained an average of forty-one ounces to the ton, or a total of nearly five million ounces of silver.

The lead ore raised has been always smelted in the county, but some of the works have gone to ruin. At Par and Devoran, until lately, lead ore was reduced and the metal desilverised.

The smelting of lead sulphide is not difficult, and if free from impurity, it could be reduced without the aid of any flux by roasting and fusion in one furnace operation, with an addition, towards the end of the melting, of some carbon to reduce the oxy-sulphide formed. When the lead ore is very poor or fouled by

mundic, &c., a preliminary roasting is advisable. About thirty hundred weight is smelted at a charge in reverberatory furnaces, the time occupied varying according to the *modus operandi*, from six to ten hours. The loss of lead in reduciug the sulphide is sometimes as much as seven per cent., but nearly three are recovered from the slag and fume chambers. The consumption of fuel required to smelt a ton is about 15 cwt.

Lead is applied in the manufacturies to the making of paints, tanks, pipes, and domestic utensils, &c., and for roof and acid chambers. The following tabular statement gives the yield of tin, copper, and lead, obtained from the mines of Devon and Cornwall, as far back as the records reach:—

Statistics of Tin, Copper, and Lead in Tons.

	Tin. *Devon & Cornwall.*	Copper Ore. *Cornwall.*	Lead. *Cornwall.*
	White Tin.		
*1726 to 1735		64,800	
1736 to 1745		75,520	
1746 to 1755	? 26,160	98,790	
1756 to 1765	26,690	169,699	
1766 to 1775	28,358	264,273	
1776 to 1785	26,837	304,133	
1786 to 1795	33,825	? 385,000	
1796 to 1805	28,109	564,037	
1806 to 1815	24,758	726,308	
1816 to 1825	† 36,195	926,271	
1826 to 1835	42,510	1,352,313	
1836 to 1845	? 73,587	1,486,840	

* From Charles I. to 1750, the returns of white tin averaged about 1500 tons per annum.

† To 1825 the returns are for Cornwall only.

	Tin. *Devon & Cornwall.*	Copper Ore. *Cornwall.*	Lead. *Cornwall.*
	Black Tin.		
1846 to 1855	95,673	1,622,152	
1856 to 1865	118,588	1,448,833	47,753
1866 to 1875	139,685	615,966	47,241
1876	13,688	43,016	2070
1877	14,142	39,225	2167
1878	15,045	36,871	1022
1879	14,665	30,371	545
1880	13,737	26,737	570
1881	12,898	24,510	409
1882	14,170	25,641	454

SILVER.

Besides the association of silver with galena, which is so pronounced in the lead lodes of Cornwall, it is found native, and in a mineralised state in every mining district. The first discovery of argentiferous ores is said to be made at Huel Mexico, north of Truro, where it occurred in nests of chloride, and native. Early in the present century much silver was obtained from Huel Brothers, Dolcoath, and Herland Mines; and later at West Darlington, Ludcott, Carnbrea, and Huel Duchy, near Callington; in the latter mine a shallow course of ore enclosed in slate near the granite, was of extreme richness. Although Carn Entral and Druids lodes yielded much silver, it is usually found in cross veins as at Herland Mine, where vitreous silver ore and the metal itself were dispersed through the veins, with quartz and mundic,

Compact Felspar and Hornblendic Rocks.

GURNARDS HEAD, CORNWALL.

which, near the surface had been weathered to gossan.

The lodes around the Gunnislake granite often include silver, which, in many instances would pay for working. Green and brown chlorides of silver were found on the back of Trelawny lead lode, and in the gossans of the Dolcoath lodes west of Camborne. In 1858 North Dolcoath sold eight tons of chloride ores for more than £100 per ton, and in the year following, some was sold for more than £500 per ton. The occurrence of silver in the gossans of the copper lodes is not unusual, and much has been thrown over the burrows in ignorance of its value: it is not improbable that a careful examination of the backs of gossans would be requited.

ARSENIC.

This metal in the form of arsenical pyrites is the close companion of tin ore, from which it is separated—after concentration into "witts" by calcination. This roasting changes it into an oxide that sublimes, and being conducted through long flues, it falls in an impure condition to the bottom, whence at intervals it is withdrawn to be refined in works specially erected at Bissoe Bridge, Roseworthy, and Hayle. With the exception of East Pool, West Seton, and South Crofty few mines in the West sell crude arsenic. In the Gunnislake district the mines of New Holmbush and Okel Tor raised in 1882 no less than 10,058 tons of arsenical pyrites, which were sold for twenty shillings a ton and produced 2258 tons of refined arsenic. The largest works in the two counties is at

Devon Great Consols, where nearly 3000 tons of refined arsenic are produced annually. From Cornwall 3473 tons, and from Tavistock 3996 tons of arsenic were obtained in 1882, and sold for £6 : 11 : 7¼ per ton. No mines in the kingdom produce arsenic, outside the limits of the Stannaries.

IRON.

Iron is widely distributed in the veins of all the metalliferous tracts, either in the form of sulphide in the depths of the mine, or as oxide in the gossans of lodes and cross-courses, and as carbonate in the Perran lode; many of the rarer combinations are frequently found in beautiful crystals.

The most noteworthy deposits of iron are subordinate to the Hensbarrow granite. They occur on the backs of some of the east and west lodes that traverse the killas near its junction with the granite; and in the crosscourses, the quantities raised from which, at Restormel, Coldvreath, Pawton, and Tolbenny, have been enormous. Ferruginous masses of less magnitude are found in the Hensbarrow and St. Just granites. The hematites of Cornwall are much esteemed in Wales as a flux for other ores, but owing to the expense of conveyance, they can only be sent there when high prices rule. Should it ever be required, the county could furnish immense supplies. The ores produced during the year 1882 were mostly brown hematite, and the tonnage was as follows:

Coldvreath	...	550
Restormel	...	848
Perran	...	4351

Equal to 5749 tons.

The produce of the ores was 46¼ per cent, and the average price half a guinea per ton. Probably *Restormel Lode* has yielded more iron than any other in the county. It enclosed beside hydrous oxide, some hematite, specular ore, and a little manganese, with many other associated minerals in minute quantity.

The **Perran Iron Lode** from its persistent continuity, its great width, and the mass of mineral matter which fills it, is held to be the most remarkable vein in the west. It courses up the cliffs at Ligger Bay in a ruddy mass a chain wide, and extends in a south-east-by-east direction through Gravel Hill, Duchy Peru and Deer Park, to Mitchell, a distance of six miles. The ores both limonite and chalybite have been raised in a fitful way for a number of years, but it was not until the iron fever of 1870 that the mines were brought into prominent notice by Mr. Roebuck, who promoted the Cornwall Minerals railway company, whose line now winds amongst the Perran mines. Much of the white iron, or spathose ore, was at one time sent to Dowlais for making spiegeleisen, for which its purity and perfect exemption from phosphorus, eminently fits it.

The back of the lode has been oxidised to brown hematite to a depth of from fifty to a hundred feet, but below the influence of the atmosphere, a solid and practically exhaustless dyke of ferric carbonate seems to extend the whole length of the lode. This spathose iron is rendered the more valuable, on account of the reported large proportion of manganese, which amounting to seven per cent (?) is equal to the most manganiferous carbonates in England; it is also said to contain several ounces of silver to the ton. The lode at times reaches

a width of 120 feet, and its dip—discordant with the strata—is about 35° toward the south-west. Much of the space between the walls is occupied by quartzose and brecciated matter, so that the width of workable ore would not perhaps average over fifty feet. It is much to be deplored that such a magnificent lode, so well opened out and provided with efficient machinery, and in direct railway communication with a not distant port, should be unable to longer struggle against a depressed and glutted market.

MANGANESE.

Minerals having manganese for their base, are not in Cornwall associated with hematites to any great extent. In the carboniferous strata, whose basset edges, intermixed with greenstone, contour from Petherwyn to Lidford, many small deposits have been worked. Pyrolusite was raised in the Tregoss Moor, near Roche, in 1754 for use in glass making, but was not discovered in the Launceston district until 1815. The usual selling price has been about £3 per ton; in 1879 it dropped to 36/-, but in 1882 its value has reached as high as £3 : 10 : 0 per ton.

The yearly production of manganese in Devon and of iron ores in Cornwall is tabulated below.

Minerals produced—in Tons.

	Pyrites. *Cornwall.*	Hematites. *Cornwall.*	Manganese *Devon.*
1854	128		
1855—1864	129,056	284,206	4,988 ?
1865—1874	52,575	204,130	36,413
1875	7,223	11,403	3,205
1876	8,244	18,390	2,705
1877	14,290	4,963	2,496
1878	3,203	1,308	1,404
1879	1,049	400	607
1880	6,369	15,865	2,383
1881	14,910	7,460	1,845
1882	11,343	5,749	862

GOLD.

This most coveted metal has been taken from all the tin stream works in Devon and Cornwall. No doubt in very early ages it was plentifully scattered through some of the tin layers, as an old record relates an anecdote of some streamers, who, in 1753 brought to the Blowing House a parcel of tin with so much gold in it, that the smelter jumped to the conclusion that it must be mundic, and rated the tinner soundly for bringing him imperfectly washed tin. Gold has been drawn most largely from the stream-works at Carnon, Pentuan, and Ladock, but in modern times the amount obtained has been very insignificant. The gold nuggets and spangles were detached from the rocks by denudation and gradually rolled down the stream.

Minute particles of the precious metal have also been met with in veins, and in the mundic of some lodes. Gold occurs in the mines of Sperris, Sparnon, Garras, Carn Brecon, Sheepstor, and others.

ZINC.

Zinc-blende, the "black jack" of the Cornish miner, is plentifully distributed in some lodes, and few are destitute of it. In Pryce's time the blende from copper lodes was used to make brass. The sulphide of zinc frequently occurs in large bunches, and is often associated with iron and copper pyrites, and with galena, and sometimes with cassiterite. The ores now sold proceed almost entirely from the Duchy Peru lode, which in 1882 yielded 4059 tons of blende, that averaged a produce of 48 %, and realised £3 per ton. Mellanear, Violet Seton, and West Chiverton sell only unimportant quantities, though a few years since the latter mine raised thousands of tons yearly.

Calamine has been remarked, though small in quantity. Zinc is rolled into sheets for roofing and lining cisterns, into wire and piping; and is used to make brass, to galvanise iron, and to produce electricity.

RARER METALLIC ORES.

Wolfram.—The tungstate of iron andmanganese is found in all the mining districts, and prevails in the mines along the northern margin of the Carn Menellis granite, most markedly at East Pool, which mine, in 1882, sold 58 tons of wolfram at £13. It contaminates the tin ore in some of the mines in the Hensbarrow moors, and was

mixed in larger proportion with the ores of Drakewalls mine, near Calstock. Tungstic acid and tungstate of soda are used in the manufactures

Uranium.—The ores of this metal have occasionally been met in mines situated in the parishes of Saint Just, Gwinear, Camborne, Illogan, Redruth, St. Agnes, St. Stephens, and St. Austell. In Huel Providence and Trenwith it was mingled with the copper ore in quantity sufficient to deterioate its value. Small parcels of pechblende (oxide of uranium) were a few years since collected at Wheal Owles and East Pool, and sold at prices oscillating between £100 and £200 per ton. Lately some lime-uranite has been found at South Terras, and sold at the rate of £500 per ton. Uranium is used in the ceramic arts for colouring.

Bismuth.—Bismuth, native and mineralised, has been met in Saint Just and Saint Ives; also in Gwinear, Illogan, Redruth, and Saint Austell. It occurs sporadically in small pieces in the lodes of Restormel and Fowey Consols, in some mines near Calstock, and at Ivey Tor. It is not often that it exists in quantity, notwithstanding that in 1876 and a few previous years, Wheal Owles and East Pool sold a few hundred weight. Alloyed with lead and tin, it is used for stereotyping, and for preparing pewter; and with mercury it is used for silvering globes, &c.

Nickel and Cobalt.—Although nickel is found in some abundance in Germany in the mineral called kupfernickel, its occurrence in Cornwall is uncommon. The nickel is generally mixed with cobalt, and sometimes with bismuth. It has been raised from Botallack, Dolcoath, East Pool, Huel Sparnon, Trugoe and Drakewalls, and

especially at St. Austell Consols, which sold during the decade following the year 1860 considerable quantities of low quality ores. A few years since East Pool and Botallack sold these ores in insignificant quantity. Nickel is used in the arts for cutlery and domestic utensils, and cobalt for ensuring permanency of colours to china, glass-ware and metal.

Molybdenum.—This metal in the state of sulphide is rarely met, but is sometimes mingled with tin ores. It has been noticed in St. Ives, Lelant, Gwinear, Gwennap, and Calstock. Pure molybdenite is said to have a high value.

Antimony.—None of the ores of this metal are now raised in the county, but the grey sulphide occurs in slates associated with trappean rocks, in the vicinity of Padstow, St. Germains and St. Austell. It was worked at St. Stephens in 1758, and in 1778 there were antimony works at Point, near Devoran.

Minerals produced in Cornwall—in Tons.

	Zinc Blende.	Arsenic.	Tungsten. W.
1854	638	477	
1855 to 1864	24,422	5,801	78
1865 to 1874	11,981	17,902	231
1875	3,087	2,412	46
1876	4,414	2,557	23
1877	4,991	1,718	15
1878	4,483	1,843	10
1879	3,202	1,655	13
1880	4,440	1,356	1
1881	7,793	2,775	54
1882	4,608	3,473	58

CHAPTER VII.

QUARRIES.

Both the crystalline and schistose rocks of Cornwall yield building material of excellent quality and durability, and that they are much sought after is made patent by the extent of the exportation. The **granites** from the quarries of Lamorna near Penzance, of Mabe close to Penryn, of Luxulyan near St. Austell, and of the Cheesewring north of Liskeard, have long been celebrated for their admirably fine grain and beautifully grey colour. As the durability and, as a whole, the appearance of granite must be attributed to the felspar, the condition of this important ingredient is always minutely examined before employing it in building, because the felspar though compact often contains the hidden germ of decomposition. Some of the excavations are very large, that of the Cheesewring being more than 100 feet deep and 400 feet wide. The granite can be cut out in large masses, and in the porphyritic granite of Luxulyan monoliths of 20 feet or more can be cleaved. The granite is squared or roughly blocked, and is exported to most of the towns in the south and west of England, Liverpool and London taking large quantities.

No statistics of the present production are available, but in 1858 the number of tons produced appears to have

been about 80,000, and its value at the quarry about 20/- per ton.

Elvan. This rock, procured from the courses of porphyry which traverse most of the county, is quarried for rough building stone and for road metal. Some elvans when first quarried are soft, but the exposure of a few days, dries and hardens them; one of these at Wheal Prudence, in St. Agnes, is much sought after to make troughs. The Pentuan elvan has been long known for its beautiful grain and colour. The St. Wenn elvan is very handsome when polished.

Serpentine. Some twenty years since, the quarries on the Lizard were much worked for this rock, which possesses a variety of agreeable shades of green and red with a silky lustre. Large buildings fitted with appropriate machinery, were put up at Penzance to fashion it into ornaments, monoliths, &c.; but the manufactory did not prosper and the trade has dwindled, but there are some quarries at work near Cadgwith, and a mill at Poltesca for the turning of ornaments, &c.

Roofing Slate. In the Upper Devonian slates along the coast west of Camelford, are several quarries producing this material. The principal, and indeed the only one largely worked, is that known as old Delabole quarry, which has supplied roofing and flooring slates for the past 300 years. Steam power was introduced in 1837, and the output increased to such an extent, that in 1847 five steam engines and 1000 persons were employed. In 1882 the workmen numbered 350, and the quantity of manufactured slates, slabs, &c. equalled about 10,000 tons. The lightness, strength, and durability of the Delabole *brand is* so highly appreciated, that the slates find markets

on the Continent, in the West Indies, and in America. The total quantity produced by the Cornish slate quarries during the above year was 11,680 tons, said to be worth 40/- per ton. The quarry is about 400 feet deep.

Hornblendic Rocks. Greenstone is much used for macadam all over the county, and hornblende schist is extensively quarried at Porthalla near the mouth of the Helford river for re-metalling the highways.

Clay Slates. These are quarried everywhere, and many of them yield a most durable and sightly building stone.

Limestone. Few quarries have been opened in good limestone in Cornwall, because of its scarcity, but vast quarries are worked in the pure crystalline lime rock of Plymouth. The blue limestone beds of Towan Head near Newquay are quarried for hydraulic cement.

CHAPTER VIII.

MINE WATER.

The enormous expense of draining Cornish mines, especially when they are deep, is the primary reason why so few of the tin mines can pay dividends. To increase the efficiency of the draught engine and to reduce the cost of fuel, the unsparing energies of generations of engineers have been employed; until, as a pumping machine, the Cornish engine has attained such perfection, that it is in demand throughout all mining countries.

To attrap the surface water, and to hinder its descent into the depths of the mine, long and expensive tunnels have been driven into the hills at the lowest level attainable; and at the surface, hollows are filled and channels often made, to accelerate the discharge of the rainfall. It has been calculated that half the water discharged by the Gwennap Great Adit, was raised from an average depth of 190 fathoms, and that £20,000 a year were saved in fuel by its existence. The temperature of the adit water, which was 60½° in winter, and 68° in summer, was more than 12° above the mean temperature even in summer.

Rains flow into the levels at various intervals after their fall on the surface, in some mines the water *percolates* quickly, in others two or three months are

required, and even longer. The water permeates more freely, through granite than slate, though in the former it does not penetrate in such large quantities to the deeper portions of the mine; massive crystalline slate includes less water than the schists. The numerous beds, joints, veins, and crosscourses in the clayslate, afford great opportunities for aqueous circulation throughout large areas; so that when the nature of the ground and the position of flucans are imperfectly known, it is not easy to recognise the area which a shaft would have to unwater.

The water pouring from the metalliferous granite is considered potable by the miners, but on the schistose rocks, salts of the prevailing metals are often held in solution, and in the mines near the sea the water is more or less salt.

TEMPERATURE OF MINES.

The late Mr. W. J. Henwood, F.R.S., who during half a lifetime devoted untiring energy to the study of the geological phenomena connected with mining, has presented us with a series of very valuable tables illustrating the temperature of the rocks and lodes underground. The general results which he has recorded are doubtless approximatively correct, but is well to notice that owing to changes introduced by the excavation of shafts and levels—which introduce air and water from the surface—the tables must necessarily register a lower degree of heat than would be normally the case. The

following are the temperatures given by Mr. Henwood as a mean of all the Cornish districts :

Depth	30	fathoms, temperature	55°
,,	72	,, ,,	61°
,,	127	,, ,,	67½°
,,	173	,, ,,	78°
,,	240	,, ,,	85½°

The heat of the schistose rocks is considerably higher than that of the granite, and this temperature has a greater proportionate value as depth is gained; so that though at 30 fathoms the heat of slate is only 55·9° as against that of granite 52·7°, yet at 240 fathoms it is 89·4° to 76·15° F. Thus in the granite it requires 51 feet of depth to gain a degree Fahrenheit of heat, whilst in the slates 37 feet appears to be sufficient. Naturally the rocks are hotter than veins, the heat increasing from the walls inwards, and lodes would possess a higher temperature than crossveins, because of the water running through the latter, and on account of the absence of workmen. Mr. Henwood convinced himself that tin lodes are colder than tin and copper lodes, and that those of copper are the warmest; and that although the difference is not great, yet it is sensible to the miners. In some levels, owing to hot currents of water welling up in them, the heat has been almost unendurable. At the 320 fathom level in Tresavean it was over 90°, and in the deep level of the United mines as high as 108° F.

Before the opening of the Great Sutro tunnel, the water issuing from the Comstock lode, at a depth of 2700 feet, had a temperature of 157° F, and men falling into it *have* been fatally scalded.

TABLE OF MEAN TEMPERATURES AT SURFACE.

	Penzance, 1836.	Truro, 1883.
Mean of year	54°F	50·8°F
Hottest month	65°	60·9
Coldest month	43°	39·7
Rainfall in inches	44·70	40·73
No. of wet days	178	195
No. of dry days	187	170

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