ORIGIN AND MODE OF OCCURRENCE OF GOLD-BEARING VEINS AND OF THE ASSOCIATED MINERALS.

By Jonathan C. B. P. Seaver, C.E., F.G.S., &c.

[Read before the Royal Society of N.S.W., 7 September, 1887.]

The origin of metalliferous veins and lodes has given rise to many conjectures and theories from time immemorial, and great have been the differences of opinion held by scientific men of all ages as regards the question. In modern times, however, the large amount of information that has been collected, and is yet in course of collection, bearing on the different modes of occurrence of metals and minerals, their chemical and physical properties, and their geological and geographical positions, has placed certain theories regarding the origin of lodes and veins upon a more solid basis from which to reason, and has at the same time relegated others almost to oblivion.

In the following notes my remarks will be confined more particularly to auriferous veins and deposits, not that I believe they have peculiarities in their modes of occurrence distinct from all other metalliferous lodes, but because this essay is understood to be one on veins and deposits containing gold in such quantities as to be principally worked or prospected for that metal. I propose, moreover, to confine my description chiefly to the gold deposits of Australasia. I not only believe that most of the peculiar phenomena connected with the occurrence of gold-veins and other auriferous deposits may be better studied in that country than anywhere else, but also because a large amount of authentic information has been collected in Australasia regarding these deposits, and I have, personally, had considerable experience there in this class of mining, and so can speak in most cases with a certain amount of authority as to the actual phenomena connected with the mode of occurrence of gold and the associated minerals.

It has generally been conceded that by whatever means the veins have been filled, the process of opening the fissures, cavities, or crevices in which they exist has been to some extent independent thereof, and so these two branches of the subject ought to be considered separately, but it must be borne in mind that gold
also occurs under conditions which cannot be classed as belonging to veins at all, being in fact impregnations through certain rocks.

As regards the origin of quartz veins and the minerals occurring in them, much has already been said by those who have advocated one or other of the theories of igneous injection, sublimation, lateral secretion, etc., to account for their forming, and perhaps it will be best to endeavour in these pages to see which of these may be most applicable to the phenomena observed in connection with the auriferous quartz veins of Australasia.

It is in Victoria that auriferous quartz mining has been carried on upon the largest scale in the colonies, and we find that the veins, or "reefs" as they are locally called (which name is synonymous with the term "ledge" used in America), may be sub-divided under two or three classes, which embrace most, if not all, of the special features of the gold veins in the colony.

No better idea can be given of the general distribution of auriferous quartz veins in Victoria than by quoting the following extract from Mr. Brough Smyth's "Gold Fields and Mineral Districts of Victoria":—"Whenever the surface of the schist rocks is touched, whether exposed as at Castlemaine and Bendigo, or hidden under basalt, as at Ballarat, or covered by tertiaries, as at Sebastian and Wahgunyah,—we find auriferous veins of quartz. The strata which they intersect are either altered or present a low degree of metamorphism. The veins vary in thickness from the sixteenth of an inch to 100 and 150 feet, and some,—as thin as the paper on which these words are printed,—intersect soft mudstone and sandstone containing palaeozoic fossils, and in such a manner as almost to cut the fossils; but the delicate structure is not altered, nor are any of the interspaces filled with quartz.

"In some of the veins we find dense white milky quartz homogeneous and breaking with almost a hackly fracture; in others, brownish and yellowish quartz, laminated, and resembling jaspery quartz or hornstone, and showing a semi-conchoidal fracture where broken; again, we find veins of laminated quartz, with pyrites and other sulphides intercalated, and pieces of blue slate included in the laminations of the quartz; and in many places quite crystalline quartz, containing crystals of galena, carbonate of copper, and iron pyrites, with free gold in the interstices of the crystals and intermixed with the sulphides and carbonates, and occasionally (not often) in the bases of the hexagonal crystals of quartz in moss-like aggregations; not only in the veins, but also in the casing of the veins does the gold occur in lumps, crystals, and small particles, with rugged edges; and in the soft mud-stones at Kamarooka, thin plates of gold lie in the planes of bedding of the rock."
But veins of auriferous quartz have also been found to exist in the granite and other igneous rocks of that Colony, and it has been shown that it is only where the sedimentary rocks have been intersected and disrupted by igneous ones that the veins of auriferous quartz exist to any extent in the former, proving beyond a doubt that the near vicinity of igneous rocks is conducive to the formation of quartz veins containing gold and other minerals. A description of some of the quartz veins of Victoria and of the other colonies of Australasia will give an idea of their different modes of occurrence, and supply reliable data to be considered in conjecturing as to the possible manner in which they were formed.

The quartz veins of Victoria may be divided into two great classes, viz.:

1st. *True Lodes*, or those that have well-defined walls and continue on a certain strike and dip for a considerable distance, excepting in places where they are heaved by subsequent faults or slides, in which cases they are abruptly broken off, but may be picked up again in the direction in which the slide or fault has heaved or thrown them.

2nd. *Segregation Veins*, or those bearing evidence of being accumulations of quartz in irregular fissures, cracks, or cavities, or upon some natural planes—such as cleavage, bedding, or jointing in the rock. The latter veins comprise a very large portion of the auriferous quartz veins of the colony; and it is a matter of opinion as to whether many seemingly true lodes are not of the same character, differing only in their more regular form.

Sometimes veins included under Class 1 (True Lodes) may bear evidence of being formed on a line of fault, and may be considered as true fissure lodes, while in other cases they coincide with natural planes of the country rock, such as those of bedding, or cleavage, etc., and an open question arises as to whether they should be considered as true lodes or segregations of ore that have accumulated on a natural plane in lode form. However, all the varieties of quartz veins in Victoria may be comprised under one or other of these two classes; the second class (Segregation Veins) embracing a great variety of deposits occurring under different conditions, as will be seen from the following description of some of the veins of the colony:

**Victorian Gold Mines.**

The rocks that contain the gold veins and deposits of Victoria are sedimentary rocks, chiefly, if not wholly of upper and lower Silurian age. These are more or less altered, and while some contain fossils, others consist of chloritic micaceous and granitoid
schist and other metamorphic rocks, and intrusive and disruptive igneous rocks also occur in great variety. A common mode of occurrence under which the auriferous quartz veins of Victoria are found is that of true lodes, either coinciding with the bedding or other natural planes of the country rock, both in strike and dip, or intersecting the rocks perfectly independent of either, or, as in some cases, coinciding with the one and not with the other.

I will now proceed to give some characteristic examples of these different modes of occurrence under which true lodes, or those that have well defined walls and a certain general dip and bearing, are found to exist in the colony of Victoria. In doing so I will borrow largely from that excellent work on the peculiar characteristics of the Victorian quartz veins, viz., Brough Smyth's "Gold-fields and Mineral Districts of Victoria," but at the same time, as often as possible, make use of my own observations as regards some of the lodes of which I have an intimate knowledge, giving as many examples of quartz veins that have been examined by myself as this essay will allow of, without subjecting myself to be considered tedious.

Of true lodes that coincide both in strike and dip with natural planes in the containing country rock, the following from Brough Smyth's work already referred to, is a good example, showing as it does the lode in cross-section at different levels. (Vide Sketches of Main Lode of the Catherine Reef at Clunes, Victoria):

Fig. 1.—Cross-section, between No. 2 and No. 3 levels.
Fig. 2.—Cross-section, 25 feet below last.
Fig. 3.—Cross-section, 25 feet below last.

As may be seen from these sections the lode varies in thickness, having, however, an average of about five feet, and the foot wall is very irregular, and has many spurs of quartz running into it. Upon the hanging wall-side of the lode is a vein of laminated quartz, varying from one to six inches in thickness, and upon this vein is a layer of sandstone, two feet thick which is overlain in turn by a 'flucan' about fifteen inches in thickness, and again by sandstone, which is supposed to be the real wall of the lode. The foot-wall is said to be slate, distinctly laminated parallel to the lode and its irregularities.

Of those lodes or quartz veins which do not seem to have been formed upon any natural planes of their containing rock, but which cut through the rock independent of such planes, there are many examples to be found among some of the richest quartz veins in the colony. Those shewn in section Fig. 5 and Fig. 6 are very good examples of this mode of occurrence, and in the course of this essay I shall speak of many others of a similar character that I have personally examined.
Fig. 5 is in Gippsland, at the Crooker River, and had a thickness of about eighteen inches, and for a depth of 80 feet gave an average yield of over two ounces and a half of gold to the ton.

Fig. 6 was also about eighteen inches thick, and yielded $1\frac{1}{4}$ ounces to the ton, being very rich in arsenical pyrites. It was in the same locality as Fig. 5.

Both these examples have been taken from Brough Smyth's work referred to, and have been chosen on account of their being good illustrations of this class of quartz vein.

The dyke lodes of Victoria are certainly a most peculiar class of auriferous deposit. They consist of dykes, or what appear to be dykes, of either a decomposed igneous rock or a sedimentary one which has been very much altered. In some cases they have much the appearance of decomposed diorite, whilst in others they are described as having a slaty cleavage. The auriferous portions, however, consist chiefly of narrow nearly horizontal veins of quartz, some of which intersect the dyke at right angles to its dip, while others lie nearly parallel with the walls, occurring in strings or lenticular bunches.

The horizontal veins are like thin floors of quartz, and some of these pass out of the dyke and for a short distance into the containing walls.

There can be little doubt that in many cases these belts of decomposed or partially decomposed rock are true dykes of igneous origin, in which the veins of quartz have been subsequently formed. They have often been proved to be very rich, but are seldom continuous to a great depth, being cut off in many cases by a hard undecomposed igneous rock, from which it appears probable that the dykes are offshoots. The Waverly dyke, of which I give a section (Fig. 7), and the Morning Star dyke (Fig. 8), are examples of this class of deposits.

The pipe veins are also a class worthy of particularizing as being a mode under which quartz veins are sometimes found in Victoria, and it may not be out of place to mention here that many of the quartz reefs both in that and other parts of the colonies, dip on their strike or bearing. Instances and examples of this will be given further on in treating of the New South Wales gold veins.

One of the most interesting districts in Victoria to the Engineering Mineralogist is that of St. Arnaud. This place contains a perfect net-work of quartz veins intersecting the strata at all angles, and occurring so close together and sometimes of such large dimensions that the question of how they were all formed, and what relation they may bear to each other, is a
problem well worthy of consideration by the highest authority on such subjects.

I will mention a few of the principal of these veins that have been worked for their auriferous contents, and as I have for years been well acquainted with the locality, I can speak with a considerable amount of assurance as to the peculiarities of its auriferous deposits.

The Wilson Hill Reef is situated upon the hill that is close to the township of St. Arnaud. This hill is about 200 to 300 feet above the valley alongside. When first discovered the reef was of enormous dimensions on the surface, being nearly 100 feet wide, and it had thrown out on the western side of the hill rich alluvial surfacing by the denudation it had undergone in times past. For about 400 feet along its strike, which was about N. 36° W. with a dip to the westerly of about 75° from the perpendicular, it was a solid lode, but there seemed to be a break up into smaller veins, both to the northward and southward. It is most likely that it has made again and is identical with the Sebastopol Reef that is on the same strike, and has the same dip approximately, and which crops to the surface after crossing the lower country and reaching the higher land some miles to the northward from Wilson Hill.

This latter reef was also of as large dimensions, or nearly so, at the surface. The quartz of the Wilson Hill Reef was, for some distance from the surface, stained yellow, or sometimes of a greenish colour, and very much honeycombed with cavities, due, doubtless to the decomposition of iron pyrites and other sulphides. It was also very rich at the upper level, as much as ten to twelve ounces of free gold to the ton being obtained by ordinary treatment with comparatively primitive appliances; but when last I visited the mine, some four years ago, the lode had run into a pyritous one, having been worked down to some distance below the water level, and only about 3dwt. of free gold to the ton could be obtained from the quartz, the rest being now all in the undecomposed pyrites with which the stone was largely impregnated. Expensive machinery was just being erected to save the pyrites for transmission to places in Europe and elsewhere where such ore can be treated. All the quartz veins in this district become highly pyritous at low levels.

The Jerygaw Reef, another quartz vein in the same district is a nearly perpendicular lode, and yielded rich quartz at the surface; some of the specimens that I saw taken from it when first opened, and which were of a highly ferruginous character, were perfectly studded with gold, as thick as plums in a plum pudding, but it became poorer as it went down.
It is, however, being proved in this district that the rich shoots or ore-bearing portions of the quartz veins lie some distance below one another; and continued sinking will probably pass through a comparatively barren portion before reaching another ore-shoot similar to the one already cut near the surface, and that still further sinking will lead to other shoots being cut. As this is certainly the characteristic of numerous quartz veins in Australasia (as will be seen by other examples given) and also agrees with the law being established in all parts of the world with reference to metalliferous lodes in general, the same law is most likely to be equally applicable to the quartz veins in this district.

Other veins in this place yielded silver ores, such as chloro-bromides, &c., in conjunction with gold, and a large Stetefeldt furnace was erected some years ago, with a dry-crushing battery and other appliances, to treat such class of ores. Many other of the quartz veins in this locality might be described. One very peculiar deposit found, I may say, almost under my own eyes, was upon the top of a small rise, upon the side of which some pieces of gold of various sizes had been picked up.

Six hundred ounces of gold, mixed with broken quartz, was obtained in a sort of cleft in the rock some few feet wide at the top of the said rise, and although a shaft was sunk about 100 feet or so, no defined vein or lode was found, nor any more gold so far as I have heard. I might say that a large amount of gold was obtained from the district from the alluvial, evidently traceable in most cases to the denudation of reefs, or some particular reef; and also, in some of the auriferous veins, copper, silver, and lead ores, and many other minerals also occurred, but mostly in small quantities. I might add that the formation of the district just described is upper silurian, largely intersected by igneous rocks in the form of dykes and veins, and granite country lays to the east at a distance of about three miles from the Wilson Hill Reef.

Perhaps no part of Victoria is more interesting in regard to the great peculiarity of its auriferous quartz veins than Sandhurst, and at the same time it is the centre of a most thriving mining district. The saddle reefs of Sandhurst are almost unique in their mode of occurrence. They appear to be irregular deposits of auriferous quartz, formed upon either two planes of the rock that intersect one another, such as bedding and jointing, or upon an anticlinal arch in the paleozoic strata.

The sketch plans illustrative of these veins (Figs. 11, 12, 14) show the manner in which they occur in the country rock, and as the sections are taken from the Garden Gully line of reef in Sandhurst, they show the actual manner in which one of the said
saddle-reefs occurs in that line. It will be seen in this case the reeves form saddles of quartz in the arch of an anticlinal, and follow along the crown of the arch (in the same bedding plane most probably) either horizontally or with a greater or less dip. They occur one below the other, but each successive reef, as it is met with in sinking, is found to be either to one side or other of a vertical line passing through the one above it, their position being dependent upon the direction of the line normal to the anticlinal arches of the beds of the strata. The quartz is richest in gold near where the legs join the arch or crown of the saddles, and Fig. 13 gives an instance where a saddle-reef is formed upon two-cross planes of the strata, instead of an anticlinal arch.

There are many other peculiar modes of occurrence of quartz veins in this district and in other parts of the colony. The flat reeves of Pleasant Creek is another form under which quartz veins exist in Victoria, and Fig. 15 gives a cross-section of one of these flat reefs in that locality.

Many of the granites and other igneous rocks contain veins of auriferous quartz. A reef in gneissic granite at Omeo occurs as shewn in Figs. 16, 17, 18, and contains large quantities of very auriferous pyrites and some galena; both pyrites and gold being sometimes found impregnating the walls of the lode to such an extent as to pay the miners to crush a portion of the rock. This lode is crossed in its course by igneous dykes of quartz porphyry and diorite, and the quartz matrix of it seems to contain a large percentage of galena and silver as it approaches the dykes of quartz porphyry.

Gold is found in the same district impregnating granite in the form of small grains, and at Kamarooka it is found in thin plates in the laminations of slate. It has also been obtained from sandstone, and there is little doubt that all igneous rocks that are impregnated with iron pyrites have a greater or less quantity of gold in them, most particularly those of the diorite and granitic classes.

**GOLD VEINS OF QUEENSLAND.**

Queensland is the colony of Australasia in which, next to Victoria, the working of auriferous veins has assumed the greatest proportions. Its gold reeves are well known for their richness and established payable character. Charters Towers, Gympie, Rockhampton, Herberton, and other fields are sites of quartz mining industry, and some of these places have peculiarities of their own as regards the modes of occurrence of their auriferous lodes and deposits.

The gold reeves of Charters Towers are principally in granite, and one thing remarkable about them, mentioned by Mr. Jack, F.G.S., &c., the Government Geologist to the colony, is that they
bear and dip in a manner that points to them as being formed around a common centre, towards which they mostly all underlay. This has been believed by Mr. Jack to have been caused by a sudden depression having taken place near the central point, and thus to have formed a system of fissures surrounding it that in most cases dip towards the centre. I give a plan of three reefs (Fig. 19) shewing their dip and strike, and also a cross section of the reefs after Mr. Jack's plan.

Fig. 20 is a cross-section of St. Patrick's lode, and it is largely impregnated with iron pyrites, which yielded as much as five ounces of gold to the ton of ore when first struck, but afterwards fell off to about two ounces; where decomposed in the upper levels it yielded about the same as the latter, viz., two ounces of gold to the ton of ore. This lode altered its underlay very much in one place, even curling upwards for some distance, as in Fig. 21.

Fig. 22, which is a cross-section of the Rainbow Reef shews the lode between the walls to consist of broken granite on the footwall, quartz without pyrites next, and quartz with pyrites on the hanging wall; both these lodes are evidently of the true fissure class, and interesting examples of such as gold veins. The mineralized or pyritous portion of the lodes are the richest in gold, and expensive machinery to treat pyritous ore exists on this field, and is continually being added to. Large quantities of comparatively poor pyritous tailings lie in heaps at the various crushing plants awaiting the day when improvements in the process of treatment will make them capable of being rendered remunerative.

The Gympie Reefing Field is noticeable for the fact that the lodes depend upon the character of different bands of rock they pass through for the extent to which they are auriferous. Bands of black slate occur with diorite and other rocks, and it is when passing through this black slate that the lodes contain most gold; being comparatively poor in other parts. Four bands of this black slate are known to exist, and so dependent are the reefs on it that the miners first sink to cut the slate and then drive to where a reef passes through it, and start to work the lode at that place.

The Rockhampton lodes are of a very pyritous character in most instances, and perhaps the most remarkable gold mine in the whole of Australasia, and also in the world that has ever been found during modern times—is situated about eighteen miles from Rockhampton, and is known as the "Mount Morgan Gold Mine." Having visited it lately for the purpose of examining it and the surrounding country, I can describe it as follows:—

The country consists of altered sedimentary strata intersected by numerous dykes and intrusive masses of a variety of igneous
rocks, of which syenite is the most prevalent. A sandstone, known as “Daintree's Desert Sandstone,” at one time doubtless overspread the country, but has been almost entirely denuded, and only now remains, capping the higher ranges in the district where it forms steep escarpments of horizontally bedded rock.

In places narrow belts of highly altered slates and sandstones occur, which have been caught up in folds of the syenite, and are the last remnants of the sedimentary palæozoic rocks of the locality. They have been greatly altered, some of them being converted into quartzite, are highly charged with iron pyrites, and are intersected by numerous feldspathic dykes. One of these belts may be traced in a north easterly direction from a point immediately south of Mount Morgan, and is closely bounded to the south, east, and west by the syenite. In this belt a wide lode formation occurs, striking N. 30° E. (which is approximately the strike of the belt of rock enclosing it), and having all the appearance of a large dyke. It underlays to the east at an angle of 10° to 15° from the vertical, and has a banded structure parallel to its strike and underlay.

In Mount Morgan itself this lode consists in the higher levels of alternate bands of ironstone (limonite) and honeycombed or porous quartz (with much foreign matter), these bands having the same strike and underlay as the lode, and most probably changing in the lower levels into a dense quartz or numerous veins of quartz, through which a large quantity of iron pyrites is disseminated as minute crystals; veins wholly of iron pyrites may also exist below, that have decomposed on the surface in limonite iron ore. The entire width of these layers of ironstone and quartz with intervening bands of altered rock at Mt. Morgan is about 1500 feet, but those that constitute the main lode that is being worked comprise about two or three hundred feet in width. It appears that the narrow belt of altered strata in this place must have been fractured and opened into immense fissures or a number of parallel fissures which have been filled in with lode matter and probably afterwards undergone re-opening from time to time, and a re-filling with or re-depositing of the quartz and other minerals constituting the lode. Feldspathic dykes which have decomposed to kaolin are also found traversing the lode and parallel to the bands of ore in it.

The honeycomb quartz is doubtless the result of the decomposition of the pyrites, the resulting limonite having been dissolved out and probably redeposited with other matter in open fissures to form parts of the bands of ironstone described above. Every stage of the change can be illustrated by specimens from the mine, the quartz charged with minute crystals of pyrites giving place to a quartz in which crystals of pyrites yet exist, but
which is cavernous in places, and this again passes insensibly into skeletons of silica the evident result of the complete extraction of the iron. The lode formation has been greatly denuded along the greater part of its course, the country being cut into deep gullies, and steep ridges which cross it at about right angles to its strike and head from the mountains capped with "desert sandstone," which bound the auriferous belt to the west.

Most of these gullies have been worked for alluvial deposits, and yielded rich returns many years ago, the gold which was obtained in them having doubtless been principally derived from the wearing away of this auriferous belt of country, some of the richest finds occurring just about where the line of the lode formation crossed the gullies worked.

Mount Morgan, standing as it does some five hundred feet above these gullies, is evidently a portion of the lode bearing formation that has not been so much denuded as the surrounding country, but on the same line and at a distance of four miles away a similar undenuded area is found which also carries gold but not so far as yet proved in the same quantities, and other smaller patches also exist.

The gold obtained from the Mt. Morgan mine is of a purer quality than any ever known to have been found before in nature, and the yields from the ore consisting of the ironstone and porous quartz is something enormous. The hill is being worked from the top like a quarry, and to the width of over two hundred feet, some of the ore giving as high as from 4 to 10 ounces of gold to the ton. Tunnels have also been put in to test lower levels.

The laminated layers of quartz in some parts of the workings have the appearance of having been cracked and fractured into minute irregular fissures, and these fissures filled in with silica from solution giving the quartz the appearance shewn in Fig. 24.

The process at present used to treat the ore is that of chlorination, the gold being of too fine a quality to save successfully by the ordinary methods of treating auriferous ores.

No metals are known to occur in the ore excepting the iron and gold, and a small quantity of manganese.

A sketch section across the Mount Morgan lode is given in Fig. 23.

**Gold Veins of New South Wales.**

The gold fields of New South Wales have in many places a great similarity to those of Victoria, but not in all, and there are certain distinctive features which are worth mentioning.

Whereas, the geological formations that contain the auriferous veins in Victoria are principally upper and lower silurian, those
of New South Wales are chiefly, so far as has been determined, upper silurian and devonian, and as the carboniferous rocks of that colony immediately overlie these formations, and although denuded from the portions where the auriferous veins shew are still to be seen, in situ crowning many of the highest hills, and in some places covering up many of the valleys, and lying in isolated patches on their sides, it is quite evident that the same amount of denudation of the palaeozoic rocks cannot have taken place in that colony, since the deposition of the carboniferous strata as in Victoria. This may be considered proved by the less extent of the alluvial leads in New South Wales, for although a certain amount of denudation of the reef bearing rocks is likely to have occurred prior to the laying down of the carboniferous strata, as seems to have been determined by the fact that some of the lower conglomerates of those measures have been proved to contain alluvial gold, still there is nothing to prove that such denudation has been nearly so extensive in New South Wales as in Victoria.

It would appear that the New South Wales quartz veins have not been worn away to as great an extent as those of Victoria, and that in many parts of the latter colony the entire mass of the upper silurian and devonian rocks have, with their contained quartz veins, been broken up and swept away, and have served to supply the truly rich and extensive alluvial leads that have been such a wonderful advantage to that colony.

A large portion of the carboniferous strata of New South Wales has undergone little or no alteration, but in some parts of the colony they seem to have been metamorphosed or altered to some extent, and to have been much contorted by the intrusion of igneous rocks, and in these places they have been found to contain auriferous quartz reefs or veins. There is, however, a doubt as to whether these altered strata are really carboniferous or whether they are not devonian beds.

I will now proceed to give a description of some of the principal gold veins in New South Wales, choosing those that are peculiarly characteristic of some mode of occurrence.

The alluvial field of Hargraves was the second gold field discovered in Australia, the Ophir being the first, and it is said to have been discovered by a blackfellow, an aboriginal of the colony, stating to those with him when taken to see the gold at Ophir, which is situated some miles away from Hargraves, that he knew where some of the same kind of stuff was, and he brought them to what is now known as Hargraves, and there shewed them on the surface a large lump of gold and quartz. This led to the working of the field, and a great amount of precious metal was obtained from a comparatively small area of ground.
But what chiefly concerns us in this place is the peculiar formation of the quartz veins that exist in it, the denudation of which has doubtless supplied the gold found in the alluvial.

The alluvial was obtained from a gully situated near the top of a high range, this gully being flanked on the one side by silurian or devonian slates and shale, and on the other by a sandstone formation, both strata being inclined at a very high angle.

Crossing this valley, but in an oblique direction, so as to cut through most of the alluvial field, is a quartz reef averaging in thickness from 8 to 10 feet in some places, and from 1 to 2 feet in others, the thickest part being on a small rise near the centre of the field, and there the vein seems to consist of a large blow on the surface with possibly two legs or branches which divide as they go down. One of these legs dips easterly, and has been worked for some distance from the surface; it coincides with the dip and strike of the shales which are about 90° from the horizontal and north west respectively.

Cutting across the field in a direction more or less oblique to the main vein, are a number of flattish veins, and these are inclined at so small an angle from the horizontal, and are in some cases so near to each other that they actually lay under one another, so that a vertical shaft of some hundred feet deep might be expected to cut one after another as it went down.

Parallel to the main quartz vein or reef, and at varying distances from it and from each other, are small veins of quartz that coincide with the strata, and are thus parallel with one leg of the main reef. These veins are from one to two or three inches thick, and are heavily charged with arsenical pyrites. They strike the flattish veins as they go down, but do not cut them, although they are found again continuing downwards on the same course, immediately below the vein they strike, and continue thus until they strike another vein. It is where these small veins strike the flattish ones that the quartz in the flattish veins is richest,—the immediate point of junction being rich beyond all comparison with other portions of the deposit; as much as 700 ounces has been taken from immediately beneath one of these junctions, and so rich was the quartz in this place that the 700 ounces were taken from only a few feet along the vein and were all crushed out of the stone with an ordinary pestle and mortar by hand labour. It is not, however, always directly under the small vein that the extraordinarily rich quartz is formed, but in a space from about six to twelve inches to one side or the other of this vein (vide Figs. 27 and 28), and a shallow gutter, or sometimes a ridge, seems to run along the flattish quartz veins, and it is in this gutter, or on this ridge, that the highly auriferous
quartz occurs and is generally easily detached from the other part of the flattish veins. The narrow vein is said to be barren, or nearly so, and highly charged with pyrites for about two or three feet above the flattish veins. Both the narrow vein and its containing wall are tinged green, the latter for about an inch, but this green tint shades gradually away from the vein inwards; arsenical pyrites occurs both in the narrow vein and its walls for about the same distance as the green tint, and in particularly large quantities for some distance above the flattish vein. Both the flattish veins (viz., those with a low angle of dip) and the narrow veins are heaved by a system of lodes that dip in an opposite direction to the former, and intersect them. These latter are of a loose barren character and of from a foot to three or four feet thick.

Sections across parts of the field shew the general mode of occurrence as described (vide Figs. 25 and 26). A somewhat similar phenomenon, I believe, exists at Ballaarat, in Victoria; the small vein being there known as the indicator vein, and is followed for its accompanying rich shoots of gold.

The flattish veins seem to have been formed upon joint planes of the country rock. The black places on diagram (Fig. 25) show the parts of the flat veins that are richest. All the quartz in this field is strongly charged with both sulphurous and arsenical pyrites, particularly arsenical, which exists in very perfect cubical crystals. Some of the alluvial gold was in very large pieces, as much as 100lbs. in weight of the precious metal having been obtained in one lump on more than one occasion. The piece of gold and quartz that the blackfellow found, and which led to the opening of the field, weighed over 100lbs., and most of this was gold. It is said to have been found lying near the outcrop of the main vein upon the small rise to the right in the diagram (Fig. 25).

The Hill End reefing field is situated some distance from Hargraves, and some extraordinarily rich patches of auriferous quartz have been obtained from the reefs in that place. A description of a portion of that field is thus given by Mr. E. Pitman, Associate Royal School of Mines, London, and now Chief Mining Surveyor of the colony of New South Wales:

"Hawkin's Hill, which has become famous on account of the enormous yield of gold obtained from its veins, is composed of beds of the altered conglomerate above referred to, dipping to the eastward. Thin layers of dark slate, with some chlorite slate, occur at intervals in the conglomerate, and carry lenticular veins of quartz, with pyrites and potash mica (muscovite). In some places the mica was found to entirely replace the quartz, and here the gold was found to be exceedingly rich. The veins are
about twelve in number, and nearly parallel. Their course is
nearly north and south, with a dip to the eastward, and they
occupy a width of from 80 to 120 feet in the aggregate.

The conglomerate Mr. Pitman describes as consisting of quartz
and feldspar crystals in a blue silico-feldspathic matrix, with
indistinct outlines of large pebbles of slate and sandstone.

At Adelong, also, there are found what are called "ore channels"
by the miner. These are narrow belts occurring in the country
rock, like large lodes, and consisting of a kind of chlorite schist.
Quartz occurs in these places either as lenticular masses or more
or less irregular veins, sometimes adhering to the walls of the
channel or belt, and at others in some other part of it. The
mines have been worked to a depth of 1050 feet. This mode of
occurrence of quartz vein is very similar to that described by Mr.
Pitman at Hill End, and it seems to be a characteristic mode of
occurrence of auriferous lodes in different parts of the colony
(vide Section of Three Ore Channels at Hill End, Fig. 29).

The following description by Mr. C. S. Wilkinson, F.G.S.,
F.L.S., Government Geologist for the Colony, of a mode of
occurrence of quartz veins upon the Wentworth gold-field is most
interesting. He says as follows:

"The reefs occur at the junction of the serpentine and
hornblende feldsparite, the latter in places passing into diorite.
Along this line of junction is what the miners term the 'lode,'
which at the surface is a fissure, six feet or more in width,
extending in direction S. 50° E. (or nearly south-east and
north-west) for a distance of 50 chains. It is filled with a red
sandy ferruginous clay, containing hard siliceous accretions of
irregular shape, locally termed 'clinker.' This lode dips to the
north-east at an angle of about 65° though in some places it is
nearly vertical. The hornblende feldsparite forms the foot-wall and
serpentine the hanging wall. In the feldsparite, at varying
distances along the lode, are quartz veins from a few inches to
six feet thick, coming in from the west and abutting against the
lode, which they appear to follow down and form irregular quartz
pipes or shoots dipping diagonally along the lode towards the
east. The veins have only been found to contain payable gold
where they occur in the lode and form the shoots."

Another lode that is interesting in its mode of occurrence is the
Marshall McMahon reef, at Watson's Creek, near Murrumburrah,
on the Southern Railway line, between Sydney and Melbourne,
and about 230 miles from the former place. This vein is situated
in granite, and was very rich in its upper levels, but has become
so heavily charged with iron pyrites in its lower levels that the
machinery necessary is of a very different kind to that used in
the first instance, such machinery is, however, being now erected,
and as the lode is one that holds out every reason to believe it to be continuous in depth, good results may therefore be expected in return for judiciously spent capital. This vein appears to belong to the true fissure lode class, and is a good example of such kind of vein. Fig. 9 is a section of a part of the vein below the water level, taken by the writer. This lode seems to have been faulted, but not heaved, and this characteristic may have much to do with the continuance or otherwise of the shoots of gold in it.

Gold veins occur in diorite and other igneous rocks in many places throughout the colony, and those in diorite are generally found to be very rich.

At the head of the Temora alluvial gold-field, which has been one of the richest ever found in the colony, is a rather low diorite hill which forms part of a large dyke or intrusive mass of that rock. This hill splits the upper part of the alluvial lead into two branches, and it is evident that the numerous reefs that intersect this hill have done much towards supplying the lead with its gold. Some of these veins are of a large size, and they all contain gold. So many reefs occur in this small hill that a 40-acre block of land on it contains the portion of seven of them.

The following sketch-plan (Fig. 31) shows the manner in which they intersect the hill at the surface, and the section (Fig. 30) is taken from one of the principal veins called the "Mother Shipton Reef." This reef has yielded in one part as much as 800 ounces from 2cwt. of quartz, and one piece of gold taken from the reef weighed 328 ounces. This magnificent specimen was sent to the Indian and Colonial Exhibition, and has since been presented to the Queen.

The quartz in this vein is tightly contained within the diorite walls and is largely charged with iron pyrites, as is also the walls of the lode for some distance from it. In the upper portion, near the surface, the walls close to the vein are much decomposed and completely filled with cubical cavities containing iron oxide from the decomposition of the pyrites. Both the croppings of this lode and the alluvial deposits close by contained a large quantity of gold, and the soft decomposed country along the junction of the diorite and the slate, which occurs close to the lode as shewn on plan, contained a number of narrow veins of quartz very rich in gold.

The lode has been heaved into the foot-wall three times in a depth of 100 feet, and some of the richest patches were obtained from near where the vein was broken by the heave or slide. The width of the lode is from a few inches to nearly two feet, having an average of about eighteen inches; in some parts the quartz is crystallized.
The South Australian Company's Reef varies in thickness from about two feet to ten or twelve or even more. It has yielded over half-an-ounce of gold to the ton of quartz on all that has been crushed, and is a very promising lode. It is also in diorite country, and has been heaved on its strike. The gold in this vein, particularly in some of the thickest parts, confines itself sometimes to about a foot or so of the quartz, either on the foot or hanging wall, but in the lower levels is more regularly distributed through the reef.

About eleven miles from Temora Gold Field, at a place called Sebastopol, is a quartz vein in talcose or micaceous schist, combined with chlorite schist. This lode has yielded some steady returns of a payable kind with ordinary appliances in years past, and is now about to be worked with more modern machinery so as to treat the pyrites contained in the stone. The following is a cross-section of this lode, and it is one of those lodes that coincides very closely with the bedding planes of the strata, both in strike and dip; for most of its course it varies very much in thickness, being as much as fourteen feet in some places and not more than two in others. It contains, besides gold, iron pyrites, and galena; cross-veins occur with it, and also parallel ones, all of which are auriferous. (A cross-section of "Morning Star" Reef, Sebastopol, is shown at Fig. 36).

The Junee reefs, near the same locality, are in granite or at the junction of slate and granite. Figs. 34 and 35 are cross-sections of two of those quartz veins.

The Muttama Reefs, on the branch of the Southern railway line to a place called Gundagai, are in a rock that appears to be quartz diorite, and which is evidently a wide belt of that rock, bounded on each side by slate. A description of them will serve to show the fact of the gold occurring in oblique shoots that dip in certain directions common to the district or locality.

The formation of the district is, as has been said, a quartz diorite, bounded upon both sides by altered slates, both classes of rock carrying quartz veins. The hills, which are steep, have been denuded to some extent, and are intersected by creeks along which alluvial flats of greater or less richness occur.

The slates are probably of silurian age, and from the nature of the diorites it would appear that they are traversed by planes which dip to the west at an angle of about 45° in the same direction as the slates, and this gives a somewhat stratified appearance to them. At one place, near a reef called "The Doctor's," the diorite is hard near the surface but soft underneath, which also favours the supposition that the beds are stratified, as alternate hard and soft belts of tufuceous rock and diorite—as at the Thames in New Zealand—and the same belt of country, with
somewhat similar characteristics, extends some miles to the southward, merging into serpentines, and proving gold-bearing throughout.

The veins in the diorite consist essentially of quartz, and in some cases they occur in the planes of the rock referred to, but cross-veins are also found upon fissures or joint planes intersecting the others at different angles. The quartz in the vein has a laminated appearance, and contains iron pyrites, galena, gold, and other minerals. The gold occurs in shoots which dip northward, the stone between these shoots being much poorer than that in them. Some of these shoots have been proved to be very rich, yielding as much as ten ounces to the ton of stone.

The veins of quartz vary from a few inches to three or four feet thick, and some of them dip on their strike (a peculiarity noticed before in Victorian gold-veins); they are formed both upon the planes spoken of as likely to be bedding, and also upon other planes that intersect these at various angles and are either due to joints or fractures.

The sections given (Fig. 31 and Fig. 32) are from two of the principal gold veins or reefs known as the "Muttama Reef" and the "New Year's Gift Reef," but as these two have approximately the same strike and dip in the same direction, as well as being nearly on a line with each other, although over a mile apart, they are most probably the same vein cutting across the country on a bearing of about N.S. with a general dip westward.

A most peculiar mode of occurrence is that of gold in serpentine in conjunction with asbestos. This is to be seen at Gundagai, some fifteen miles from Muttama, and is a continuation of the same belt of country just described. A vein of foliated serpentine exists in a diorite and serpentine formation, and between the leaves of this vein (for the lode readily splits into thin pieces or laminations) gold is found as thin gilding in patches sometimes as large as a five-shilling piece. I have split the leaves off with my knife quite easily and obtained the gold as described. Lumps of crystallized dolomite occur in the same vein, having the dog-tooth form of crystal, and veins of crystallized dolomite, carrying gold, intersect the serpentine wall in some parts.

A section of the foliated serpentine vein shows it to be divided into two parts differing in appearance from each other. Asbestos occurs near to this vein, and is said to have gold in it also.

Quartz veins also are found in the neighbourhood, and some of the gullies have been worked for alluvial gold with success.

Cross Section of Foliated Serpentine Vein (with pieces of crystallized dolomite) containing gold, is shown in Fig. 33.

At Solferino quartz veins occur that have been found to contain marvellously rich patches of auriferous quartz.
One of these I examined is in altered slate near its junction with a granite containing much black mica. It contains calcite as well as quartz, and in many places the calcite occupies the whole of the vein. Both the quartz and the calcite contain gold and iron pyrites with some galena, and often enclose portions of country rock. Some of the patches of auriferous vein-matter have given tons that yielded at the Sydney Mint as high as 600 ounces to the ton. Five tons of stone treated at that place gave over 2,600 ounces of gold. The lode, however, varies much in richness, the intervening quartz and other lode matter between the patches sometimes only equalling 5 dwt. to the ton. It also varies much in thickness from a few inches to about three feet, and it strikes across the bedding of the slate obliquely. The gold is chiefly in a free state, and the quartz has a bluish tint.

The Gold Veins of New Zealand.

The most important gold fields in this Colony are situated at Reefton and the Thames.

At Reefton, and within twelve miles radius from that town, a great number of reefs have been worked, some with good and others with unpayable results, and although the conditions have been somewhat similar throughout, the reefs themselves have varied a good deal both in size, productiveness, and distribution of the stone and gold. A sketch section Fig. 32a, across the field shows that several series of formations occur, in only one of which have reefs been hitherto discovered.

These gold bearing rocks, which are of lower carboniferous age, consist of fine grained silky slates, interstratified with sandstone and are folded into anticlinals and synclinals, the sides of which dip at angles of 60° and less from the horizontal, and they are traversed by dykes of diorite and reefs of quartz. The diorite, however, is seldom associated with the reefs themselves where worked, but the most productive country has been the slate band referred to.

Most of the reefs here are steep, underlying from 60° to vertical, and in one case at least, the Welcome Mine at Boatman’s, not only does the gold occur in shoots, but the stone itself is found under the same conditions. This mine has been worked to a considerable extent, some 500 feet in depth, and the quartz is frequently three feet in width, but pinches out in every direction and then makes again, a series of blocks of quartz occurring, which although following the same line are almost disconnected from one another, and there have been times in the history of the mine when neither quartz or gold were to be seen in the levels. Notwithstanding this fact, there is distinct evidence to
be found in the walls of the lodes, that movements have taken place, and consequently that they belong to the true fissure lodes. At the Thames some most instructive reefs may be examined, including both true fissure lodes and others, which will be mentioned further on.

Amongst the first class I may mention the Queen of Beauty, Caledonian, and Alburnia Reefs, as affording fair types of those which are worked.

Of these the Queen of Beauty Reef stands nearly vertical, and has been worked to a depth of nearly 650 feet. The country rock consists of tufaceous sandstone, which varies in character from the surface to the 600 foot level, but at that point a breccia comes in which is found cropping out on the surface in Karaka Creek.

The reef changes its underlay from north-west to south-east, and is intersected three or four times in the shaft which has been sunk. The yields from this mine have been more uniform in character than those from any other mine on the field, but even here there have been richer and poorer parts of the stone.

After the breccia was met with, although there was still gold in the stone, it was not sufficiently rich to pay the expenses of raising and treatment.

The Caledonian Reef, on the other hand, underlays at an angle of about 45° and has been worked in three claims: the Manukau, Golden Crown, and Caledonian, as shewn in the plan, Fig. 34a, taken from the plans at the mine.

One continuous shoot of gold was followed from the surface to the 400 feet level, at which point it was cut off, close to the boundary of Tookey's claim, a change in the character of the country rock coming in there.

Through the Manukau and Golden Crown claims a hanging wall leader was traced following the shoot of gold, and this appears to have aided the country in increasing the productiveness of the shoot in the reef.

In the Caledonian the shoot was considerably enlarged, as shewn on the plan, and there is a very interesting feature in the reef itself in that Claim, for instead of being one reef only, as in the upper levels, it splits into three bands, which form a net-work of veins as in the following sketch, which separate and come together, and while the average course of the lode is N.N.E., it is when the branches strike more nearly north-east that the best stone is found.

The sketches Figs. 33a and 34a are taken from Mr. S. H. Cox, F.C.S., F.G.S., Report on the Gold Fields of the Cape Colville Peninsula.

In the Alburnia Claim the reefs are standing at a steeper angle than in the Caledonian, but are not so steep as the Queen of
Beauty reef, and the following sketch, taken from the same source, will show the distribution of the richest parts of the stone.

It will be seen in this claim again that the richer stone is confined to certain belts of rock, but at the same time certain junctions of lodes occur along which rich deposits of gold have been found.

**South Australian Gold Veins.**

South Australia, including the Northern Territory, comprises a very large tract of country, inasmuch as it extends right across the Continent of Australia from south to north, being bounded on the east by Victoria, New South Wales, and Queensland, and on the west by Western Australia. Gold veins exist in many places throughout this tract, and comprise many of the different modes of occurrence of such veins, but much of the country is but partly known and very little prospected as yet.

In the hills about Adelaide, the capital of the Colony, quartz veins carrying gold occur and some of them are being worked; they exist in sedimentary rocks possibly of lower silurian or pre-silurian age, in various metamorphic rocks such as mica schist, &c., and dykes of coarse granite and other igneous rocks intersect the country. The quartz veins are somewhat similar to those of Victoria and N. S. Wales, a large amount of iron pyrites occurring in many of them.

One of the most interesting districts in the colony is that of Waukaringa and Tetulpa, and as a reefing country I am sure it will yet become much noted.

The country consists in that part of large open plains, covered with salt-bush, and having barren-looking hills as ridges crossing them. Highly tilted and partly altered sedimentary rocks comprise the formation. The rocks are possibly early paleozoic, and they become more and more altered as you travel eastward until they pass into mica schists. Along the ridges and across the plains are to be seen numerous quartz reefs intersecting the strata and continuing on their course for miles.

The fact that very little alluvial covers the rock on the plains, and that it therefore shews in many places quite bare, enables the quartz veins to be easily followed on their strike across the country. These veins are auriferous, and some of them have been and are being worked. One of these, called the "Alma Reef," is a large vein, having two parallel veins that sometimes run quite close to it, only a foot or so being between them, and at other places diverge from it to some hundreds of feet.

The Alma Reef can be traced for about ten miles across the country; most of the way it runs along near the top of a hill and its sloping continuation as a low ridge. At one place, where
worked, it has an underlay to the northward of about 30° from the horizontal, the strata dipping about 45° in the same direction. It carried most of its gold in the upper levels in a decomposed iron ore or gossan and in a ferruginous quartz of a very hard character. In the lower levels it ran into a solid highly pyritous ore. Other reefs in the same locality seem to be of a similar nature, while some of them contained a very large amount of galena and copper.

The thickness of the Alma lode was from about eighteen inches to four feet in the underlay shaft at the principal mine, but in other parts of its course it sometimes became even thinner than above, while in others it was over four feet thick; its underlay also decreased as it went easterly, the dip of the vein becoming greater from the horizontal. I have not, however, visited it for years, but I believe it is being worked at the present time.

At the Uooloo old alluvial diggings some nice alluvial gold was obtained. Large iron-stone reefs occur, and one of the leads was richest where a lode of this sort crossed it. The formation of the strata at this place is very peculiar.

Of gold veins in other parts of the world, those of the United States hold the greatest prominence, and the "Comstock Lode" is certainly the most remarkable auriferous one in that country, and one of the most remarkable in the world. It is situated in the State of Nevada, and occurs upon the side of a diorite hill named Mount Davidson. It occupies for part of its course a line of contact between diorite and diabase rocks, but further north is contained wholly in diabase, and to the south it just touches metamorphic rock on one side while being bounded on the other by diabase. It has been traced for a distance of over four miles in a nearly due N. and S. direction, and it dips towards the East at an angle of about 45° and has a general thickness of from 20 to 60 feet. The fissure upon which it has formed is a line of fault. Its vein matter consists of country rock, clay, and quartz, all of which have been much crushed, probably due to the moving of the walls of the fissure on each other. A great heat commenced to prevail in the lower levels of the workings on this lode, which were over 3,000 feet in depth, and I understand that this has so much increased of late that the miners are unable to work for any length of time.

This lode has yielded enormous returns, over $300,000,000 worth of bullion having been taken from it up to 1st June, 1880, and of this $175,000,000 was silver and the remainder gold; $115,871,000 of this had been paid in dividends.

Some very interesting investigations connected with metalliferous lodes have been made at these mines, to some of which I shall refer further on in my dissertation on the origin of quartz veins and other auriferous lodes.
The Bassick Mine in Colorado, in the United States, is certainly one unequalled for its peculiarities in any other part of the world. It consists of a hill of trachyte and felspathic conglomerate about 200 feet above the surrounding country. In this hill is an irregular fissure, elliptical in horizontal section, and about 100 feet long by 20 feet wide; it has been followed for over 800 feet downwards. The ore in this fissure is composed of concentric layers surrounding individual worn and rounded boulders of country rock. These boulders are from the size of small pebbles to two feet in diameter, and the ore that surrounds them is in three or sometimes four layers. The first layer consists of sulphides of zinc, antimony, and lead, with about 60 ounces of silver, and from one to three ounces of gold to the ton. The next layer contains more lead, silver, and gold than the last, — frequently as much as 100 ounces of gold, and 150 to 200 ounces of silver per ton. The third layer consists of blend, with from 60 to 120 ounces of silver and 15 to 50 ounces of gold to the ton. The fourth layer, when it occurs, is formed of chalcopyrite (copper pyrites) and varies much.

Near the centre of the deposit the boulders are larger, and the layers of ore thicken and contain more of the precious metals; but the boulders gradually become smaller, and the layers of ore thinner and poorer, as the sides of the fissure are approached, until they merge into a pebbly conglomerate in a felspathic base and from thence into the country rock trachyte.

The interspaces between the boulders are filled with quartz and tetrahedrite (grey copper ore), and this quartz has the appearance of being deposited from solution in a gelatinous state. Graphite occurs in cavities between the boulders. This deposit is thought by some to have been the site of a geyser or mineral spring carrying minerals in solution in its waters.

The El Callao Gold Mine in Venezuelan Guiana, is one of the richest in the world. It is said to be in felstone, containing pyrites, the quartz of which the gangue consists, being white occasionally tinged with green. I have examined specimens from this mine, and they are very similar to some of the stone taken from the quartz veins in the Australasian Colonies. From 1871 to 1879 a total quantity of 67,362 tons of quartz is said to have been crushed from this mine for a return of 252,973 ounces of gold; and in 1880, 18,624 tons of quartz for 54,013 ounces of melted gold.

The gold of the Ural Mountains is contained in quartz veins in such rock as diorite and serpentine. Deposits of gold are found enclosed in the country rock. The quartz veins in that place are said by the late J. A. Phillips, F.R.S., to be especially interesting on account of the influence exercised upon them by
ORIGIN AND MODE OF OCCURRENCE OF GOLD-BEARING VEINS.

The crystalline schists are traversed in the locality by dykes of finely granular granite, and it is said to be only in the vicinity of these that the quartz veins are found to be productive. The granite near the auriferous veins is impregnated with iron pyrites, which has become partially converted into brown iron ore. The average yield of gold from these veins is about 8 dwts. to the ton. The gold is accompanied by galena, grey copper, and other minerals, including native silver and bismuth ochre.

An essay on the peculiarities of gold veins would not be complete without mentioning those of Transylvania in Hungary. The most remarkable of the auriferous deposits of that part are to be found at Voeroespatak, and they may also be classed amongst the most remarkable and interesting in the World, and some of them have been worked for a period said to date back to the time of the Roman Empire. A description of the principal workings in Voeroespatak is as follows:—A Mount called the Csetatye, composed of a decomposed igneous rock probably propylite, is surrounded by tertiary sandstones of Eocene age. In this Mount a large lode formation occurs consisting of a perfect network of veins. These veins are of the character of true fissure lodes, and they pass out of the igneous rock into the tertiary sandstone, and are prolific in both. The sandstone in the near vicinity of the Csetatye Mount is much silicified and interbedded with tufa strata and conglomerates. Upon the top of the Mount is a large excavation made probably in the time of the Romans, and immense cavernous workings exist underneath. The lode matter thus worked consisted of a network of veins containing gold both in them and in the intervening country rock. These veins are said to have been nearly vertical and irregularly columnar; they consisted of quartz, calcite, and iron pyrites, and sometimes of diallogite, and contained gold in minute grains or in a crystallized state. Some of the diallogite veins are found at times perfectly permeated with crystalline gold, and when cut and polished have a beautiful appearance. Blende, tetrahedrite, and many other minerals are found associated with these veins, and the whole mountain is impregnated with metallic sulphides, chiefly iron pyrites.

The telluric veins (called locally "clifts") of this district are also remarkable as containing sylvanite, nagyagite, and other telluric minerals, with native gold, galena, blende, stibnite, pyrargyrite, and native silver, the principal gangue being quartz and diallogite. They are said to be richest in a slightly decomposed rock, but fall off in richness both when the rock becomes much decomposed or not decomposed at all. They exist principally in the igneous rock propylite, but segregation veins also occur in a
granular limestone in the same locality. Offenbanya and Nagyag are the names of the principal places where the veins are worked in the district. A slight difference exists between the gangue of the lodes in these two places, but otherwise they are essentially the same.

In 1873 no less than 416 Mining Companies are said by J. S. Phillips to have been at work in the gold districts of Transylvania, giving employment to 8,369 miners; and in 1877 this region produced 27,870 ounces of gold, and 20,108 ounces of silver, besides other metals.

Many other parts of the world have auriferous veins, but I believe sufficient examples have been given in this essay to embrace all the different and most interesting modes of occurrence at present known. I will, therefore, now proceed to the most probable origin of these various lodes and deposits, and the manner in which they have been formed.

Before doing this, however, I must devote a few lines to a description of certain special modes of occurrence of gold which appear to bear somewhat closely upon the origin of the reefs. The deposits to which I allude are instances in which rocks have become impregnated with gold.

There are several remarkable instances of this mode of occurrence of the precious metal, and every year brings to light fresh evidence of certain rocks being charged to a greater or less extent with it.

It has been known for some years that the granites of the Timbarra Gold Field, New South Wales, contain a certain amount of free gold, more especially where the granite is in a decomposed state, and works have been started to sluice away the soft portions of the rock. It has, however, been proved by assay that in a number of places in the same district the undecomposed granite also carries gold to the extent of several pennyweights to the ton, and I have seen specimens from there in which free gold was visible in the rock (granite), sometimes in good sized specks. I may also mention the Yal Wal Gold Field, likewise in New South Wales, in which district the rock impregnated is a slate.

The lowest rock of the district is granite, which rises in the spur of the hill west of the Danjera Creek, and may be traced for many miles through the country; and resting upon this, and standing at angles from 45° to vertical, a series of schists, slates, quartzites, and breccia occur, striking north and south, and dipping east away from the line of elevation. It is only in the softer belts of sedimentary rock that payable gold has yet been obtained, and the characters of the different deposits are very curious. The ore deposits vary from a few inches to 100 feet
in width, and gold has been obtained both in quartz veins, striking approximately north and south; in thin leaders which traverse the auriferous belts in all directions; and again in slates, which compose the entire mass of the ore channels in some parts of the ground. The claim, which is working on the widest of these channels, has saved £15,000 worth of gold since 1882, and the last 1,498 tons crushed yielded at the rate of 1\(\frac{1}{4}\) ounces to the ton.

In many cases the tufaceous rocks of the Thames (N.Z.) are impregnated with sufficient gold to make it worth while crushing them, and in the Waiotahi Mine especially the rock is frequently crushed for the gold it contains.

The gold-bearing character of the granite at Omeo, Victoria, has already been referred to. I would mention the fact that the late Rev. W. B. Clarke, F.R.S., was the first to call attention to this mode of occurrence of gold in his work entitled the "Southern Gold-fields."

Gold has also been found in lodes of antimony and bismuth, and also in veins of calcite; and it is known to exist in the Hawkesbury sandstones of New South Wales which are comparatively unaltered strata of Triassic age.

**The Origin of Gold-bearing Veins.**

In investigating the origin of gold-bearing veins or the manner in which they are most likely to have been formed, I think the foregoing notes have shewn that they have so much in common with other mineral lodes, as regards their actual physical peculiarities and the manner in which they occur in the rocks, that we may consider them to have been formed under very similar circumstances and are dependent to a great extent upon the same laws of nature for their modes of occurrence.

In seeking therefore to determine the most probable manner in which gold veins and other mineral lodes have been formed, it will be well first to mention some of the different theories that have been propounded on the subject, and after having briefly referred to the various arguments for and against each of these, to consider which, if any, have the best claim to be accepted as most applicable and best able to account for the various phenomena observed in connection with the occurrence of metalliferous lodes, and more particularly those in which gold is the most prominent metal. The various theories proposed may be classed under the following heads:

1. Igneous injection.
2. Sublimation.
3. Aqueous ascension.
4. Aqueous solution.
5. Lateral secretion.
7. Electrical currents.

The theory of igneous injection supposes that the quartz or other matrix of the veins or lodes together with the contained metals or minerals has been forced into fissures, cracks or cavities, caused in most cases by the same igneous force that injected the vein matter and that these having become solidified in the fissures, the lodes were thus formed. It therefore supposes the formation of veins and lodes to have taken place very rapidly and in close proximity to violent volcanic disturbance.

The sublimation theory considers that vein fissures were filled by the condensation of volatilized metals and minerals derived from some portion of the interior of the earth where intense heat prevailed.

The advocates of the aqueous ascension theory argue that the mineral waters containing the metals in solution have risen in fissures or cracks in the earth, and precipitated their contents upon the walls or sides of these fissures, (and in any cavities they could obtain access to) until they were almost or entirely filled with lode matter.

Those who support the aqueous solution theory believe that all the contents of mineral lodes were washed in from above.

Lateral secretion accounts for the formation of most veins and lodes by stating that the rock enclosing the lodes contains in itself nearly or all the constituents of the veins, and that these have gradually accumulated in the lodes in consequence of water dissolving various minerals and metals from the country rock, and then after filtering through the walls of the fissure redepositing all or some of them.

Molecular aggregation considers that the minerals and metals of the veins have collected together in a somewhat similar manner to that in which minerals collect together in the crystalline rocks, for instance like pegmatite in granite and the concentric layers in orbicular diorite.

Those who support the electrical hypothesis, say that both the formation of the fissures and the collection of the minerals in them could be produced by electrical action.

The advocates of each of these several theories have proved to a certain extent the possibility of veins of minerals being formed in accordance with their views, and interesting have been the experiments made to support their arguments. Magnetite for instance has been formed by sublimation in reverberatory furnaces as well as in volcanic fissures, and Daubrée succeeded with the aid of flourine in forming tin ore, oxide of titanium, and quartz by sublimation. Durocher passed gases and metallic vapours into heated glass tubes and obtained crystals of blende, iron pyrites,
galena, sulphide of silver, sulphite of antimony, and sulphate of bismuth. Electricity is shown to be capable of creating fissures and filling them with metals by an experiment made by Mr. R. W. Fox, who produced fissures in clay and filled them with metallic substances by means of electrical currents generated artificially.

Water under heat and pressure has been shown to dissolve or decompose certain minerals and redeposit their constituents or some of them in other mineral forms.

Fissures are known such as the Steam Boat Springs, about fourteen miles from the Great Comstock Lode, that are in the actual process of being filled with a deposit from heated water and vapours. Veins of crystallized mineral have been found in cracks in the masonry in the bottom of a furnace, either through injection of the metals composing them in a molten state or by sublimation, and every one with any chemical knowledge knows how metallic compounds can be produced in the laboratory by precipitating metals from solution, and how these may be redissolved and deposited again in other mineral forms.

Many believe that lodes have been formed under all or most of the various conditions described, and that no particular one can be made to account for all the phenomena observed, and it is quite likely that such has been the case to a certain, but I believe only to a limited extent, and that most modes of occurrence can be accounted for by the theory of lateral secretion, combining with it the probability that the minerals have not in all cases been deposited at the very spot at which they entered the fissures, but may in some instances have been carried by circulating currents for some distance before being precipitated. This will allow the theory of ascending water holding metals in solution to be sometimes, but not necessarily always the one by which the metals or mineral matter have been conveyed and lodes formed.

As regards the auriferous lodes of Australasia and other parts of the World, they certainly do not in my opinion bear any sign of igneous injection, for not only does it seem impossible for such a complete ramifications or network of quartz veins, as commonly occurs in rocks in our gold fields, to have been formed by the injection of molten matter, but deposits of quartz and ore are found completely separated from any other lode or vein, and show no inlet through which molten matter could have found its way. One would naturally also expect to see some evidence of intense heat in the baking or hardening of the sides of the fissures, as may be seen where sedimentary strata are in contact with igneous rocks, such as dykes of dolerite or other rocks of volcanic origin, which have been at one time in a highly heated state.

The sublimation theory is also met by somewhat similar difficulties, as to the way in which metals could reach such places
as we often find them in, and we should moreover expect to find, were this theory correct, that all veins become richer in character the deeper they are worked. I need hardly say this is not universal in the history of our mines.

Having, however, done away with the igneous injection and sublimation theories, as regards the mode under which the greater number of mineral lodes have been formed, and having endeavoured to show their entire inapplicability to the quartz veins of Australasia, I think before seeking to prove that lateral secretion or any other mode is best applicable to auriferous lodes, I should try to account in the most reasonable way for the forming of these fissures or openings in the rocks, that afterwards became filled with the materials of which the lodes consist, for as I have put injection aside, which considers the containing channels of the veins and lodes to have been formed for the most part about the same time as the injection of the molten vein matter, no other theory, unless it be that of molecular aggregation considers these channels were not already open to some extent before the deposition of the vein matter commenced.

As true fissure lodes may generally be seen to have been formed upon a fault in the country, the origin of such channels is at once apparent, and can be seen to have been caused by a violent rending of the rocks, making immense cracks in them, generally independent of all natural planes. These cracks may be opened either by tilting of the rock on both or either side, or through the walls sliding on one another, or by a separation of the walls to form a gaping fissure. In the second case the opening for the lode matter may be brought about in the manner shewn in diagram, the irregular line being the crack before it has opened to any extent, and the other diagram showing how it would appear after the walls had slid on each other in opposite directions, and it will be seen by this how veins formed in such a manner must be of irregular thickness. Fig. 10 also gives an illustration of how veins may be formed by the sliding of the walls of fissures on each other, caused by the depression of a portion of the country rock.

This disturbance of the rock, leading to such fissures being formed, may be due to one of two causes. 1st. A sinking of the strata in a certain place while another portion remained firm would lead to the formation of a system of cracks or fissures. 2nd. The intrusion of an igneous rock would act in a similar but more violent manner.

In both cases fissures would be formed, but in the former the action being possibly slower, the fractures would be most likely to follow natural planes in the country rock, and hence the instances in which we find systems of veins coinciding with and
often crossing each other in the bedding and joint planes of the rock.

The folding of strata into anticlinals and synclinals may also lead to fractures somewhat similar to those which would be formed by bending a piece of iron or wood, and this may cause such cavities or fractures as those that contain the saddle reefs at Sandhurst in Victoria.

I have very little doubt that many fissures are increased in size by the circulation of subterranean waters, and are sometimes worn into irregular cavities and openings that are afterwards filled with ore, and it is also quite likely that such chambers and pockets as seem to have no inlet or outlet, may have been excavated by the action of solvent waters that carried away the minerals through the pores of the country rock, and the reason for believing this to be the explanation of such cavities will be seen further on when I treat of lateral secretion.

The theory that veins have been formed by a molecular substitution and aggregation of minerals like pegmatite veins in granite, must terminate with the fact that such veins have not smooth and regular boundaries like the wall of lodes, but gradually merge into the adjoining rock, large crystals of felspar often occurring, part in the vein and part in the granite.

The idea held by some that veins of quartz and lodes in general have been formed upon natural planes in the slightly open or fractured rock, and that the included mineral has by its expansion during crystallization forced open the cracks, and by repeated action of this sort quartz veins or other kinds of lodes of various dimensions have been formed, can only be held on the supposition that the lodes were formed very near the surface, and do not extend to any depth.

Experience has proved, however, that we have as yet no right to limit the depth at which lodes may be formed in any way whatever, as quartz veins and other lodes are worked for over 2,000 feet below the surface, and certainly extended at one time for thousands of feet above where the surface now exists, and have by being broken up, together with the containing rock, supplied immense alluvial leads, as in Victoria and elsewhere.

The faulting and heaving of lodes by others which have been subsequently formed shows that intense action has occurred, and to think that the expansion due to crystallization of silica or any other substance, could move a mass of rock even 2,000 feet thick cannot for a moment be entertained.

It is a noticeable fact that mineral lodes are in districts in which the strata have been broken through by the intrusion of igneous rocks or by other means, and that this is always the case.
FILLING OF VEINS.

Having adopted the theory of lateral secretion to account for the formation of most metalliferous lodes and of auriferous quartz veins in particular, let us consider what action must have taken place in nature to render such a theory comprehensible and legitimately entitled to be taken as the most feasible method of accounting for the various phenomena connected with lodes and veins. Lateral secretion supposes that the following actions may have taken place because they are in accordance with experiments and observed facts.

1. That water containing carbonic acid and other solvents is capable of dissolving all minerals and metals, and when the temperature is high this solvent action is greatly increased.

2. That such waters will retain these metals and minerals in solution until a change of condition causes the re-deposition of all or some of them, and it also affirms:

3. That certain, non-metallic minerals have been proved to contain the metals we find in lodes and veins, and that these minerals frequently occur in the rocks which contain lodes or ore in close proximity to them.

4. That the metalliferous contents depend to a great extent upon the containing country rock, and that lodes and veins are generally richer in certain metals when they occur in or close to rocks that are largely composed of the minerals that contain such metals.

5. That water is capable of dissolving most if not all minerals to a greater or less extent, may be taken as proved, for all natural water contains some mineral in solution. It has also been ascertained by actual experiment that water will act upon certain rocks and clays when the conditions of pressure and temperature are varied so as to effect a re-arrangement of the elements to form fresh minerals, and the structure of the crystalline rocks of the granite type, affords evidence that they have been transmuted or changed from sedimentary rocks under the action of water at great depths below the surface where the temperature would be high and the pressure great.

6. That the mineral waters of our mines even at a low temperature contain metals in solution is most certain, as analyses have proved it to be the case, and that they deposit their metals combined as minerals is also known. Organic substances are frequently found silicified in our veins and alluvial leads and such minerals as marcasite and siderite formed.

It is also strongly worthy of notice that the quartz and other matrices of metalliferous veins, and the metals and minerals associated with them, are often found in the lodes in separate layers parallel to the walls of the lode or to each other, and having all the appearance of being deposited consecutively as from mineral waters.
or vapours carrying their constituents in solution. The laminated quartz veins and other auriferous lodes of Australasia give numerous instances of this phenomena, and not only does the quartz or other matrix have a laminated appearance, but the gold, iron pyrites, and associated minerals occur continually in seams parallel to the walls of the lode or vein, and between the layers of quartz are often found very thin leaves of a kind of slate (mostly chlorite slate). Flucans or slickensides sometimes exist between the lodes and their walls. Amongst other instances, given in this essay, of laminated lodes may be mentioned the Marshall McMahon Reef at Murrumburrah, New South Wales, the Mount Morgan lode in Queensland, the Catherine Reef at Clunes in Victoria, the St. Patrick and Rainbow Reefs at Charter's Towers, Queensland, and the Bassick lode in Colorado, United States; this last being a most remarkable instance of consecutive deposition of minerals, and if we depart from auriferous lodes to those worked chiefly for other metals or minerals the instances of laminated veins are innumerable.

In connection with this it will be well to refer to Mr. Wilkinson's experiments on the deposition of gold from solution in the presence of organic matter, and without quoting these experiments which may be seen detailed in Locke's book, entitled "Gold," attention should be called to the fact that they conclusively prove that gold can be precipitated from solution in the presence of organic matter by either pyrites, antimony, or several other minerals.

It is of course well known that gold is present in sea water in small quantities, and it must consequently be inferred that many of the subterranean streams of water also carry gold in solution.

Mr. Skey has stated that he obtained the same results as Mr. Wilkinson, even when no organic matter was present in the solution, and ascribed the action to the formation of a voltaic pair between the pyrites and gold. Both these gentlemen have applied their observations to account for nuggets in the alluvial deposits, but the information given appears to me of much greater value in accounting for the occurrence of gold in veins situated in the internal laboratory of the earth.

The Hot Springs of New Zealand which deposit silica as a sinter, and the Steam Boat Springs in America which are gradually filling up fissures with silica containing metals which are precipitated from heated water in course of circulation, are instances of what water can do in this respect.

That the contents of lodes and veins are influenced by the rocks containing them has not only been held by scientific men, but also recognised as an axiom by the practical miner in his prospecting and working of lodes and veins.
Certain formations and classes of rock are associated with certain metals, for instance, granite with tin, clay slate with copper, quartz porphyry with silver, and limestone with lead, and although such an arrangement has been shown to have many exceptions, these, only tend to prove the rule.

It is well known how the tin, copper, and lead lodes of Cornwall generally alter the leading metals when the formation changes, and we have ourselves seen how gold veins form no exception to such a rule, but not only generally occur with certain rocks, but also depend for their richness on the different belts of country they pass through,—the same lodes being always poor in one kind of rock and richer in another in the same district.

The Charters Towers reefs in Queensland, and others mentioned in this essay are instances of such influence being exerted by different rocks on lodes.

It may be considered as a fact that the rocks that are associated with auriferous lodes are principally those that contain magnesian minerals—such as hornblende, olivine, augite, and biotite,—all of which abound in those rocks that contain or are in close proximity to gold veins; and this is not only known to be the case in Australasia, but seems to be so elsewhere.

As to those minerals that are found in conjunction with gold in veins, iron pyrites is by far the most common, after which come galena, zinc blende, arsenical pyrites, and copper pyrites. None of these, however, hold such a prominent place as iron pyrites, in fact, most of the gold found in our veins is either in iron pyrites or was in it before the decomposition of the pyrites set it free.

Iron pyrites exist in many of our rocks to a great extent; granites and other rocks that are commonly associated with our mineral veins are often largely impregnated with it, and where gold is found disseminated through such rocks, it has doubtless been chiefly derived from the pyrites.

It will be clearly seen, therefore, how lateral secretion accounts for the formation of auriferous lodes.

That mineral waters have dissolved the metals contained in the rocks adjoining the lodes or close to them, and re-deposited the same in the veins, seems most feasible, and more in accordance with observed facts than any other theory that has been advanced. Of course, such deposits as dyke lodes or ore channels may be formed either by lateral secretion or igneous injection, so far as the main body of the lode is concerned, but the metalliferous parts of the lodes are generally veins of quartz or some other matrix, and these have been formed in the dyke or channels by the process of lateral secretion in every instance, whether the main body of lode was so or not. If metals are found as well in other
portions of a dyke, they are of the nature of impregnations, and may either be contemporaneous with the rock itself, or afterwards deposited there by infiltration of mineral waters.

In the Comstock lode, not only has the country rock been proved to contain in its minerals all the matter found in the veins, but also the gold and silver are in the same proportion to each other in the rock as in the veins. The decomposed portions of the walls of the lode have not the same amount of gold and silver in them as the undecomposed, and sufficient decomposition of the walls is said to have taken place to account fully for as much matter as is found in the veins, by supposing such to have been derived from the decomposed parts.

The intimate association of iron pyrites with gold has been already referred to, and the fact that in the lower levels of our gold mines, the larger proportion of the gold occurs in this mineral has been shown. This will not appear so remarkable when we consider that nearly all metals are found as sulphides in the lower portions of metalliferous mines, in other words, in those parts that are least altered or decomposed, and appear to have retained to the greatest extent the original state in which they were first formed.

As to whether gold ever exists in a sulphide form in the pyrites is not known, although some experiments seem to imply that such is probable, but the sulphide of gold being a most unstable compound, renders it exceedingly difficult to determine whether it ever exists in nature in that state. It is certain, however that iron as a sulphide is the most usual associate of the precious metal, and therefore, if these two, iron pyrites and gold, are deposited from solution in the veins and lodes, they must be precipitated together by the same agent, or one is the precipitant of the other. Experiments in the laboratory have proved that sulphate and sulphide of iron will precipitate gold from a solution of chloride of gold. Quartz also may be produced by a heated solution of carbonic dioxide decomposing silicates and depositing the silica on cooling.

Noting such facts as these, and then taking into consideration the intense heat, great pressure, and other known and unknown agencies that must be at work in the internal laboratory of the earth, it seems that there are good grounds for believing in the strong probability of most of our metalliferous or mineral veins, and lodes, being deposited from mineral waters that obtain their contained metals and minerals from the country rock through which they percolate, by the strongly solvent powers they possess under certain conditions; conditions that are at present only partly guessed at and may never be fully understood practically, but always remain as theories, although based on strong circumstantial evidence.

View This Item Online: https://www.biodiversitylibrary.org/item/131307
DOI: https://doi.org/10.5962/p.359031
Permalink: https://www.biodiversitylibrary.org/partpdf/359031

**Holding Institution**
Smithsonian Libraries

**Sponsored by**
Biodiversity Heritage Library

**Copyright & Reuse**
Copyright Status: Public domain. The BHL considers that this work is no longer under copyright protection.

This document was created from content at the Biodiversity Heritage Library, the world's largest open access digital library for biodiversity literature and archives. Visit BHL at https://www.biodiversitylibrary.org.

This file was generated 17 September 2023 at 03:52 UTC