NOTES ON THE MOUNT LYELL MINE.

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The western coast of Tasmania possesses but few indentations that can serve as reasonable harbours. Of these the most important one, commercially speaking, is Macquarie Harbour, on which is situated the port of Strahan. The country north of Strahan was subject to enormous fluctuations of level during early Silurian days, and deep seas alternated with wide, but shallow, lagoons, which in time rose into rugged hills, only again to disappear beneath the waters and lose their identity under the mud and pebbles that filled up the depressions and levelled the sea floor as with a smoothing iron. The mud and silt brought down by the ancient rivers, hardened into clay, slate, and schist, the pebbles were cemented into the ubiquitous conglomerate; the blanketed sea floor, unable to lose its heat by radiation, sank deeper and deeper, causing the crumpling and upheaving that led to the last cycle of mountain-building, and the general configuration of the country became perhaps something as we now see it, though no doubt much lowered and scored, as well as filled up, by erosion and glacial action. Let us for a moment go back to a period just before this last upheaval, and imagine a shoal pond or series of ponds nearly filled with the pebbles brought into it by the foaming rivers of that period, and undergoing, in common with the region surrounding it, a slow subsidence, say something like the coast of Norway at present, which I believe amounts to a considerable number of inches in a century. Owing to causes that we have no time to consider, the roaring mountain torrents were diverted or suppressed, and were replaced by more sluggish and feebler streams, that flowed through extensive bands of a schist rock before entering our chain of ponds. This belt of schist contained then, as it does still, specks of sulphides of iron and copper—pyrites—scattered through it, and although the amount of these sulphides in a single cubic yard of the rock was very small, yet their aggregate in even a single quarter of a mile of the belt was enormous, as can easily be determined at the present day. Pyrites, under these conditions, decomposes very rapidly, and forms soluble sulphates of iron and copper, whilst a considerable proportion of any silver that may be present is also dissolved by the waters of the stream. Even gold will go into solution to a minute extent, especially if the waters of the stream contain a little chlorine. This extremely dilute "mineral water" enters our pond, or ponds, through many different little trickling rills, and we can easily imagine the flow to be so slow, and the evaporation from the extensive surface of shoal water to be so great, that the solution is perceptibly concentrated in its sluggish passage toward the outlet of the chain of lagoons. The evaporation might even equal the supply, in which case we should have a "great salt lake," with a decided admixture of the metals referred to above. But there are no evidences to warrant any such conclusion, whilst there are strong grounds for believing that the amount of salt in the water was not only very small, but that the lakes had an outlet. But a new element must now be introduced, without which I fear that the wealth now locked up safely in the Mount Lyell mine would have quietly flowed out of the ponds exactly as it went into them, and eventually have gone to augment the metallic contents of the oceans. In most parts of the world, though apparently very rarely in Australia or Tasmania, nearly any local geologist could point out to you a swamp or peat bog into which streams discharge that have percolated through slate or schistose rocks carrying pyrites. If you watch carefully at the point where the sluggish, acrid waters of the stream begin to mingle with the black, peaty liquor of the bog, you will find fresh bright crystals or nodules of iron pyrites. Select a blade of grass or stem of a plant that has a little bunch of these crystals hanging to it, and after counting them and drawing an exact sketch of them in your notebook, return in a month and investigate again. If the conditions are favourable, you will not only find many new crystals, but a great augmentation in size of the original ones. This is without question the key to the formation of Mount Lyell and all similar pyrites deposits, and it is almost universally accepted as such by those who have given the subject attention. I myself feel no doubt in the matter. Organic, peaty acids have this power of reducing soluble sulphates of certain metals to insoluble sulphides, and precipitating them *in situ.* If it is done very slowly, the metals will be thrown down in a more or less crystalline form. If rapidly, in an amorphous and massive form. The subsidence of the land, and the consequent filling up of the ponds with sulphides, continued through many hundreds or thousands of centuries. But at last came a time when the elevation of a ridge, or some change in the configuration of the country, the supply of metallic waters was cut off from our pond-holes, or, more probably, lost in the inundation of muddy waters that blanketed all this region with a thick layer of hydro-mica-schist, and the sulphides disappeared from view, to undergo, under its heavy covering of mud rocks, the changes and metamorphoses that time and heat are sure to bring about. Successive layers of pebbles, of sand and of other *debris* buried our hydro-mica belt, till at last came the final act in the great drama, and the stage was set for the last act, the period which we now see. This last shifting was, perhaps, the most striking and dramatic of any of the various scenes that I have endeavoured to portray, and furnishes us with many interesting and obvious details, that if I could only dwell upon would tend greatly to prove the correctness of the theory here advanced, as well as to explain many interesting, and apparently difficult, details that we now notice in the deposit. This was the last period of mountain building, in which the present great elevations were reared, and the strata between them were dislocated and set on edge. Wherever a break happened to come across one of our bog-hole deposits of sulphides we are enabled to find and utilise them. But the chances are infinitely against such a piece of good fortune, and no doubt dozens of such pyrites masses are buried unsuspected under the rocks that we daily walk over in the vicinity of Lyell, some of them hundreds of thousands of feet from daylight, and others, quite possibly, within a few feet of our unsuspicious boot soles. I can only compare it to a flat cake, containing a very few plums scattered through its interior. Let us break this cake across in two or three places, and set the fragments up on edge in a plate. Out of the dozen or more plums that our supposititious cake may contain, we may, perhaps, bring one or two to light, and in the same way nature and accident have opened to us such deposits as those under consideration. Many other deposits, equally good or better, may exist in close proximity to the single one or two that happen to be brought to the surface by the breaking and tilting of the strata, but nothing betrays their presence, and unless we find them by deep boring, or by running prospecting tunnels at a venture, their wealth will remain wasted to us. Let us assume, therefore, that the strata have been broken across in such a manner that the line of fracture comes across one end of our bog-hole, now filled with pyrites, and deeply covered by other strata of rocks. Let us further assume that the fractured strata are next tilted so that the exposed end of the sulphide body comes to the surface, and the whole mass of pyrites, instead of lying in its original horizontal position, is now standing on edge, so that what was originally its depth is now its thickness, and what was once its lateral extent is now its depth. This is the present condition of the Mount Lyell mine, and, bearing this in mind, it is possible to form some slight opinion as to its probable extent in depth. Take any ordinary lagoon, or shallow swamp-hole, and we may say in a general way that its length or breadth is many times its depth. An ordinary shoal pond of this kind might be perhaps 10ft. deep, and certainly 500ft. to 5,000ft. in length. And if it were 100ft. deep we should expect its length and breadth to be very considerable. But the Mount Lyell mine had an original depth—present width—of over 300ft., so that we may reasonably expect that it will continue in depth—former horizontal extent—to a distance far beyond our powers of penetration. The experience of such mines all over the world bears out these theories to perfection, and I cannot, at present, recollect a single large body of pyrites that has "played out" in depth. The 200ft. tunnel in the Mount Lyell mine shows that at this depth the deposit is thicker than at the surface—a plain indication that we are as yet working at or near to its upper edge, for it is likely to go on increasing gradually in thickness until the centre of the former swamp-hole is reached, after which it will gradually grow thinner, as the pond shoaled towards its farther bank. The filling of an ordinary pond will usually give us a more or less lens-shaped body, and it is a notable fact that this is so commonly the shape of these deposits that they are often called "pyritic lenses." While this great body of sulphides was deeply entombed under hundreds of feet of more recently formed facts, it is probable that but few changes occurred within itself, as air and water, the two great agents of decomposition, were practically absent. But as soon as one edge of the deposit was raised to the surface, the unceasing action of these powerful agents began, never to entirely cease until every particle of sulphides in the entire deposit have been modified up to their highest possible pitch of oxidation and hydration. In the case of iron pyrites this final stage is a hydrated oxide of iron, or frequently a hematite. The copper of the pyrites, being easily changed into a soluble sulphate, is soon dissolved and carried away by water. With these facts in mind, let us examine the present upturned edge of the deposit at some point where it has not been covered by gravel and *debris* rolling upon it from the hill above it, and see how actual results correspond with our theories as to what *ought* to take place. Here we find, just as we should expect, an immense mass of oxide of iron, partly hydrated and partly non-hydrated. It contains no copper—copper as I have explained being so extremely soluble that it quickly disappears in a wet climate—the silver veins, is, on the whole, increased. The latter phenomenon may seem peculiar at first sight, but it is strictly as we should expect from our knowledge of the properties of this metal. Gold is almost insoluble, whilst copper is extremely, and iron slightly, soluble, as sulphates, and the sulphur itself all disappears by oxidation or solution. Hence from the mere change of the sulphides into an oxide, we have a decided diminution in weight, and a consequent concentration of the gold. But a still more potent agent assists the enrichment of this surface ore, or gossan, in gold, especially very close to the surface. This is the removal of oxide of iron mechanically in minute particles, either as a dry dust, by the wind, or more deeply by the trickling of drops of water through the easily permeable gossan, and the mechanical removal of particles of oxide of iron as fine scum, to be deposited, perhaps, a few feet further on, as a bed of iron-ochre or iron-sinter, entirely free from gold. Plenty of such material is found near the surface of this and similar deposits. Thus certain portions of the gossan lose all their copper and sulphur, and much of their iron, and having lost 2 3rds to 5-8ths, or perhaps even 19-20ths of these elements, become correspondingly richer in gold. The accuracy of this explanation is very curiously and beautifully attested by the presence of a substance that I have not yet mentioned, but that exists in the Mount Lyell mine ore to an extent so minute, to be sure, that only chemical analysis assures us of its presence, but that yet does exist in every pound of sulphides in the entire deposit. This is the well-known mineral heavy spar, or sulphate of baryta, a common enough gangue-rock in many regions, and one that is always dreaded from its stubborn and infusible character. In the average ore of the Mount Lyell mine there is too little heavy spar to have any perceptible effect upon the metallurgical treatment of the ore. This mineral is absolutely insoluble and undecomposable under any ordinary conditions, and thus during the oxidation and removal of the sulphur, copper, and part of the iron, the heavy spar remains behind together with the gold and the rest of the iron. If you will take the trouble to examine an average sample of the Mount Lyell gossan, you will find that instead of containing, as does the ore, about 2 per cent. of heavy spar, this mineral has risen to 30, 40, or even 50 per cent., whilst the iron has diminished accordingly, and the gold has increased from 3dwt. to 20dwt., 30dwt., 40dwt. or more. Surely no prettier harmony between theory and fact could be asked for. There is little more to be said about the rest of the deposit. As already explained, it is a great lens-shaped mass of mixed iron and copper pyrites set slantingly on edge, with its upper edge slightly decomposed on the extreme surfaces. Its average width may be regarded as 300ft., while it has been followed for about 1,000ft. in length, and about 300ft. in depth, at which point it is gradually widening. After getting a few feet from the wall-rock, and fairly into the deposit, the pyrites is so pure and massive, that in four months' residence at the mine I never saw a fragment of gangue rock as large as a cherry. The average composition of the unaltered ore is about as follows:—

Iron pyrites	83 per cent.
Copper pyrites	14 ,,
Heavy spar	2 ,,
Silica	1 ,,
Total	100

And the average contents of the ore in the valuable metals, throwing off enough to cover ordinary losses, is

Copper	4½ to 5 per cent.
Silver	3 to 4oz.
Gold	2½ to 3dwt.

Although the ore is simply an ideal sulphur ore for the manufacture of sulphuric acid, not only containing 50 per cent. of sulphur, but also being an almost perfect burning ore mechanically speaking, the company will be obliged to forego this advantage for the present. For the new process for making soda has so injured the acid market that pyrites ores are simply a drug, even if it would pay to transport the Lyell ores to the coast, and thence to England. To make acid on the spot can of course not even be considered, as there is no market for it at home, and the cost of the very lowest freight to a market would be about twice and one half the value of the best acid. I need hardly say that the treatment must necessarily be the amplified form of the old blast-furnace method, *i.e.*, roasting in stalls under cover, smelting the roasted ore for a matte containing the copper, silver and gold, blowing this matte up to a 96 per cent. pig-copper in Bessemer converters, shipping the pig-copper to England, where the gold and silver will be separated by electrolysis, which consists in dissolving the pigs of copper in weak sulphuric acid at one pole of the battery, whilst chemically pure copper is re-deposited at the other pole, and the gold and silver fall to the bottom of the tank as mud. To institute a business commensurate in importance to the site of the deposit, and the magnitude of the entire scheme, 1,000 tons of ore daily should be treated, yielding, say—

50 tons copper, worth £44 per ton	£2,200
3,000oz. silver, worth 2s. 6d. per oz.	375
3,000dwt. gold, worth 4s. per dwt	600
Making a daily output of	£3,175

This paper is not intended to touch at all upon the commercial aspect of the mine, and I only mention these few facts, that have already been made public in my report, for the satisfaction of those who cannot understand how such low grade ores can be made to pay. I cannot possibly go into details of cost or treatment of the ore, but to furnish a clue to those who may desire to make their own calculations, I will state that the one important item of cost in the entire treatment is the cost of smelting the ore. The mining will be done by open quarrying for 20 years. The stall-roasting of similar ore has not cost me 1s. per ton any time in the past 16 years—reduced to Tasmanian wages and conditions. The bessemerising and remaining operations come solely on the matter, so that they are reduced to a very small sum for each ton of ore, but the smelting comes on the original roasted ore, and is always the heavy expense. A modern water jacket will put through 100 tons of ore daily, per 24 hours, will require five men per shift, and 1 ton of coke to each 7 or 8 tons of ore. As the company possesses a water power far beyond the needs of all its machinery, very little need be added for blast. From these rough statements it will be seen that even the smelting cost need not be very alarming, when executed on this large scale. To return to our proper subject. There is yet one point more that I have to speak of, and it is in this point that the Lyell mine is unique. In all points—except its unusual richness and width—it is almost precisely like scores and hundreds of similar pyrites deposits in other parts of the world. All have the same decomposed gossan on top, except where glacial or other causes have scored them clean. All are richer in gold above than in pyrites below, and all that contain gold invariably run into pyrites in depth. All, or nearly all, have the same sinter and iron-ochre amongst the gossan in places that makes inexperienced people regard them as geysers or hot springs, when in reality this phenomenon is simply a secondary metamorphosis of the gossan. I have even been told that some geologists have pronounced these characteristically aqueous deposits as volcanic, and the heavy spar a result of sublimation. But I am not willing to believe this, for surely every geologist knows that heavy spar is one of the few substances that are absolutely non-sublimable, and can only be formed by aqueous solutions, whilst iron pyrites is bi-sulphide; that even if there were no air present to roast it, would at once lose one atom of sulphur on the slightest approach of heat, and become a mono-sulphid magnetic-pyrites, whilst the sublimed sulphur would be deposited in the crevices of the rocks. But it is as idle at the present day to argue in favour of the deposition of these deposits by the means I have described, as to waste time in trying to prove that the earth moves around the sun. Everybody who is familiar with these deposits—and they are amongst the most common in many countries—is agreed as to their method of formation, and instead of their being unique, as I have heard one or two people call them, Mount Lyell and Mount Morgan, and similar deposits are the commonest and best known class of mines that we have. The infinitesimal extra percentage of gold that they happen to contain gives them an enormous commercial interest, but, geologically-speaking, they are almost too common and their mode of formation too well understood to be interesting. Where their wall rocks contain much felspar there are sure to result great beds of kaolin from the action of the decomposing sulphides upon the same. I have never seen or read a description of Mount Morgan, but after hearing of the rich gold in hematite and beds of kaolin I am as certain of the existence of pyrites below as though I had seen it uncovered. Either of these two points prove the existence of sulphides below. The single unique feature that Mount Lyell can show is the existence of a very extensive mass of very solid oxide of iron, containing about as much gold as the pyrites, but free from silver or copper. As it is evident that this ferruginous mass was derived in some manner from the pyrites it becomes interesting to learn what can have become of the large amounts of copper and silver that belong to this mass of half-a-million tons or more of iron. Recent explorations at a depth of 250ft. seem to have solved this question. For at this point, on getting under one corner of the mass of iron-stone on the foot-wall of the deposit, a series of shoots of argentiferous copper pyrites have been discovered and worked, that are, I think, unparalleled for their richness in the history of these low grade ores. The massive copper pyrites is sometimes 6ft. or more in width, and not only carries some 600oz. to 800oz. silver per ton, but is filled with grains, nodules, and masses of pure sulphide of silver—87 per cent. silver—sometimes as large as a cocoanut, and increasing the bulk value of the ore to something like 2,000oz. per ton. Over 100 tons of this ore have already been mined and shipped, and we have every reason to believe that we are only on the edge of the deposit. I mention this peculiar feature of the Mount Lyell mine more to explain how it is that a deposit consisting of such low grade ore as I have been describing can ship such extraordinarily rich material as the Mount Lyell is known to be now doing, than because it has any bearing on the "genesis" of the deposit itself. As you see, this rich ore is quite a secondary affair, and has no bearing on my subject. This completes all that I have to say in this brief paper. I must apologise for its fragmentary and unsatisfactory form. But I have been forced to write at sea, and in the intervals of more serious labours. I can hardly imagine a more interesting subject for an enthusiastic student of the natural sciences to investigate than this very Mount Lyell mine, for there are many minor, though extremely interesting and important, points yet to be investigated that I have not even touched upon.