ART. XXVII.—*Notes on the Grass Valley Gold-mining District;* by Prof. B. SILLIMAN.

GRASS VALLEY DISTRICT has obtained a well-earned celebrity as the most prosperous of all the gold-quartz mining districts in California. Quartz mining was begun here as early as 1850, and has been continued with, on the whole, a steadily increasing success, to the present time.

It is difficult to obtain exact statistics of the total product of the Grass Valley quartz mines, but it is believed by those best able to form a trustworthy opinion on this subject, that the product in 1866 was probably not less than $2,000,000, while for the whole period from 1851—say fourteen years—it was probably in excess of $23,000,000.

Wm. Ashburner, Esq., in his remarks on the gold mining interests of California, in J. Ross Brown's Report on the Resources of the States and Territories west of the Rocky Mountains, speaks of the Grass Valley region (page 46) thus:

When we consider the richness of the veins, the length of time some of the mines have been worked, and the amount of gold annually produced, the most important quartz mining region of California is, without any doubt, that of Grass Valley, in Nevada county. Here mines have been worked uninterruptedly since 1851. It is true there have been periods when the interest was more than usually depressed, and several of the mines, which are now regarded as among the best, were thought to be exhausted and were abandoned for the time being, but in many instances where work was resumed new bodies of gold-bearing quartz were opened up, which proved rich and valuable. The veins in this district, and particularly those which have been most productive, are noted for their narrowness, as well as for the richness of the quartz. They are encased in a hard metamorphic rock, and the expenses of mining are, as a general thing, higher here than anywhere else in California, amounting as they do in some instances, to from $20 to $26 per ton. Within the last fourteen years the total production from the quartz mines of Grass Valley District has been not far from $23,000,000. The most prolific vein has been that situated upon Massachusetts and Gold Hills, which alone has produced more than $7,000,000 worth of gold during this time, from a lode which will average only a foot or fourteen inches in width.

The gold bearing rocks at this place are mostly highly metamorphic schists or sandstones passing into diorite or greenstone syenite. These greenstones seemingly crystalline, are probably only highly altered sedimentary rocks, containing a large amount of protoxyd of iron with sulphuret of iron. In some parts of

the district, slaty rocks occur, more or less talcose or chloritic in character; masses of serpentine also abound, forming at times one wall of the quartz veins. This serpentine is probably metamorphic of the magnesian rocks last named. The red soil, seen almost everywhere in the Grass Valley district, has its origin in the peroxydation of the iron contained in the greenstones and diorites, and set at liberty by their decomposition.

The line of contact between the gold-bearing and metamorphic rocks of Grass Valley, and the granites of the Sierra Nevada is met on the road to the town of Nevada, about half a mile before coming to Deer creek. The talcose and chloritic slates are seen to the north, in the direction of the Peck lode, and in the slate districts of Deer creek.

The dip and strike of the rocks in the Grass Valley region is seen to vary greatly in different parts of the district. Following the course of Wolf creek, a tributary of Bear river, it will be observed that the valley of this stream—which is Grass Valley—as well as of its principal branches, follows in the main the line or strike of the rocks. In the absence of an accurate map of the region, it may not be easy to make this statement evident. But all who are familiar with the chief mines of this district, will recall the fact, that the course of the veins in the Forest Springs location, at the southern extremity of the district, is nearly north and south—N. about 20° E.—with a very flat dip to the east, while at the Eureka mine, on Eureka hill, about four miles to the northward, the course of the vein is nearly east and west with a dip to the south of about seventy-eight degrees. Again, commencing at North Gold Hill and following the course of the famous vein which bears the names of Gold Hill, Massachusetts Hill and New York Hill, we find the veins conforming essentially to the southerly course of the stream with an easterly dip. The North Star, on Weimar Hill, has likewise the same general direction of dip. Near Miller's ravine, at El Dorado mill, Wolf creek makes a sudden bend to the left, or east, leaving the Lone Jack, Illinois, Wisconsin and Allison Ranch mines to the west. All these last named mines are found to possess a westerly dip, showing the existence of a synclinal axis running between the base of New York Hill and the mines having westerly dips last named, along which probably the veins will, if explored in depth, be found "in basin." The dip at Lone Jack is about 30° W., at Allison Ranch it is about 45° W. Just below the Allison Ranch mine, Wolf creek again makes a sharp turn to the left, nearly at a right angle, and then resumes its former course with the same abruptness. A mile lower down, where it strikes the Forest Springs locations, we find the Norambagua inclosed in syenitic rocks, dipping at a very low angle to the east, a dip seen also at still less angle in the Shamrock,

yet farther south. There is probably a saddle or anticlinal axis below the Allison Ranch mine, due to the elevation of the syenitic mass, which, it seems probable, sets in at the sharp bend in the stream, before alluded to, and where the ravine trail joins it. The stream probably runs pretty nearly in the basin of the synclinal.

The rocks on the east side of Wolf creek, and above Forest Springs locations, dip westerly. Such is the case at Kate Hayes, and with the veins on Osborn Hill. The middle branch of the creek sweeps around to the east, forms its junction with the north fork, and the veins explored there near its upper waters, as at Union Hill, the Burdett ground, Murphy vein, Lucky and Cambridge, all dip southwest or south, conformably to the Idaho and Eureka, and at a pretty high angle. The Eureka vein going west, faults in the Whiting ground, and having previously become almost vertical has, west of the fault, a *northerly* dip at a high angle. At the Coe ground, this northerly dip is also found at an angle of about 50°. At Cincinnati Hill the vein dips southerly, in a direction exactly opposite to that of the North Star, there being a valley between the two, and a saddle or anticlinal between Cincinnati and Massachusetts Hills.

These facts, which, by a more detailed statement, could be easily multiplied, seem to warrant the conclusion that the course and dip of the Grass Valley vein is especially conformable to that of the rocks, and that the streams have, in general, excavated their valleys in a like conformable manner.

The quartz veins of Grass Valley District are not generally large. Two feet is probably a full average thickness, while some of the most productive, and those which have given, from the first, a high reputation to this region, have not averaged over a foot or possibly eighteen inches in thickness. There are some exceedingly rich veins which will hardly average four inches in thickness, and which have yet been worked at a profit, while at the same time there are veins like the Eureka which have averaged three feet in thickness, and the Union Hill vein over four feet. The Grass Valley veins are often, perhaps usually, imbedded in the inclosing rocks, with seldom a fluccan or clay selvage or parting, although this is sometimes found on one or both walls. The walls of the fissures and the contact faces of the veins are often seen to be beautifully polished and striated.

The veins are, as a rule, highly mineralized and crystalline, and afford the most unmistakable evidence of an origin from *solution* in water, and not the least evidence of an igneous origin. Chalcedonic cavities and agatized structure are very conspicuous features in many of the best characterized and most productive of the gold-bearing veins of this district. These indisputa-

ble evidences of an aqueous origin are seen in Massachusetts Hill, Ophir Hill, Allison Ranch, Kate Hayes and Eureka.

The metallic contents of Grass Valley veins vary extremely, some carry but very little or no visible gold or sulphurets, although the amount of gold is found in working in mill to be satisfactory, and the sulphurets appear on concentrating the sands from crushing. This is the case in the Lucky and Cambridge mines, for example. But in most cases, the veins of this district abound in sulphurets, chiefly of iron, copper and lead, the sulphuretted contents varying greatly in the same vein; zinc and arsenic are found also, but more rarely. The most noted example of arsenical sulphurets are in the Norambagua and on Heuston Hill; lead abounds in the Union Hill lodes (as galena,) and the same metal is found associated with the yellow copper in parts of the Eureka mine. The gold when visible is very commonly seen to be associated with the sulphurets—this was particularly the case in Massachusetts Hill; while in Rocky Bar and Scadden Flat, on the same vein, the gold is found sometimes in beautiful crystallized masses, binding together the quartz and almost destitute of sulphurets. Mr. William Watt informs me that in working some seventy thousand tons of rock from Massachusetts Hill vein, the average yield of gold was about $80; but at times this vein was almost barren, while again the gold was found in it so abundantly, especially where it was thin, that it had to be cut out with chisels. It is matter of notoriety that in the Gold Hill vein (continuation of the vein in Massachusetts Hill) portions of the lode were so highly charged with gold that the amount sequestered by the miners in a single year exceeded $50,000. On the other hand, in the Cambridge and Lucky mines, yielding about $35 to $60 of gold to the ton, the precious metal is seldom visible. In the Eureka, where the average yield of gold in 1866 was $50 per ton, it seldom exhibited what may be called a "specimen" of gold.

The structure of the veins in Grass Valley varies, in different portions of the district, especially in respect to the distribution of the pyrites and of portions of the adjacent walls. On Eureka Hill, the veins possess a laminated structure parallel to the walls, enclosing portions of the diorite or talcose rocks, forming closures or joints in which the vein splits easily. On these surfaces of cleavage minute scales of gold may often be detected by close inspection. The sulphurets are also seen to be arranged in bands or lines parallel to the walls. In many other cases, this kind of structure is found to be wholly absent, while the sulphurets and gold appear to follow no regular mode of distribution. In a few mines the sulphurets are arranged very distinctly in bands of zones, parallel to the walls, forming "rib-

bon quartz." This is especially distinct in the Norambagua, where, as before mentioned, the sulphurets are arsenical, and the gold very finely disseminated.

The average amount of gold in the Grass Valley veins is believed to be considerably in excess of what is found in most other portions of California. In Allison Ranch, Massachusetts Hill, Rocky Bar, Ophir Hill, and Eureka, this average has probably reached $50 to the ton. In many other mines it has been considerably less, but on the whole, $30 may not be far from the general average for the whole district; meaning of course, the amount actually saved by milling operations.

The loss of gold is very various, but is probably nearly always greater than owners are willing to confess—if indeed they know, which is doubtful. It is certain, in one well known mine, my own samples of quartz sands, and sulphurets from "pans," assayed respectively $23 and $57 per ton—a result which was later confirmed, quite independently, by the researches of a very competent mining engineer. In other cases, as at Eureka and Norambagua, my own researches show the loss in the tailings to be very small, not exceeding seven dollars to the ton in the latter, and less than that in the former.

The gold in many of the Grass Valley mines is very easily worked, being clean, angular and not very small, hence it is readily entangled in the fiber of blankets, together with a considerable portion of sulphurets, naturally leading to the method most commonly in use in Grass Valley for treatment of the gold ores.

What may properly be called the Grass Valley method of amalgamation consists in the use of heavy stamps, seven hundred or a thousand pounds, crushing usually two tons, sometimes two and a half tons of ore each in twenty-four hours—through screens not exceeding No. 6, rarely so fine. Amalgamating in battery and copper aprons are usually omitted. In some mills, murcurial riffles are placed in front of the discharge, but commonly the whole body of crushed stuff is led at once over blankets, which are washed out every few minutes into tanks where the free gold and sulphurets are allowed to collect preparatory to being passed through the "Attwood amalgamators." These simple machines are designed to bring the gold into thorough contact with mercury contained in little vats sunk in the surface of an inclined table, over which the stuff is fed to the vats in a regulated manner by a stream of water, while iron blades slowly revolve in the vats to cause a mixture of the sands and quicksilver. By this apparatus, at the Eureka mill ninety per cent of all the gold is obtained which is saved from the ore. Beyond the amalgamators, the sands are carried over amalgamated copper sluices, and are put through various ore-

saving processes with a view especially to concentrating the sulphurets. These processes vary much in different mines. In some mills, especially the Ophir, much more elaborate mechanical apparatus has lately been introduced—with what results still remains to be seen. It is certain that if the method of treatment just sketched seems imperfect, (as it undoubtedly is,) it is the method which has hitherto yielded the large returns of gold for which Grass Valley has obtained its well-deserved renown. As the development of the district goes forward, cases will occur of veins containing gold in a state of very fine division, to which other methods of treatment must be applied. Such examples indeed already exist, and the problems which they offer will be met by the use of other systems of amalgamation, or by suitable modifications of the existing system.

The sulphurets occurring in the Grass Valley District are usually rich in gold—some of them remarkably so. In quantity they probably do not on an average amount to over one per cent of the mass of the ores, although in certain mines they are found more abundantly. For a long time there was no better mode known of treating them than the wasteful one of grinding them in pans and amalgamating. In this way rarely was 60 per cent of the gold saved. After many abortive efforts, at length complete success has been met with in the use of Plattner's chlorination process. Mr. Deetken, now connected with the reduction works of the Eureka mine, is entitled to the credit of having overcome the difficulties which formerly prevented the successful use of this process in Grass Valley, a more detailed description of which will be found in our notice of the Eureka mine.

Of the length of the productive portion of quartz veins and the depth at which they commence to become productive, Grass Valley offers some instructive examples.

The North Star vein, on Weimer Hill, has been proved productive on a stretch of about one thousand feet, while the proportion of gold has gradually increased with the depth, from an average of twenty dollars in the upper levels to nearly double that in the lower levels. The limits named are rather those of exploration than the known extent of the productive ore. In the vein on Massachusetts and Gold Hills, on the contrary, the distribution of the "pay" has been found much more capricious, being at times extremely rich, and again with no apparent reason yielding scarcely the cost of milling. The Eureka mine offers the most remarkable example, however, of a steady increase from a non-paying amount of gold near the outcrop to one of uncommon productiveness. An opinion has found advocates, and has been perhaps generally accepted by most writers on the subject of gold-bearing quartz veins, that they were richest near the

surface and in depth became gradually poorer. There is nothing in the nature of the case, as it seems to me, to justify such a generalization, more than there is to sustain an opposite opinion. If we accept facts as a guide, we find in California that the deepest mines, for example, Hayward's Eureka, in Amador, 1,200 feet, North Star, 750 feet on the slope, Princeton, in Mariposa county, 800 feet, Eureka (Grass Valley) 400 feet, Allison Ranch, 525 feet, etc., as a rule have an increasing amount of gold. If the Allison Ranch, the Princeton mine, and some others appear to be exceptions, the answer is, we may reasonably expect the same variations of productiveness in depth which are known to exist in linear extent. The Princeton, after an excellent run of good ore, became suddenly poor, at a depth of over six hundred feet, in 1865; but I am informed by Mr. Hall, the present superintendent, that the good ore came in again in a short distance. Mr. Laur, the French engineer, whose papers on California mines is often quoted, cites the Allison Ranch mine in evidence of the theory of a decreasing amount of gold in depth, but it is in proof that since the date of Mr. Laur's visit (1862-3), this mine has been at work on ores which have yielded over one hundred dollars value, its present suspended activity being due to causes quite unconnected with the intrinsic value of the mine. The rich "chimneys," or productive zones of ore ground, are known to be of various extent in quartz veins, from a few feet to many hundreds of feet, and it is impossible to assign any valid reason why we may not expect the same changes in a vertical direction which we find in a horizontal. As the ore-bearing ground or shoots of ore have in many, if not in most cases, a well determined pitch of the vertical, it is self-evident that a vertical shaft, or incline at right angles to the vein must, in descending, pass out of the rich into poor ground, at certain intervals, and it is perhaps due to ignorance of this fact that miners have abandoned sinking because they found the "pay" suddenly cease in depth, when a short distance more would probably bring them into another zone of good ore. The experience of every gold mining district offers examples in illustration of these remarks. In quartz veins containing a considerable amount of sulphurets, it is evident that the outcroppings should offer much better returns to mining industry than will follow after the line of atmospheric decomposition has been passed, because above this line nature has set free the gold formerly entangled in the sulphurets, leaving it available for the common modes of treatment, with the added advantage often times that the particles of free gold formerly distributed through a considerable section of the vein, are found concentrated in a limited amount of ore. It is easy to reach the conclusion in such cases, that the amount of gold in the vein is less in depth,

after the real average amount is reached, while in fact it is neither greater nor less; but the metal is no longer available by common methods of treatment.

The Eureka mine.—From the date of its location, February 7, 1857, to the close of 1858, the mine proved only a source of expense to its owners, and its history is instructive as suggesting that shallow surface explorations, in gold mining, may be as unsatisfactory as they are known to be in other mining enterprises. So late as 1858, it is said, that five thousand tons of quartz taken above the drain level, or thirty feet from the surface, yielded in mill less than ten dollars per ton in gold, not returning expenses. A shaft sunk to a depth of about fifty feet afforded quartz, however, which yielded about fifteen dollars per ton, and the amount of gold rapidly increased to twenty-eight dollars at one hundred feet. Between the one hundred and two hundred feet levels the average yield was about thirty-seven dollars per ton, and between the two hundred and three hundred feet levels the average has been about fifty dollars per ton, rising to sixty-four dollars in the last four months of 1866.

There are in fact two distinct veins in the Eureka mine, separated from each other by a mass of greenstone or metamorphic sandstone, about twenty-eight or thirty feet in thickness. The smaller of these veins is on the south and has not been explored, but is a well-defined vein at the points where the shaft and cross cuts have exposed it. The greenstone forms the hanging wall of the main vein, and is particularly regular and smooth, in some places beautifully polished. The foot wall consists in some parts of soft serpentine, and when the vein pinches it appears to be from swelling of the foot wall. No other mine in this region has such a structure as the Eureka, so far as I know, and there is very much in the peculiarities here described to favor the highest confidence in the permanence of this great ore channel, both in depth and extent.

It is interesting to analyze a little more in detail the returns of this mine, as illustrating a point already alluded to, viz—its progressive increase of gold with an increase of depth.

From October, 1865, to December 31, 1865, the quantity of quartz crushed was twenty-four hundred and forty-five tons, yielding an average of $33.87 per ton, and costing to mine and reduce $13.51.

From January 1st to June 1st, 1866, the crushing was forty-seven hundred and three tons, averaging $42.68 per ton, at a cost of $12.52 per ton.

From June 1st to September 30, 1866, the amount of quartz crushed was forty-two hundred twenty-seven and three-fourths tons, giving an average yield of $60.33 per ton, at a cost of $15.78 per ton.

For the whole year ending September 30, 1866, the total crushing was eleven thousand three hundred and seventy-five and three-fourths tons, yielding a general average per ton of $47.15, at a mean cost per ton of $13.75.

The net profits for the year ending September 30, 1866, were $368,042.18. The ratio of costs of mining to the gross product was, for the three periods named above, respectively, 40½, 29½ and 26½ per centum. In the mining costs are included all charges for dead work, machinery, etc. The profits of the Eureka mine have, therefore, for the period named, averaged in round numbers from sixty to seventy-four per cent of the gross product of the mine. The earnings are divided every twenty-eight days, making thirteen annual dividends.

The bullion of the Eureka mine is about 850-thousandths fine, worth $17.57 per ounce. This value is, of course, slightly variable, say within five-thousandths.