

ART. XXXV.—*Underground Temperatures on the Comstock Lode*;  
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DURING the summer and fall of 1877, I was engaged in making an extended examination of the mines situated on the Comstock lode in Nevada.\* Though investigations of the kind described in this paper were but a subordinate part of the proposed work, and the time given to them necessarily restricted, enough facts were accumulated to show on how vast a scale the heat phenomena of the district are exhibited.

The Comstock mines are not only the only hot ones of note in this country but they appear to be the hottest in the world. The highest mine temperature reported to the British Coal Committee was 106° F., but some of the Cornish mines have shown an air temperature of 100° to 113° F. There the air was hotter than the rock, which is never the case on the Comstock. The hottest water reported in a Welsh mine had a temperature of 125° F. (J. A. Phillips). All of these observations are surpassed by the extraordinary conditions of the Comstock.

\*This examination was made in connection with the United States Survey of the Territories west of the 100th meridian, in charge of Lieut. Geo. M. Wheeler, Corps of Engineers, U. S. A.

The rock in the lower levels (1900–2000 feet) of the Comstock mines appears to have a pretty uniform temperature of 130° F. This was the reading obtained for me on several occasions by Mr. Comstock, foreman of the Ophir mine, and about the same temperature was found by Mr. Perrin, foreman of the Chollar Potosi, by Mr. Cosgrove, foreman of the Yellow Jacket (139½° F. and 136° F., 2200 foot level), and by myself in the Crown Point and other mines. These readings were obtained by placing a thermometer in a drill-hole immediately after the hole was finished, and leaving it there for periods varying from ten minutes to half an hour.

The holes in which the thermometers were placed were not sunk especially for this work of testing, but were the ordinary drill-holes made for the purpose of blasting the rock. They varied therefore from about ten inches to three feet in depth, but their shallowness by no means indicates that the results obtained are vitiated by alteration of the conditions through exposure to radiation.

Mining on the Comstock proceeds with extraordinary rapidity. The drifts are advanced steadily at the rate of three, five, and sometimes even eight and ten feet a day, and therefore the ground in which the miners are working is always fresh ground. The drill-hole which is made to-day was covered a week ago by thirty to fifty feet of rock. Very often the holes were in ground which had been exposed only one or two hours, having been sunk immediately after a blast which threw off four or five feet of the rock. The surface which was thus thrown down itself had not been exposed more than twenty-four hours. The high temperature and small flow of air in the heading forbid the supposition that any sensible diminution of heat could have taken place at the bottom of a drill-hole made in material of such low conductivity as rock. These facts give the results as much value as if they had been obtained from holes twenty feet deep.

The surface of the rock exposed to the air of the drift was found on one occasion to be about 123° F., the experiment being made near the "header" or end of the drift. The air itself was found to show considerable uniformity when its temperature was taken under circumstances that were at all similar. In freshly opened ground it varied from 108° to 116° F., and higher temperatures are reported at various points, reaching in fact as high as 123° F. in the 1900 level of the Gould & Curry.

The temperature of the air is subject to more fluctuations than that of the rock, for the simple reason that it is artificially supplied to the mine, and varies according to the distance to which it is carried, the quantity, velocity in the pipe, its initial temperature, and moisture in the drift. The most important

causes of variation are the length of the drift and the presence or absence of water. In general the variation at similar depths is not more than eight degrees. Drifts that do not exceed two or three hundred feet in length are *usually* not above 110° or 112° F. in temperature and often they are below this. But when the length increases to 1200 and 1500 feet the temperature may rise to 116° F. without any other change in the circumstances. But much higher temperatures are encountered in places where the increase cannot be attributed to artificial causes.

These limits are, however, not in the least degree true of the water which enters the drifts from the country rock, and also from the lode rocks. That approaches more nearly 150° F. The vast body of water which has filled the Savage and Hale & Norcross mines for two years, and from which it is safe to say a million tons of water have been pumped within twelve months, gave me a temperature of 154° F. Even after being pumped to the surface through an iron pipe exposed, in the shaft of the Hale & Norcross, to a descending current of fresh air for more than a thousand feet, and then flowing for one or two hundred feet through an open sluice in a drain-tunnel which discharges into a measuring-box, the water in this box was found to have a temperature of no less than 145° F.

But the water varies in temperature in different parts of the lode like the rock and the air. In the East crosscut 2000 foot level, of the Crown Point Mine, which is noted for its extreme heat, a small stream of water, after flowing for nearly one hundred and fifty feet over the bottom of the drift, was found to have a temperature of 157° F. Here the drift was closed so that the water was but little exposed to evaporation. On the contrary, in other places the water is much less hot, but I believe it is always hotter than the air, and in many cases it appears to be hotter than the rock is found to be, except in especially hot spots.

These places of exceptionally high temperature are very numerous throughout the lode and they appear to occupy narrow belts. The East crosscut of the Crown Point 2000 foot level, which was temporarily abandoned and boarded up on account of the heat, gave me an *air* temperature of 150° F., the thermometer being thrust through a crack in the boarding. I felt convinced that at the head of this crosscut the heat must be higher than this, and Mr. Balch, foreman of the mine, informed me that it had been proved so. Another hot spot is in the Imperial Consolidated Mine. Here the Black Dike splits, sending a shoot off to the northeast, and a drift has been run on the two thousand foot level, along the eastern side of this branch dyke. This proved to be a very hot spot indeed. Rock, air and water were all so much above the usual limits of

temperature even in these hot mines that the work of cutting the drift must have been extremely severe. It might not have been accomplished had not the expedient been adopted of boarding or "lagging" up the sides of the drift with a double thickness of plank, breaking joints. This confined the water, which poured down the walls, to a tight chamber, and left the main part of the drift for the men to work in comparative comfort. The lagging remains, and has been carried around into the main drift, which is still in active use. Its joints are calked with tow, and, one of these being stripped for me, the steam from the water immediately poured out and proved to be scalding-hot when tested by the finger. I did not, however, succeed in getting a fair reading of the thermometer, because the crack was too small to admit more than the end of the bulb. The thermometer must have cooled by the evaporation of condensed moisture from its bulb; but, even under these adverse circumstances, the temperature of the steam was taken at 123°.

The Belcher south incline has a hot belt of rock, quite narrow, a short distance above the 1900 station, and in fact similar hot places are found in most of the mines.

It is noticeable that the neighborhood of a dike is apt to be hotter than other portions of the rock. This is the case in the Julia, and in the Imperial, the branch dike is hot, as just mentioned, and the main incline, which is quite near the Black Dike has always been noted for its extreme heat. But nearness to the Black Dike is also a characteristic of most inclined shafts on the lode. Some are west of it; some in it for long distances; others east of it. These inclines do not all exhibit unusual heat and it will be shown farther on that there is a special cause for the exceptions.

Belts of excessively hot ground are not the only noticeable phenomena in these mines. More remarkable still are the belts of unusually *cold* rock. These are fewer in number than the hot belts, but they are also strongly marked. They are always wet, and the water that drips through the crevices of the shattered rock that composes them is noticeably cold to the touch, and cools down the air of the drift. Such a wet, cold belt of rock exists on the eight hundred foot level of the Justice Mine, and there is a very decided change of temperature in passing from one side of it to the other. Lest the low temperature of this spot should be attributed to the water which drains through it from the surface, it is well to add that water drips from the rock in numerous places in these as in most mines, and that usually it is hot, or at least warm.

Other cold belts are found in the mines which are not so cool as that in the Justice, but are perceptibly cooler than the rock at a short distance from them. They complete a well-

linked chain of heat phenomena, extending from rocks that are sensibly cold to the touch, and may not have a temperature above 50° or 60° F., through rocks that have the average atmospheric temperature, and those which are as hot as surface rocks ever become in Nevada, to those which have a temperature of 157° F. There is no reason to doubt that the gradation is quite regular, and the transition from the lower to the higher temperature is made through a much larger series of intermediate steps than the accidental thermometer readings taken show.

The rock is usually dry. Wet portions exist, but these are disposed in comparatively narrow bands parallel with the lode and separated by thick masses of rock; the lode is usually perfectly dry, and never exhibits more than the average leakage of mines. Wet rock is the exception, and dry rock the rule, through the whole lode. In the drifts cut through this hot, dry rock, the walls of the freshly exposed surfaces are painful to the hand, and the air is often filled with dust. The rock is both hard and tough, but, in spite of its strength, it gives an impression of fine porosity to the touch, due probably to its trachytic character. It often has the odor of clay, but not always. It may be slightly adherent, or the impression of dryness upon the tongue may be due to its heat.

The plan of the Yellow Jacket mine is simple and such as to eliminate complications from the single problem of heat absorption by moving currents of air from rock surfaces. From the 1,531 level two parallel winzes are sunk on the lode, inclining with it. They are four hundred and thirteen feet apart, and connected on every lower level by the main north and south drift. The Yellow Jacket is a downcast mine, and the air current passes down the vertical shaft to the 1,119-foot level, thence down the incline to the 1,531 level, through a drift to the south winze, and thence down this winze to the 2,200 level, the bottom of the mine. On its way from the 1,531 it sends a current through the 1,732, 1,935 and 2,040 levels, these currents being reunited in the north winze, which is the upcast. The north winze does not reach to the surface, and no air rises "to day" in the mine, the entire current flowing into the Imperial and Bullion mines, both north of the Yellow Jacket, and both of them exclusively upcast.

Captain Taylor has placed Fahrenheit thermometers of the common kind, with japanned tin cases, at the surface, foot of the vertical shaft (1,119 level), 1,732 south and north winzes, 1,935 north winze, and 2,040 south and north winzes. The south winze is downcast, and the thermometers placed here on the different levels measure the increase of heat in the winze itself, while those which are hung at the north winze measure

the increase of heat, which each "split" of air gains in moving through 413 feet of drift, that being the distance between the winzes. This fortunate arrangement of the ventilating currents presents the most favorable opportunity I have ever observed for studying the problems involved. The thermometers should be replaced with standard instruments, and the air current measured twice a week for a year, in each drift. The result would be the best series of observations obtainable, probably in any American mine, for the comparative shortness of the paths followed by the air, when contrasted with the long drifts of some coal mines, is compensated for by the high temperature of the rocks, and the marked increase of heat in the air. It is also extremely rare to find the conditions of heat absorption so little complicated by artificial additions.

The air-current entering the mine July 2d, 1877, was measured and found to be 18,140 cubic feet. On the 1732 level the "split" or secondary air-current was found to contain 7200 cubic feet, and for the purpose of illustrating the steady flow of heat from the rock, we may reasonably assume that 18,000 cubic feet of air enter the mine every minute, and that this current is divided into three splits of 6000 cubic feet each, which pass from the south winze 413 feet to the north winze, on each of the three levels, 1732, 1935, and 2040. The second of these is out of consideration, from the fact that there is only one thermometer on it, so that no comparison of the initial and final temperatures can be made.

The following tables contain a summary of all the observations which I have been able to obtain. The record is imperfect on account of the destruction of some tally boards, and this has compelled me to omit some records that are preserved, because the corresponding observations in the same drift are wanting. Where the omission takes place, the figures are included in brackets. The figures given are monthly averages, and the final averages refer only to numbers not in brackets.

Only the observations on the 1732 and 2040 foot levels will be made use of, as these are the only ones where a horizontal air current has its temperature measured at two points in its path. Omitting November from the period of the 1700 foot level and December from that of the 2040 foot level, we have for the average of nine months' observations a difference of temperature between the south and north winzes amounting to

1732 foot level	(89·39°—78·06°)	11·33° F.
2040 " "	(92·30°—85·35°)	6·95° F.

This difference represents the heat which the air current has absorbed in passing a distance of 413 feet on these levels. In my report made to Lieutenant Wheeler, and also in a paper on this subject presented to the American Institute of Mining

Engineers, these quantities are given as 10·56° F. and 7·87° F., the difference being due to the fact that they were the average of seven instead of nine months' observations.

*Yellow Jacket Mine.—Morning Temperature, 6 A. M.*

	Surface.	1119 feet.	1732 feet.		1900 feet.	2040.	
			S. Winze.	N. Winze.	N. Winze.	S. Winze.	N. Winze.
December, 1876, ----		59·27°	80·23°	92·99°			
January, 1877, ----		52·55	73·42	86·90		85·35°	93·22°
February, " ----		49·75	76·99	83·71		86·59	93·99
March, " ----		53·81	78·13	89·20	90·29°	83·68	94·99
April, " ----		49·87	77·40	88·13	89·97	85·90	93·77
May, " ----	(44·48°)	53·77	83·42	90·45	90·99	83·39	93·61
June, " ----	56·07	57·40	79·39	91·47	93·27	88·26	93·63
July, " ----			(84·00)		94·07		
August, " ----			(83·23)		94·50		
September, " ----	56·67	60·80	81·86	91·67	96·60	88·37	92·13
October, " ----	46·10	55·13	73·65	90·44	92·07	83·23	88·36
November, " ----	39·90		(76·53)		88·50	81·27	87·23
December, " ----			35·84				
January, 1878, ----		33·39					
February, " ----		33·93					
March, " ----		39·84					
April, " ----		42·37					
May, " ----		51·10					
Average, -----	43·52						
Time taken, -----	10 mo's.	9 mo's.	9 mo's.	9 mo's.	9 mo's.	9 mo's.	9 mo's.

*Yellow Jacket Mine.—Evening Temperatures, 6 P. M.*

	Surface.	1119 feet.	1732 feet.		1932 feet.	2040 feet.	
			S. Winze.	N. Winze.	N. Winze.	S. Winze.	N. Winze.
December, 1876, ----		59·20°	80·84°	90·92°			
January, 1877, ----		50·77	77·82	86·10		83·23°	93·36°
February, " ----			76·71	84·03		86·82	93·43
March, " ----		55·52	74·07	88·58	90·29°	86·68	95·00
April, " ----		52·83	77·57	88·33	89·93	85·87	93·80
May, " ----	70·47°	61·50	79·42	91·77	93·03	87·16	93·48
June, " ----	70·33	61·50	79·40	91·77	93·03	88·20	93·73
July, " ----			(84·16)		94·29		
August, " ----			(83·42)		94·29		
September, " ----	69·13	62·76	81·82	91·11	96·67	87·90	92·00
October, " ----	54·55	57·30	72·99	91·00	92·10	83·32	88·58
November, " ----	45·43		(77·40)		89·50	81·13	87·23
December, " ----			39·58				
January, 1878, ----		38·84					
February, " ----		37·61					
March, " ----		44·87					
April, " ----		52·37					
May, " ----		60·77					
Average, -----	53·09						
Time taken, -----	11 mo's.	8 mo's.	9 mo's.	9 mo's.	9 mo's.	9 mo's.	9 mo's.
Average, morning and evening, ----	48·30	56·19	78·06	89·39	92·41	85·35	92·30

The 1732 level affords us the best evidence that the incessant drain of heat cannot be maintained by supply from a store accumulated in the rock. This drift was probably completed by January 1, 1876, or perhaps some months earlier. It has been constantly in use as an air way, but after this long exposure no diminution in its heating power has been noticed. It has lost the intense heat it had when first opened, but remains at an average temperature of about 90° F.

In other respects I have not observed any circumstances which throw serious doubt upon the thermometer readings. The instruments are not standards, it is true, but they are properly hung on timbers, and usually with ten or twelve inches of wood or air between them and the rock surface. Whenever compared with one of the survey thermometers, hung in the center of the moving air-current, they have not shown a variation of more than one degree. The daily readings are quite uniform, the fluctuations of more than one degree not exceeding twenty-three in a series of about 360 observations. The highest fluctuation noticed is three degrees.