time to save it, and finally it was hidden in the woods just east of where the Mining School now stands. Mr. Mabbs and his brother had in each case handled the oil themselves. They finally loaded it into a yawl boat and started with it for Marquette, which place they reached in safety after a narrow escape from being lost in a storm on the lake. They got permission to try it on some of the hard heads in the iron mines, and were so successful that they had no trouble in closing out their stock and the use of this material was continued there to a limited extent until the present method of making it was adopted, when its use became immediately general." (Pope.)

Early in the fall of 1864 a discovery was made in the woods thirteen miles north of Portage Lake. At that time there were no mines near there and no settlement to induce any search. It was here on Sept. 17, 1864, that Edwin J. Hulbert first located the famous Calumet conglomerate. Hulbert was a surveyor, and during the summer of 1858 he noted a violent deflection of the needle on Section 23, Township 56 North, Range 32 West. This put him on the alert and he carefully noticed signs for mineral discovery. He soon found pieces of conglomerate containing copper but different from any other conglomerate by being brecciated. Later he discovered a big block of it that was covered with moss and a depression which he took to be an ancient pit. With these for aids he after careful and diligent exploration discovered the famous belt. At his suggestion Section 13 was bought and the Calumet Mining Company formed. Later the Hecla Mining Company was formed and Section 23 bought.

One peculiar fact is that the only place where the Calumet conglomerate held a paying amount of copper was bought by Hulbert's advice. Companies were formed to work the extensions of it both to the north and south but were unsuccessful. Another peculiarity is that this conglomerate is the only one that can be considered of value. It is true that the Allouez and Albany and Boston have worked on the Allouez conglomerate but their success is not very noteworthy. The Tamarack is now working the Calumet and Hecla but cannot be considered as working another part of this belt.

As most people know the Calumet and Hecla soon established itself as the largest and richest of any mine in the world. In 1872 it produced 8747 tons of refined copper and during that time paid $2,800,000 in cash dividends. Is it a wonder, when a mine in its seventh year pays dividends greater than its capital, that the



copper country should become famous and draw largely on Eastern capital? As one writer says: "First in the history of the copper country of Lake Superior, fissure veins, charged with enormous masses of metallic copper, had to gain favor; next stamp lodes had to fight their way into popular estimation, and lastly, the conglomerate belts astonished the scientific world."

The year of 1875 can be considered the close of a second epoch in the history of the copper country. During the first period we have the growth of the mines of Keweenaw and Ontonagon Counties. Then the mining industry began to fill in the intervening space forming the Portage Lake district. During our second period we have the growth of this intervening country until it is on a solid footing. In our third period the amygdaloid mines of Houghton County become the chief source of copper while the mines of its neighbors begin their decline. At our present day the amygdaloidal deposits are being found farther north and farther south and following closely upon it are the Portage Lake mining methods. With these changes, Keweenaw and Ontonagon counties once more become the undeveloped regions of the copper country.

By this time the explorer was a man of many accomplishments. He was well versed in woodcraft, knew something of the geology of the country, has studied the working mines and if necessary could do some surveying. Usually his attention was first called to float copper. This float had been torn from the lode and carried along by the glaciers. Upon finding this he would turn in the direction from which the glaciers came attempting to discover if the float became more frequent. If such were the case he kept on until he came to a line beyond which there was no float. At this point he directed his men to trench across the formation or rather at right angles to the strike of the lode. After the lode was found, pits were sunk on the longitudinal course of the lode to sufficiently prove its value. At this time it was believed that lodes which did not show at surface sufficient percentage for regular mining, would not pay farther down. During the last few years, however, this idea has been abandoned. In many mines paying shoots of copper are not found until a depth of a thousand feet or more is reached.

If, however the pits did prove encouraging one or two shafts were sunk to a depth of about one hundred feet. This depth, however, was not fixed, the deciding point being whether the ground were solid enough to allow drifting on the lode. This drift was then run in a horizontal direction along the lode and if two shafts were sunk the one from the other shaft meeting this one connected these shafts. As these shafts are usually from three to fifteen hundred feet apart a good-sized block of copper ground was thus exposed on four sides and if sufficiently rich a permanent plant for mining operations was erected.

Besides this method of exploring the diamond drill was beginning to come into favor. This helped not only in locating copper deposits when hidden by the drift but when found were of some importance in proving the value of the lode. This proof is used only for deciding whether it will pay to further explore by sinking and drifting on the lode. The Quincy was beginning to use the drill for underground exploration in their mine. Here the copper occurred in scattered paying sheets but which would not pay to work if it were necessary to break down all the rock in order to find them.

The compass and dip needle were and are not as a rule used, though it can be seen by referring to the discovery of the Calumet conglomerate that it is of some use. There is certainly a deflection in the vicinity of the richer copper belts.

In the conglomerate and amygdaloidal mines the shafts were sunk in the copper bearing rock. The number of shafts depended upon the size of the mine and the length of the lode which lies on their property. They varied in size, but 10x14 feet was an average size. They were cribbed from surface to solid rock with square timbers and planks and were divided into two or more compartments. One compartment was used for hoisting, another for a ladder way and a third for pipes and pumps. These shafts were continued down on the lode to any depth which might show copper values in paying quantities.

Levels were laid off from the shafts at convenient distances, ranging from sixty to one hundred and twenty-five feet. These levels were usually six feet high and four feet wide and ran in almost horizontally connecting all the shafts. A slight grade was made rising away from the shaft so that all the water could be conveyed to sumps near the shafts. These mines, however, were not wet and a small pump working but part of the time would take care of all the water.

Between the shafts, for the purpose of ventilation and convenience in stoping, minor shafts or winzes were opened up. Thus a longitudinal map of the main workings of a copper mine could be compared to a map of a city plat, the shafts and drifts being the streets while the winzes would represent the alleys. These solid blocks of veinstone thus laid off were, if the whole lode were workable, taken out except for pillars of rock left to support the hanging wall and keep the mines from caving. Heavy shaft pillars had to be left and companies who did remove these were always confronted with a constant and increasing expense.



The method of working was overhand stoping, being done either by hand or by compressed air drills. At this time, however, the air drills were not in great favor as they were very heavy and much time was lost in setting them up and moving them. "No attempt is usually made to fill up the space left by what is taken out of the mine, unless the material is close at hand. In the bed called the 'Ashbed,' at the Copper Falls mine, immense chambers, seventy-five feet square have been left without any support of any kind. The roof is very firm and has stood for many years, but there is no excuse for such methods, for eventually the roof must yield.

There must come a time when wooden props will crush, and then the future of the mine will be compromised, even supposing the shaft or level is kept in order. If a timber be replaced, it must be every time shorter, as the roof descends the surface water is let in, and constant expense of repairs necessary, as witness some of the first levels of the Calumet & Hecla. After a certain time the openings will be either too low to work in, or the roof must be taken out, a hazardous and expensive operation in yielding ground. If the proper pillars had been left, the workings would have remained good for years.

Each company is obliged to own woodland and to select the best of their wood for supports or, as is the case of the Calumet, go long distances, and raft their wood. The method is otherwise bad, as when the ground begins to crack, the superficial waters must come in.

In looking at the vast chambers in many of the mines without any support of any kind, one has an involuntary feeling of dread lest the roof should cave. The solidity of the ground is remarkable, but it must one day give way. The immense amount of rock which has been thrown on the burrows suggests the advisability of filling the old workings of the mine with it and this has sometimes been done in a limited way. If it had been adopted as the policy at the commencement of mining operations, much would have been saved by it." (Eggleston in 1877.)

The rock was picked as much as possible in the mines, the poor rock being left there, and the rest sent to surface. In dumping the rock into the skip, the skip was usually supported upon a beam of wood thrown across the track. Thus the strain of "dumping on the rope" is eliminated. When filled a signal would be given for hoisting and as soon as the skip reached surface another man would give signals informing the engineer when the skip had approached the dump and when dumped. Some skill was required at this position as any failure on his part might cause the skip to be pulled to the top where it would be caught while the rope was pulled in two.

Skips were made of half inch rolled iron and would hold from one to two tons but these small skips are now used only for exploration work. Many of the present mines use skips holding as much as eight tons of rocks.

The cables which were used for hoisting the skips were of iron or steel. In order to lessen friction and to prevent corroding they were greased with coal tar. "As this substance is always acid from the process of refining the petroleum, this greasing often does more harm than good, as it corrodes the strands and weakens the rope. It would be very easy to saturate the acid, by adding lime and boiling before using as is done in Pennsylvania, but it is not generally done." (Eggleston.)

The drum of the hoisting engine was so arranged by means of marks on it and by a tell-tale dial that the engineer could tell the position of the skip. The velocity was regulated by a strap brake passing around the revolving drum. It was attached to a very long lever of wood upon which the engineer would sit, bearing more or less of his weight.

The present dumping arrangement is the same as was then used. The front wheels were allowed to drop in between the rails while the back ones being wider were carried up the incline. The contents were in this manner dumped onto the grizzlies, the finer pieces falling through while the larger pieces slid into the rock house. These large pieces were usually broken by large sledges but the Calumet and Hecla had installed a steam hammer. This broken rock was then loaded into a tram car and sent to the rock house. One rock house had to answer for a number of shafts, being connected to them by means of an elevated tramway known as the Frue Automatic tramway. The product was then crushed by Blake rock crushers, just as large in size as is in use at present, and stored in bins.

At regular intervals this rock was sent to the stamp mill usually located on the nearest lake. The abundance of water is of great importance. The mass mines were no longer the paying ones and were it not for the fact that the finer particles were readily re-



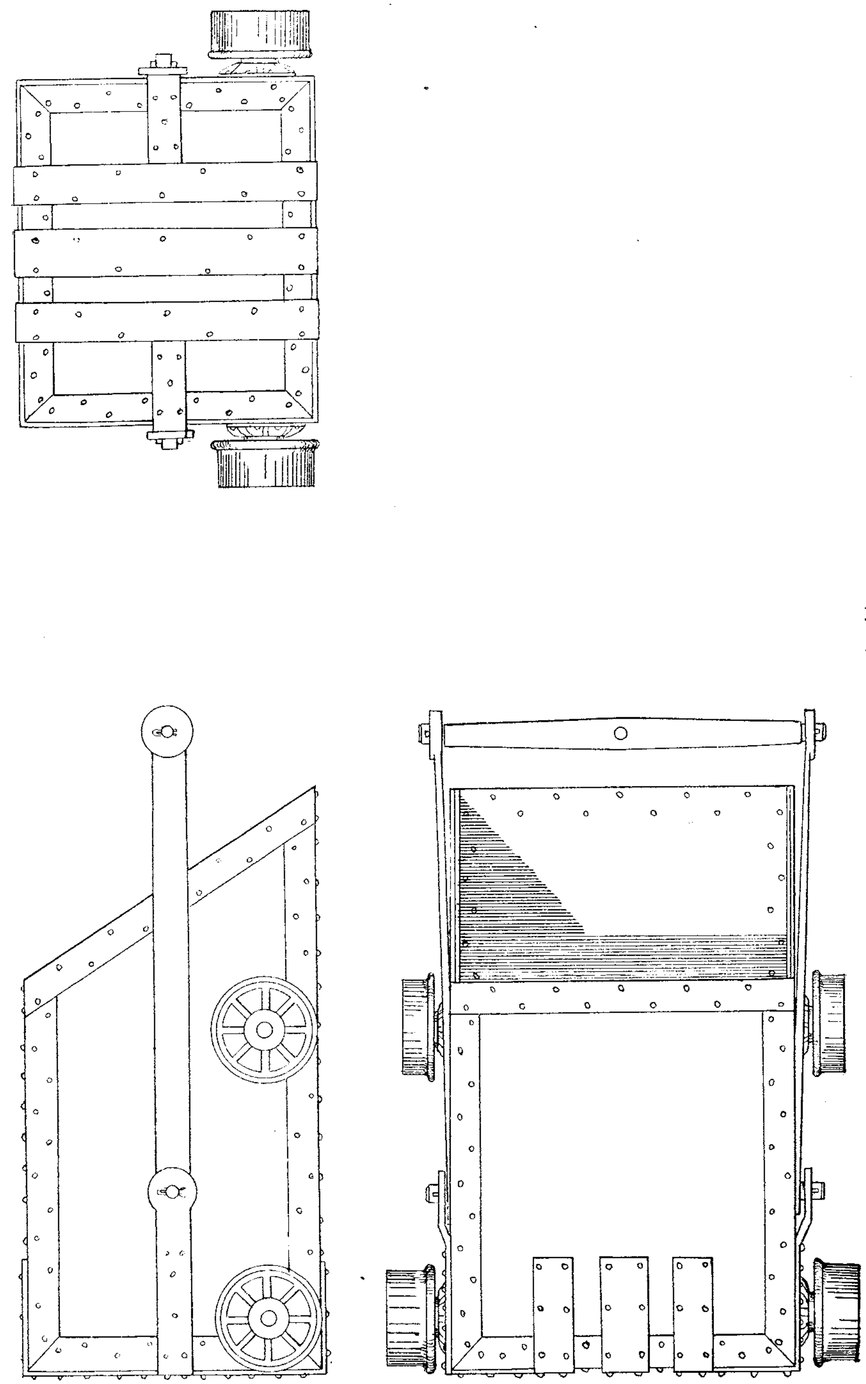

Fig. 65. Atlantic skip.

covered, Keweenaw peninsula would not long have remained a mining region.

At these mills the rock was thrown into the hoppers of the steam stamps. Unlike the present steam stamp these were on spring timbers and a foundation of wood. These stamps were nothing more than steam hammers but the stroke was made regular by having the valves to the steam cylinder operated by an independent engine. This engine was also used to run the washing machines, lathes, etc. A stamp with a twelve inch cylinder making 80 strokes per minute could stamp 120 tons of rock per day with a boiler pressure of 87 pounds.

The next machine to interest us is the Collum Jig. Here the crushed rock is separated from the copper. The crushed rock mixed with a large amount of water spreads itself evenly upon a wire screen, through which a pulsating stream of water flows. The object of the pulsations is to keep the particles in motion thus allowing the heavier particles to settle to the bottom and the lighter ones to collect on top. Those pieces heavy enough to overcome the upward current of water and small enough to pass through the screen fall into a catch box below. The lighter particles are gradually worked off as fresh ore is being constantly added. This machine makes three products; hutch, ore that which falls through the screen, being largely copper, those heavy pieces, mainly copper, that stay on the screen and the tails, which pass over the end of the screen and go to the waste launder.

The slimes which are made by crushing the rock are treated on the Evans Slime tables. This consists of a flat cone having a slope of one in twenty-five, upon which the slimes are deposited. This table revolves and the slimes being deposited upon the table, the water runs down and off the table going to waste. The heavy particles which remain on the table are washed off into a box. These heads are later keeved and a certain percentage of copper removed from them.

In some of the mills the heads, instead of being keeved are treated upon a precussion table. This table was the forerunner of the Wilfley table and operates very similarly.

At this time the tailings from the mill were run to a tail house where the No. 5 copper was recovered. These tail houses hardly paid for their maintenance. While some copper was recovered it took over fifty operations, most of which were manual, to get it. Their main use was to act to some degree as a check on the working of the mills. They were soon abandoned.



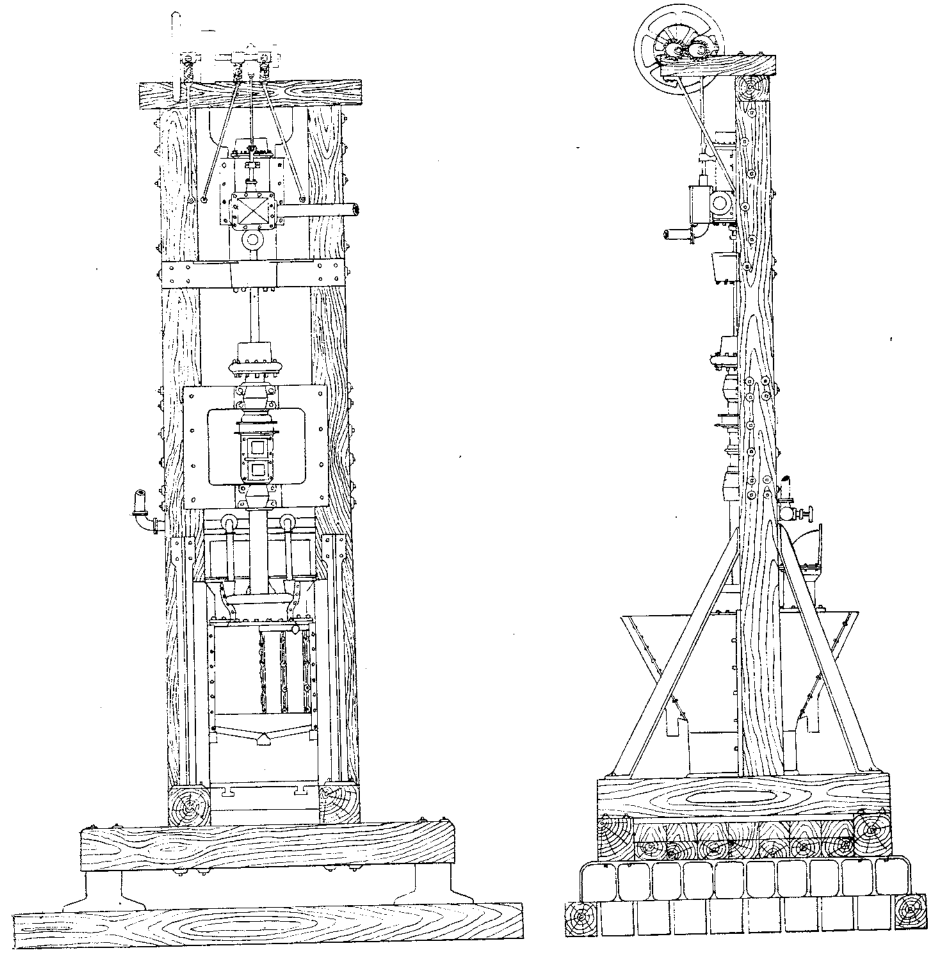

Fig. 66. Ball Stamp of 1875.

"The difficulty of the region does not lie in the want of copper for there is an abundance of it, nor in mining, for, in general it is skillfully done, but in dressing. The following assays of tailings from washers yielding the different grades of copper, I made in the winter of 1875-6. The samples were taken from a mill whose ore yielded less than two per cent.

| | |
|---|---|
| Tails from Nos. 2 and 3, copper..... | 1.325 per cent. |
| Tails from Nos. 2, 3 and 4 copper.... | 1.210 " |
| Tails from Nos. 3 and 4 copper..... | 1.030 " |
| Tails from Nos. 5 copper........... | 1.360 " |

Much of this copper is attached to small pieces of rock and is carried off with it. This has led to re-stamping the tails, as is done in the Calumet and Hecla; this produces other rich tails, and a large loss in float copper." (Eggleston.)

During this time of gradual development in the mines and stamp mills an equal development was taking place in the smelting of the mineral. The first attempt to smelt copper in the copper country ended in failure. Up to 1850 all the copper was smelted in Boston and Baltimore. The masses were a new proposition to the smelter. All refining furnaces had small side door openings for the charging of the copper ore. At the Baltimore works a large side door was made and masses were dragged into the furnace by chains passing through a door opposite and fastened to a windlass. The result of such a method of charging was serious damage to the furnaces.

The famous "Lake Brand" of copper was originated in 1850. A Mr. Grout together with some brass companies in Waterbury, Conn., organized the Waterbury and Detroit Copper Co. Their object was to get a brand of copper on which they could depend. Before this other brands of copper were not even in quality and equal to their requirements. With this in view the Detroit works were built in 1850 and Mr. James R. Cooper was put in charge.

In 1860 the Portage Lake Smelting works were built in Ripley and they began refining copper in 1861. The Calumet and Hecla sent their product here. In 1867 these works were consolidated with the Detroit works as the Detroit and Lake Superior Copper Company. Thus the position of Lake Copper has been maintained,—not so much to the superior character of the copper but to the purity due to the care in refining.

A few years later than this the various mines erected their own smelters. The initiative was taken by the Calumet and Hecla in 1886. Rolling mills had been erected by 1877 and copper wire and sheets were manufactured in the copper country. This manufacturing has been kept up to some extent ever since.



We might consider that the year of 1894 closes another chapter in this history. At this time all the mines in Ontonagon County were closed and but one mine, the Central, was in operation in Keweenaw County. Copper at this time was selling at ten cents a pound and the country was demoralized. People in Ontonagon County were devoting their time to farming while Keweenaw was practically deserted.

Thus mining was concentrated to Houghton County. The Marquette, Houghton and Ontonagon R. R. had laid an extension from L'Anse to Houghton. Thus the copper country was no longer isolated during the close of navigation. The Mineral Range had connected Calumet with Houghton before this. At the time of writing this article the Copper Range Railroad follows the trap range very closely and runs from Calumet through Lake Linden and Houghton to Mass City where it connects with the Chicago, Milwaukee & St. Paul Railroad. A railroad, the Keweenaw Central, runs from Calumet, along the range to Lac La Belle. Thus Houghton County is connected with both Ontonagon and Keweenaw. Houghton and Hancock are the harbors for the county. All supplies are distributed from here and most all products of the two counties are shipped here. With these two roads as feeders the copper producing district is once more extending into the two counties. This time, however, the mass veins are no longer looked for. The amygdaloidal lodes now attract the attention of the explorers.

Two lodes of great value have been found. These are the Kearsarge and Baltic lodes. While the Kearsarge lode dates back to 1880 it produced in a poor manner and only two mines operated on it. These were the Kearsarge and Wolverine. In 1898 the value of the lode was recognized and it now has more producing mines operating on it than any other. Including prospects there are the Gratiot, Mohawk, Ahmeek, Allouez, North Kearsarge, Wolverine, South Kearsarge, Centennial, Calumet & Hecla, La Salle and Caldwell.

The Baltic lode was first discovered in 1883 and a ninety-foot shaft started on the lode. The lode had a dip of 72° being steeper than any known. This original shaft was sunk on an inclination of 55° and soon ran out of the lode. Disheartened by this, work was dropped and not opened until 1898. With the boom of copper then on the interest was revived and work was started. Within a short time its value was recognized and many other mines commenced work on it. Among these were the Champion and Tri-Mountain. The Globe south of the Champion has located it but it is 250 feet under the glacial drift. In order to get to it a drop shaft has been started. Up to date this has not been completed. (1906.)

Mining in the copper country is no longer looked upon as a venture but is considered more as a business. Changes have taken place and new factors now enter into mining. There is a constant attempt to cheapen the cost of the product. The cost of production has dropped from fifteen and sixteen cents a pound in 1875 to six and seven cents at the present writing. If a person who has not been in any of these copper mines for the last thirty years, were to go underground in them now he would see great changes and vast improvements. New factors are now to be considered. One no longer thinks of discovering huge masses. The compressed air drill has almost entirely replaced "single" or "double jacking." The drill is no longer so heavy as to cause trouble in removing. Two men can easily handle a drill and a hole can be punched into the rock very rapidly. Lately a hand drill has been devised so that all "block holing" is done by machines. Powder has been replaced by dynamite. Much of this is made in the copper country. Various strengths are used. Thirty-five and forty per cent "powder" is used for stoping, while fifty to sixty-five per cent "powder" is used in drifts, shafts, and for blowing loose small pieces of mass. No large masses are found—two or three tons being the limit.

The next change is in the depth of the mines. A shaft 2,000 feet long is not unusual but a very common occurrence. No. 4 Calumet occupies the position of being the deepest inclined shaft in the world. Measured from its collar to its lowest level it is 8,100 feet. From this level a winze is driven 190 feet farther to the extreme end of the Calumet and Hecla property. They have also sunk one vertical shaft, the Red Jacket, which is down to a depth of 4,920 feet.

At this point the story of the Tamarack will be of interest. They owned land to the west of the Calumet and Hecla. The apex law does not apply to Michigan. In buying land or mineral rights you are entitled to all the mineral directly beneath the surface enclosed by the boundaries set forth in the deed. They realized that on their property were the Allouez conglomerate, the Calumet conglomerate and the Osceola amygdaloid. The last two had proven paying lodes and the former had given promises of being rich at



some point. None of these lodes outcropped on their property, so in order to work them it was necessary to intersect them by vertical shafts.

They hit upon this plan and started No. 1 shaft as far to the east as was possible in order to strike these lodes the least distance from surface. They expected to cut the Allouez at 500 feet and the Calumet conglomerate at a depth of 2,000 feet from surface. That they were successful is putting it mildly. The Calumet conglomerate proved of high quality. Now they have five vertical shafts, one of which is the deepest in the world—No. 3 being bottomed at 5,229 feet, only 51 feet short of being a mile, below surface.

It was necessary for the Tamarack to use the vertical shaft. Other companies having copper bearing lodes on their property but not having the outcrop have adopted similar or different schemes, depending upon the circumstances. The Allouez does not carry any portion of the outcrop of the Kearsarge lode. Going as near as convenient to their eastern boundary they proceeded to sink a shaft at an angle of eighty degrees from the horizontal until the lode was encountered at a depth of 1390 feet. At this point, by using a curve seventy-five feet long the shaft was flattened to the plane of the lode which is 38½ degrees. The steeper portion of the shaft is provided with back runners to prevent the skip from jumping the track. So smoothly does the skip travel that these runners are rarely called into use.

Still another scheme was adopted at the Centennial. They owned the N. W. ¼ of N. W. ¼ of Section 18, T. 56 N., R. 32 W., and Section 12, T. 56 N., R. 33 W. The Kearsarge lode outcropped on their forty of Section 18 but being but 860 feet from the corner was not enough to make a mine. At this corner their part of the lode was squeezed to a point since the Calumet and Hecla owned the property to the south and the South Kearsarge to the north. They, however, bought a small strip of land from the South Kearsarge Mine and thus managed to get a width of 260 feet along the lode at this point. Two shafts were sunk from the outcrop through this narrow point. No. 1 shaft is straight and was sunk along the dip of the lode. No. 2 shaft, after passing the narrow point turned a little to the north and runs away from No. 1 shaft. This twist has caused the shaft to be likened to a cork screw.

Other factors for consideration are the disadvantages of using timber to support excavations and lining shafts. The copper country today is almost barren of big timbers. They have been used underground and in building construction. With this scarcity comes the increase in price. Another objection is that it will not support an excavation for any length of time. The pressure in the deep mines is enormous. Assuming rock to weigh one hundred and fifty pounds per cubic foot we find that at a depth of 4000 feet there is a pressure of 600,000 pounds per square foot. Placing timbers far enough apart to allow room for working, what chance have they with such pressures? A common sight underground is to see timbers as much as two feet in diameter broken in two as one would break a twig. Another fault, and not by any means the least, is that wood is not fireproof. Some of our mines have been closed for long periods on this account. A fire broke out in the Tamarack on January 11, 1906, and burned in No. 1 shaft until August 1907. No. 2 shaft resumed operations a little over a year after the fire began.

Not only is the timber incapable of holding open the enormous workings of these mines but so is everything else. Pillars of rock left standing in the mines crushed within a certain time. Today the Atlantic is a wreck because the pillars would not support it. Thus the methods of mining have had to change. No longer do they expect large excavations to remain open. Neither can they allow a stope to remain idle any length of time. The mine must be worked steadily and the rock taken out while there is time. Typical methods of mining are to be described so as to illustrate these principles.

Unique in its conservative and economical methods stands the Wolverine. Here the dip is flat—being about 40°—so that the miners stand and set their machines on the foot wall. When the rock is broken, most of it rolls down the slope to the level. The roof is strong and no timber is used in the mine. Some pillars are left while men are working, but they are eventually taken out. Thus everything is removed except shaft pillars, leaving a large open stope. Without any support the roof in time falls and the opening becomes closed.

Next in order comes the method in use at the Calumet and Hecla mines. Here the slope is not much steeper than at the Wolverine, but the rock scales off and large slabs are liable to fall at any time from the hanging wall. This means that timbering must be used. The lode here averages a width greater than in most amygdaloid mines. To reach from foot to hanging would require long timbers of the finest kind. This being too expensive the square set timbering has been adopted.

In opening up the ground preparatory to working, a drift is run in from the shaft half way to the other shaft. This distance in one case was six hundred and seventy-five feet. At the end of the drift a raise was started to run up to the next level. Two blocks three hundred feet long are then marked off and a pillar seventy-five feet thick is left to support the shaft. The block farthest from the shaft is then removed. As the work advances the timbermen follow them up so as to make the place safe for the workmen. When the first block is removed, the second block is attacked and the space left by the first block is allowed to fill by the crushing of the roof. These workings hold open but a short time. All the expensive timber simply serves for a short time. The two blocks are hardly removed before the whole stope begins to settle. The shaft pillar will only be removed when the shaft has reached the end of its usefulness. Then they will begin from the bottom to withdraw these pillars.



Great care is taken to prevent fires. Fire doors are erected in the drifts in the shaft pillar which can be readily closed. The timbers are all treated with a coating of chloride of zinc and then whitewashed.

In the Tamarack heavy stull timbers are used to support the hanging. Here also the timberman must follow closely upon the miners. "The copper bearing rock of the vein is all mined out as they go for the reason that the life of the timber is little more than a year, and it will not do to leave ground untouched too long after it is opened. They clean out the levels as they go downward letting the hanging come in as it will. The timbermen do much of the barring of loose ground in the hanging and act a very important part in the underground work."

The Atlantic was opened on an amygdaloid having a dip of 54° and an average thickness of fifteen feet. The copper is very evenly distributed. There is no selection of rock and almost all can be considered good stoping ground. In this mine work is entirely done by contract. The plan of working is as follows: Leaving a suitable shaft pillar, the ground is divided in 100 foot blocks and is let for those lengths. These contracts include drifting and stoping. First they cut out the drift, putting in heavy stulls, about twenty inches in diameter, to support the hanging and give a safe tramway. Lagging is then put on these stulls and the broken rock allowed to pile back of these. The miners getting on top of these timbers break away the rock. It accumulates on this lagging and the men stand on the broken product. This stoping is continued to within ten or fifteen feet of the level above. When a level on one side of a shaft has been cut out, they begin to draw off the ore from the farthest end and work back towards the shaft. In this way they get out all the rock.

One of the latest methods adopted and hence one of the most interesting is the "Baltic Method" now in use at the Baltic, the Tri-Mountain and at the Champion mines. Here the lode averages thirty feet in width and in some places is wider. The dip of the lode is 72°. Thus it can be seen that no ordinary method of timbering could be employed. If overhand stoping is used something must be had for the miners to stand on in order to keep close to the back of the ore.

The copper is in pockets, being very rich in some places and lean in others. Some large masses have been taken from this lode. This fact has led to underground sorting and to filling the old stopes with the waste rock. The stoping starts right with the level itself and is cut out the full width of the lode. With the waste rock dry pack walls are built so as to keep open a place for tramming. This is covered over with heavy timbers and lagging and the waste rock is thrown around the walls and on top of the lagging. Thus the old stopes are kept filled with the waste rock. In order to dispose of the copper rock a mill is carried up at regular intervals from the drift and down this the copper rock is thrown. It is noteworthy that even these chutes or mills are built of pack walls. Owing to the inclination of the lode it is necessary to have both the drift and the mill built on the foot wall side of the lode.

The sorting is done by the sense of feeling rather than by sight. Copper in the rock very often cannot be seen but if the hand is rubbed gently over the surface of the rock the presence of copper is readily detected by the prickliness of the sharp particles of copper.

In this method they even take out the pillar between the levels. When the level above has been worked out and abandoned, the miners, starting at some one point blast out the pillar until they break through to the level above. This allows the loose rock to run through and spread itself as a cone on the broken rock below the pillar. The men then work on the sides of the cone and keep cutting back the pillar. The waste from the level above pushes the newly blasted rock to the base of the cone or wedge where it is sorted. Having mills at various points it is not necessary to commence this method of drawing pillars at the farthest end of the stope. Thus everything is cleaned out of the mine. The only pillars left in the mine are the shaft pillars but if the shafts were driven



far enough in the foot wall even these would not have to be left.

The advantages claimed by this method are the small amount of timber used, hence the lessened dangers of fire, the great safety to the men, no waste rock having to be hoisted to surface, and not having to leave pillars in the ground which may contain a large amount of copper.

To return to the general changes of mining it will be seen that as the mines grow deeper there is a marked tendency to have fewer shafts. This is particularly true of mines such as the Tamarack, which do not expect to work the ore body until they get quite a distance below surface. Having fewer shafts they naturally would be placed farther apart. This has led to the use of mechanical tramming underground. The Quincy has electric locomotives on some of the levels. In the Tamarack an endless rope system has been devised. This was first adopted in the long cross-cuts but within the last few years has been extended to use in the drifts themselves.

There has been another tendency which has largely counteracted the use of fewer shafts. This is an increased output. In 1875 the Calumet and Hecla produced about 21,000,000 pounds of copper while in 1906 the product was over 82,000,000 pounds of refined copper. The two tendencies have forced each shaft to do more work and consequently has led to the improvement of them. All shafts in producing mines have been enlarged to have a double skip compartment. Skips, instead of holding say one ton of rock are made for two or three in some of the mines, while those of the Quincy hold eight tons of rock.

Some of the mines hoist only from certain levels. This is true at the Quincy. Here the shafts are in the footwall. A pocket is cut in the footwall of the lode, or the hanging wall of the shaft. This pocket is filled from two or three levels above. At the level where the skip is to be loaded a chute is built directly above the track so that the skip is brought to this point, the lip of the chute is lowered and the rock runs into the skip.

The travelling of the skips at high speed is also causing its changes in the shafts. The road has had to be improved. If the rails were held loosely and were not smooth the skips would jump the track. These skip roads are constructed with the greatest care and are carefully watched. In two instances the use of wooden ties has been abandoned and the rails are laid on concrete stringers. These two mines are the Allouez and Baltic.

These concrete stringers are laid directly on the foot wall of the shaft to which they are held by means of steel pins fastened into the foot wall and projecting into the concrete moulds. The concrete being laid around them, thus binds itself to the solid rock. They are usually one foot wide and the rail is bolted directly on its face.

The use of vertical shafts is another change. So far the only mine that has used a vertical shaft when not absolutely necessary is the Calumet and Hecla. The advantages of a vertical shaft are obvious. It gives a shorter way of getting to the ore body and allows of greater hoisting speed than does an inclined shaft (4,000 feet per minute at the Whiting shaft).

The No. 5 shaft of the Tamarack is a five compartment shaft, four of which are used for hoisting, the other being used for ladders and pipes. The Red Jacket shaft of the Calumet and Hecla is a six compartment shaft, the two easterly being used for ore, the westerly for hoisting and lowering men and materials, while the middle compartments are used for hoisting water.

The methods of hoisting ore at these vertical shafts are interesting. At the Tamarack, the tram cars themselves are hoisted in cages, which are used for all purposes, including the hoisting of men. The cages are double deck, thus two tram cars are hoisted at once. Each tram car holds three tons of rock, making a total of six tons hoisted at one time. At No. 3 Tamarack the capacity is about 1,000 tons daily. At the Whiting shaft, this method has been abandoned, owing to the time required in removing the cars, dumping and replacing them on the cage. Here the Kimberly skip has been adopted. This is a form of self dumping cage used in a vertical shaft. These have a capacity of nine tons each, thus allowing 4,000 tons to be hoisted from the one shaft during a period of 24 hours.

Vertical shafts are now being sunk by the Globe and Challenge mines. The reason for adopting them here is on account of the overburden. This is 125 feet thick at the Challenge and about twice that thickness at the Globe. In both cases drop shafts were used in order to get to the ledge and these being vertical the shafts through the rock were continued vertically downward.

To allow the shafts to be run to their capacity, new methods have had to be adopted in getting the men in and out of the mines quickly and without tiring them. While ladders are placed in every mine, being required by law, they are used only by men working on the upper levels or for going from one level to another. It would take too long and prove too tiresome for a man on the



lower levels of the Calumet and Hecla to climb say 8,100 feet of ladders. Another of the pet schemes of a decade ago has also been abandoned. This is the man-engine.

A brief description of this machine might be introduced to show the ingenuity of the device and also to show its defects. Primarily it consists of two reciprocating rods A and B (Fig. 6) extending into the mine. Each rod has platforms a, c, e, g and b, d, f, h placed at equal intervals apart—generally twelve feet—but always twice the length of the stroke. On each platform there is an upright rod by which the men can steady themselves in ascending or descending. The action can best be described from the diagram. A man wishing to descend is standing on platform a. He steps on platform b when it is opposite him. The rod B then descends until platform b is at b′. In the meantime rod A has ascended so that platform c is in position of c′ or opposite b′. The man steps over to the platform c which then descends and allows him to step to platform d. In this way he is carried into the mine. By reversing the operation he is carried up. The engine operating the two rods is usually governed by a fly wheel so that the speed of the strokes is most rapid in the center of the stroke, slowing down to a stop when the two platforms are together.

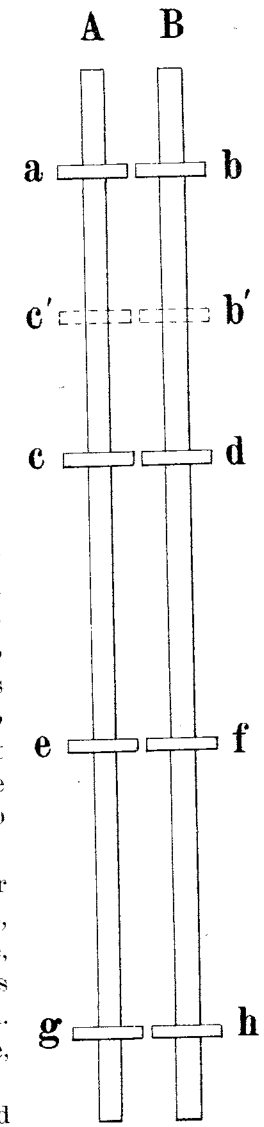

Fig. 67. Sketch of man-engine.

Such a machine may be adopted in either a vertical shaft or in an inclined one. It is, however, clumsy and costly in the first place, in operation, and in repairs. It is not safe as men have often become dizzy and confused. Besides this it does not save much more time, if any, than does the old fashioned ladders.

The universal practice now is to hoist and lower men in either cages, skips or man-cars. In the vertical shafts and in the more steeply inclined shafts, as the Baltic and Champion cages are used. These are generally double deck affairs, so that from 20 to 30 men can be hoisted at once. The older practice in the inclined shafts was to allow the men to ride up and down in the skips. They would pile into these until one would wonder how so many human beings could get into such a small space. When they get to surface they are very often jammed in so tight that one man has to be pulled out before the others can be loosened so that they may help themselves.

The man-cars can be likened to a set of steps set on wheels. These are wide enough to accommodate three men to a step and being ten steps long hold 30 men when full. It is an interesting operation to watch them remove the skip from the track and place the man-car there. At the Quincy there are four cranes to the shaft, two for each hoisting compartment. One of these removes the skip from the track. The other holds the man-car. This is then swung to the track, the rope fastened to it and the man-car is then lowered into the mine. The time required to make the change is less than one minute.

Some of the mines have special shafts, as the Wolverine, or special compartments of the shaft for hoisting and lowering men. In these cases this operation does not interfere with the hoisting of ore. It is noteworthy that the Calumet and Hecla have special ropes and special engines for hoisting and lowering the men.

These extensive improvements underground have led to improvements on surface. Separate shaft and rock houses connected by the Frue Automatic tramway are very seldom seen. Now that one shaft has a capacity equal to that of an entire mine in 1875 it has been found necessary to combine the two and have one rock house for each shaft. The sorting and crushing have changed but little. For the same reasons that wood is being abandoned underground it is being replaced by steel in surface construction. Gradually steel shaft houses are replacing the old wooden ones. With the use of steel comes a change in shape. The bins to the rock houses are being made circular. This is due to the greater ease of spreading the ore and entirely filling bins of this shape.

The hoisting engine has risen from one of forty horsepower with a six or eight-foot drum as a maximum to one of eight thousand horsepower with a twenty-four foot drum at a few of the mines. These first engines simply operated one skip, hoisting them to surface and by releasing the break, allow them to run back into the mine. Now each hoist controls two skips with their ropes so wound on the drum as to allow one skip to descend while the other ascends. This is known as hoisting in balance since the weight of the skips are equalized, thus giving less work for the



engine to perform. At the Red Jacket shaft of the Calumet and Hecla the weight of the rope is also equalized by hanging the ends of a rope to each cage and allowing it to pass to the bottom of the shaft. The hoist here is peculiar being the only one of its kind in the copper country. The large drum has been discarded and instead two drums of a narrow face have been used. Only one hoisting rope is used. This is connected at one end to one cage. It passes around the two drums three or four times, then back into a tail house where the proper tension is kept and at last connected to the other cage. To these two cages is hung the tail rope. The whole system may be likened to a cable car system.

Where the large drum is still used we often see, instead of a flat faced drum, a double conical drum with the rope so wound on it that when the skip is hoisted and the weight becomes less the rope is wound on a constantly increasing diameter, thus increasing the speed of the skip and keeping the strain on the engine more constant. These conical drums have their friends and enemies and much can be said for and against them.

The engineer no longer sits on the brake lever in order to stop his engine. Steam cylinders now control the brake so that an engineer merely operates a lever. By means of floating levers and oil cylinders the pressure of the break is very closely regulated.

The floating lever is used to regulate the oil and steam cylinders, operating the break and receives its name because the fulcrum is not a fixed point. This lever is held by three rods at points A, B, and C of the diagram. The rod attached at B is connected to and operated by the engineer's lever. The rod connected at C is connected to and operated by the piston rod of the steam cylinder operating the brake. The rod A operates the valves to the oil and steam cylinders.

If the engineer wishes to lift the piston rod he lifts, by his lever, the point B to the position of B′. C now acts as the fulcrum, AC as the lever arm, and the lever assumes the position A′ B′ C. The rod at A, being lifted, allows the steam to enter below the piston and it rises, pushing the rod connected at C with it. Now B acts as the fulcrum and the lever assumes the position AB′ C′. Thus the rod A is pushed back to its original position closing off the steam from the steam cylinder. In order, however, that the expansion of the steam in the cylinder will not carry the point C too far the piston rod of the steam cylinder is made to operate through an oil cylinder and when the rod at A shuts off the steam it also closes the valves for the oil cylinder and thus locks the piston. The distance which the point C moves is in direct proportion to the distance which B moves. As the brake moves proportionately to C and B moves proportionately to the engineers lever it is possible for him to regulate the pressure of the brake very readily. To reverse, the point A must be pushed down to point A″.

Safety devices now form a part of all hoists. By means of a worm screw the steam is thrown off and the break set when the skip reaches a certain place, thus preventing overwinding. There are two dials on each engine marking the position of the skips in the shafts. This of course is merely approximate. On the drum itself are marked in chalk the exact positions at which it should be stopped so that the skip can be exactly stopped at any desired level.

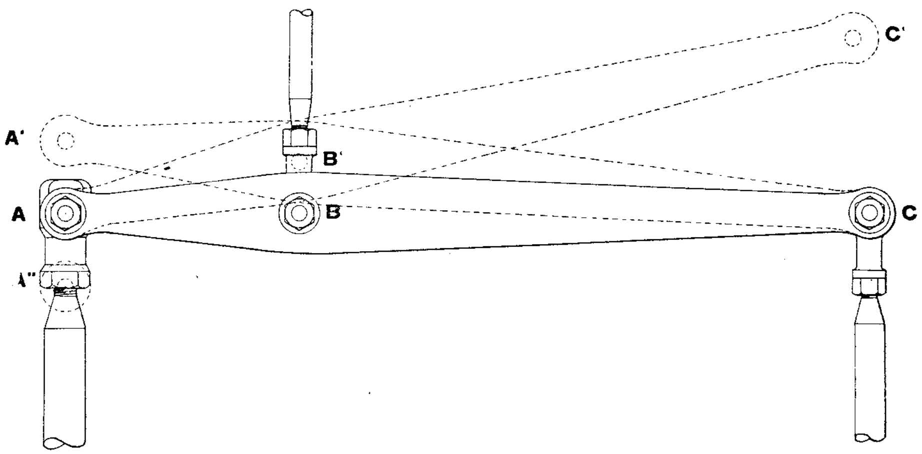


Fig. 68. Floating levers. Sketch by A. H. Meuche.

Before closing, a few remarks on drainage may not be out of place. Fortunately this is not much of a problem for the copper mines. One or two of the mines have their upper levels drained by adits. Most of the water in the mines is surface water and flows in on the first thousand feet of workings. Below this the water is very acrid in character, so much so that pumps and pipes are readily coated with rust. The amount of water is very small and does not pay for the installation of pumps on these lower levels. Most of the deeper mines, such as the Tamarack, Calumet and Hecla, and Quincy, allow this "mine water" to collect in sumps at the bottom of the shafts and bail it out in large bailers.

The stamp mill practice has changed but little during the past



thirty years. The greatest change has been in decreasing the cost of production by increasing the capacities of the various units. The steam stamp of today, with the aid of rolls have a crushing capacity of over 700 tons. This stamp is fed from a hopper by gravity into this stamp. A man with an iron hook stands here to regulate the feed or hold it back when necessary. He also watches for pieces of mass which he casts aside. The total crushing or falling weight is three to four tons and the actual stroke is from 20 to 24 inches.

In the mortar (at the Isle Royale mill) the rock is crushed to pass a five-eighths inch screen. Large lumps of copper, the size of small potatoes which are contained in the rock will not pass this screen. They are removed by a hydraulic arrangement. A four inch opening is left in the mortar just below the lip. This is connected to a pipe through which water is forced into the mortar at such a speed that only these lumps of copper can force themselves through it. They fall into a receptacle outside of the mortar. These are termed headings and make up about one-fourth of the product of the mill. Another and almost equal amount is extracted between the stamps and the trommels.

The annexed flow sheet will serve the purpose of tracing the product through the mill. The rock after leaving the stamp goes to a trommel with a 5/16″ hole. The oversize passes to a set of rolls and is crushed to a smaller size. The ore then passes to a hydraulic classifier. In each section of the mill there are three such classifiers with three sets of roughing jigs, each doing the same work. The rock from the trommel is divided into three equal parts, each of which goes to a classifier. In these classifiers the rock is classified into five parts, the heaviest settling first and so on until the fifth or slimes is washed over the end and taken to settling tanks. The other products are jigged on two separate jigs, the hutch of which goes to the finishing jigs and the tails are waste. A certain amount of copper collects on the screens of the jigs and is scraped off at regular intervals. The hutch product of the finishing jigs runs to settling boxes and is ready for the smelter or subsequent treatment. The slimes are first allowed to settle. The settlings are treated on Evans tables the heads of which are treated on Wilfley or Overstrom tables and the tails go to waste.

In the operation of the stamp mill copper is taken off at every point. It is picked from the feeding hopper, discharged in big lumps from the stamps. It comes from the roughing jigs as red gravel, as fine sand from the finishing jigs and as red mud from

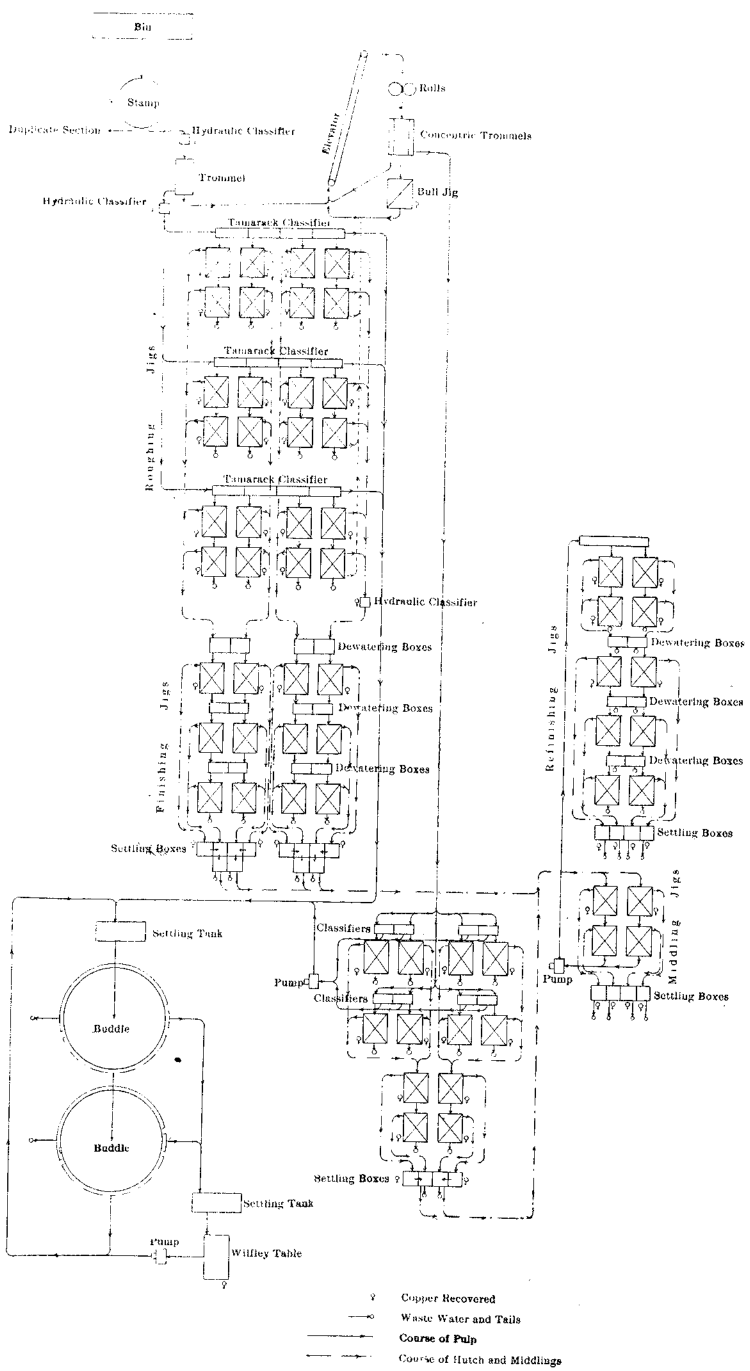


Fig. 69. Flow sheet of Stamp mill. Sketch by Meuche.



the concentrating tables. Some native silver is found with the copper. At some stamp mills a boy is employed to pick silver out of the mineral but if the pieces are very small but of rather high percentage (2%) the mineral is refined at the smelter and cast into anodes. These are then shipped to an electrical refinery where the silver and copper are separated. No reliable estimate can be made of the amount of silver in these mines as it is stolen by the employees underground, in the mills, and smelters.

The amount of water used is something enormous, being something like thirty tons of water to one of ore or three and one-half million gallons per day for each stamp. The cost of stamping has been reduced from two dollars a ton in 1854 to as low as twenty-eight cents. (Tamarack report for 1907.)

It must not be supposed that all the copper is recovered. The criticism of Prof. Egleston still holds and as stated by a more recent writer: "This will emphasize the observation that during late years the endeavor to lessen costs has been pushed at the expense of any improvement in extraction; that is, it has not realized that while the expenditure entailed by the treatment of copper ore has decreased, there has been no commensurate diminution in the amount of copper lost. Five cents worth of copper, per ton, lost in the tailing is worth just as much as a five cent decrease in milling cost."

## APPENDIX.

BY A. C. LANE.

### 1. *Introduction.*

Between the writing of so voluminous a report as this and its actual issue, some time must elapse. This report is part of my report for the year 1909. I had to make a hard and fast rule, in order to ever get through, in reading proof, to make no changes, except where actual errors or failures to clearly convey my meaning were involved. The temptation was strong to try to include more recent drilling, but as dozens of drills had been and are continuously at work, I should never have known where to stop. The wisdom of this rule is shown by one of the few exceptions made to it. In a few cases, where I thought the reader should be forewarned of a change of views or different use of names due to it, more recent work has been mentioned. One of these references, that to the "Mayflower lode" in the foot-note of page 371, called attention to the fact that the lode recently so named is not the one so named in Figure 39 and in earlier explorations. But, misled by press accounts of recent drilling, I misstated the horizon of the new "Mayflower lode," which, according to G. S. Goodale, in the annual report of the Company for 1911, is several hundred feet below the St. Louis conglomerate.

A few reports have, however, appeared since the transmission of my manuscript and a few explorations of such importance made that I have inserted this appendix, so that, although I may not give them all the attention they merit, I may not seem to ignore them.

### 2. *Bibliography.*

I have not given a complete bibliography of titles pertaining to the Keweenawan series. Work thereon is so covered by the reports of the Canada, Ontario, Minnesota, Wisconsin and Michigan Geological Surveys, and especially the bibliographies of Monographs 5 and 52 of the United States Geological Survey, and its annual bibliographies, that it would be what R. S. Woodward has called "a platitude of research." I have, however, listed a few papers overlooked in the bibliographies and some of the more recent works to which I would call attention.



The Proceedings of the Lake Superior Mining Institute, the Canadian Mining Institute, the American Institute of Mining Engineers and the Michigan Academy of Science will naturally not be over looked by the thorough enquirer. The Michigan Engineering Society and Michigan Miner mainly concern themselves with Lower Michigan.

The losses in copper dressing at Lake Superior, by Adjunct Professor H. S. Monroe. Transactions of the American Institute of Mining Engineers, September, 1879.

The copper-bearing rocks of Lake Superior, by R. D. Irving. U. S. G. S. Monograph V; also 3rd annual report U. S. G. S., 1883, pp. 93-188.

Geologic maps of Michigan, by Jules Marcou and John Belknap Marcou. U. S. G. S. Bulletin No. 7, 1884, pp. 77, 78, 79, 80, 81, 82, 83, 85, 87, 88.

On the classification of the early Cambrian formation, by R. D. Irving. U. S. G. S. 7th Annual Report, 1888, pp. 365-454.

Notes on some diabase dykes of the Rainy Lake region, by Andrew C. Lawson. Proceedings Canadian Institute, 1887.

Las aguas minerales de Chile, by Dr. L. Darapsky. Valparaiso, 1890.

The copper region of Michigan, by Frank B. Phelps. Engineering Magazine, Vol. IV, 1892, pp. 47-63.

Building stone from Michigan, at World's Columbian Exposition. M. R., 1893, p. 567.

Excursion to Lake Superior—Pre-Cambrian geology of the Lake Superior district, by C. R. VanHise. Int. Cong. Géol. Compte Rendu, 5th session, 1893, pp. 110-50.

Basic massive rocks, by W. S. Bayley. Journal of Geology, Vol. I, 1893, pp. 433-56, 587-96.

On powellite from a new locality, by George A. Koenig and L. L. Hubbard. American Journal of Science, 3rd ser., Vol. XLVI, 1893, pp. 356-8.

The copper resources of the United States, by James Douglas. Sci. Am. Suppl., Vol. XXXV, 1893, pp. 14183-6.

A reconnaissance of the abandoned shore lines of the south coast of Lake Superior, by F. B. Taylor. American Geologist, Vol. XIII, 1894, pp. 365-83.

Ueber powellit von einem neuen Fundorte, by Georg A. König and Lucius L. Hubbard. Zeitschrift für Krystallographie, etc., XXII 5/6 1894, pp. 463-6.

Changes of level in the region of the Great Lakes in recent geological time, by F. B. Taylor. American Journal of Science, 3rd ser., Vol. XLIX, 1895, pp. 69-71.

On underground temperatures at great depth, by A. Agassiz, American Journal of Science, 3rd ser., Vol. L, 1895, pp. 503-4.

A northern Michigan base-level, by C. R. Van Hise. Science, new ser., Vol. IV, 1896, pp. 217-20.

A central Wisconsin base-level, by C. R. Van Hise. Science, New ser., Vol. IV, 1896, pp. 57-9.

The crystallization of the calcite from the copper mines of Lake Superior, by Charles Palache. Michigan Geological Survey, Vol. VI, Pt. II, Appendix, 1898, pp. 161-84.

The origin and mode of occurrence of the Lake Superior copper deposits, by M. E. Wadsworth. Transactions American Institute of Mining Engineers, Vol. 27, 1898, pp. 669-96.

Some dike features of the Gogebic iron range, by C. M. Boss. Idem. pp. 556-63.

On the thermal conductivities of certain poor conductors, by B. O. Peirce and R. W. Willson. Proc. Am. Acad. Arts and Sciences, Vol. XXXIV, No. 1, 1898, pp. 3-56.

Powellite crystals from Michigan, by Charles Palache. American Journal of Science, Vol. VII, May 1899, pp. 367-9.

Altitudes in Michigan. U. S. G. S. 21st Annual Report, Pt. I, 1899-1900, p. 465.

Note on a method of stream capture, by A. C. Lane. G. S. A. Bulletin, Vol. X, 1899, pp. 12-15.

The development of the copper industry of Northern Michigan, by James Ney Wright. Michigan Pol. Sci. Ass. Pub., Vol. 3, No. 5, Ann Arbor, 1899.

On the thermal diffusivities of different kinds of marble, by B. O. Peirce and R. W. Willson. Proc. Am. Acad. Arts and Sciences, Vol. XXXVI, No. 2, 1900, pp. 13-16.

On mohawkite, stibiodomeykite, algodonite and some artificial copper-arsenides, by George A. Koenig. American Journal of Science, Vol. X, December 1900, pp. 439-48.

Note sur la région cuprifère de l'éxtremiteé nordest de la péninsula de Keweenaw (Lac Supérieur), by Louis Duparc. Archives sci., phys. et Nat., Vol. X, 1900, p. 21.

The geothermal gradient in Michigan, by A. C. Lane. American Journal of Science, 4th ser., Vol. IX, 1900, pp. 434-8.



The origin of the native copper in the Michigan deposits, by J. F. Blandy. Engineering and Mining Journal, Vol. XX, 1900, pp. 278-9.

Suggestion from the State Geologist, by A. C. Lane. Michigan Miner, Vol. 3, No. 10, 1901, p. 9.

Annual report of the State Geologist (Michigan), by A. C. Lane. Michigan Miner, Vol. 3, 1901, pp. 13-22.

Work of the Geological Survey in the Upper Peninsula, by L. L. Hubbard. Michigan Miner, Vol. 3, No. 3, 1901, p. 9.

Geological Survey of Michigan. Report of field work for 1900, by W. V. Savicki. Idem. pp. 9-11.

On artificial production of crystallized domeykite, algodonite, argentodomeykite and stibiodomeykite, by George A. Koenig. Proceedings Am. Philosophical Society, Vol. XLII, No. 173, pp. 219-37.

Crystallographic properties, by F. E. Wright. Idem, pp. 237-49.

On the thermal conductivities of certain pieces of rock from the Calumet and Hecla mine, by B. O. Peirce. Proceedings American Academy of Arts and Sciences, Vol. XXXVIII, No. 23, 1903, pp. 651-60.

Copper mining in Upper Michigan, a description of the region, mines and some of the methods and machinery used, by J. F. Jackson. Mines and Minerals, Vol. 23, 1903, pp. 535-40.

The theory of copper deposition, by A. C. Lane. Michigan Miner Vol. 6, No. 2, 1904, pp. 9-11, No. 3, pp. 9-11; American Geologist, Vol. 34, 1904, pp. 297-309.

Copper mines of Lake Superior, by T. A. Rickard. Engineering and Mining Journal, Vol. 78, 1904, pp. 585-7, 625-7, 665-7, 705-6, 745-7, 785-7, 825-7, 865-7, 905-7, 945-50, 985-7.

The geology of some of the lands in the Upper Peninsula (Michigan) by R. S. Rose. Mining World, Vol. 21, 1904, pp. 205-7; Engineering and Mining Journal, Vol. 78, 1904, pp. 343-4; Proc. Lake Superior Mining Institute, pp. 88-102. See Monograph LII.

Historical review of the geology of Michigan, by A. C. Lane. Michigan Academy of Science, 5th Annual report, 1904, pp. 184-95.

Comment on the "Report of the special committee on the Lake Superior region," by A. C. Lane. Journal of Geology, Vol. 13, 1905, pp. 457-61

The Tamarack Mine cross-section and the Keweenawan lodes, pp. 271-94; also—

Waters of the Upper Peninsula of Michigan, pp. 111-67; also—

Report of progress in the Porcupine, by F. E. Wright. Michi-

gan Geological Survey. Annual Report for 1903, 1905, pp. 33-44. Also preliminary geological map of the Porcupine Mts. and vicinity, by F. E. Wright and A. C. Lane. Michigan Geological Survey, Annual Report for 1908, 1909, Plate I.

Notes on the rocks and minerals in Michigan. To accompany the loan collection issued by the Michigan College of Mines, by F. E. Wright, Houghton, 1905.

Mines of the Lake Superior copper district, by Horace J. Stevens. Program for 12th Annual meeting Lake Superior Mining Institute, 1906, pp. 9-27; also Proc. Lake Superior Mining Institute, Vol. 12, 1907, pp. 8-24.

An ecological survey in the Porcupine Mts. and Isle Royale, Michigan, by A. G. Ruthven. Michigan Geological Survey, Annual Report for 1905, 1906, pp. 17-47.

The copper mines of the United States in 1905, by W. H. Weed. U. S. G. S. Bulletin No. 285, 1906, pp. 93-124.

The Nonesuch sandstone, by G. W. Corey. Engineering and Mining Journal, Vol. 82, 1906, p. 778.

Material for geography of Michigan, by M. S. W. Jefferson, Ypsilanti, Michigan, 1906.

Peat, essay on its origin, uses and distribution in Michigan, by C. A. Davis. Michigan Geological Survey, Report of State Geologist for 1906, 1907, pp. 93-395.

The Newark (Triassic) copper ores of New Jersey, by J. Volney Lewis. Annual report of New Jersey State Geologist, 1906, pp. 131-64.

Die Enstehung der Kupfererzlagerstätte von Corocoro und verwandter Vorkommnisse in Bolivia, by G. Steinmann. Festschrift Harry Rosenbusch, Stuttgart, 1906, pp. 335-69.

Copper deposits of the New Jersey Triassic, by J. Volney Lewis. Economic Geology, Vol. II, No. 3, 1907, pp. 242-57.

Structure and correlation of Newark trap rocks of New Jersey, by J. Volney Lewis. G. S. A. Bulletin, Vol. 18, No. 4, 1907, pp. 195-210.

Ninth annual report of the State Geologist of Michigan for the year 1907, by A. C. Lane. State Board Geological Survey report, for 1907, 1908, pp. 1-31.

A reconstruction of water planes of the extinct glacial lakes in the Lake Michigan basin, by J. W. Goldthwaite. Abstract: Science, new ser., Vol. 27, May 8, 1908, pp. 724-5; Journal of Geology, Vol. 16, No. 5, 1908, pp. 459-76.

The altitude of the Algonquin beach and its significance, by J. W. Goldthwaite. Abstract: Science, new ser., Vol. 28, Sept. 18, 1908, pp. 382-3.



Features indicative of physiographic conditions prevailing at the time of the trap extrusions in New Jersey, by C. N. Fenner. Journal of Geology, May-June, 1908, pp. 299-327.

Use of "ophitic" and related terms in petrography, by A. N. Winchell. G. S. A. Bulletin, Vol. 20, 1908, pp. 661-67.

In the Michigan copper country, by R. E. Hore. Canadian Mining Journal, Vol. 30, July 15, 1909, pp. 421-2.

Michigan iron mines and their mine waters, by A. C. Lane. Mining World, Vol. 31, August 21, 1909, pp. 413-16.

Geology of the Porcupine Mts., Michigan, by A. C. Lane. Mining World, Vol. 30, June 12, 1909, pp. 1115-17.

The decomposition of a boulder in the Calumet and Hecla conglomerate and its bearing on the distribution of copper in the Lake Superior copper lodes as indicating the trend and characters of the waters forming the chute, by A. C. Lane. Economic Geology, Vol. 4, No. 2, 1909, pp. 158-73.

Mines waters and their field assay, by A. C. Lane. Geol. Soc. Am. Bulletin, Vol. 19, 1909, pp. 501-12.

Tenth annual report of the State Geologist of Michigan to the Board of Geological Survey for the year 1908, by A. C. Lane. Michigan Miner, Vol. 11, No. 2, Jan. 1909, pp. 9-17.

Salt water in the Lake mines, by A. C. Lane. Michigan Miner, Vol. 11, No. 4, March, 1909, pp. 24-26.

The Watchung basalt and the paragenesis of its zeolites and other secondary minerals, by Clarence N. Fenner. Annals of the New York Academy of Science, Vol. XX, No. 2, Pt. II, Aug. 4, 1910, pp. 93-187.

The crystallization of a basaltic magma from the standpoint of physical chemistry, by Clarence N. Fenner. American Journal of Science, Vol. XXIX, March, 1910, pp. 217-34.

Copper-bearing amygdaloids of the White River region, Alaska, by Adolph Knopf. Economic Geology, Vol. V. No. 3, April 1910, p. 247. See also U. S. G. S. Bulletin No. 417, Moffit and Knopf.

Copper, a weekly review of the Lake Superior Mines, (published by Gay and Sturgis, A. L. Carnahan, Editor), Vol. 3, No. 23, September 3, 1910.

Copper in the red beds of Oklahoma, by William Arthur Tarr. Economic Geology, Vol. V, No. 3, April, 1910, p. 221.

Ein Beispiel der "Zeolith-Kupfer-Formation" in Andesit-Massiv

Osterbeins, by Stud. M. Lazarevic Leoben. Zeitschrift für Praktische Geologie, February, 1910, p. 81.

Das Vorkommen und die Gewinnung des Kupfers, by Prof. Dr. Krusch. Naturwissenschaftliche Wochenscrift, Nos. 51 and 52, December, 1910.

The effect of leakage at the edges upon the temperatures within a homogeneous lamina through which heat is being conducted, by B. Osgood Peirce. Proc. American Academy of Arts and Sciences, Vol. XLV, No. 13, April, 1910, pp. 355-60.

The geology of the Lake Superior region, by Charles R. Van Hise and Charles K. Leith. U. S. G. S. Monograph LII, 1911. Chapter IV (Physical Geography) by Lawrence Martin; W. J. Mead, R. C. Allen, A. N. Winchell and Edward Steidtmann also mentioned in the table of contents as co-authors.

Some modes of deposition of copper ores in basic rocks, by Waldemar Lindgren. Economic Geology, Oct.-Nov., 1911, Vol. VI, No. 7, pp. 687-700.

The Copper Handbook, by Horace J. Stevens, 1900-1911 inc.

Some practical suggestions for diamond drill explorations, by A. H. Meuche. Lake Superior Mining Institute, Vol. XVI, 1911, pp. 77-81.

Genesis of copper with zeolites in basic rocks, by Waldemar Lindgren. Mining and Engineering World, Vol. 35, No. 27, Dec. 30, 1911, p. 1311.

Appraisal of mining properties of Michigan by the State Board of Tax Commissioners, 1911, by J. R. Finlay.

Native copper in basalt, by R. Braums in Bonn. Zeitschrift für Krystallographie, 1911, p. 493; Central Blatt, 1908, pp. 705-9.

The copper-mining industry of Michigan, by R. E. Hore. Mining World, Vol. XXXVI, No. 11, 1912, pp. 601-3, No. 12, pp. 656-58, No. 13, pp. 707-10, No. 14, 763-67.

Notes on the paragenesis of the zeolites, by J. Volney Lewis. Preliminary list of papers for 24th meeting of G. S. A., Dec. 27-30, 1911, p. 5; also Science, February 23, 1912, Vol. XXXV, p. 313.

Diamond drilling at Point Mamainse, Province of Ottawa, by A. C. Lane. Bulletin 6, Department of Mines, Canada, 1912.

### *Divergences.*

It would be pleasant and not profitless to point out in detail where the observations herein recorded confirm, agree with and strengthen the conclusions of Fenner and Lewis in New Jersey and of Van Hise, Leith, Steidtmann, Martin and Thwaites on the



Keweenawan. I shall do this to some extent by seeing that not merely their names are thoroughly indexed, but also certain headings under which are grouped references to observations on subjects of especial interest to them, such as: prehnite and other zeolites, paragenesis of; Keweenawan, signs of origin of; Upper distribution and relations; water, effect of; copper, formation of.

Although less pleasant, it may be of more use to point out wherein there are divergences, so that the reader of this report may be duly warned thereof.

With Monograph LII, there are three main points of divergence; (1) as to the intrusive character of the Greenstone[1]; (2) as to the age of the Keweenawan; (3) as to the age and connate character of the salty mine waters.

As to the Greenstone, the authors of Monograph LII, on page 381, cautiously suggest that it may be, at least in part, intrusive. The coarseness of the grain of this, perhaps the coarsest single lava flow that is known, and the cliffs above the Cliff Mine, like those of the intrusive Palisades of the Hudson, make the suggestion natural. But, on the other hand, we have the following facts:

(a) So far as it is always at one horizon, just above the Allouez conglomerate, and never seems to cut across strata we have a very strong argument for its being a flow. How far this is true can only be judged by a detailed study of Chapter V. The authors of Monograph LII are hardly inclined to accept my correlations of exact beds of the section on Isle Royale with beds on Keweenaw Point; (b) it has not the contact effect of the igneous rocks, neither producing tourmaline as under the Palisades nor changing augite to such hornblende as produced in the ophites by the gabbro of Mt. Bohemia; (c) the occasional induration, and especially the occasional production of steam bubbles in the originally muddy upper layers of the bed below, which are now filled with calcite, are quite characteristic of an effusive contact; (d) the coarseness of the grain clear to the center is much more likely to occur in a thick flow than in a thick sill, as shown in Chapter IV; (e) even the lighter streaks, the diorite streaks of Marvine, or doleritic streaks, in which the feldspar is coarser than in many gabbros, show by the fact that the nearer they are to the center of the Greenstone as a whole the coarser they are, while they show no change in coarseness in their contact with the darker, poikilitic part, that they are an essential part of the original flow. They do, indeed, look very much like some gabbro pegmatites, and are,

[1] Note the capitol. The term is used on Keweenaw Point as a proper name applied to the bed above the Allouez Conglomerate.

I believe, due to a similar segregation of mineralizers, which tended to produce a greater power of crystallization and more perfect crystals, and possibly delayed, also, the crystallization. For details regarding this, see the references indexed under Greenstone, doleritic texture, Allouez conglomerate.

(2) As to the age of the Keweenawan, owing to the work of Thwaites, we are now happily agreed as to almost all the facts summarized on pages 416 to 426 of Monograph LII. I still adhere to the conclusion of my report for 1908, drawn from these facts, that the Cambrian age of the Keweenawan is probable. That the Keweenawan is "largely subaerial" and (naturally therefore) "not fossiliferous," I find no argument against its Cambrian age, but quite the reverse. That the Cambrian contrasts with the Keweenawan in lacking volcanism, is certainly not true of the Upper Keweenawan, which is later than any volcanism in the Lake Superior region, unless, indeed, Wilson's suggestion that there are Cretaceous lavas near Nipigon Bay should prove to be correct. (Monograph LII, p. 369.) On the other hand, the early Cambrian of eastern Canada and New England, as well as the typical Welsh Cambrian, contains coeval volcanics. This does not show anything as to Lake Superior of course. I only wish to point out that the statement of Monograph LII must be qualified until it, too, does not prove anything. Though the "Upper Cambrian is flat lying," so is the Lake Superior sandstone of the Apostle Islands, which Thwaites recognizes as conformably above and part of the Upper Keweenawan. That the upper marine Cambrian rests unconformably upon Middle Keweenawan beds is quite to be expected, when the latter are land volcanics.

"The similarity of lithology and accordance of structure between Upper Keweenawan and Cambrian" might, indeed, be the result, as the authors say, of a very much later transgression of the sea over flat lying sediments, but since the Lake Superior basin began to form before the Keweenawan, and seems to have never ceased to be a basin, there should have been continuous deposition in the center. This would be true whether it were a marine or a desert basin, a bolson or a playa, and this, indeed, seems to be accepted by the authors of Monograph LII, in their resumé (on page 416) of the course of events, but in that case, the whole Cambrian must be represented in the series of red sediments between the Jacobsville sandstone and the Freda sandstone, which can hardly be more than a few thousand feet, while Walcott gives for the Cambrian section of the Rocky Mountains (National Geographic Magazine, Vol. 22, No. 6, p. 514) 3,590 feet Upper Cambrian, 4,963 feet Middle Cambrian, 4,524 feet Lower Cambrian, largely limestones and shales, which are generally supposed to be very much more slowly accumulated than the sandstones. Under any hypothesis, the Keweenawan beds "constitute a marked local variation" from general conditions, but to me they seem lithologically far more allied with the Upper Cambrian than with the Pre-Cambrian. This is shown by the fact that for a long while almost everyone supposed that the Bayfield or Western sandstone of the Apostle Islands was of the same age as the Jacobsville or Eastern sandstone, which the Limestone Mt. section seems to show to be Cambrian.



Again, not only the Porcupine Mt. monadnocks referred to by Van Hise, which, as he says, were (Science, new ser., Vol., IV, 1896, pp. 57-9) more nearly reduced to base-level during a time extending down to the Cretaceous, but numerous contacts of the Jacobsville sandstone that show relations of contact against cliffs of the Lower Keweenawan beds, while they indicate, indeed, much erosion during intervening time, also seem to me to indicate that the Lower Keweenawan was by no means base-leveled at the time of the Upper Cambrian transgression nor lay beneath the Pre-Cambrian peneplain. But the profound discordance of the Keweenawan and Huronian on the Gogebic Range and not merely that, the whole relation of distribution and attitude of the Keweenawan to the Huronian folds and formation, as A. E. Seaman has suggested, seems to show almost at a glance relations like those of the Triassic sandstones and traps (which the Keweenawan so much resembles) to the Palaeozoic. The main movement, much folding, many synclinal axes, much iron ore concentration, much erosion, took place before the Keweenawan. In other words, the master gap, at the beginning of the Palaeozoic, comparable to that at the end of the Palaeozoic, occurred prior to the Keweenawan, rather than after. The problem thus seems to be analagous to that of the "Red Beds" of Pennsylvania-Permian-Triassic age. Final conclusions must come from a valid correlation of volcanic outbursts, continental uplifts, and world-wide changes of strand line. The nearer we can get marine Cambrian, in which there are signs of contemporaneous volcanic action, the surer we shall be that the Keweenawan volcanics are Cambrian in age.

Seaman's map of the Keweenaw Point district (Plate XXVIII, Mono. LII) seems to draw the line between Upper and Lower Keweenawan at the base of the Great Conglomerate,—a suggestion stratigraphically worthy of consideration, though it does not accord with Irving's original division, nor with the text.

M. Collen in Economic Geology, 1907, page 572, (Vol. II, No. 6) describes a series of copper deposits in the Belt formation of Montana. This is unconformably overlaid by the Middle Cambrian, Flat head sandstone, and is said to be separated by great unconformities both from it and the "Archean" beneath. It is divided into two series by an unconformity. The upper and lower series contain black fetid limestones, and certain beds of this are impregnated with chalcopyrite and chalcocite. There is also a great thickness of red shale,—the Spokane shale. These red beds carry copper ores sometimes in veins and sometimes in bedded deposits associated with "intrusion" of diabase. The copper is most abundant when the diabase is thoroughly altered. He believes it has been leached by circulating ground water from the diabases. These diabases should correspond very closely to the Keweenawan. It is notable that the sulphides are mentioned, not native copper, and intrusives not effusives.

(3) The third question is as to the "explanation for the characteristics" of the deep waters high in chlorides. The authors of Monograph LII are not inclined to accept my suggestion that these characteristics are connate, that is original, "for all the essential kinds of conditions which produce the salt water of the ocean are present." (p. 544) "Chlorine is present," as they say, "in minute quantities in original igneous rocks and in nearly all surface waters. Its salts tend to remain in solution, while the salts of other acids are more largely precipitated. With a given amount of water, there seems likely to be, therefore, a progressive relative accumulation of chlorine salts. Such is the case in salt waters at the earth's surface, where a large factor in the accumulation is the lack of sufficient circulation to carry off and dilute the salt waters that are developing by evaporation. In deep underground waters there is essentially the same condition of stagnancy, and therefore we suggest progressive accumulation of soluble chlorine salts."

Is not evaporation an "essential kind of condition" for surface salt waters? The only thing that can replace it underground is rock hydration and the absorption of water into solid minerals. This may be a factor, but one would not expect it to be of much weight, especially when these salt waters occur in limestones and pure sandstones.

It is gratifying to notice that Van Hise realizes the importance of stagnant water. The more stagnant the water, the more largely



must it be connate. That the chemical composition of connate waters may be changed after burial, one can not deny, but the only way that one can suppose such stagnant connate waters could acquire the large percent of salts they often contain is to suppose that a small percentage of interstitial waters in the pores has leached a good part of a very small amount of chlorine from the fresh rock. A rock with a half percent pore space filled with water or say five ounces of water in a cubic foot would have about a sixth of a percent, of the weight of a cubic foot of rock. The segregation of enough chlorine to make this a strong solution of chlorides would be less than a tenth of a percent,—so small a quantity that no chemical work yet done, to be sure, is enough to prove that it may not have happened. Neither is there chemical or petrographic evidence, such as corroded apatite adduced to show that it has taken place. Stagnant waters would certainly retain strong traces of their original character, and I see no reason why my assumption that the chlorine is almost wholly connate does not better agree with the facts.

For in the first place, the term "progressive," as above used, must be understood as referring to time, not to space or distance from surface. If anything stands out from my mine water studies, it is the rather sharp change from fresh to salt. The fact that the salt water at the top has much more sodium in proportion to the strength than the stronger, deeper water, seems to show most surely that it is not by the increase of chlorine, first taking up sodium, then "when the sodium is taken care of by the chlorine," the calcium, but by a direct reaction of the calcium chloride waters, either with rocks that contain soda or surface waters containing sodium silicate or carbonate that these waters, intermediate in position, but not in composition, have been formed. I wish I had printed as a figure some diagrammatic tabulations of the composition of the waters in which this clearly comes out. The suggestion of Van Hise and Leith is, however, very interesting and important, if true,—that the percent of chlorine can be taken as an index of the degree of stagnation. In this, I should be inclined to agree myself.

With regard to the formation of copper (see especially page 558 of Monograph LII) we are agreed that the formation of the copper was but shortly after the formation of the beds in which it is found, and that the copper-bearing solutions were hot. I am inclined to dwell on the fact that they were unequally hot and think that they tended to throw down the copper in the hotter parts;

that the turning of calcium chloride into sodium chloride helps to throw out copper I do not doubt, but am inclined to emphasize the presence of trap rocks that help to make an alkaline solution. We agree that the water was "both juvenile and meteoric." I think the chlorine was also, and suggest that there may have been some concentration in desert pools, which lava streams may have helped to evaporate. We both are inclined to consider the effusive rather than the intrusive rocks as the source of copper. In that, we differ from the explanation of Volney Lewis of the New Jersey zeolites and the copper associated with them.

In 1911, I went down the Somerville mine, one of the deepest of the New Jersey mines, to the bottom. I saw no reason to believe that the formation of the copper was there different from that at Lake Superior. The occurrence is directly under and in the joints of an effusive lava sheet and seems to be where the water impregnating the sandstones and shales below (in which shales steam bubbles were formed by the lava) was hotter and more alkaline, being near the alkaline trap. The native copper appears to be an original ore as it is in Lake Superior and oxide and sulphide largely secondary. Fenner and Lewis have recently gathered numerous facts as to the paragenesis of the zeolites and the flow of lava on land and in lakes that entirely fit with what I have seen in Lake Superior. I wish I had read their works twenty years ago. But it must not be forgotten that the mineralizers or magmatic waters of a magma do not cease to exist, if, instead of being intruded, the molten lava reaches the surface, and there is no reason why the boron, found so often in borax lakes in volcanic arid regions, should not be efficient as a mineralizer, if buried under hot lava flows, even though it had seen day-light. The difficulties as to the source of boron raised by Lewis may thus be removed.

The "circulation" seems to me rather an imbibition or absorption with an ionic migration toward points where precipitation is going on. Long ago, de Lapparent called attention to the fact that the traps are alkaline and have a reducing action.

It would be foolish to deny that intrusives in many places have a large part in ore deposition. Intrusive traps occur at many places and at many ages, but the primary ore associated with them is generally chalcopyrite. Only in the formation of native copper does it seem as though it were needful for them to reach the surface so as to give the sulphur a chance to oxidize to sulphate and be carried in one direction, while the more readily reduced silver and copper, which have less affinity for oxygen than the sulphur, are reduced without it.



Native copper deposits, as I have pointed out, appear to be associated with certain former physiographic surface conditions.

The report of J. R. Finlay was made for purposes of taxation and this report is pretty closely confined to geology, but there is one sentence (p. 33) that I would challenge geologically, viz.: that "the copper district has been pretty thoroughly explored." According to the authors of Monograph LII and myself, the occurrence of copper has but little to do with the present surface, though there may have been some mainly pre-glacial, perhaps pre-Ordovician impoverishment connected with a surface not unlike the present. If, as I have suggested, certain lava flows evaporating certain pools in the desert tended to produce some concentration of copper, certain horizons must be regarded as more favorable than others. This might apply to the Kearsarge or Pewabic lodes. The Nonesuch horizon also shows heavy decomposition of basic rocks and there may have been copper dissolved in that connection, and while it shows signs of copper almost everywhere, it has been closely tested for copper but for a very few miles. The horizons of very few lodes have been explored for more than a small fraction of their distance.

Again, if I am right in thinking that the mineral crests or richest parts of the lodes are in the belt of middle waters, it is obvious that only explorations of lodes of something over 1,000 feet, on the average, is a fair test of their worthlessness.

Finally, when we remember that the surface of the range is largely covered by thirty to three hundred feet of drift, and that there is not the slightest reason, so far as I know, to suppose that there is any such connection between drift and the copper that the copper should be found mainly where the drift was thin; that the only way of testing drift covered regions at all is by diamond drills or shafts and that diamond drilling has been used not much over twenty years and is, at best, like probing for a needle in a haystack, with a long steel rod, it seems very unlikely that we have already pretty thoroughly explored and developed the best copper mines. It is quite likely that the cost of preliminary exploration may grow, but that, as fast as more copper is needed, more exploration will be done to find it and more will be found. I may say that I have some times, by request, refrained, in this report from reporting visible copper, so that the references to copper in the drill core, sections given in this report are not on a uniform basis and cannot be used to determine the relative value of lodes.

*Recent Explorations.*

The geological and diamond drill exploration in the years 1909-1912 has been mainly in two districts. The one is from the Adventure and Lake Mines northeast. To some extent, drilling later than 1909 has been incorporated in Plates XIII and XIV. The formation is, no doubt, broken by many faults, but I know of no serious changes required in these or in Plate VIII, except (according to a theory I can not yet accept) in the neighborhood of the Lake lode.

The question as to the relation and direction of the Lake lode is still an open one. One theory is that it curves around, forming a synclinal and so continues with certain copper bearing belts of the South Lake. This would naturally imply a belt of at least some distance in Section 31, T. 51, R. 37 and 36, T. 51, R. 38, where the dips, instead of those everywhere else universally present through the Copper Range toward Lake Superior, would become southeastward. This is the theory which has been naturally attractive to the South Lake Mining Company and which is illustrated in the map accompanying their annual report for 1910. It is also favored in the Lake Mining Company report for 1911. One objection to it seems to be the apparent dip of the beds in Adventure drill hole 1, shown especially in the sandstone at 779. It will be remembered that that hole dips about 65° to the southeast, so that the bedding of the sandstone makes an angle of something from 40° to 70° against the direction of the hole. These observations would seem to agree with a northward dip such as we found at the Algomah and Lake properties, and would make it rather difficult, though not impossible to suppose that the dips were so suddenly reversed. The Algomah drilling shows northerly dips, I believe.

Another way to account for the apparent southward dips in Holes 4 and 6 of the South Lake is shown by studying the section of the Mass in Figure 52[1], these South Lake holes occupy a position relative to the formation between Mass d 5 and 1 of Figure 52. If there is a series of faults as therein indicated, throwing the southeastward side downward, it is quite easy to see that if one correlated horizons directly across, from one hole to the other, one could infer southward dips.

[1]In Fig. 52 the number to Hole 1 is carelessly omitted. It is the vertical hole just north of No. 2.



Which of the theories illustrated is the correct one, only further drilling, probably, can determine, and I may have been too much influenced in my feeling that there is no such fold, by the fact that no similar folds have heretofore been noticed.

The Contact, formerly Elm River Company, give in their report for 1912 an account of drilling in a heavy drift covered region, confirming, on the whole, the lines of Plate VIII, where it was a good deal guess work.

The second district is in the neighborhood of Calumet (Plate IX) where the Mayflower, Old Colony, Oneco, New Baltic and New Arcadian have been drilling. Many of the holes are not far from the lines of Conglomerate 8 of Plate IX, or, as it is often called, the St. Louis conglomerate. Its flat dip in the Torch Lake section (Fig. 38) becomes (according to the report of the mining company) steeper to 43° on the Old Colony and 50° on the Mayflower. The course of Conglomerate 8 may be rectified slightly.

The structure of the Torch Lake section, like the structure along the Keweenawan fault at the Lake and a number of other places, may be easily accounted for by the explanation given on the figure, i. e., by supposing that there was an uplift of the Lower Keweenawan accompanied by more or less normal faulting and that upon the uplifted and eroded edges of this Lower Keweenawan the Jacobsville sandstone was laid down, and that after this, disturbances still continued along the same line which here, and not infrequently elsewhere, took the shape of over-thrust faulting.

In Plate IX, there is an error whereby the base of the Eagle River group is placed at Conglomerate 17, just covering Marvine's groups b and c. Both Seaman and I agree that the more important change in the character of the trap is not at Conglomerate 17 but at Conglomerate 18 which in the Tamarack Mine is (394) feet above. Conglomerate 17, as the horizon of mining work at the Copper Falls, Arnold, Phoenix and Atlantic Mines, is, however, an economically important horizon. The boundary of the Eagle River group, as I have defined it, is at the top of Conglomerate 18 and should, therefore, be about 500 feet farther northwest in Plate IX.

With regard to Plate X, also, it should be noted that not only has the culture been revised, but the geology also, for which I, therefore, must now bear the responsibility rather than Dr. L. L. Hubbard. With regard to the densities of the rocks (pp. 66-97), it may be worth noting that the Calumet and Hecla Mining Company assume 12 cubic feet to a ton or 18 feet to a fathom

(6x6x6 = 216 feet) of ground of their conglomerate broken, and usually the same for the amygdaloid, which they say runs but little more—18.07.

To correct § 12 of Chapter I. (pp. 48 and 51), Leverett sent me the following interesting notes of his work.

In 1909, he found a well-defined beach on Centennial Hill in north part of Calumet which reaches 1303 feet A. T., and a lower one at 1,245 feet. Northwest of the Tamarack mine, are beaches at about 1,240, 1,220, 1,200, 1,170 and 1,135-40 feet. These beaches are all tilted in a north-northeast to south-southwest direction, the fall between these and the Quincy mine being about 3 feet per mile. The beach which is 1,135 feet at the Tamarack mine falls to about 1,080 feet west of the Quincy mine. The fall keeps about the same rate clear to the south shore of the old lake. The beach which is 1,303 feet A. T. on Centennial Hill falls to only 554 feet above Lake Superior on the north side of the Porcupine Mts., and 1,134 feet A. T. at Bruces Crossings or 169 feet in about 60 miles. It is doubtful if any beaches except the ones at 1,303 and 1,245 on Centennial Hill can be carried into the St. Croix outlet of Lake Duluth. It is also doubtful if any between 1,245 and 1,100 feet A. T. in the vicinity of Calumet belong to Lake Algonquin. The beaches at 1,220, 1200, 1,170 and 1,135 feet are suspected to pertain to a lake stage with outlet northwest into the basin of the Red River of the north which, at one time, held a large glacial lake —Lake Agassiz.

Regarding the mine waters, I should like to add an analysis of a salt water on the Baltic lode, where it was explored by the Atlantic mine, close to a fault. This was from a diamond drill on the 25th level, at a depth of 2,240 feet. The composition according to G. A. Koenig is

| | | | |
|---|---|---|---|
| | $CaCl_2$ | 11.58 | per cent |
| | $NaCl_2$ | 1.07 | |
| | $MgCl_2$ | 0.06 | |
| | $SO_3$ | 0.00 | |
| that is: | Ca | 41.7 | per thousand |
| | Mg | .2 | |
| | Na | 4.2 | |
| | Cl | 81.0 | |
| | Sum | 127.1 | |

Na : Cl = .052
Ca : Cl = .515



The sodium is abnormally low.

Sp. Gr. at (20° C.) 68° F.,1.1043. Temperature of the flow in the mine 62.6° F.

Absorbed gas 33.5 cc. per liter of which there was oxygen 6.27 present; nitrogen 93.73.

It is noteworthy, if this is correct, that while the gas is not the reducing inflammable gas which I had supposed associated with the rocks and the lower water, the oxygen is much less than in normal air, showing that if this gas is derived from air, it has been been exposed to reducing action. Occasionally, probably through some artesian circulation, the water is quite salt at a shallow depth. The dip of the rocks toward Lake Superior is such that one would expect such salt wells along the shore, if the strata were broken by fissures or joints, to give effect to the artesian pressure. An example seems to be met at Green, a hamlet west of Ontonagon, on the Lake shore. The Greenwood Lumber Company, in a well 100 feet deep, struck a water which was not a strong brine but in which the ratio of NaCl:$CaCl_2$ was, according to Dr. G. A. Koenig, as 0.06: 0.04. Another well, about 1,000 feet farther along the shore, was not quite so salt. This seems to indicate a mixture of a surface water with a little of a strong brine, like that of the Freda well, uprising from a depth or a fault (?)

The identification of the various zeolites is probably somewhat uncertain, especially as regards thomsonite. Inasmuch as I did not have the advantage of so thorough a treatment of the same, as is given in Winchell's "Optical Mineralogy," (pp. 394-410) very probably some of the minerals called thomsonite are other zeolites.

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