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The Canadian Society of Civil Engineers.

INCORPORATED 1887.

ADVANCE PROOF—*(Subject to revision.)*

METHODS OF MINING AND TIMBERING IN LARGE ORE BODIES IN BRITISH COLUMBIA AND MICHIGAN.

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(To be read before the Mining Sect. on 25th February, 1904.)

The method of mining to be adopted in any particular mine depends upon a number of important considerations. Among these may be mentioned the size and attitude of the ore body or deposit, the hardness and rigidity of the ore and adjacent rock, the quantity and quality of timber available and its cost, the price of labour, and the value of the product to be mined. Generally speaking, if a narrow vein is to be worked, stull timbers are used, the limit being a width of about 15'. As the vein widens beyond this, stulls are out of the question, and another system must be adopted. The method then employed may be the square sett system, or a filling method, except in case of soft ore, when a caving system may be followed. There are a great many modifications of all these systems to suit circumstances and conditions, and it is the intention in this paper to describe and discuss them as carried out in those mines in which the writer has worked, and in which he has become more or less familiar with the methods in successful operation.

The names of the mines treated, and location, are as follows:—

Le Roi Mine	Rossland, B.C.
Old Ironsides	Phoenix, B.C.
Baltic Mine	Baltic, Mich.
Atlantic Mine	Atlantic, Mich.
Barnum Mine	Ishpeming, Mich.
Section 16	Ishpeming, Mich.
Soft Ore Hematite	Ishpeming, Mich.
Queen Mine	Negaunee, Mich.

In nearly all these mines the methods used apply principally to mass mining in large bodies of ore. The one exception is the Atlantic Mine, which has a narrow deposit, and is mined entirely by the old fashioned stull method.

Le Roi Mine, Rossland, B.C.

In this mine there are one or more veins or ore chutes of varying width and carrying the minerals pyrrhotite, chalcopyrite, and iron pyrites, and mixed with these more or less disseminated gold. It is the gold, however, that affords the principal value of the ore, and without it there would be no Rossland. The vein is of a pockety nature and some of the pockets are of very large size. The dip is about 70°, and an incline shaft was sunk at about this slope. As depth was attained it was found that the vein pitched a little steeper, and the shaft was given a steeper pitch also, thus forming what is called a "knuckle" in the shaft. This knuckle afterwards became a source of considerable trouble, because, at high speeds, the skip was liable to leave the track.

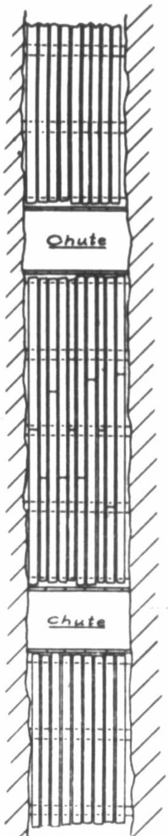
At intervals of 100′ drifts were run on the lead, and the deposits thus opened up. The first shaft had three compartments timbered with the ordinary square shaft setts. Sinking was carried on with three shifts of miners working eight hours each, and the rock broken was hoisted to the level above with a bucket and air hoist. As the shaft became deeper the ore and rock were hoisted by skips, run on the balanced principle. A pentice of about 15′ of rock was always left in the shaft at each level, and served as a protection to the shaft men working below. It was located under the two hoisting compartments, and connection was made below by a passage at the side. Each lift was usually excavated before being timbered.

At each level, drifts were run on the vein in the ordinary manner, dimensions being 6′ x 9′. In the earlier workings the tracks were laid very poorly, and were often the cause of a great deal of trouble and delay, when a large output was desired. But as time passed improvements in this, and many other respects, were inaugurated, and the tracks were laid to a grade of from 7″ to 10″ per 100′. Track-laying is a very important matter in the economy of a mine, and a good track will always pay for itself many times over. The tracks should not only be good, but there should be plenty of them, and placed so that they will be close to the rock to be removed. In drifts moveable lengths of 8′ or 10′ should be used. This saves shovelling to a long distance by placing them in position as soon as there is room, and enables the mucker to work to advantage, until there is sufficient space for the ordinary 16′ or 20′ rails. The rails are laid on 4″ x 6″ ties, 3′ in length, and placed about 4′ apart, the rails weighing 16 and 20 lbs. to the yard. The waste rock encountered in development was trammed to the shaft and sent to the surface, though now most of it is filled into the stopes of the upper levels.

When the miners began to stope on any level, an upright post was rigged, and the holes pointed upward and backward. On a narrow part of the vein a cross-bar was often employed, which enabled the muckers to tram beneath from another part of the level, while drilling operations were being prosecuted. Whenever convenient, however, the miners prefer to rig upright, as they can drill more advantageously from that position. As they climbed higher on the vein, hitches were cut in the foot-wall, and stulls were put in from foot to hanging walls. One end was fitted into the hitch, and the other end cut with such a bevel that it fitted against the hanging wall, which had been previously faced if necessary. (See Fig. 1.) The greater weight coming on the stull, the more securely it would remain in place. These stulls were placed tightly in position, and wedged if necessary or possible. If there was any liability of their being knocked out by blasting, a hitch was also cut in the hanging wall. Stulls were used to form floors to work from at intervals of nearly 20′, and such a distance apart horizontally, that the lagging placed upon them would not be broken by the blasts above. They were also put up against any bad ground that required them. The lagging used on the stulls consisted of round poles, and plank chutes were run up the stope at convenient intervals.

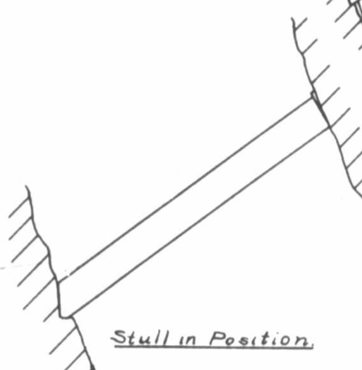
An idea of the stope and chutes may be gathered from Figs. 2 and 3. A cross-bar and stage is shown in Fig. 2, but usually most of the work is done from the broken ore resting on the stulls, and an upright post is rigged, either on this ore or on benches on the footwall.

But where the ore body widened stulls could not be used. Here the stope was started by enlarging the drift to the total width of the deposit, and a face obtained right across the vein. In one case the width varied from 40′ to 80′, and, as a back or roof of this size would be dangerous to work under without some support, the timber had to be quite close to the face. When the muck was removed mudsills



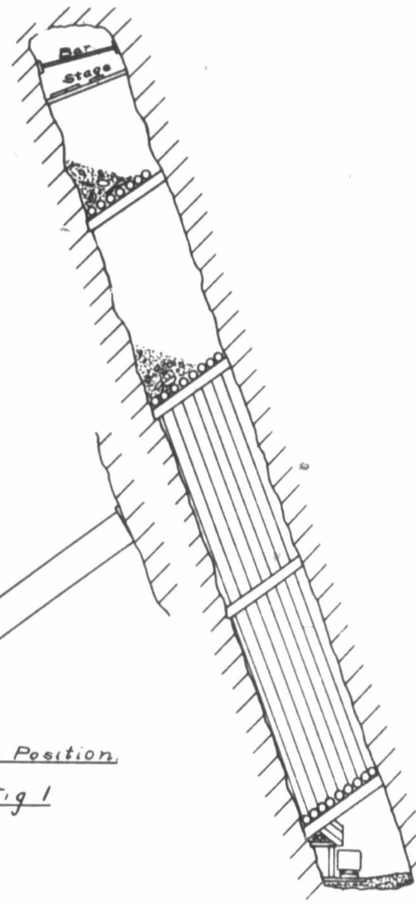
Plan Down Stope

Fig 3



Stull in Position.

Fig 1



Elevation of Stope.

Fig 2

Stull Timbering – Le Roi Mine.

were laid down, upon which the sill posts were erected. These sills were carefully placed, and tamped with fine dirt. They were braced apart by cross ties, and had a length of 10′ or two setts. The framing and manner of laying them is shown in Fig. 4. At first the sill

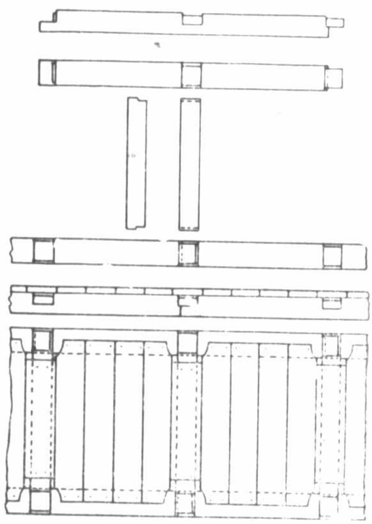


Fig. 4.

Mud Sills and Ties.—Le Roi Mine.

floors were not planked over, but later it was seen that a plank floor was economical to shovel from, as often there would be rock tumbling down, or breaking through from the floors above.

On one level in the Le Roi, the 700′ level, there were no less than 8 machines working at the same breast simultaneously. This meant that the rate of advance was very rapid, and difficulty was experienced in keeping the timber close enough to the face. Two parallel tracks were laid to remove the ore, one along the footwall side and one along the hanging wall side, and a large gang of muckers and timber men became necessary. When the sills had been laid down square setts were erected upon them, and securely braced or spragged. Spragging a set of timber requires considerable experience on the part of the timberman. Spraggs are pieces of round lagging, cut square at each end and of varying length, and placed between the ground and the caps or ties, as the case may be, and securely wedged. They serve to keep the setts rigidly in their proper position, and thus prevent them from falling down during concussion after blasting.

The details of the square setts are shown in Fig. 5. These were at one time framed by hand, but now a framing machine does the

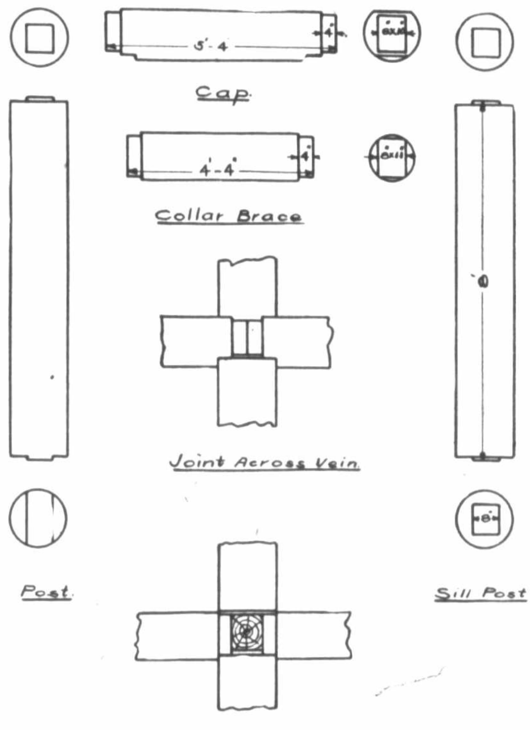


Fig. 5.

Joint Along Vein.

Details of Square Setts—Le Roi.

work. The setts are shown in position in Fig. 6. This is a view of a section across a rather narrow part of the vein. One post on the foot wall is placed in a special manner to avoid the necessity of cutting a large hitch in the rock, which is very hard. A hitch is often made when it can be cut without too much trouble. On the hanging side an extension cap is shown, no hitch or support being made for the end of it. The top "butt" cap on the hanging side is supported at the end of a heavy pole instead of a post. The plank floor, lagging and spraggs are shown at the top.

The posts, used in the Le Roi ranged from 12″ to 24″ in diam., the caps 12″ to 15″, and the collar braces or ties somewhat smaller. In the old days it was the custom to cover the caps with round lagging, 16′ long and up to 7″ in diameter. They thus reached over three setts, but they were difficult and awkward to handle, on account of their length. After several years of this inconvenience it was decided to cut them so they would reach only two setts. The lagging was then brought to the mine in lengths of 20′, and they were sawed in half on the surface. A double tier of lagging was then used, one tier being laid on the caps and the other at right angles to them. Still later in the history of the mine 3″ planks in 5′ lengths were laid on

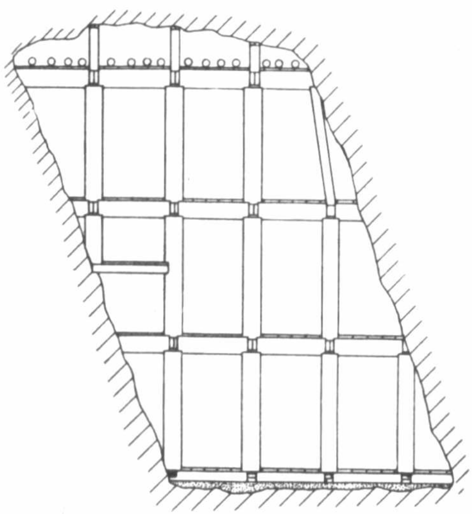


Fig. 6.

Square Setts in Position.

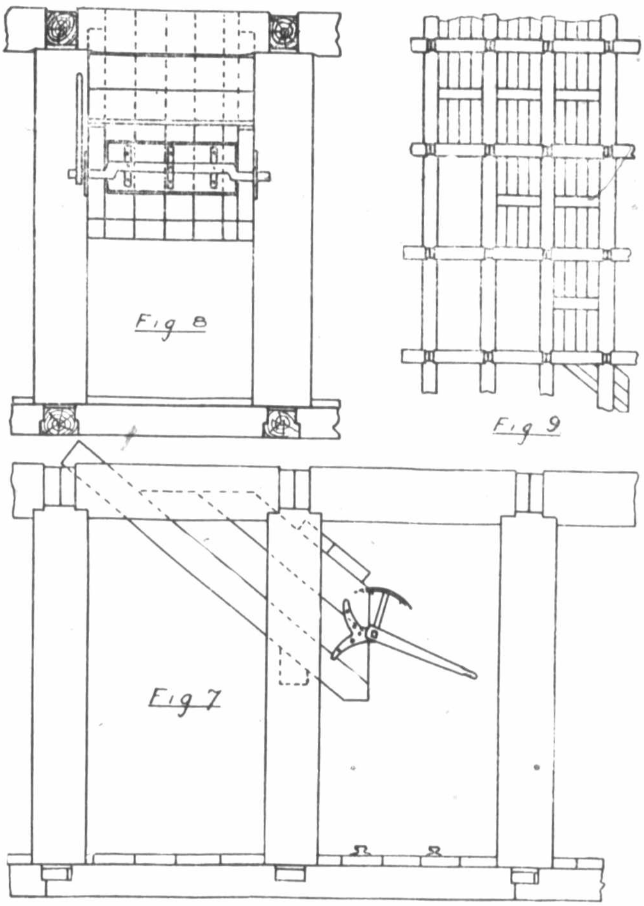
the caps, and a few rough holes placed on top of them, to prevent the plank being broken by the blasts. These planks were spiked with one spike in each end, and served to stiffen the timber considerably.

When the excavation on the level had advanced a reasonable distance, say about 60′, another floor was started on top of the timber. Overhand stoping now commenced and rock or ore was broken much more readily than on the sill floor, as it had a better chance to break, there being more free surfaces. Holes were drilled in a face about 7′ or 8′ in height, and placed so as to bring the ore down to the best advantage, viz., enough holes were drilled and enough powder used to break the ore to convenient size for economical handling. If it was broken too fine it would take too long to shovel into chutes, while if it came down in the form of large bowlders it was necessary to blast. The sizes most conveniently handled were lumps weighing from 25 to 50 lbs., which could be rapidly and easily thrown or pulled into chutes. The holes were generally drilled in the direction of the vein or ore body, and not across it, the depth being about 7′. At each set-up the miners moved across the face from foot to hanging, or vice versa, as the case might be. In this way the muckers cleaned out the broken ore behind, and, as soon as there was room, the timbermen proceeded to put up the timber.

To get out the ore, chutes were built in every other sett, or every third sett at most. The bed pieces were made of 8″ x 10″ timbers, placed at proper slope for the rock to roll down, one end being on the collar brace, and the other supported by a cross-piece inserted between the posts, and high enough to enable the one ton ore cars to pass beneath. Figs. 7 and 8 show a side and front view of a chute respectively. The chute door or gate consisted of a semi-circular sheet iron plate, with suitable stiffening to prevent deformation, and a lever attached by which to operate it. By means of these chutes properly made, and with dry ore, the car could be filled in a very few seconds.

As more floors were constructed above, the chutes were carried up the full size of a sett, by spiking plank 8′ 8″ in length on the caps and collar braces. To bring them closer to the ore, as in a large stope, the chutes were expanded to take in two, three, and even four or five setts. (See Fig. 9). The chute planks were all placed vertically, and where it became necessary a bottom of short lagging was made for the rock coming from above to fall upon. A stiffening was made for the chute planks by cross brace between the posts, half way up and well spiked. In a wide stope, two rows of chutes and two lines of track were constructed. By this means the muckers were enabled to get the ore into the chutes without being compelled to throw it far, or to use wheel barrows or any other device.

While any level was being developed a winze was sunk from the level above to provide ventilation. These winzes were always located in the stopes, and provided a sort of chimney by which the smoke had a chance to escape. They were also used as an easy route by which timber could be lowered to the upper floors, and later, when the ore had been all removed, or nearly so, waste rock was run in through them to fill up the stope.



Views of Chute—Le Roi Mine.

As more and more floors were attacked and carried forward, more faces were worked simultaneously. Care had to be exercised in regard to approaching too near the front line of timber. The blasts might jar the timber, and possibly cause it to throw forward a few inches, even if they would not knock it down. When square setts have been disarranged in this manner, it is a very difficult matter to force them back into position again. The writer has had occasion, as a timberman, to use jack-screws in cases of this kind, and to spend considerable time on work which, with a little more caution on the part of the miners or the management, would have been unnecessary. One machine at a face and one machine at every other floor appeared to be a good method. This allowed the men of the

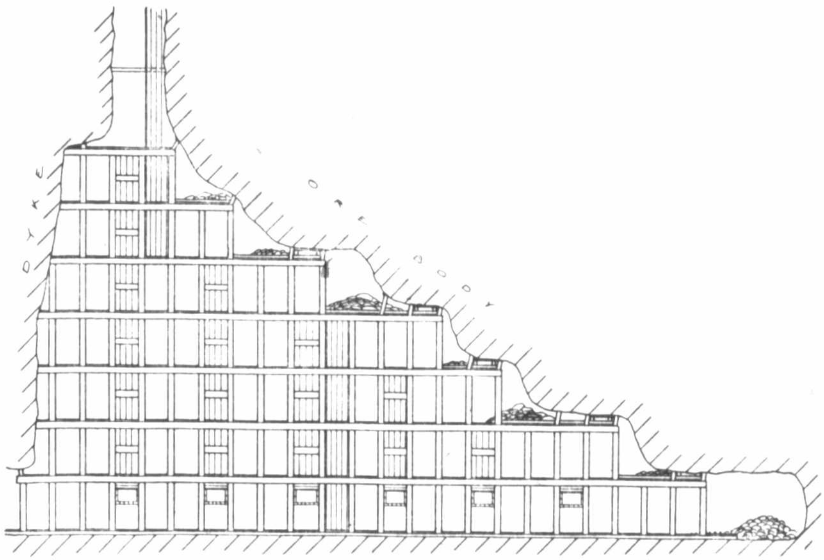


Fig. 10.

General Scheme of Stope.—Le Roi Mine.

timber gang to put up a line or two of timber on the intermediate floors, and they were not interfering with either the muckers or miners.

An idea of the method of attack in a stope may be gathered from Fig. 10. In this view, however, the writer has unfortunately shown the limit of advance on each floor rather than the actual working condition. As illustrated in the diagram it would be necessary to carry the lower faces ahead to allow a chance to work on the upper ones.

As the floors became more numerous and farther and farther away from the winzes, some method had to be adopted to get the timber into the stopes more easily, quickly and economically. An excellent plan was introduced in the Le Roi in the large stope on the 700′ level. A track was laid the full length of the stope on the first floor above the level, up out of the way of the tramming tracks, and a truck carrying a small air hoisting engine placed on it. From the drum of this hoist a manilla rope was carried up a special timber chute, over a pulley on an upper floor, and then down the chute to the level below. Here the timber was attached with a hook and half hitch, and hoisted to any floor desired. An idea of this arrangement may be gathered from Fig. 10, in which one timber chute is shown beside an ore chute. The timber chutes were made of 2″ planks, spiked to the collar braces, and inclined with the vein. They were erected every 80′ or less, and were convenient for hoisting drills and machines, as well as timber. The timbers could be readily dragged to any place desired by means of the "come-alongs," which were a pair of hooks attached to the centre of a small pipe 3½′ in length. A man on each end of this pipe could drag a post anywhere over the floor.

The ore was not sorted in the mine, but sent to the surface to be treated there. It was trammed to the shaft and dumped into large pockets from which the skips were loaded. The tracks at the shaft were laid directly over the pockets, and the ore was dumped from the car between the rails, or at one side of them. These pockets were capable of holding a good many tons so that, if anything happened to the hoisting apparatus, the trammers could still work away, and fill the pockets. In the new shaft, which was put through by means of raises from each level, pockets were made with a capacity of about 200 tons.

From this somewhat detailed description it will be seen that a great deal of timber is used in this mine. The timber is not used merely to hold up the hanging wall and roof, but principally to furnish a convenient method of reaching all the ore, and to prevent loose slabs and bowlders from dropping on those who must work beneath. The workings are kept closely timbered, and thus liability to accident is reduced. No staging is needed in rigging machines, the muckers have a good floor to shovel from, and chutes are handy and convenient, more so than could possibly be the case in any other mining method.

By this system all the ore is taken out between levels. The sills of one level are caught up from beneath, and timber connections made with the level below.

When a stope or level is worked out the only timber saved is the rough lagging and plank flooring, which is readily torn up and used again. Waste rock from development work in other parts of the mine is dumped down, and the old stope gradually filled up. This rock is brought up from the lower levels on cages in the new five-compartment shaft. No great attempt is made, however, to fill the stopes.

Old Ironsides Mine, Phoenix, B.C.

In this mine and the adjacent Knob Hill, we have a still wider and larger ore body than at any point in the Le Roi. Not only is the deposit of immense size, but the grade of the ore is much lower, necessitating a much lower cost of extraction, in order to mine it at a profit. To accomplish this a large output is essential, and cheap and rapid means of handling it, from breaking the ore down until it finally reaches the smelter.

The ore is mined in three ways in these deposits:—

(1) By open cuts,
(2) By the milling or "glory hole" method, and
(3) By the ordinary overhand stoping with the use of square setts.

The open cut was on a level with the railroad track, and a tramway was built with an incline to enable a small hoist to bring the ore up high enough to dump into the railroad cars. This is quite an ordinary method and needs no further comment, the ore being broken down in the usual way. Later, however, when a considerable excavation had been made, a steam shovel was used, which handled rock of much larger dimensions. Bowlders too large to go into the bucket were picked up by means of a chain. They were loaded either directly into the shipping cars, when the ore was crushed at the smelter, or into small wooden cars, and taken to the crusher first by horses, and at the present time by a small locomotive. Three steam shovels are now at work for this company in their low grade ore bodies, and they will tend greatly towards solving the problem of decreasing the cost, and, at the same time, largely increasing the shipments.

The milling or "glory hole" method also applies more particularly to the Knob Hill than to the Old Ironsides Mine. It consists essentially in driving a tunnel into the deposit to be excavated, as low as can be conveniently worked without the sides caving in, and then a raise to connect with the surface. At the bottom of the raise a very substantial chute is constructed from which the ore can be readily withdrawn into cars. Operations then begin on the surface and the ore is milled or broken down, being blasted into the raise. Suitable faces and benches are soon established, and a better command obtained of the size of the rock going down the chute or raise. Very deep holes are drilled and very heavy blasts set off, thus breaking the ore quite rapidly and economically. The benches are arranged in such a manner that a great amount of the rock rolls down into the chute, which is always partially filled, without much handling.

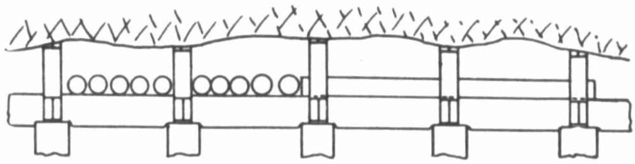
The advantages of this method are as follows:—

Practically no expense for timber.
No bad air to work in and hence no time lost.
Few drill holes needed and comparatively little powder used.
The ore is handled mostly by gravity.

The disadvantage is that there is a limit to the depth at which the ore can be excavated, because of the caving or falling in of the sides.

On the deeper levels of the mine the usual method of underground development was carried out. The system of mining the ore was very similar to that in vogue in the Le Roi, which has been already described. The timbers, however, were stouter, and the method of lagging was different. In arranging the lagging the object was to place it in such a way that the broken ore could be rolled into the chutes with the least possible amount of shovelling. To accomplish this, lagging, about 10′ long was laid on the caps, close together, and, if the poles were weak, perhaps a double layer. A space two setts square had the poles laid parallel, and the adjacent squares were poled at right angles to these. The caps and collar braces were of the same dimensions, hence it did not matter which way the lagging was arranged. In this way the poles had a good support at both ends, because they reached well over two 5′ setts. When it was desired to remove the muck, all that was necessary was to move a pole so that the ore could drop through. As it rolled down, with the aid of a pick or bar, another and another pole could be rolled from beneath it. In this manner the writer has rolled into the chute 40 or 50 tons in four or five hours. Any very large bowlders, of course, were smashed with a sledge hammer. Fig. 11 is meant to show the arrangement of the lagging. It is a plan of the floor immediately under the ore to be mined, while Fig. 12 is an elevation of the same.

A special method of chute building was adopted here. Above the first floor they were built in the shape of a long trough-like V, running from one brace down and across to the next. Poles were used for this work, and spiked securely to the square setts. Figs. 13 and 14 show the arrangement of the chutes in plan and elevation.



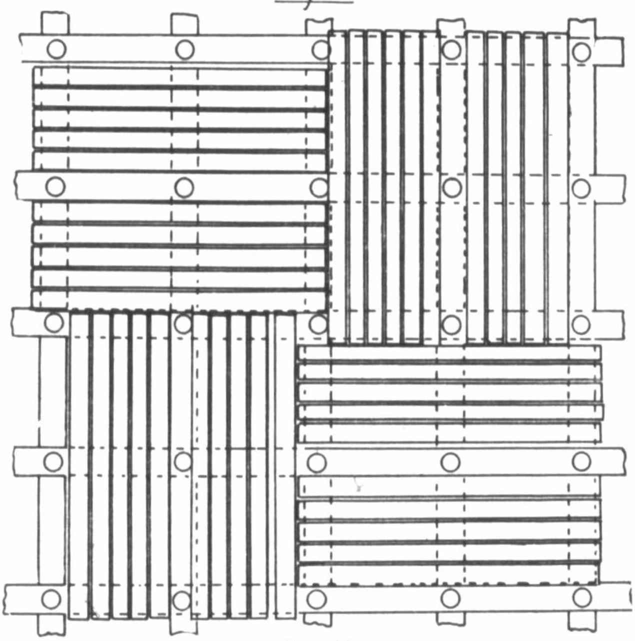


Fig. 11.

Lagging Arrangement—Old Ironsides, Phoenix, B.C.

At convenient intervals an outlet was made, and between each chute gate the ore was allowed to pile up a little. The ore was trammed to the shaft in ordinary one-ton cars, and hoisted to the surface on a cage through a vertical shaft.

It will thus be seen from this brief account that a very easy and economical method of removing the ore was in vogue at the Old Ironsides.

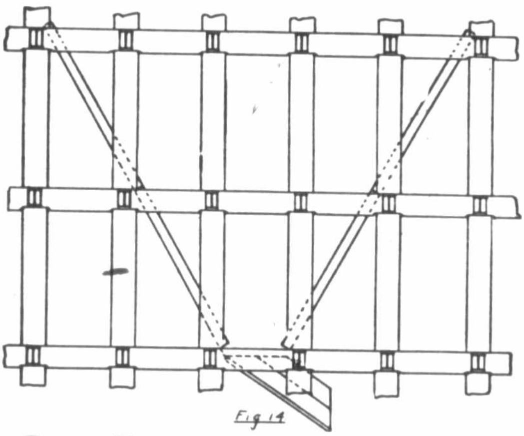


Fig 14

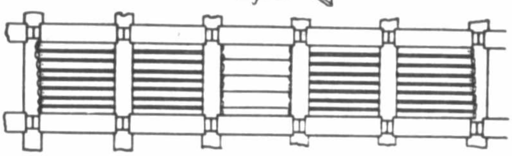


Fig 13

Chute Arrangement—Old Ironsides, Phoenix, B.C.

BALTIC MINE, BALTIC, MICH.

The method adopted in the Baltic is peculiar to this mine, and is not used, as far as the writer is aware, at any other mine in the Copper Country. It is a simple system of walling up each tramway with waste rock, thereby keeping a roadway open, and filling in above with the gangue and country rock, as convenient. In this way the expense of putting in timber is minimized, which is offset by the walling and filling. The method is only applicable when the vein carries waste, or when waste rock is easily and cheaply obtainable.

The material mined is native copper which occurs in a vein of lava rock both as "shot copper" of varying size scattered throughout the rock, and as "mass copper," which is solid copper of more or less irregular shape. The pitch of the vein is about 70° or 72°, and the width varies from 20′ to 50′. Parts of the vein are more or less barren of copper, and this rock, called "poor rock," is picked out by the "copper pickers," and forms a good part of the filling.

The vein was opened up by shafts and drifts, and when stoping began, the drifts were widened out to the full width of the vein. After the copper rock was cleaned out from the face, the poor rock was taken back in cars, and shovelled to one side. When the "wallers" had enough rock to start on they began and walled it up on each side of the track, leaving a space of 7′ for a tramway. The walls were made about 7′ high, and heavy stull timbers laid on them as caps. These caps were placed about 3′ apart and covered with cedar lagging, so that no rock could come through. (See Fig. 15.)

At intervals of about 40′ spaces were left for chutes on one side of the track. They were built up with rock and had a timber margin for planks to be spiked to. In the bottom of the chute flatted hemlock timbers were laid, and a heavy sheet iron plate was fastened to them with drive bolts. The bottom of the chute was made flat because very large bowlders were handled in it. For a gate a spout was used, one end of which was raised and lowered by means of a long stout lever. The copper rock thrown into the chute was pulled out by the trammers into two ton cars, taken to the shaft, and dumped directly into the skips.

When the work had progressed far enough on the station level, overhead stoping began above the caps and walls, by drilling with machines and blasting in the usual manner. The rock broken down was picked over by the copper pickers, the copper rock being thrown into the chutes, and the poor rock thrown back to fill up the excavation. As more and more filling accumulated, the chutes were carried upward in the form of a hole 5′ square, by means of heavy cribbing flatted at the ends and spiked. (See Fig. 16). Sometimes the pickers needed wheelbarrows to get the rock into the chute or "mill."

In stoping a good breast was carried along, and heavy holes drilled, since no damage could be done by heavy blasts, though it was not advisable to shatter the roof too much. As the room grew in height the back got farther and farther away from the filling. This necessitated the use of long posts for the machines and staging for the miners to work from. The idea, of course, was to work as much as possible from the top of the broken rock, but as there was 100′ between levels, and not a very high percentage of poor rock, it became necessary to cut out the foot or hanging walls to fill in, and thus reach the back. This should always be done after the copper rock has been picked out, as otherwise much poor rock would be

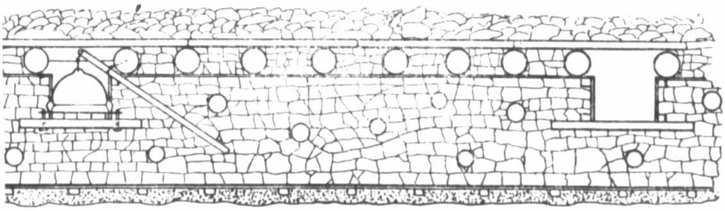


Fig. 15.

Section along Tramway, Showing Wall, Mills, etc.

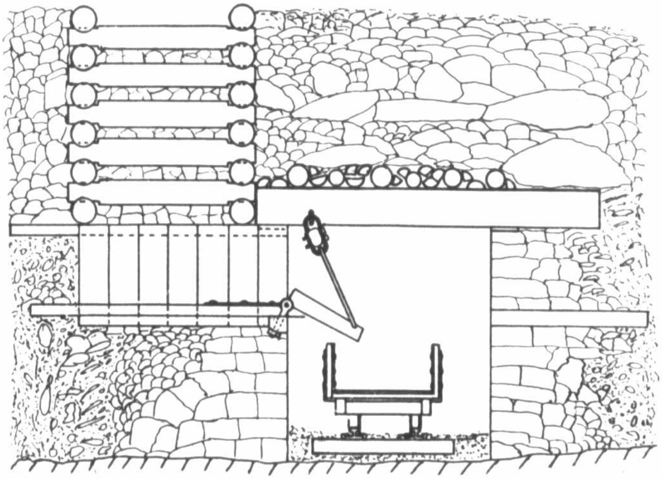


Fig. 16.

Cross Section at a Mill—Baltic Mine.

mixed with it. An attempt is made to convey an idea of the stope in Fig. 17.

This method is supposed to take out practically all the ore, and the only use made of timber is to crib the chutes, and cover the tracks. The vein rock is quite tough, and, with a slight arch in the middle of the roof, there is comparatively little danger from over-

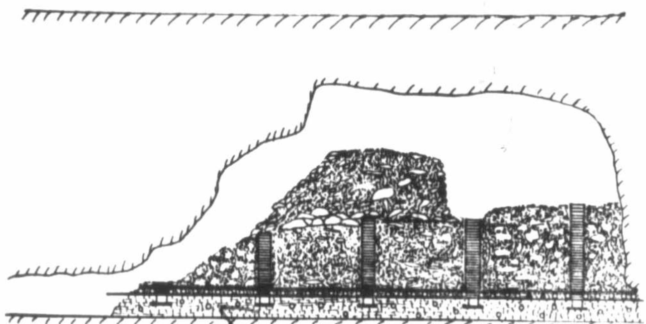


Fig. 17.

Longitudinal Section of Stope—Baltic Mine, Mich.

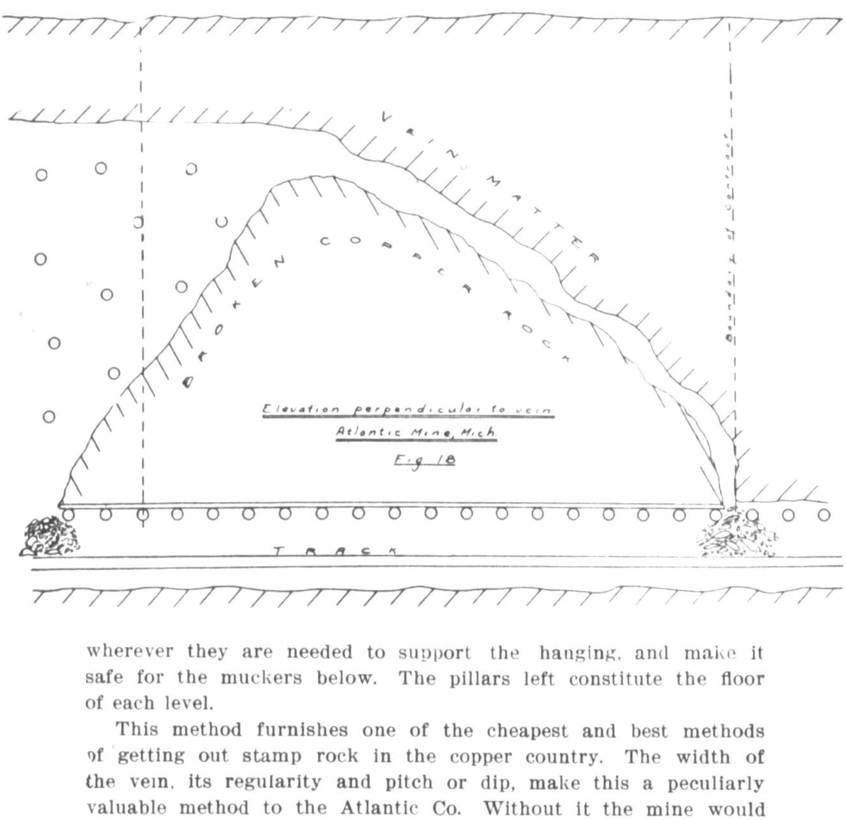
head. The greatest difficulty to be encountered will be in making connections between levels. Here the filling from the level above will run down and mix with the copper rock below. Taken altogether, however, this is an excellent method of mining, and has given the Baltic people satisfaction up to the present time.

Atlantic Mine, Atlantic, Mich.

The Atlantic vein is similar to the Baltic, though it only averages about 15′ in width, and it does not carry so much copper. This rock is not picked over, but the total product mined goes to the stamp mill. Thus no filling can be obtained from the rock broken and the vein, being narrow, stulls can be used.

When the levels have been opened up the miners take contracts to stope out the pay rock. Each contract includes a part of the 99′ in length and extending between levels, which are about 85′ or 90′ apart, and the price is paid on a basis of at least a width of 15′. The contractors first run a drift to the end of their ground and commence stoping, taking out enough rock to put in the stulls to protect the level for tramming.

These stulls are very heavy, about 20′ or more long, and placed in hitches cut in the walls. They are inclined at an angle of about 70° to the horizontal, thereby leaving room for a track between the stulls and the hanging walls. (See Fig. 18). At the same time they were quite steep to prevent them taking up more weight than they could safely bear. They are covered with lagging, which prevents the muck from coming down on the track. When this line of stulls is finished stoping is commenced higher on the vein. The miners keep rigging up on the rock they break, and it is trammed out from below when they are crowded for head room. In this way they are always close to the back, and work to the best advantage. They work up to within 15′ of the level above, and then, as the rock is withdrawn, the timbermen place stulls



Elevation perpendicular to vein
Atlantic Mine, Mich.
Fig 18

wherever they are needed to support the hanging, and make it safe for the muckers below. The pillars left constitute the floor of each level.

This method furnishes one of the cheapest and best methods of getting out stamp rock in the copper country. The width of the vein, its regularity and pitch or dip, make this a peculiarly valuable method to the Atlantic Co. Without it the mine would probably be operated at a loss, as the copper values do not exceed 25 lbs. per ton of rock.

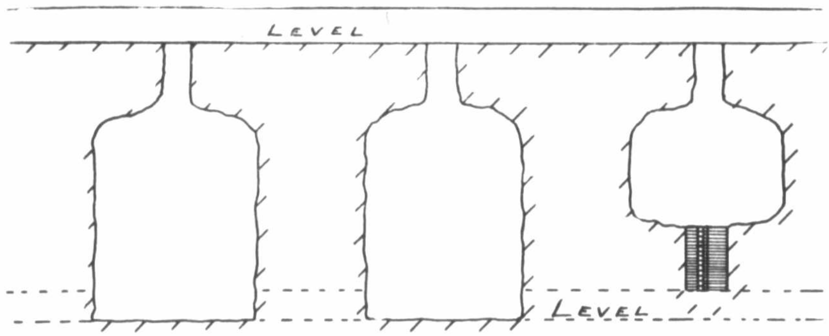
Coming now to the Iron Country of Michegan we find a somewhat different order of things. Here we do not have the ores in regular well defined veins, as is the case in the copper country. On the contrary, the ore occurs in blankets or deposits of more or less irregular shape, and the sustaining power of the adjacent rock is a far more uncertain quantity. The ore itself varies a great deal, some being soft and capable of caving, while much is hard, and a caving system could not be adopted. Some again is intermediate between hard and soft ore, and a combination of a caving system with some other method becomes a necessity.

Barnum Mine, Ishpeming, Mich.

This is a hard ore mine producing a hard hematite. The system of mining is simple and inexpensive, although about one-third of the ore is left for pillars. The levels are from 40′ to 50′ apart, and after being driven, raises are run up to the level above at convenient intervals. When the raises are completed the miners begin at the top and mill the ore down the raise in a manner similar to the glory-hole method already described, except that the work is, of course, underground. They work from convenient benches and gradually cut out large chambers. Care must be exercised in scaling any loose rock from the roof while the men are close to it, because when they get lower down the roof will be out of reach. Wherever necessary pillars are left 22′ square, one being as nearly as possible directly above the one below. Machines and tripods are employed, and the rate of drilling is slow, varying from 4′ to 15′ of hole per shift. The ore is also hard to break, and a 50% dynamite is used. There are no pockets in the mine, and the cars are hoisted to the surface by a single compartment shaft. As the method at the Barnum is so simple little more need be said, suffice it to say that the method is very wasteful of ore, because such a large percentage of it is left in the mine.

Section 16 Mine, Ishpeming, Mich.

The ore from this mine was also fairly hard and a similar method of mining was adopted. Levels were run from the shaft to the ore body at intervals of about 60′, and a drift run along the foot or hanging wall as desired. From this drift raises were driven every 50′ to the level above, thus making a passage for timber and ore. At 15′ below the upper level the raise was enlarged into a stope or room, and made of such a size that it would be safe to work in, dividing pillars being left on each side. The ore was thus removed down to the level below, and pillars were left extending across the ore body.



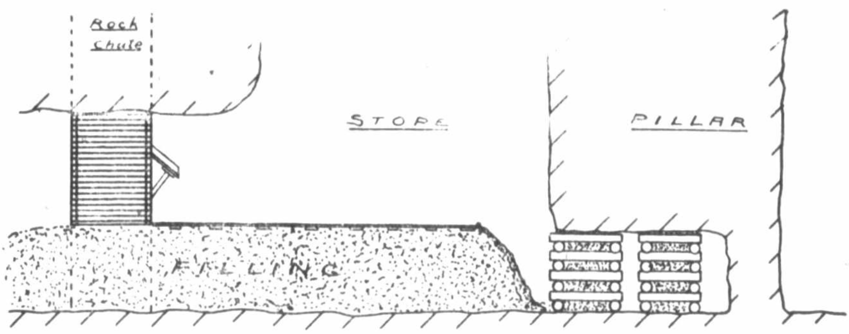
Stopes and Pillars.

When the rooms had all been excavated in this manner the robbing of the pillars began. The pillars were usually 25′ through, and they were undercut on one side to a distance of about 9′, and right across the vein. The timbermen then built cribs of timber 8′ square in this space, and as many as they had room for, leaving a space of 3′ between each for a passage. These cribs were built right up to the back, wedged down and filled with rock.

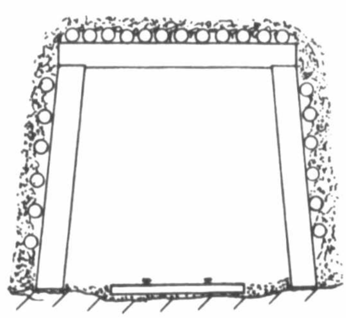
The next step was to undercut another 9′ and treat it with timber cribs and rock in a precisely similar manner. Finally the last portion of the pillar was removed and cribbed, and the pillar rested now entirely on the crib supports. The stopes on either side of the pillar are then filled with loose rock to the level of the top of the cribs, and also in between them, a passage way, of course, being left for tramming.

The pillar having been undercut to a height of about 8′ another slice is removed in much the same manner, at a higher level. Mills become a necessity in order to let the ore down through the rock filling, and these are made of round poles and placed at convenient intervals. As the pillar was attacked at a higher point the work proceeded on the top of the filling, hence by this method it was possible to remove practically all the ore.

The filling used is obtained from two sources. Part is furnished by the ordinary development work, and the remainder is obtained from the dump of a neighbouring mine. It is loaded into railroad cars, and dumped directly down a raise for that purpose. This raise is tapped where desired by a rough chute, and the rock trammed in small dump cars running on tracks laid on the filling. These tracks are readily moved laterally so the rock is conveyed to the place desired without very much shovelling being required.



Robbing and Filling



Filling System
Section 16 Mine
Fig. 19

Tramway Sett

In parts of the mine where the ore body is of such a nature that ore pillars are not necessary, a method of overhand stoping is prosecuted. This operation is followed directly by the filling, the ore being mined out and the excavation filled with waste rock. Where the roof is not good cribs are built on the filling to support it.

Again, in other parts of the mine, filling is not used, but the ore is mined from each level upwards, and the regular square sett timber erected.

The methods of mining at this mine are therefore somewhat special and varied. The cause of this variation is due to the fact that the ore body changes from place to place in hardness, width, and accessibility. In some parts of the mine it is hard to introduce the filling, while in others it is a cheap and efficient adjunct in extracting the ore. Wherever used it forms a compact and satisfactory substitute for timber, which, to perform the same duty, would be quite expensive.

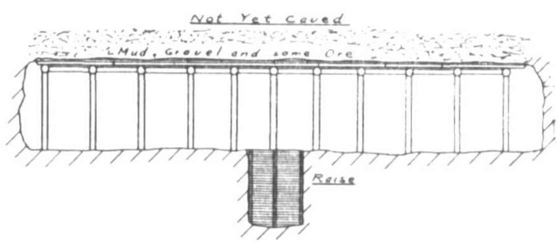
Soft Ore Hematite Mine, Ishpeming, Mich.

Here we have a mine which was formerly covered by Lake Angeline, a body of water of about 100 acres in extent, and 50′ deep in the deepest part. The water was pumped out by means of powerful pumps, and the lake bed became comparatively dry. On the margin of the old lake, shafts were sunk, and the mining of the large deposits of soft ore began. The ore, being a soft red hematite, was very easy to break down, but it was impossible to have large chambers excavated, because of its heavy settling nature. As the soft ore caved so readily, a caving system of mining was soon inaugurated.

Haulage ways were, as far as possible, made in solid rock. Then raises were driven to the top of the ore deposit, at intervals of from 60 to 100 feet, and cribbed with two compartments. One for a ladder road and the other for ore. Sub-levels were also made to facilitate operations. The ore was loaded into cars holding about 2½ tons, which were attached to a "bull-dog", and taken to the shaft in trains of six or seven. The bull-dog was operated by a cable, each end of which passed around a drum run by compressed air. One engine was located at the shaft and the other at the end of the haulage way. At the shaft the cars dumped directly into the skip, and were moved up to, and away from, the shaft by hand. The idea of the bull-dog is to facilitate coupling, the cars being connected to the bull-dog instead of directly to the cable.

When the chutes were completed a "top-slicing" scheme was begun. A drift 8′ x 8′ was driven parallel with the deposit, and timbered with square setss. These setts consisted of legs and caps as shown in Fig. 20, and placed 4′ apart. At the raise it was important to have rather stout timber, because here the timber was expected to stand the longest, and was therefore subjected to most pressure. Farther from the raise or chute the timber was much smaller, 6 to 12 inches, and the caps were covered with light lagging. The caps, as a rule, were a few inches larger in diameter than the legs.

The second step in top slicing is to begin at the farthest end of the drift and crosscut to both foot and hanging walls. These drifts are also 8′ x 8′ and are driven parallel, and one after another, until the whole area is excavated, that around the chute being taken out last. The same proceedure is followed on the opposite side of the chute. The floor is then all lagged over to prevent mud, gravel, etc., from mixing with the ore when subsidence takes place. The legs of the setts are blasted out and the overlying burden is lowered, as a consequence, all over the area in question.



Top-Slicing

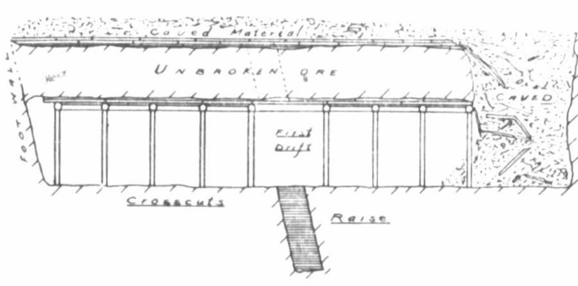


Fig. 20.

Caving System. Soft Ore.—No. 2 Hematite Mine.

Mining below this is now done by the real caving system. The miners drop down 12′ or 15′, depending on the hardness of the ore, and run a drift as before. Side rooms are run to foot and hanging also, and when these are reached the most remote setts are blasted, and the roof is caved in. By working as they retreat practically all the ore is removed from beneath the lagging above, only one sett being usually blasted at a time. Sometimes several rooms are worked out before caving, but it is unsafe to leave them for any length of time. It is deemed advisable to finish one room before beginning another. In this manner a whole slice is taken out, and overlying debris or "gob" is lowered once more. Then a drop is made for another and another slice, until the bottom of the deposit is reached.

Contrary to what might be expected this is a comparatively safe method of mining. The men work near the back all the time, and, should there be any danger, warning is given by the gradual crushing of the timber. No large rooms are excavated at any one time, and there is practically no danger from this source.

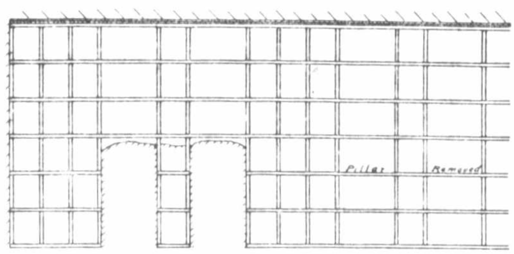
The system is also cheap, comparatively little timber is used, and even that is of an inferior order. Very little powder is necessary, and there is not much drilling done. Holes are drilled with machines, augurs, or hammer and drill, as the particular hardness of the ore may make advisable. The cost of mining is low, and contracts run at $4.50 for an 8′ x 8′ drift per foot of advance. The miners make from $55 to $60 per month after deducting all expenses for powder, caps, fuse and candles.

Queen Mine, Negaunee, Mich.

In the Queen Mine, as its name implies, we have a fine example of systematic iron mining. The ore body is large and fairly regular and lends itself particularly well to methodical and well laid out development. The ore is not very hard, and it is not soft enough to cave, as in the Hematite. A special method has been adopted and seems to answer the purpose very well. The system in vogue starts out as a square sett system and develops a caving system as the work proceeds.

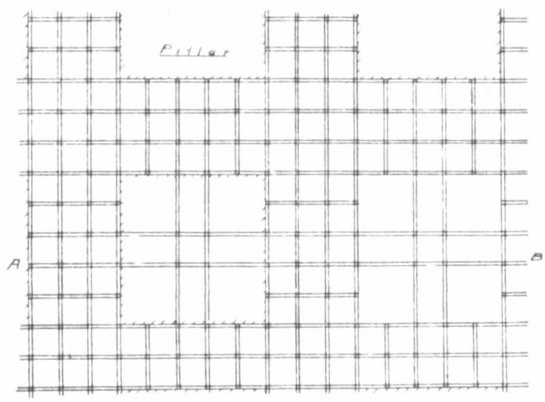
The ore body is in the shape of a lens, and dips to the north at an angle of 38°, and also pitches to the west at 45°. Six shafts have been sunk, the first three on the eastern side being now worked out. From the shaft a well laid out system of haulage ways has been driven, special attention being given to prevent interference of cars with timber and vice versa. The timber can be handled on one line of tracks often at right angles to the haulage tunnels. The main ore drift has been double tracked, and an endless cable picks up the loaded cars of ore as desired, and takes them to the shaft. The cable is operated by an engine at the shaft with a special device to keep up uniform tension. The cars are attached to the cable, which is always moving, by hand, and are detached automatically when they reach the shaft. They are dumped into pockets and sent back by the cable on the other track. The expense of operating this haulage system is only ½ cent per ton.

Coming now to the mining system proper, we find a face of 3 setts wide or 25′ carried forward, and timbered with good substantial square sett timber. Then parallel to this another similar face is driven, but with a pillar 5 setts, or 40′, left between. Crosscuts are also run blocking out the pillars into squares. (For plan and elevation of stopes and pillars see Figs. 21 and 22). At the same time these faces are being worked on the level, another and an-



Vertical Section Through A-B

Fig 22



— Plan of Stope, Queen Mine —

Negaunee, Mich.

Fig 21

other slice is stoped out and timbered above. In this way the ore body is honey-combed to the top of the deposit, pillars and rooms alternating throughout the level.

After the ore has been excavated in this manner the work of taking out the pillars and caving begin. A raise 8′ x 8′ is now run up through the centre of the pillar, and timbered with the usual setts. Thus between the centre sett and the timber in the rooms outside, there is a distance of two setts. The top of the pillar is taken out to the depth of one sett, and caps of double length are used to connect the centre with the outside setts. This is done on the four sides and the top heavily lagged. The ore is then worked downward using the long caps at each step, but without lagging. The material of the pillar is readily broken up and sent down the chutes in the outside setts; in fact it is the most rapid method of breaking ore in the mine.

When the pillars have all been robbed the tracks are taken up, a flooring of poles is laid, except where there is a rock floor, and every second leg is blasted out, thus bringing down the whole mass of timbers as well as the roof.

A system called "scramming" is used to mine on the level below. The level is divided into 50′ squares, and in each a raise 4′ x 9′, in two compartments, is run up to the lagging above, the levels being 85′ apart. Starting 9′ down a drift is driven from the raise 25′ each way, and timbered with light setts. The ore is shovelled directly into the chute or a wheelbarrow is used. A second drift is run beside the first, though not always, and the bottom is lagged over. Then the legs are blasted, and the overlying debris caved, as in the Hematite Mine. The process is repeated until the 2,500 sq. ft. is lowered 9′. The miners now drop once more, and repeat the operation, and so work down to the level.

While work is progressing in the drift the timbers begin to crack, which is a good sign, because it shows that the mass above is slowly settling. If the timbers do not show that they are supporting great weight the debris has become "hung up," and is liable to come down at any moment. Seeing this the miners either blast it down, or get out of the place. When the timbers show pressure the workmen are safe, as the mingled rock and timbers settle very slowly, an inch or so a day.

This method of scramming is also used in new workings under gravel, sand or loose rock. In that case great pits are formed on the surface immediately above.

In the foregoing description of these several mining methods, little attempt has been made to go into the minute details of the various schemes presented. The systems taken up represent the actual practice, in their most essential features, of underground work in Western America, outside of coal mining. Much more might be said in regard to many matters connected with them, such as their comparative expense, the percentage of ore recovered, their suitability to general conditions, etc. To go farther into these matters would make the paper unduly long. No references have been consulted, as the data have all been gathered by the writer at first hand. With apologies for an inadequate presentation of a very interesting and almost unlimited subject, this article is respectfully submitted.