Adams Township, MI

Mr. Lucien Eaton,
Consulting Engineer.

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COPPER RANGE COMPANY
89 BROAD STREET
BOSTON

February 27, 1942

Mr. W. H. Schacht, President
Copper Range Company
Painesdale, Michigan

Dear Mr. Schacht:

I am enclosing herewith copy of estimate on White Pine prepared by Lucien Eaton for Morris.

The estimate does not include the mill, water supply, townsite, railroad extension, surface crushing plant, power development and power line.

Lucien's figures seem quite high in some respects, but I think they are safe, and a few hundred thousand dollars on the safe side should make little or no difference in this kind of a deal.

Morris and I thought Lucien's estimate might be helpful to you in assembling your data to be submitted at Washington.

Very truly yours,

P. F. Beaudin

Vice-President

PFB/J
Enc.

Original Report given to Mr. F. A. Ayer -- 7/2/44

COPPER RANGE CO.
W. H. SCHACHT, PRESIDENT
RECEIVED
MAR 2 1942
Ans'd
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Copies

Adams Township, MI

Feb.11,1942

Morris F.LaCroix, Esq.
24 Federal St.
Boston, Mass.

Dear Morris:

I enclose an estimate of the cost of opening and equipping the White Pine Mine fora a production of 5,000 tons per day, or 1,500,000 tons per year. This should yield 45,000,000 lb. of copper per year.

If the plans on which this estimate is based are followed, production of copper from No.4 shaft could be started in 6 months and from the main shaft in a year, but the mine would not be on a production basis for two years. Actual production of copper could start as soon as one unit of the mill is ready.

I have not included in this estimate the mill, water-supply, townsite, railroad, fine-crushing plant, power-line or transformers.

Because of its bearing on the plan of development and the equipment required, I have decribed the proposed mining system first.

Sincerely yours,

Lucien Eaton

Lucien Eaton.

MINING SYSTEM.

In order to maintain a production of 5,000 tons a day all mining operations, and especially stoping, must be carried out systematically and with precision. It might be possible to obtain such an output from a large number of working places, each of which produces a relatively small amount, as is customary in places where loading is done by hand, but the cost of collecting the ore from so many places and the tremendous amount of development that must be done before full production is possible are against it. A better scheme is to work a smaller number of stopes intensely, obtaining a relatively large production from each. This is possible with modern loading machinery, if stoping operations are so arranged that frequent movement of the loading equipment is unnecessary.

The mode of occurrence of the copper in the White Pine ore is so different from that in other parts of the Michigan Copper Country that an entirely different control of stoping is indicated. At the other mines the native copper is visible to the naked eye, and is impossible to sample satisfactorily in small lots. Control of stoping operations is largely a matter of eye, and depends on the judgment of the miner and his bosses. At White Pine, however, although some of the copper in the sandstone is visible, the most important copper content is in the shale between the upper and lower sandstones, and cannot be distinguished by eye from the enclosing rock. Control of stoping widths and ore limits must therefore depend on sampling and analysis.

To be effective the sampling and anlysis must be done in advance of stoping as much as possible. In the method of mining proposed the importance of this procedure is recognized.

Except close to the main fault the ore lies at too flat an angle for broken ore to run by gravity. In some places it may be flat enough to be loaded directly into cars by machines of the Conway or Finlay type, but in most places it will apparently be best to do the loading with scrapers, using short chutes or slides to get it into the cars.

Taking into account the dip and thickness of the ore, the closest parallel to White Pine conditions that I know in the United States is the iron ore at Birmingham, Alabama. A very successful technique, using large scrapers for moving the ore, has been developed in the Birmingham District, and a modification of this system should work well at White Pine. Not all the companies operating in the Birmingham District follow the same details of practice, but the essentials are the same at all mines.

Adams Township, MI

1. The is mined by breast stoping with rooms and pillars.

2. The rooms are turned off from a drift driven along the foot-wall, and are driven up the dip for 250 to 300 ft.

3. The ore is moved by large, box-type scrapers, hauled by 50-H.P. electric hoists, which are mounted on trucks. One hoist serves three to five rooms.

4. Because the loading capacity of one scraper crew is greater than the drilling and blasting capacity of one stope, two or three crews of miners are employed to each crew of loaders. For example, in a three-room unit two mining crews, each using two drills, drill and blast in two rooms, while the loading crew cleans out the third room with the scraper. By working the rooms in rotation, each breast is blasted twice before it is cleaned out. 125 tons of ore is broken at each blast, and the scraper has 250 tons to work on, when it starts to clean out a stope. In the five-room groups the discrepancy between drilling and loading capacity is even greater.

5. The ore is loaded into 5-ton cars hauled by electric locomotives. At the foot of the room, a simple ramp, or slide, built out of timber and channel-irons, has a lip that extends over the side of th e car. The truck on which the hoist is mounted, runs on a track parallel to and behind the main haulage track, an d is moved along this track from room to room as

as required. Usually, however, the scraper is not moved from room to room, each room having its own scraper, which is left in the slide, when not in use.

6. Variations in practice are mainly in the manner of leaving pillars. At some mines long narrow pillars with few break-throughs separate the rooms. At others large pillars are left around each group of rooms, and small random pillars are left in and between the rooms. At some mines narrow rooms are driven upgrade, and are then widened by stripping the pillar on each side. At others the rooms are driven full width on the advance, or three breasts may be carried up almost as one stope, being separated only by small random pillars.

In Birmingham there is a water-bearing stratum in the hanging-wall, and it is considered to be unsafe to allow the hanging-wall to cave, until ultimate depth has been reached. Only 60% of the ore is therefore mined on the advance, and it is planned to recover part of the pillars later, retreating from the bottom upwards. At White Pine the Freda Sandstone, overlying the None-Such Shales, at the base of which the ore occurs, is water-bearing, but it can probably be drained, and the shale below it is thick enough to act as an effective seal. Consequently it will be safe to remove 75% to 80% of the ore, mining the ore on the retreat.

By reducing the size of the pillars just before the stope is abandoned they will be crushed and the hanging-wall will not be badly shattered, when subsidence takes place; and the weight of the capping will be taken off the adjoining rooms, thereby preventing a general squeeze.

The plan that I have in mind for White Pine contemplates following Birmingham practice to a large extent. I would drive the levels 100 ft. apart vertically, which over a large part of the mine will permit rooms about 300 ft. long on the dip. In the flatter ore of the upper levels it may be expedient to drive intermediate levels rather than to lengthen the rooms. If experience at White Pine is r the same as at Birmingham, however, rooms 500 ft. long can be mined economically.

In somewhat similar shale in Rhodesia long, narrow, continuous pillars were better than shorter and wider pillars with break-throughs between them, and I think that the same thing would be true at White Pine. My recommendation is to lay out the stopes on 45-ft. centers, rooms being 33 ft. wide and pillars 12 ft. The pillars can finally be stripped to an average width of 8 ft. or less.

In starting a stope the first thing will be to drive a raise 12 ft. wide from level to level following the center-line of the stope and taking out the full thickness of the ore, if the ore is not over 12 ft. thick. In thicker ore a thickness of 8ft. to 10 ft. would be mined, and the raise would follow the hanging-wall. One left on the foot-wall would be mined by ring-drilling from the raise, when the stope was widened. By using a burn-out cut 12-ft. rounds can be pulled, and the raise is so large that the ore can be broken economically. When the raise is up about 20 ft., a ramp or chute will be built at the bottom, and thereafter the broken ore will be loaded directly into cars by a scraper. In this ground a 12-ft. round should be pulled in two shifts.

When the raise has been holed through to the level above, it will be widened 11 ft. on each side just above the chute so as to form a hopper. The ore above will then be broken by successive rows of horizontal holes drilled into the rib on each side of the raise, each row being in a plane normal to the dip. A little experimenting will soon determine the most economical distance between holes and the proper burden. I think that holes can be spaced 3 ft, apart in the row and can carry a 4-ft. burden. Drilling will be kept well ahead of blasting, and the whole raise can be drilled on both sides for its full length, if desired, before blasting starts. Enough holes can be blasted every day to keep the scraper supplied with ore, and the hoist will not have to be moved until the stope is finished.

If the drills are mounted on columns with universal arms, and the columns are set up normal to the dip, reaching from foot to hanging, two rows of holes can be drilled from each set-up, and not more than two set-ups in a shift will be needed for each machine. Since the holes are all parallel, and the spacing and burden are determined in advance, miners can be paid on contract or bonus according to footage drilled without loss of efficiency in blasting, and all holes can be measured before they are fired. The holes can be laid out in advance, and their position marked on the rib, so that there will be no mistake.

White Pine ore drills very readily, and should break well. In this ground a reasonably good miner should be able to drill well over 100 ft. of hole in a shift, and a very good man might drill as much as 200 ft. An average burden of .7 ton of ore per foot of hole can be reasonably expected. This would make the tonnage broken per machine in this part of the work anywhere from 75 to 150 tons per shift. The lower efficiency of the raise-work would reduce the average to possible 50 or 60 tons per machine shift.

If there are enough working places available, it is proposed to drill and load ore on the day and afternoon shifts, and to blast and trim back on the "grave-yard" shift, using a special crew for this work. By this arrangement the miners can drill for the full shift without delay for trimming and blasting.

Another advantage of having the raise put through to the level above is that the men drilling the side-holes will always be working in a narrow place that is safe from falls of ground. When the stope is widened, if the back shows signs of weakness, single props or batteries of stulls can be set up on the center-line without interfering with either drilling or blasting.

By using the center raise control of stoping width, i.e. the thickness of ore that should be mined, will be greatly facilitated, for the rest of the stope. While the raise is being put up, sectional samples should be taken from every cut to determine the commercial limit of the ore, and the top and bottom of the ore should be marked clearly on both ribs for the guidance of the miners, who will widen the stope. If the center raise is carefully sampled, the ribs will not need to be sampled again.

Although the ore at White Pine is in general unusually regular in its occurrence, as indicated by the drilling, small cross-faults were found in the old mine, which dislocated the lode for a few feet. These may be connected with the formation of the ore, and are to be expected in the vicinity of the main fault. The presence of such a fault in a stope will be shown by the center raise, and this advance knowledge will be helpful in mining the rest of the stope.

The number of crews that will work as a unit depends on the loading capacity of the scraper. A scraper large enough to load 300 tons a shift will prove economical. Each unit will then produce 600 tons a day. Depending on the skill of the miners, three machines should drill the necessary side holes to produce this tonnage. Three or possibly four more machines are needed to drive two raises fast enough to keep pace with the side-hole work, and these will produce 200 tons more per day, if they are provided with separate loading equipment. A 12-ft. advance should be made in each raise every day. Theoretically therefore we should be able to get 800 tons a day from each stoping unit, but it will be safer to count on only 600 tons.

In normal procedure it would be good practice to have one stoping unit on each side of the shaft on each level, and to retreat towards the shaft from each end of the level. The drifts at White Pine however, will be so long that it will be possible, by having a transfer raise 4000 ft. or more from the shaft, to work as many as 6 units on one level.

two retreating towards each transfer raise and two retreating towards the shaft. From current development and eight stoping units it should be quite feasible to produce 5,000 tons per day, and it might even be done with six units working at full speed. If there are four units on each of two levels and a a third level is being developed, production and development will be in balance.

Because White Pine ground drills so easily, I think that as good speed can be attained with 3-in. machines as with 3½-in. machines, and the smaller machines would be preferable, because they are really one-man machines, and are easy to set up. All drifters should have automatic feed and 36-in. shells.

Each unit would require six or seven machines in regular use, and there should be three spares. We shouldd therefore count on 10 machines for each unit. Each unit will require seven saddle-clamps and seven 3-in. universal arms, and at least 12 3-in. columns of various lengths. One 50-ft. air-hose and one 50-ft. water-hose will be needed for each machine.

For loading ore from the raises each unit will require one 25-H.P. double-drum electric hoist, mounted on a small truck, and a 48-in. hoe-type scraper with cheek-plates, which will weigh about 1000 lb. Rope-speed should be 250 f.p.m.

For the stopes I recommend a 60-in.hoe-type scraper with cheek-plates about 2 ft. long, weighing about 2500 lb. The hoist should preferably have three drums and a rope speed of 250 to 300 f.p.m. It would be driven by a 50-H.P. motor, and would be mounted on a truck that can run on the main track. Each unit would have onehoist of each kind, and there should be two spares of each kind for the mine.

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DEVELOPMENT.

The main hoisting shaft should be about half-way between D.D.H.'s 732 and 734, about on the south line of Section 10 about 1800 feet west of the south-east corner of the section. This location is opposite the deepest part of the lode, and the drifts on both sides will be of approximately the same length.

The shaft should be vertical, and should be of the "square" type, in design like that of the Beatty Shaft of Roan Antelope Copper Mines, which is 18 ft. 3 in x 12 ft. 6 in. inside timbers. It is lined with steel sets made of 23-lb. 6-in. H sections of copper-bearing steel, and sets are placed at 6 foot intervals. There are two skip-roads, each 5 ft. 9 in. x 6 ft., across one end, a cage compartment 12 ft. 6 x 8 ft. in the middle, and a pipe compartment, ladderway and counterweight for the cage on the other end. This is very similar to the new Mather Shaft of the Negaunee Iron Co. (See p.11, Practical Mine Development and Equipment).

The skips hold 10 tons each, and the cage carries 50 men on a deck. Cars and locomotives can be run on the cage directly.

The shaft will be eventually 1100 ft. deep, but need be sunk only 750 ft. at this time.

For ventilation and second outlet there will have to be an opening at each end of the mine. No.4 shaft will serve this purpose at the north-west end, but a new shaft will have to be sunk at the south-east end. These shafts will extend to the 600-ft. level. Both of these auxiliary shafts will be down-cast, and the main shaft will be up-cast.

The general plan of development is to sink the main shaft 750 ft., turning off levels at -400, -500, and -600. The plat will be cut at the -700 level, and the measuring pockets will be just below the level, so that development of this level, when it becomes necessary, can proceed without interfering with normal hoisting operations.

A 20-in. gyratory crusher will be set up a little below the 600-ft. level, and there will be a 500-ton storage pocket under it, with 10-ton measuring pockets below. There will be a small bin above the crusher to receive ore from the 600 ft. level, and above it there will be an ore-pass extending to the 500-ft. and 400-ft. levels. There is also a waste-pass from the 700-ft. level to the 600, 500 and 400 ft. levels.

The 600-ft. level will be connected with the sixth level in No.4 shaft, requiring about 9,000 ft. of drift, which should be driven from both ends. On the south-east side of the 600-ft. level and on both sides of the 500-ft. and 400-ft. levels the main drifts should be driven about 5,000 ft. before full production is reached. At about 4,000 ft. from the shaft on each side there should be a transfer-raise connecting the 400 and 500 ft. levels with the 600 ft. level. This will make it possible to work 4 stoping units each on the 400 and 500 ft. levels, retreating both ways from one point on each side of the shaft, and these will be enough for full production, while the rest of the level development is being carried out.

Production can be started and ore mined up to the capacity of No.4 shaft soon after this shaft has been put in commission, a matter of months only, and the ore can be accumulated for treatment in the mill as soon as it is completed. As soon as the main shaft is equipped, drifting can be carried on on all three levels, and soon thereafter center raises for stopes can be started, three on each side of the shaft on each level, and a production of 2,000 tons a day should be quickly reached. Unless there are undue delays in getting equipment, the mine should be on full production in a little over two years. It should be possible to produce 685,000 tons before going on a production basis, containing 20,000,000 lb. of recoverable copper.

If adequate mechanical loaders are provided, either scraper-slides with 48-in scrapers or loaders of the Conway class, and if the headings are provided with "jumbos", the main drifts should be advanced 500 ft. or more per month in each heading.

HOISTING.

The head-frame should be made of steel or concrete, and need not be very high. Concrete will probably be quicker and cheaper. It should contain the equipment for the disposal of waste. The coarse crusher will be underground, and the secondary crusher, a 7-ft. Symons cone or its equivalent, may well be placed in the shaft-house. The mine product will be elevated to the mill bins by a belt conveyor.

Two hoists are required, one for the skips and one for the cage and counterweight. Both hoists should be driven electrically through herringbone gears. The lift is so short that a first motion hoist is unnecessary. A speed of 1000 f.p.m. will be sufficient for the skip-hoist and 600 f.p.m. for the cage-hoist. These speeds can be increased later, when greater depth demands it.

The skip-hoist should have a cylindrical drum 10 ft. in diameter, and should be driven by two 500-H.P. or one 1,000 H.P. D.C.motor with Ward Leonard control. The power capacity of the power company is large enough to make a fly-wheel set unnecessary, but the generator should be driven by a synchronous motor. If provision is made for larger pinions or faster motors to be substituted later, a second M.G. set can be added, when the shaft has been sunk to full depth, the gear-ratio or motor speed being changed to give the necessary increase in hoisting speed.

The cage-hoist should be like the skip-hoist, except for the motor and controls. A wound-rotor A.C. motor will do.

The skips will hold 10 tons each, and three will be provided. The design of the Roan Antelope skips is shown on p.261 of Practical Mine Development and Equipment. Two cages will be provided. Head-sheaves will be 10 ft. in diameter, and will have steel linings. The rope will be 1½ in. in diameter. There should be a Lilly hoist controller for each hoist.

AIR COMPRESSORS:

Three 2500 c.f.m. air compressors should provide sufficient air for the drills. Ingersoll-Rand Type PRE compressors are recommended.

The air-receivers should have a capacity of 7500 cu. ft. A cooling-pond of 1500 cu. ft. with 15 spray nozzles and a circulating pump with 300 g.p.m. capacity will be needed also.

The air-pipe to and down the shaft should preferably be 12 in. in diameter, but 10-in. pipe will not cause too much loss in pressure. Main-level distributing pipes should be 6 in. in diameter for 5,000 ft. from the shaft and 4 in. from there on.

UNDERGROUND TRANSPORTATION.

This is a very large item, but the hauls are long, and production is scattered. Because the hauls are so long, $6\frac{1}{2}$-ton trolley locomotives are recommended, hauling 6-ton Granby cars. The track gauge should preferably be 36-in. gauge for cars of this size and type. Cars should have roller-bearings and automatic couplers. Each of the eight stoping units requires one long-haul and one gathering or service locomotive. Three development headings and two transfer raises require one locomotive each, and there should be three spares. This is 24 in all. Storage battery locomotives could be used for gathering, but there would be no saving in investment.

Each stoping unit requires 13 cars, each development heading 5 cars, and each transfer-raise 8 cars, a total of 135 cars, including spares. In addition there should be a man-car for each stoping unit, 8 in all; and there should be 10 timber, supply and powder cars.

Three 100 K.W. rotary converters in the engine-house will supply current at 275 volts, allowing for a line-drop of 25 volts. The trolley wire should be of 0000 size, and there should be a feeder wire of 00 or 000 size for half the length.

Track should be laid with 50 lb. rail, but 40 lb. rail will do.

I have estimated the locomotives at $6,000 each, cars at $1,000 each, track at $2 per ft., and trolley wire at 40¢ per ft. These are the big items.

PUMPING.

The flow of water to be expected should be relatively small. The pump-house should be on the 600-ft. level, and an auxiliary pump at the bottom of the shaft should throw to the 600 ft. level. Two two-stage 600 g/p.m. high-speed centrifugal pumps, good for 600 ft. head, such as were used at the Isle Royale Mine for unwatering should suffice. I think that some of these pumps are on hand at the Isle Royale Mine.

The water-column should be of 8 in. pipe with steel flanges or Victualic couplings.

DRILLS AND DRILL STEEL.

I have planned on 3-in. drifters for the stopes and 3½-in. drifters for the main headings, 65 outfits in all, plus spares. I have also included 6 stopers for raising, and 5 jumbos for the headings. Drills, drill-steel, hoses, lights, etc. come to $1,000 per active machine, and this includes spares.

I have planned on detachable bits, but the cost for standard steel is about the same. This is true also for sharpening equipment, which is included in Shop Equipment.

LOADING EQUIPMENT.

I have estimated 8 scraper slides with 48-in. scrapers and 25 H.P. hoists, for the drifts, 9 scraper-hoists and 48-in. scrapers for the center-raises and 9 50-H.P. scraper-hoists and 60-in. scrapers for the stopes. The hoists will get their power from the trolley circuit. A.C. cables and motors can be used instead.

White Pine — Adams Township, MI

ESTIMATE
OF
COST OF OPENING AND EQUIPPING THE MINE.

1. General Expense $130,000

Opening Mine.

2. Sinking main shaft 750 ft. 160,000
3. Sinking south air shaft 600 ft. 60,000
4. Repairing No. 4 shaft. 20,000
5. Cutting 4 plats, main shaft 20,000
6. Storage pocket and crusher house . . 10,000
7. 2 Transfer raises at shaft, 300 ft. . 10,000
8. 2 Measuring pockets 10,000
9. Drifting. 34,000 ft. : $680,000
   Raising. 1,000 ft. : 20,000
   Total : 700,000
   Less copper recovered: 350,000
   Net 350,000 . . . 350,000
10. Unwatering old mine 63,000
11. Underground crusher installation . . 50,000
12. Equipment for No. 4 shaft 50,000
13. Preparing site 30,000
14. Temporary equipment for shaft-sinking 30,000

Equipping.

15. Main building, 500 ft. x 70 ft. 225,000
16. Headframe. 60,000
17. Coal-dock. 8,000
18. Rock-trestle (waste) 10,000
19. Waste disposal equipment 11,000
20. Storage building and garage 10,000
21. Change-house equipment for 800 men . 20,000
22. Fire-fighting, prevention, and first aid 10,000

White Pine.

(Cost of Opening and Equipping Mine, Continued.)

23.	Engineering equipment.		$4,000
24.	Office and warehouse equipment . . .		3,000
25.	Hoisting plant.		
	Skip-hoist . .	$80,000	
	Cage-hoist . .	42,000	
	Crane, etc.. .	3,000	
		125,000	125,000
26.	Compressor plant. 7,500 c.f.m. . . .		75,000
27.	Pumping plant.		20,000
28.	Electric haulage, cars & track . . .		366,000
29.	Shop equipment		40,000
30.	Trucks, tractors and automobiles . .		20,000
31.	Ventilation.		15,000
32.	Air pipes		35,000
33.	Drills and drill-steel		75,000
34.	Loading equipment		75,000
	Total		2,200,000
	Contengencies		200,000
	Grand total		2,400,000

One the basis of 5,000 tons per day and 300 days per year, giving an annual production of 1,500,000 tons per year, this is a capital investment of $480 per ton of daily production, and only $1.60 per ton of annual production.

Air 5000 / 7500 cfm = 1½ cfm per ton capacity

1,500,000 tons
×23
34,500,000 lbs / 2000 = 17,250 tons of copper per year

$2,400,000 / 17250 = $140 per ton annual metal produced

Estimate of Cost of Opening White Pine Mine
(By Lucien Eaton)

****

On Dec. 29, 1937 I presented a general estimate of the cost of opening the White Pine Mine. This was based on the following plan of development.

1. A vertical shaft, large enough to accommodate two 8 ton skips, and a cage and counterweight, is to be sunk to a depth of 1100 ft. at a point approximately 400 ft. NE of D.D.H. - 7 E 2.
   1100 ft. @ $200. = $220,000.
   2 Loading pockets and 2 storage pockets would be built below the 1000 ft. level (Sea Level) and these would be connected by ore - and waste - passes to the levels above, and a spillage pocket would be built below.

   Plats will be cut on the -500, -600, -700, -800, -900, -1000 and -1100 ft. levels.

   Plats & pockets are estimated at $110,000.

2. No. 4 shaft is to be unwatered and connected to the main shaft by drifting from its bottom level to meet the -600 ft. level from the main shaft.
   Unwatering & equipping No. 4 shaft is estimated at $60,000.

3. Another air-shaft is to be raised to surface from a point near D.D.H. - 13 E 2. This can be put up in the ore, and can be used as a service shaft for this part of the mine. The logical connection for this shaft is on the 1000 ft. level.
   1000 ft. @ $50. = $50,000.

4. Including connections to the air-shaft 20,000 ft. of drifting and raising is to be done in advance of stoping. About 2/3 of this will be in ore.
   This is estimated at $16. a foot
   20,000 ft. @ $16. = $320,000.

5. The railroad would be rehabilitated and extended to the new shaft-site at a cost of $40,000. There are 7 miles of road-bed graded and ballasted.

6. The mine-buildings would be of fireproof construction and all under one roof, situated at the main shaft.
   The cost is estimated as follows:

a.	Temporary equipment	$ 25,000.
b.	Preparing site	25,000.
c.	Buildings	125,000.
d.	Head frame and crusher	60,000.
e.	Coal-dock and track	6,000.
f.	Waste-disposal	6,000.
g.	Timber treatment	10,000.
h.	Dry-fittings	10,000.
i.	Safety	10,000.
j.	Laboratory	8,000.
k.	Engineering	2,000.
l.	Office	2,000.
m.	Power-lines	11,000.
	Total	$300,000.

7. Mechanical Equipment, both on surface and underground was estimated as follows:

a.	2 Electric hoists at main shaft with skips, cage, counterweight etc.	$150,000.
b.	Air compressors with 6000 C fm. capacity	50,000.
c.	Pumps & pump-houses	65,000.
d.	Haulage	80,000.
e.	Timber handling	20,000.
f.	Surface transport	15,000.
g.	Shops	30,000.
h.	Ventilation	15,000.
i.	Air-pipes	8,000.
j.	Drills & drill steel	30,000.
k.	Loading equipment	30,000.
l.	Lighting	2,000.
m.	Tools	5,000.
	Total	$500,000.

8. A town-site to accommodate key-men and part of the labor is planned to cost $200,000. The rest of the labor can live in the older houses or be transported from Ontonagon.

9. A mill with a capacity of 3500 tons per day, using flotation, is estimated to cost $500,000. The ore is to be crushed at the shaft to 3/4 in., transported by belt conveyor to the mill-bins, from which it will go to ball mills, classifiers & flotation machines.

10. Water-supply for the mill is estimated at $100,000. If taken from Lake Superior it may cost more.

11. Overhead during the construction period (3 yrs.) is estimated at $100,000.

Recapitulation

1.	Main shaft	$220,000.
	Plats & pockets	110,000.
2.	No. 4 shaft	60,000.
3.	Air-shaft	50,000.
4.	Development	320,000.
5.	Railroad	40,000.
6.	Mine buildings	300,000.
7.	Machinery & equipment	500,000.
8.	Town-site	200,000.
9.	Mill	500,000.
10.	Water supply	100,000.
11.	Overhead	100,000.
	Total	$2,500,000.

This estimate is tentative only, but is based on actual figures. Empirically it is as follows:-

Mine	4000 tons a day @	400.
Mill	4000 tons a day @	150.
Overhead	4000 tons a day @	25.
Town-site	4000 tons a day @	50.
	Total	625

4000 tons a day @ $625. or
1,250,000 tons annual production @ $2.00.

Partial Development along the lines laid down but done through No. 4 shaft might profitably be done to save capital outlay, if the price of copper is 12¢ a lb. or higher.

No. 4 shaft should be unwatered and equipped with second-hand machinery. The railroad would be relaid to Ontonagon, and all ore produced would be shipped to the mill at Freda at a cost of 50¢ per ton. The ore would be crushed to 3/4 in. by crusher and rolls at the mine. By opening a few stopes, enough to produce 300 to 400 tons a day, the stoping can be made to pay for development drifts and possible for the new shaft, depending on the price of copper.

The capital expense is roughly estimated as follows:

1.	No. 4 shaft	$ 60,000.
2.	Railroad	30,000.
3.	Buildings	20,000.
4.	Equipment	80,000.
5.	Overhead	10,000.
	Total	$200,000.

Cost of Production is estimated as follows:

Mining	$1.20
Milling	.40
Smelting	.30
Overhead	.20
	$2.10

At 30 lb. copper per ton, cost per lb. is	.07
Plus depreciation & depletion	.01
Total	.08

This is based on 90% recovery from 33 lb. ore.

Note: The following was not given to the directors:
If the ore is shipped to Freda for treatment add 2¢ per lb.
If ore is mined through No. 4 shaft add another 1¢ per lb.

If development is done through No. 4 shaft, costs will be about as follows:

Mining		$1.50	
Milling		.50	
Railroad		.50	
Overhead		.20	
	Total	$2.70	
Smelting		.30	
	Total	$3.00	10¢ per lb.

If copper sells at 12¢ there will be 2¢ a lb. available for development, amounting to 60¢ a ton and $180. to $240. per day, possibly 400 ft. of drift per month.

Adams Township, MI

COPPER RANGE COMPANY
89 BROAD STREET
BOSTON

September 11, 1937

Mr. Bernard Manderfield
The Copper Range Company
Painesdale, Michigan

Dear Bun:

I enclose a short account of what I saw at the Sudbury Mines and a list of suggestions of possible adaptations of their practice to our conditions.

If you have anything to add to either the subject matter or the suggestions, I shall appreciate a memorandum of it. If you have not already written down what you saw, won't you jot down a memorandum of it, before you read my account, and then compare the two?

I expect to be with you again in about two weeks.

LE/J
Enc.

Sincerely,

Lucien Eaton

COPY

Mr. F. W. Paine,

I enclose a short report of what we saw at the mines in the Sudbury District, when Vanderfield, Rodeher and I visited the International Nickel Co., a month ago.

Among the things that we saw that may be useful to us, I tentatively list the following:-

1. The mining system at Frood may well be suited to our conditions at Globe.

2. The skip-loading system may be adapted to loading skips at the 46 or 48 level at Champion and at White Pine.

3. The chute-closers are cheaper than those at Champion and can be adapted to our conditions.

4. The chute-linings may be useful at Globe.

5. Our locomotives should be equipped with head-lights, and cars and locomotives with automatic couplers, and we should have tail-lights on trains. We have already adopted whistles for signalling.

6. The bonus system for shift-bosses deserves study and trial.

7. Sharpening drill-steel with hot millers should be tried, unless we decide to go to detachable bits.

8. Their drill-steel straightener is superior to ours.

9. They use an entirely independent system of signalling, when calling for skip or cage, instead of using the hoisting signals, as we do at Champion.

10. Their system of estimating costs and making time schedules on new construction is well worth adopting.

September 8, 1937

Lucien Eaton
L. Eaton

The International Nickel Company of Canada.

FROOD MINE

The Frood Mine of the International Nickel Co., is at Frood about 4 miles north of Sudbury, Ontario. There is a small townsite near the mine, but most of the employees live in Copper Cliff or Sudbury, and go to the mine by automobile.

Geologically the ore-body is on the southern rim of the "Sudbury Basin", and occurs in the norite in conjunction with shear-zones and possibly drag-folds. There is a gossan that extends for some three and a half miles, and as early as 1912 diamond-drilling indicated the presence of a large ore-body; but the ground under the gossan has never been explored in depth for its whole length, and it was not until after the War that the rich ore-bodies at Frood were discovered. At this time it was thought that the Creighton Mine was nearly finished, and an intensive search for a mine to take its place was undertaken.

The ore that is being mined at Frood is a pyrrhotite containing nickel and chalcopyrite containing copper, with a little gold, silver and platinum. Down to about 2000 ft. depth the ore is rather siliceous and low-grade but in places is as wide as 600 ft. Below 2000 ft. massive sulphides are found, containing about 5% copper and 2½% nickel. It is this ore that is being mined. The ore dips about 70°, and is 100 to 200 ft. wide. At present prices of copper and nickel, the ore is worth at the mine about $10 a ton for copper, $10 a ton for nickel and $4 a ton for precious metals.

Frood Mine. (Continued)

The Frood is opened by two hoisting shafts and two ventilation shafts. The two hoisting-shafts are Nos. 3 and 4. No. 3 shaft formerly belonged to the old International Nickel Co. and No. 4 shaft to the Mond Nickel Co. After the consolidation of these two companies the mine was opened through these two shafts, leaving a large pillar 1000 ft. or more long between the workings. This pillar was cut by only a few drifts, and the ore-body near each shaft was developed to such an extent that the expected requirements of ore could be produced at either shaft, in case the other shaft was closed by fire. The demand for ore has increased so much, however, that now not only are both mines being worked to capacity, but the intermediate pillar is also being stoped.

Both shafts are vertical and have a large cross-section. Each has two skips and two cages, a ladderway and a pipeway. The skips at No. 3 shaft carry 11.2 tons each and those at No. 4 shaft carry 9.8 tons. No. 3 shaft has a capacity of 480 tons per hour and No. 4 shaft has a capacity of 270 tons per hour. The daily output of the mine 11,800 tons per day. The ore-hoist at No. 3 shaft has two 12-ft. cylindrical drums, driven at 40 r.p.m. by a 3200 H.P. 600 V.D.C. Motor with Ward Leonard control.

In each shaft the ore is sent down through ore-passes to a storage pocket above a large jaw-crusher, where it is crushed to less than 6 in. From the crusher the ore falls to a storage pocket at the shaft, from which it is drawn into measuring pockets, each of which holds exactly a skipful. In passing to the measuring pockets, the ore slides down an inclined chute, in which there is a vertical undercutting gate, which is pulled up through the

Frood Mine. (Continued)

ore-stream by a large air-cylinder, cutting off exactly the right amount to fill the skip. The pocket is discharged through an opening closed by a vertical overcutting gate. The time required to fill the skip is 6 to 10 seconds.

The room-and-pillar system of mining is used with square sets and fill. The rooms are transverse to the strike and are 5 sets wide. Pillars are 3 sets wide. The level interval is 200 ft. Formerly the rooms were silled out 30 ft. above the level, but are now silled out only 7 feet up, at the top of the main-level drift sets, and are carried up to the floor of the level above, where the drift-timbers are caught up on sills which rest on the fill in the stope. This leaves ore only one set high to be mined on the main level.

The main haulage drifts are large, about 9' x 10' in cross-section, and are driven well in the foot-wall. From them cross-cuts are driven through the ore to the hanging-wall at intervals of about 200 ft. From these cross-cuts drifts are turned off in the ore near the foot-wall and at 44-ft. intervals towards the hanging-wall, the number of drifts depending on the width of the ore. The hanging-wall drift is used for ventilation and for tramming fill. In the other drifts chutes are built at 22-ft. intervals, two chutes being opposite each other at each station. They are operated from pony-sets opened in the back of the drift. Each chute is closed by a stop-log hung in loops of chain, and the fine dirt is stopped by an overcutting gate. These chutes have to a large extent taken the place of the elaborate undercutting gates formerly used. It is a good design, easy and cheap to build and easy to operate, but requires two men. The chutes are offset for one set and then carried up vertically through the fill,

Frood Mine. (Continued)

as the stope is worked out. In the stopes the chutes are on 22-ft. centers (4 sets) each way, so that there are always two rows of chutes for a room and a pillar (8 sets). At each floor in the room four inclined slides are built in the four sets on the four sides of each chute, and these are moved up each time the floor is worked out and filled. There is a grizzly of heavy rails with 11-in. opening at each slide. In this way there is only one set between slides, and over 50% of the ore is run directly into the chute without shoveling. Short chutes are lined with 4-in. jack-pine plank. Elm plank was tried, but it twisted too badly. Present practice is to line the high chutes with wood blocks. These are 8" x 10" in cross-section and 13" long, and are packed in tightly between the sets, the grain being horizontal and the end sticking out five inches beyond the line of the timbers. The blocks are put in dry, and swell when they become moist, so that they are held tightly in place. Chutes lined with blocks have been carried up 200 ft. without any repairs, and this is impossible with any other lining that has been tried.

In the lower part of the rooms the timber is peeled jack-pine flattened on two sides to be 8 in. thick. Sets are 7 ft. high, center to center, and are 5'6" center to center horizontally. Lagging is 2-in. pine. In the upper part of the room, when the pressure increases, 9-in. and even 10-in. timber is used. The annual consumption of timber is over 30,000,000 bd. ft., approximately 15 bd. ft., per ton.

In the 5-set rooms a favorite method of timbering is to put up a vertical row of square sets on the center-line of the room, and to use long girts to reach from these sets to the posts on

Frood Mine. (Continued)

the side of the room, where the gob-wall is built. When the room has been filled up to these long girts, they are removed, and there is thus a complete wall of fill for the length of the room (i.e. across the ore-body) without any timber in it that might carry fire across to the adjoining timber. A gob-wall of 2-in. cedar plank is spiked to the inside of the last row of legs on each side of each room, before the fill is run in.

Mining is carried on on two floors, a drilling floor above and a mucking floor below. Mining starts at the hanging-wall, and the face is carried across to the foot-wall. The full width of the room is shot down at once, holes being drilled approximately horizontally, and the ore falls to the mucking-floor below, where over half of it is run into the chutes without shoveling. Some sledging is required. There is one mucker for each miner, and each mucker puts 60 to 70 tons of ore per shift into the chute.

There is a stope-boss for every two rooms, and the work is so arranged that in one room men are mucking and mining on the morning shift and timbering on the afternoon shift, and in the other room timbering is done on the morning shift and mucking and mining on the afternoon shift. The "grave-yard" shift is devoted to the handling of timber and other supplies. Production is 10 to 12 tons per man for every man in the stope including the timbermen and the boss, but not including the men who deliver supplies. The men are paid a bonus over and above the day-rate for production beyond the standard, and all the men in the stope share in it, including the boss. Wages average more than $6 a day.

The mine is beginning to take a little weight on the lower

Frood Mine. (Continued)

mining levels, but there has been little ground movement, because all openings are thoroughly filled. Some of the pillars are under a good deal of pressure, but this is relieved as soon as the ore under the hanging-wall is removed. In some places chutes and man-ways have been left open on the side of the filled room, and these can be used in mining the pillar, but the preference at present seems to be for the long-girt method of timbering in the rooms, and that makes it necessary to carry chutes and a ladder-road up in the pillar. If the pillar is not much broken, it may be possible to mine it three sets wide, its full width, but more often it is mined one or two sets wide, going up, the balance being taken underhand from the top down. Production in pillar-mining is only 10% less than in the stopes. In pillar-mining excavation always starts at the hanging-wall and works towards the foot.

Drilling is done with 3-in. drifters mounted on 3-in. columns with arms. The steel is 1-in. quarter octagon, hollow, without lugs, and is made up in standard lengths of 3 ft., 5 ft., 7 ft., and 9 ft., with 1/16-in. changes of gauge. The bits are double taper cross-bits with 90° cutting edges. The ore is not hard to drill, and four or five feet of hole is drilled with each bit. Water for the drills is brought down from surface, and the pressure is regulated by Ford reducing valves.

There is one fill-raise for each room-and-pillar. It is put up to connect with the hanging-wall drift on the level above, and fill dumped into it on that level by cars, which haul it from the main fill-pass. Waste from development is used as fill, but most

Frood Mine. (Continued)

of it comes from the Creighton Mine, where it is drawn from the old glory-hole workings or from caved shrinkage stopes. It is crushed to 2½ in., and sometimes to 1¼ in.,and is screened, the minus 3/4 in., material going to the mill for concentration. It is hauled to the Frood Mine in railroad cars and is dumped down the main fill-pass.

Formerly fill containing a small per cent of sulphide ore was preferred, because the sulphide oxidised and cemented the rock together, so that it stood well over short spans, when unsupported, and there was a little contamination, when pillars were mined alongside filled rooms. It had the disadvantage, however, of causing an uncomfortable amount of heat in the rooms, and there was some danger of fire. When the mine began to take a little weight, it was found that the cemented fill crushed badly and ran "like a bag of beans". The management is now trying to find a proper mixture of clay and rock that will not flow or run. About 40 tons of fill is needed per 100 tons of ore stoped.

Fill is distributed in the stopes in ½-ton scoop-cars similar to those used at United Verde. These cars are on the breaking floor, and dump onto the mucking floor, the face of the fill being kept as close as is convenient to the mucking face, a distance usually less than 20 ft.

No scrapers are used for mucking or distributing fill, one of the reasons given being that no electric power is allowed in the stopes on account of danger of fire. If scrappers were used, more than half of the chutes could be eliminated, but this might not

Frood Mine. (Continued)

be much of a saving, because repairs would be increased proportionally.

Both ore and fill are hauled on the main levels in 5-ton Granby cars, equipped with automatic couplers, running on 36-in. gauge track. The cars are handled in the ore-body by storage-battery locomotives, which make up trains on the sidings. These trains are then hauled to the shaft by trolley-locomotives. The reason given for the small cars is that the length of the car has to be an even fraction of the distance between chutes, so that cars can be loaded at two chutes at the same time. Larger cars and larger chutes would probably give the same capacity with fewer men. Locomotives have head-lights, and trains have storage battery tail-lights, and swit men have whistles for signalling.

Production at present is 11,000 tons of ore per day, approximately 3,800,000 tons a year, and the number of men employed is 2,740, so that production per man per day is approximately 4 tons. This is the same figure obtained, when production was 3,000 tons per day. Cost of production was given as $2.10, but this probably does not include overhead. Actual cost is probably between $2.25 and $2.50 per ton.

Ventilation in the mine is artificial. There are two ventilation shafts, which are lined with concrete and steel. Friction in the shafts has been reduced to a minimum. There is a 400,000 c.f.m. fan at each shaft on surface, and air is taken off at each level through fire-proof doors, the opening of which is regulated to control the "split" of the air-current. Other special regulating doors are used on the level to control the flow of air to

Frood Mine. (Continued)

different parts of the level. Ventilation is good throughout the mine, and there is almost no trouble from silicosis. But this is partly due to the absence of free silica in the rocks.

A great deal of attention is paid to the safety of employees, and special attention is paid to fire-prevention. No open lights are allowed, and no electricity, except from storage-battery equipment, is allowed in the stopes. On the "graveyard" shift special inspectors visit all the stopes on the look-out for fire, and on each level is a large room equipped with fire-proof, air-tight doors, electric lights and air and water supply, into which the men can retire in case of fire. These rooms are normally used as lunch rooms. There are nine five-men rescue crews at Frood, five at Creighton and three at Levack, all of whom are available in case of fire at any one of the mines.

Shift-bosses receive a cash bonus monthly for excellence, based 25% on the general appearance of their territory, 50% on their safety record, and 25% on production. The different levels and departments are running a Derby in safety work, their ratings, based on lost time accidents, being shown by horses. The men are showing a great deal of interest in this race.

Drill-steel is taken out of the mine on special supply cars with articulated trucks, and goes directly to the drill shop. The steel is heated, then punched, then upset in a sharpener, then finished both as to cutting-edge and gauge on a hot miller, all in one heat. An increase of 21% in penetration has been obtained since the hot millers were used. There are 16 men heating and sharpening, using 4 sharpeners and 2 double hot millers, and 4 men tempering

Wood Mine. (Continued)

and 1 straightening. 9 men distributing, gathering and sorting, and there are 4 men on two forges, but these are mostly on other mine work. The shop sharpens 5,000 to 5,500 steels per day, about 2 tons of ore per bit. The cost of sharpening and distributing is given as 9.4¢.

Creighton Mine (Continued)

It has two 10-ton skips and two large cages. The skips are made of nickel-steel, welded, and are oval in cross-section. Only one hoist has been erected. It is similar to the Homestake Hoist, but was built by the Allis Chalmers Co.'s Canadian subsidiary instead of by Nordberg. It has two single conical drums in tandem, driven by three interlocking herringbone pinions and two D. C. motors with Ward Leonard control. The motor-generator set has no fly-wheel, and is driven by a synchronous motor set between two D. C. motors. The A. C. power is 3-phase 25 cycles.

Production through No. 1 shaft is 6,000 tons a day, but half of this is lean material drawn from the caved ground of the old open pit in summer and from caved shrinkage stopes nearby in winter. It is put through grizzlies, and falls through a waste-pass to the 24 level, where it is crushed. It is crushed again on surface and is screened, and the 3/4-in. material is sent to the mill 300 to 350 tons per day, and the balance, about 2700 tons, is sent to the Frood Mine to be used as fill.

Of the 3,000 tons of ore also hoisted about 600 tons a day comes from square-setting on sub-levels along the foot-wall under old shrinkage-stopes, where considerable ore was left behind. Ore is also run from old caved stopes on the upper levels through small chutes put up through the foot-wall; but the principal source of ore is shrinkage stopes and square-set rooms. The shrinkage stopes are finished, but are not all drawn. The new stopes are square-set. The ore on the lower levels will be mined by square-set rooms and pillars exactly as it is done at the Frood Mine.

Creighton Mine (Continued).

On the 48 level in No. 118 ore-body cross-cuts have been driven through the ore, and a foot-wall and a hanging-wall drift have been driven in the ore 44 feet apart, chutes are being built, and rooms 5 sets wide, extending from foot to hanging, with 3-set pillars between, are being opened one set high 7 ft. above the floor of the level. The ground stands well, and timber is not put in until excavation has been nearly completed.

The ore is hauled by storage-battery locomotives in 2-ton rocker-dump cars and $2\frac{1}{2}$-ton Granby cars equipped with link-and-pin couplers. The track is 24-in. gauge, and is laid with 45-lb. rail. Equipment is not as elaborate as at Frood, and apparently the danger of fire is not considered to be as great.

On the 58 level, which is the bottom level at present, at a depth of 3800 ft., a long cross-cut 9' x 9' in cross-section is being driven in rather tight hard ground. Three miners and a helper drill a round of 34 holes in 8 hours with 3 machines, and pull 10 to 12 ft. per round, using a burn-out cut. Drilling is done on the morning shift, blasting on the afternoon shift, and mucking, using a small Finlay loader, on the graveyard shift. Progress is 225 to 240 ft. per month.

Water for the drills is sent down from surface, and the pressure is controlled by Ford reducing valves placed at 400-ft. vertical intervals, giving pressure enough for 200-ft. raises. Other valves reduce the pressure on the level for drifting.

Drill-steel is 1.in. quarter octagon hollow, cut in 3, 5, 7 and 9 ft. lengths for stoping and longer for drifts. The gauge

Creighton Mine (Continued)

change is 1/16 in. Steel is sharpened in the same way as at Frood.

On the 52 level a large crusher-station, where there will be a 48 x 60 jaw crusher, is being excavated and lined with steel and concrete. The loading station will be 200 ft. lower at a depth of 4000 ft., and will be similar to that at Frood.

LEVACK MINE

The Levack Mine is on the north rim of the Sudbury Basin at Levack. The ore occurs in the norite in connection with local folding and shearing. It contains about 2% nickel and less than 1% copper, i. e. it is a Monel ore-body. This property was formerly owned by the Mond Nickel Co., and the equipment is largely second-hand.

The old shaft is an incline, and is both inadequate in capacity and in danger of collapse, because it is too near the ore-body. The ore-body is normally 100 to 200 ft. wide, but on one side of the shaft it widens out to more than 600 ft. This ore has been mined by shrinkage stopes and pillars, and when these pillars are removed, the surface is bound to cave, and will probably wreck the enginehouse and the collar of the shaft. Accordingly plans have been made and construction has been started on a new shaft farther back in the foot-wall. This will be a vertical shaft like No. 3 Shaft of the Frood Mine, and will have very large capacity, upwards of 450 tons per hour.

The engineers are allowing an angle of break for the rock over the ore-body of 45° and for the sand 35°. This is conservative. The ore occurs is a little valley, through which a stream flows, and no provision has apparently been made against flood-waters entering the caved ground.

Production is now 1600 to 2000 tons per day, but this will be much increased, when the new shaft goes into operation.

The new construction has been thoroughly planned out, and has been estimated in detail, and is scheduled both as to time and money. Apparently a thorough check is maintained on all construction of this kind.