112. Wolverine No. 3, 300 feet S. of 22nd level, drip.

Cl	11.705
Ca	5.071
Na	1.784
Sum	18.560
Difference	.800
Total solids determined	19.360
Sp. Gr. 1.015	

We compute:

Na : Cl .153

This is apparently somewhat diluted of the same type as the water at the 17th and 20th levels.

113. Wolverine No. 3, 300 feet S. of the 24th level, dripping.

Cl	33.640
Ca	15.600
Na	4.088
Br	.868
SO_4	.130
Sum	54.326
Difference	.174
Total solids determined	54.5
Sp. Gr. 1.039	

We compute:

Na : Cl .122

The lowest water is well established. Note as compared with the other levels the sudden rise in solids, almost double while the sodium ratio drops.

This is about the same concentration as the 30th level Centennial, No. 108.

114. Wolverine No. 3, 300 feet S. of 26th level, dripping.

Cl	55.765
Ca	26.800
Na	5.912
Br	.930
Sum	89.407
Difference	.393
Total solids determined	89.8
Sp. Gr. 1.071	

We compute:

Na : Cl 0.106

115. Wolverine No. 3, drip 300 feet S. on 28th level.

Cl	75.231
Ca	36.347
Na	7.367
Br	1.085
Sum	120.030
Difference	.270
Total solids determined	120.3
Sp. G. 1.092	

We compute:

Na : Cl 0.098

116. Wolverine No. 3 shaft, 300 feet S. of 30th level, dripping.

Cl	64.390
Ca	31.271
Na	5.756
Br	.940
Cu	p.n.d.*
Sum	102.357
Difference	.143
Total solids determined	102.5
Sp. Gr. 1.079	

Nos. 114, 115 and 116 are nearly the same kind of water varying slightly in concentration and the Na : Cl ratio slowly falling. In this it is:

Na : Cl .0895

The varying concentrations of these deep waters may be partly due to evaporation and partly to very recent circulation of fresh water incident to the mining.

The Centennial 30th level water is about as strong as the Wolverine 24th level water and the Na : Cl ratio is the same.

117. North Kearsarge mine. 26th level, 700 feet S. of No. 3 shaft.

Cl	83.400
Ca	38.667
Na	9.826
Cu	p.n.d.**
Br	.905
Sum	132.798
Difference	.202
Total solids determined	133.000
Sp. Gr. 1.099	
Na : Cl .118	

This is much stronger than any of the Wolverine waters but the Na : Cl ratio is similar to that on the 26th level.

*Estimated from 2 to 8 mg per liter.

**All samples from N. Kearsarge contain from 2 to 8 mg per liter of Cu as estimated.

118. N. Kearsarge, 300 feet S. of No. 3 shaft, on the 27th level.

Cl	71.240
Ca	31.822
Na	9.822
Cu	p.n.d.*
Br	.945
Sum	113.829
Difference	.371
Total solids determined	114.2
Sp. Gr. 1.089	
Na : Cl .1375	

This is less strong than 119 at the N. end or than No. 117 on the level above, but has just about the same amount of sodium.

119. N. Kearsarge 450 feet N. of No. 3 shaft, 27th level.

Cl	76.363
Ca	32.937
Na	11.597
Cu	p.n.d.*
Br	.725
Sum	121.622
Difference	.178
Total solids determined	121.800
Sp. Gr. 1.091	

We compute:

Na : Cl .151

These are running a good deal higher in sodium than the Wolverine at the same levels and concentration.

120. N. Kearsarge, 28th level, 150 feet S.

Cl	60.480
Ca	25.618
Na	9.722
Br	.675
Sum	96.495
Difference	.245
Total solids determined	96.740
Sp. Gr. 1.074	
Na : Cl .161	

As we go north toward the Allouez Gap the amount of sodium at about the 26th to 28th levels seems to increase.

Mohawk Mine. Shaft No. 1. 10th level dripping.

121.

Cl	.357 grams per liter
Ca	.067
Na	.154
Sum	.578
Difference CO_3, SiO_2, etc.	.122
Total solids determined	.700
Na : Cl .43	

This is a typical upper level water like the S. Kearsarge 109, but only half as strong.

122. Mohawk, shaft No. 1, 11th level, dripping.

Cl	.285
Ca	.057
Na	.1198
Sum	.4618
Difference	.1382
Total solids determined	.600
Na : Cl .42	

This is essentially like 105. Note how sharp the change is at the next level.

123. Mohawk, shaft No. 1, 12th level, dripping.

Cl	3.172
Ca	.993
Na	.914
Sum	5.079
Difference	.276
Total solids determined	5.355
Na : Cl .294	

This is fairly in the middle zone.

124. Mohawk, shaft No. 1, 13th level, pool.

Cl	3.299
Ca	1.241
Na	.711
Sum	5.251
Difference	.349
Total solids determined	5.600
Na : Cl .216	

125. Mohawk, shaft No. 1, 20 feet S. of 14th level, dripping.

Cl	21.546 grams per liter
Ca	10.560
Na	1.824
Br	.124
Sum	34.054
Difference	.346
Total solids determined	34.400
Na : Cl .085	

This is quite characteristic of the lower zone.

Isle Royale Mine. Arcadian, i. e. Isle Royale amygdaloid epidote, and possibly Grand Portage lodes. This is close to Portage Lake just back of Houghton, and is 400 feet or 500 feet above it, i. e. above Lake Superior. It is the old Huron mine re-opened. This went down about 16 levels or 1000 feet.

On the Grand Portage lode shafts to 500 feet were sunk. This opened on many levels by crosscuts, but is about 200 feet (above) west of the Isle Royale lode on which the shaft is sunk.* This is worth mentioning since dripping from the levels might well have been affected by surface water standing in the levels a good while. The College of Mines have a list of some 30 minerals from this mine.

*N. B. This is not on Isle Royale.

126. Isle Royale. 300 feet N. of No. 2 shaft 15th level, dripping.

Cl	9.204 grams per liter
Ca	4.321
Na	.994
Sum	14.519
Difference	.581
Total solids determined	15.1
Sp. Gr. 1.007 low!	

We compute:

Na : Cl .0925

This is a dilute deep water.

127. Isle Royale, 18th level, dripping, 300 feet N. of No. 2 shaft.

Cl	34.920
Ca	16.751
Na	3.058
SO_4	.179
Cu	p.n.d.*
Sum	54.908
Difference	.792
Total solids determined	55.70

We compute:

Na : Cl .089

This is a typical dilute deep water

*Estimated 2 to 8 mg per liter.

128. Isle Royale, 19th leevl, N. of No. 2 shaft, from a pool from dripping.

Cl	45.178
Ca	22.201
Na	3.837
Br	0.320
SO_4	.234
Cu	p.n.d.*
Sum	71.770
Difference	.330
Total solids determined	72.1
Sp. Gr.	1.057

We compute:

Na : Cl .085

129. Isle Royale, dripping 50 feet S. of No. 2 shaft on 20th level.

Cl	7.626
Ca	3.249
Na	1.204
Cu	p.n.d.*
Sum	12.079
Difference	.241
Total solids determined	12.32
Sp. Gr.	1.009

Here is lower down a distinctly weaker water with

Na : Cl .158

The contrast between this and No. 126 is worth noting. Though they have about the same strength the deeper water is in one case diluted with fresh water that has found its way rapidly and directly down, while in the other case there is much sodium, presumably derived by decomposition of the rock.

*Estimated 2 to 8 mg per liter.

130. Victoria mine, Rockland district. This is at a low horizon in the formation. The sample was taken by Dr. L. L. Hubbard from the 19th level crosscut, about 600 feet from the shaft in a thin conglomerate underlain by 10 feet of amygdaloid then succeeded by 60 to 70 feet of conglomerate and sandstone, mainly sandstone.

Sp. Gr. 1.004; Total solids.....6.465 grams per liter
Chlorine.....3.159 grams per liter

A number of less complete tests for chlorine, and other supplementary data are here omitted, since they simply sustain the inferences which may be made from the above data.

ORIGINAL SOURCE OF WATERS CONNATE.

The widespread occurrence of these calcium chloride waters points to an original source, they are connate—original sea waters—modified by downward leaching. It is hardly conceivable that any upward circulation could so fill the Keweenawan rocks with salt water through a set of fissures that *everywhere* below the 21st level the content of salts is to be measured in per cents. And they are by no means confined to the copper and iron countries.

The well at Grand Marais struck, I am told salt water at the bottom, 1200 feet deep, and the Hon. Geo. Shiras 3d, called my attention to a salt lick southeast of Marquette, which gave Mr. F. B. Wilson,

Total solids	2.484 per thousand
Chlorine	.862
Sulphuric anhydride	.008
S. from sulphur anhydride	.027
Calcium and potassium carbonates present, indet. in 25cc	
Magnesium	tr.

I have just visited these licks at the south end of Whitefish lake, Sec. 3, T. 46 N., R. 22 W. The water seems to ooze from the upper part of the Potsdam sandstone, and I obtained up to 2.37 Cl.

In U. S. G. S. water supply paper 114, p. 240, there is an analysis of a well 50 feet in the Potsdam sandstone which is rich in calcium chloride, and I have elsewhere cited calcium chloride analyses from a wide variety of places.*

*Science, 1908, August 2, 1907, p. 127.

American Jour. of Sci., May, 1908.

Geol. Soc, of Am. Bull. Vol. XVII, (1905) p. 691.

For convenience of comparison one recent analysis may be given from the Lower Peninsula—from decidedly younger rocks, however.

Grayling water, Hanson No. 2, 2,800 feet.

Ca	25.044 parts per thousand
Na	52.953
Cl	147.344
SO_4	0.137
Mg	5.361
Br	1.840
NH_4	1.033
K	0.705
Sum	234.417
Li. Ba. Sr. Fe	trace.
Fe, Cs, Rb	none.

Calculated as follows:

	parts per thousand
$Ca\ Cl_2$	72.627
$Na\ Cl$	134.684
$NH_4\ Cl$	3.070
$Mg\ Br_2$	2.116
$Mg\ Cl_2$	20.128
$K_2\ SO_4$	0.248
$K\ Cl$	0.873

Water of crystallization not figured.

Signed, F. B. WILSON.

If the theory of the gradual concentration of salts in the ocean, and especially sodium, is true then the original ocean must have been essentially a weak solution of calcium and other chlorides. It is, however, quite possible that its composition was more or less influenced locally by volcanic emanations, the evidence for which has recently been collected by Lincoln, (1907, p. 258, of Economic Geology).

The present mine waters are often as strong as present ocean water and stronger, and to explain their present concentration, and incidentally throw light on the concentration of the ores also, is our remaining task.

THE PRODUCTION OF NATIVE COPPER IN CHLORIDE SOLUTIONS.

It will be convenient, to save interrupting our discussion of the effects of leaching in modifying the original connate waters, to give here a brief account of some experiments by Dr. G. Fernekes then of the Michigan College of Mines, now of Pittsburg, in which he succeeded in forming native copper from chloride solutions such as the mine waters.

DR. FERNEKES' EXPERIMENTS IN ARTIFICIAL PRODUCITON OF COPPER.

These he has already described.* We may sum up his work, modeled after Stokes,** in a diagram as follows:

		WATER.
Cold water jacket around upper end.	18-inch tube of glass filled with water and sealed.	Solution of ferrous chloride $FeCl_2$ nearly neutral with sodium carbonate. Few crystals potassium bromide K Br. .2 gram Cuprous chloride $Cu_2\ Cl_2$.
Lower end in sand both at 200° C. to 280° C.		5 grams calcium hydrate CaO_2H_2 or " carbonate $CaCO_2$ or " silicate $Ca\ SiO_3$ or prehnite H_2O, $2CaO$, $2Al_2O$, $3SiO_2$. or datolite " " , B_2O_3, $2SiO_2$. in fine powder.

*Economic Geology, 1907, pp. 580 ff (II. No. 6, Sept. and Oct.)

**Economic Geology, 1906, pp. 644 (I, No. 7, July-August).

Dr. Fernekes then describes the following reactions as taking place.

1. $2\ FeCl_2 + 2\ CuCl_2 = Cu_2Cl_2 + 2\ FeCl_3$.
2. $2\ FeCl_2 + Cu_2Cl_2 = 2\ Cu + 2\ FeCl_3$.
3. $FeCl_3 + 2\ H_2O = Fe(OH)_2Cl + 2HCl$.

—and 10 below.

Now in Stokes', experiments in unequally heated solutions like this, sulphate instead of chlorides were used,* so that his equations were:

hotter end. | 4. $2\ CuSO_4 + 2\ FeSO_4 \rightleftharpoons Cu_3\ SO_4 + Fe_2\ (SO_4)_3$ | cooler end.

hotter end. | 5. $Cu_2\ SO_4 \rightleftharpoons Cu\ SO_4 + Cu$ | cooler end.

hotter end. | 6. $Fe_2\ O_3 + 3\ H_2\ SO_4 \rightleftharpoons 3\ H_2\ O + Fe_2\ (SO_4)_3$ | cooler end.

There is another experiment by Stokes** of interest to to-wit:

hotter end. | 7. $AuCl_3 + 3\ \overset{\text{ous}}{Cu\ Cl} \rightleftharpoons Au + 3\ \overset{\text{ic}}{CuCl_2}$ | cooler end.

We may apply this to the silver which we find most in the upper levels on and later than the copper. While silver chloride is quite insoluble it is soluble enough in these strong chloride solutions for the following reaction slowly to go on.

hotter end. | 8. $AgCl + CuCl \rightleftharpoons Ag + CuCl_2$ | cooler end.
9. " $+ FeCl_2 \rightleftharpoons$ " $+ FeCl_3$

Now as Dr. Fernekes remarked the copper shown in equation 2 did not appear as such, because it would be attacked and redissolved by the HCl set free by reaction 3, until a neutralizing agent was added (eq. 10).

Possibly in nature electric currents or very great length of tube and slow action might help, but there was one obvious reaction, one suggested, too, by the geological conditions[x] we were trying to imitate, to-wit, the neutralization of the acid (HCl). This was successful, first with calcium hydroxide CaO_2H_2, then $CaCO_3$, then calcium silicate in the form of powdered wollastonite. Copper was deposited within 10 to 15 minutes heating at 200°C. Complete precipitation took a longer time.

*Economic Geology, 1906, p. 644 (Vol. 1, No. 7S July-August.)

**Loc. Cit., p. 650.

x In nature the copper is persistently associated with calcium carbonates or silicates and often deposited on corroded surfaces of calcite.

We may add then to the three reactions 1-3 above one more.

10. $2\ H\ Cl + Ca \begin{cases} O_2H_2 \\ C\ O_3 \\ SiO_3 \end{cases} \rightleftharpoons Ca\ Cl_2 + 2 \begin{cases} H_2O. \\ H_2CO_3. \\ H_2O + SiO_2 \end{cases}$

The above reaction worked freely and rapidly; the copper came down in a fluffy mass.

To obtain it crystallized it seemed natural to use a less soluble neutralizing agent. The following minerals

occurred to me from the geological conditions as especially worth trying:

Labradorite Ab_1 An_1 to Ab_2 An_3

(NA_2O, Al_2O_3, 6 SiO_2 + 1 to 1.5 ($2Ca_2$), $2Al_2O_3$, $4SiO_2$)

Prehnite, H_2O, Al_2O_3, SiO_2 + 2 (CaO, AlO_3, SiO_2)

Laumontite 4 H_2O (Ca, Al_2O_3, 4 SiO_2)

Datolite H_2O, 2 CaO, B_2O_3, $2SiO_2$

Pectolite (Ca, Na_2H_2) SiO_3

Analcite 2 H_2O (Na_2, Ca)O, Al_2O_3, 4 SiO_2

Labradorite and laumontite gave no results. As a matter of fact neither are intimately associated with copper, the labradorite occurring in the fresh unaltered trap, and the laumontite through a secondary zeolite being notoriously a bad sign for copper, though at times pseudomorphs of copper after laumontite do occur.

On the other hand prehnite and datolite both gave positive results, and both frequently occur in nature colored pink with finely divided copper. Capt. J. Vivian has a wonderful collection of flesh colored datolites.

The tubes were heated intermittently, for 10 hours a day, the heat removed in the evening, and again applied the next morning.

After heating the solution and prehnite in this manner five days an explosion took place at about 250°C. A portion of the side of the tube about 5 cm from the bottom was blown off, leaving a cake of mineral underneath which could be seen under a hand lens to be interspersed with shiny particles of crystalline copper. That they were such was proved by tests.

The prehnite had become much darkened, and the particles of the mineral were *stained red with iron oxide*.

Datolite was acted on in a similar manner for six days at the end of which time minute crystals of copper could be detected throughout the mass of the mineral.

It might also be profitable to consider the reactions from the point of view of electro chemistry and ionic dissociation. There is this extra justification for this that experiments by J. M. Longyear and W. W. Stockly have shown measurable differences of electric potential near lodes, and abnormal magnetic variations are not uncommon. In fact from the almost northerly direction of the main chute of the Calumet & Hecla deposit and the greatest sensitiveness of the copper to electricity it has been suggested that certain electric currents were the determining factors in its deposition.

Schematically Ave may express the reactions 1 to 3 and 10 in terms of beginning and final products.

11. $2FeCl_3 + 2CuCl + 3CaSiO_3 = 2Cu + Fe_2O_3 + 3SiO_2 + 3CaCl_2$.

That this reaction, which is only a slight modification of that suggested 30 years ago by Pumpelly is really *schematically* the one by which native copper has been formed seems to me almost conclusively proved by the facts:

1. Dr. Fernekes has shown that it actually takes place.

2. The end products are actually the common products of the veins, *and the most abundant constituent of the mine water.*

REACTIONS OF ROCK AND WATER IN THE KEWEENAWAN ORIGIN OF COPPER.

We have then only slight modifications to make to adapt the results of Fernekes to the conditions under which copper occurs in the Keweenawan rocks. This is a great series of ancient lavas separated either by originally porous seoriaceous lava tops or agglomerates or ordinary sediments, the copper occurring in the porous parts, whether amygdaloid, conglomerate or sandstones. It is not certain that these conglomerates were all laid down beneath water. The agglomerates especially may have been laid down beneath the air. But the fact that a conglomerate like the Calumet & Hecla for instance has so little material from the underlying dark trap and so much from felsites which tend to rise above the ocean more than the fluid and less viscous lavas containing more iron would suggest that it was truly marine. Moreover the persistence of these conglomerates as definite horizons for miles points the same way. If they were land deposits there may have been salt lakes in the desert. The fact that the conglomerates are relatively fresher than the amygdaloids may be due simply to the fact that their minerals are on the whole less hydrated, and so have absorbed less water. It seems safe then to assume that some of the conglomerates and some of the amygdaloids were filled with sea water—and it also seems safe to assume that it contained some chlorides, even though not so great a ratio as at present. When the next lava flow would come over it it would be heated. But the amount of heat given off at once would be but a small proportion of that which existed in the lava flow, as lava is a poor conductor and quickly chills at the surface while the interior remains hot. In fact one can walk on the surface while yet the interior is so hot that a walking stick thrust into a crack bursts into flames and the cracks produced by contraction and cooling show a dull red heat.

As I have elsewhere pointed out* in case of lava flows 240 feet thick there is some reason to think that it may be 20 or 30 years before consolidation at the center was finished and that it was nearly 10 times as long before the temperature at the center would drop to say 100°C.**

In the meantime no doubt many other lava flows might have come. Much of the heat of the lava would probably escape upward, and since the specific heat and heat of evaporation of water is very great, and the diffusivity of lava small the water in the underlying beds might or might not be turned to steam.

*Annual for 1903, p. 248.

**Annual for 1903, p. 248.

We had then at the close of the Lower Keweenawan period a series of many thousand feet of lavas containing here and there streaks of hot water or vapor. These hot waters attacked the lavas and produced the chlorite and zeolites so characteristic of the melaphyres. At first the products of these reactions probably take up more room that the original minerals. Olivine changing to serpentine and magnetite Van Hise* cites as giving an expansion of 30 per cent. And for a change of augite to chlorite, epidote, quartz, and hematite** an expansion of 8.58 per cent is estimates, and most of the changes of the albite and anorthite molecules to minerals of the zeolite group are also changes which produce expansion, though few of them are directly applicable to our problems.

The net result of this first work must also have been that much of the water was absorbed. The deepest and freshest specimens of the traps are hydrated, chloritic, so that what remained was relatively stronger in chlorides. There may also have been some exchange of bases, but the older and deeper seated secondary minerals produced by alteration do not contain sodium and in sections of trap from diamond drill cores the feldspar is often quite fresh. The olivine and then the augite alter first. What sodium was absorbed, if any, most likely came from the glass. The chlorine does not come in any of the secondary minerals formed and so must have accumulated and was[x] either originally present in the water or in the silico-chloride glasses. But calcium carbonate which is insoluble in hot water, is found everywhere and to all depths and chlorite and epidote are equally widespread among secondary minerals. Thus since calcium occurs also in the glasses it would not be safe to venture any guess as to the original amount of lime in the connate water from that in the present mine waters.

*Treatise on Metamorphism, p. 388,

**loc. cit. p. 378.

x Apatite is not recognized in the lavas generally.

With regard to the iron and magnesia dissolved at this stage, the iron may have partly been precipitated and may have partly remained in solution, mainly as ferrous chloride, since it is ferrous iron that mainly occurs in olivine and augite. But the magnesium according to T. S. Hunt's reactions* would in the presence of calcium carbonate and silicate be thoroughly reprecipitated as hydrous magnesium and ferrous, more or less aluminous silicate. This is so characteristic of melaphyres that green earth (chlorite, diabantite, delessite) has been taken to be an essential constituent. The mine waters, though nearly free from magnesium, may once have contained more in proportion. The ratio of calcium to chlorine in the waters originally may have been more or less than that now, since calcium has been taken up from the augite and thrown down again in epidote, etc., but in the waters of the deep mines the ratio of sodium to chlorine was probably about the same since there are no secondary minerals in which sodium or chlorine have been precipitated and little or no sign of any change by which chlorine could be leached. The present ratio must be greater, if anything. So far as hydration has gone on the concentration is likely to have increased unless affected by circulation of fresh water taken in at the outcrop. Cooling after the first stage of immediate reactions must still have gone on and the water enclosed must have shrunk, and if the rocks had already been so much cemented, that as they cooled they no longer settled so as to squeeze the water out, then—since for water the cubicle expansion** and contraction by change of temperature is greater than for rocks***—there would have been a tendency to contract within the rock and draw in fresh water at the outcrop.

*Chemical and geological essays, pp. 138, 122.

In hot solution $CaCO_3+MgCl_2=CaCl_2+MgCO_3$
$CaSiO_3+MgCl_3=CaCl_3+Mg\ SiO_3$.

**Chem. Cal. O5, p. 85.

Water.

Between 100° & 200° $Vt = Vo\ (1+.0001082t+.000003\ t^2 \ldots\ldots\ldots)$
75 100 $(1+.000086\ t+.000003\ t^2 \ldots\ldots\ldots)$
50 75 $(1+.000059\ t+.000003\ t^2 \ldots\ldots\ldots)$
28° 50° $(1+.000067t+.0000023\ t^2 \ldots\ldots\ldots)$

For calcium chloride solution Chem. Kal., '05, p. 83
Between 31° & 54°V=V at 29° (1+.000438 (T--29°)+…
Glass .000023t .00003 '05, p. 82.

***Which is natural as the amount of heat given off in lowering a given volume 1 degree in temperature is about twice as much

Thus a drop in temperature of water from 100°C. 212°F to 28°C. 82°F. would mean a shrinking of volume of something like 4 per cent. while the contraction of rock for the same change would probably be less than 0.4 per cent.

If now we assume some porous bed of the Lake Superb basin extending from Keweenaw Point to Isle Royale (say the Allouez conglomerate) to have a length of 60 miles across and the water therein to have contracted equally from both sides as it cooled then the early salt waters might have shrunk (.04 x 30 x 6280) about 6300 feet on each side. This would not be equal of course all along the outcrop. The relatively fresh water sucked in by this shrinkage would penetrate farther where topographic conditions and greater porosity favored it and then spread laterally. If any part of the formation was filled when buried not with water but with gas the shrinkage in cooling would be very much greater.[1]

Thus so far as the amygdaloids were buried with the bubbles filled with gas only, and occasional bubbles occur scattered all through quite massive beds of trap, there are tremendous possibilities of absorption. The regularity of this shrinkage and absorption circulation must have been interfered with in various ways. Let us enumerate some of the factors, each of which will be effective only so far as other factors do not interfere.

[1] from 200 degrees to 100 degrees for instance it would be something like $\frac{100+273}{200+273} = .71$, something like 30 per cent. of its volume. To this might be added its condensation or absorption.

1. It must have been extensive in the most porous beds.

2. But slide faults, seams or slips on pinches or anything that tends to check the continuity of the porous beds might have checked this circulation as illustrated by the following figures 3 and 4:

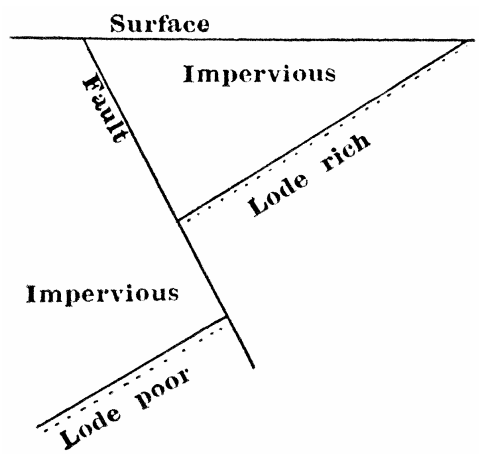


FIGURE 3. Illustrates how a fault may cut off the downward circulation and upper deposition in a bedded lode.

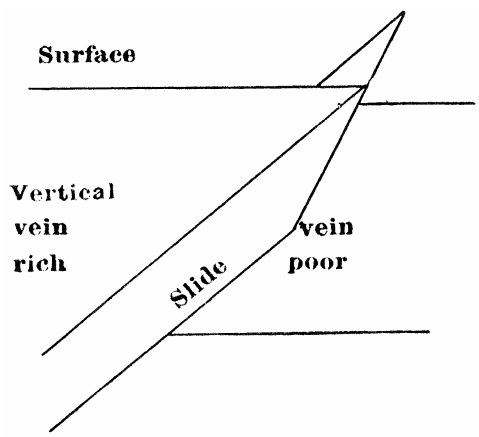


FIGURE 4. Illustrates how a "slide" may cut off the downward circulation in a vertical vein.

3. Topographic conditions such as to produce an upward pressure or circulation will tend to check downward circulation especially in artesian basins or regions that tend to become such. The *circulation may be active for* a limited depth, however.

4. On the other hand beneath higher ground especially if so located as to have water fed in freely at the outcrops there should be an active downward circulation.

There seems to be one factor worthy of special mention. When a bed thickens away from the outcrop, and has but relatively small or thin porous areas at which it reaches the surface the tendency to suction of the upper waters along them will be exceptionally strong if the connections to the surface are kept open.

II. We have then as our second stage the imbibition of the cooler waters from the surface *which may average several thousand feet* and may be more or less than this according to circumstances. This process must have been very slow as we know from hot springs that heat lingers around such enormous masses of volcanic materials for ages.

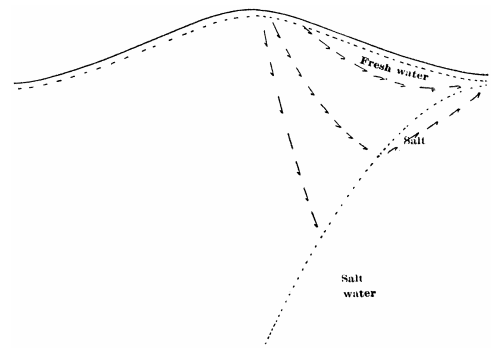


FIGURE 5. Theoretical circulation of water from beneath high ground.

And this brings in a second stage of alteration, an alteration by descending waters, either (a) the original connate chlorine waters migrating nearer the center of the basin, or (b) the same more or less mixed with waters drawn in from the surface. The pressure will increase. The temperature will increase decidedly when they travel in much faster than the formation is cooling and as underground temperatures always increase slightly, will increase anyway somewhat. Moreover we must remember that these upper waters will be pulled in in streaks and sandwiched between quarry moisture of the deeper type in the less porous layers.

Thus along every porous channel on its foot and hanging will be contact zones of the upper water against the lower water, and this is precisely what we really find.

This slow secular sucking of water on a large scale may tike the place of Fernekes' repeated action of the same sort described above.

Now what will be the general tendency of reaction of such waters?

1. We may be sure that as they warm up they will tend to dissolve silica and cause it to migrate with them, but as it comes down into waters strong in calcium chloride it may be precipitated (forming prehnite, epidote, etc.) if there is anything else to take care of the lime.

2. Carbon dioxide from the air, or from the rocks will, as in boiler waters, react with calcium chloride and be precipitated as calcite.

3. Sodium carbonates and probably silicates will be be decomposed, if in contact with calcium and iron chlorides, and sodium chloride left in solution.

4. Sulphates will be precipitated in strong salt solution as barite, selenite, etc.

But it is time to leave the purely theoretical and connect with the actual. Real conditions are so complex that

pure deduction is unsafe, and it is by no means probable that the relations are everywhere the same.

I shall describe elsewhere somewhat fully the decomposition of a Calumet & Hecla boulder. In this it appears that the abstraction of water glass $(KNa)_2O_4$ SiO_3, the oxidation and addition of iron, the deposition of copper and of magnesia aluminum silicate seem to be the essential factors. One may perhaps add the formation of epidote.

I will simply give a couple of analyses of altered boulders from the Calumet & Hecla conglomerate, (3) by Heath, the other (2) by F. B. Wilson, and also (1) an analysis by F. P. Burrall, of the kind of rock from which they appear to have come judging from the remains of their texture and the porphyritic crystals therein, which are relatively unaltered. At any rate we may be reasonably sure that the original rock contained as much or more silica, and less of iron.

Pumpelly in Vol. I, described the alteration even of quartz porphyries in the same way. It is worth noting that the boulders are less silicious than the traps above and below that the alteration is not a mere transfer between adjacent beds.

	1.	2.	3.
Silica	52.83	31.42	36.75
Alumina	16.30	16.83	27.34
Ferric oxide	9.60	15.58	
Ferrous oxide	2.48	12.08	
Magnesia	3.98	3.36	23.24
Lime	2.98	2.84	
Soda	6.54	1.04	
Potash	2.49	1.04	
Water	2.76	14.52	11.07
Manganese	tr.	tr.	
Titanium oxide	n.cl		
Difference	0..04	0.34	1.6
Sum	100.00		

In the Keweenawan *igneous* rocks we may make out the two stages of decomposition as follows:

I. 1. Primary reactions, glass decomposes, chloritic filling to cavities, ferric minerals (olivine, etc.) attacked. Chalcedony, agate, quartz, delessite and serpentine, and epidote formed; laumontite, thomsonite and chlorastrolite in amygdules?, iron bearing red calcite, orthoclase? and ankerite?. Some of these reactions may not be all primary.

II. Secondary reactions.

2. Prehnite, other kinds of chlorite, also epidote and quartz formed lime bearing minerals dominant.

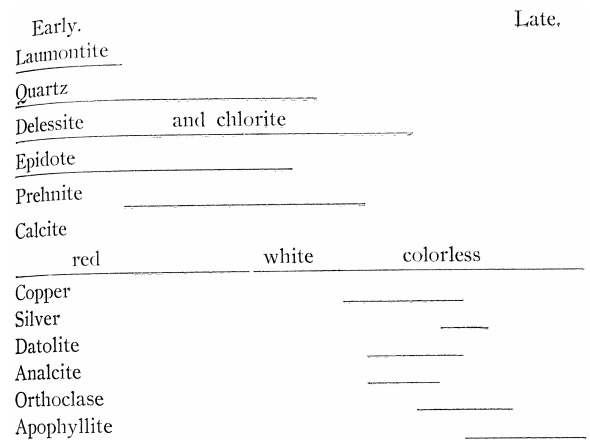
3. Iceland spar (calcite) and copper formed.

4. Datolite, orthoclase, natrolite, apophyllite, analcite, and the sodium bearing minerals, flucan.

In the four groups above it must not be understood that the order is absolute but that on the whole the copper is most intimately associated with calcite, but at times occur sprinkled through the prehnite and epidote as the contemporary.

It is, however, true that the minerals of the last group are rarely if ever formed before those of the earlier ones. It is understood of course that primary orthoclase of the original felsites may be and often is replaced by the others, and calcite occurs of all ages. An older calcite is often bright red.

These studies are adapted from Pumpelly's original studies of the order of crystallization, Volume I, part 2, p. 32, of these reports, with additions,



Coming back to our idea of the sucking in of surface waters and picking out from the numerous ions existing in the waters-only those most necessary to understand the reactions* we have:

1. $Na_2CO_3 + CaCl_2 = 2\ NaCl + CaCO_3$
$CO_2 + O + CaCl_2 = 2\ Cl + CaCO_3$

*But not forgetting that the presence of other ions may be necessary in order that these reactions may go on.

Good sized salt crystals have been found in the upper levels of the Calumet & Hecla and the middle belt of waters rich in sodium chloride is thus easily accounted for. Bi-carbonates of lime and magnesia might go farther down without being precipitated through in stronger solutions of $CaCl_2$ they are less and less soluble.

2. $NaCl + AlCl_3 + 2SiO_2 + Aq = Na\ Al\ Si_2O_8 + Aq + 4Cl$

This is merely a theoretical reaction that may go on momentarily in the zones where the analcite, orthoclase and apophyllite are formed. By slight changes the same type of reaction may be made to apply to orthoclase and datolite. If is noteworthy that this leaves Cl in the downward working water.

In the presence of salt (sodium chloride) iron tends strongly to rust, and salt and red rocks are everywhere associated. So with a reaction that produces sodium chloride it is natural to add one that produces ferric oxide if there is any iron chloride in the solution.

3. $3\ H_2O + 2FeCl_3 = Fe_2O_3 + 3HCl$

Put the HCl of this reaction in the place of NaCl of 2 and combine 2 and 3 and we have a reaction that will produce the red flucan clays. It is noteworthy that the

secondary orthoclase is generally reddish and brick red orthoclase and analcites are not unknown.

Capt. J. Pollard has a pebble from the Calumet & Hecla dissolved out so as to leave a vug lined with beautifully crystallized orthoclase and hematite.

This reaction very probably does not take place except in the presence of other ions, but it went on as Fernekes' test with prehnite showed to some extent under those conditions, as red oxides; were formed.

But reactions 1, 2 or 3, or in fact *any reactions* in which chlorine is crowded out from union with chlorides *must* give us chlorine ions to migrate. Then this chlorine in breaking up any silicates with the formation of silica will release oxygen, and may form ferrous chloride which in the presence of an excess of oxygen may make ferric iron, or if there is no such excess, may be oxidized as in Fernekes' test, while the copper is thrown down in metallic shape.

We also *know* that the substances mentioned in the equations exist in some of the upper waters, and that the minerals marked as precipitated are in fact precipitated in the upper levels and among the late constituents.

These reactions 1 to 3 also tend to produce an excess of chlorine* and in the presence of this chlorine copper cannot be deposited, nay rather copper already deposited would be dissolved, and moved on down to where the chlorine could be neutralized as in Fernekes' experiments. But silver would be much less readily dissolved than copper and so would occur higher up, as indeed it does, and when moved on would lag behind the copper and be deposited on it. This is also true. The Calumet & Hecla was distinctly richer in silver at the south upper end, and speaking generally the upper levels are said to be rich in silver. Thus in the process of down migration from the surface, waters which have undergone reactions 1, 2 and 3, may give us:

4. $Cu + Cl_2 = CuCl_2$

and with more difficulty if already well saturated with $CuCl_2$, and Na Cl.

5. $Ag + Cl_2 = Ag\ Cl_2$.

At the same time the chlorine set free in equations, 2 and 3 will attack calcium carbonate if originally present and if by any displacement or change in circulation the calcium carbonate formed by equation (1) should get back into the way.

*I do not mean to say that there is an excess of chlorine in the waters. There is not. Nor does the chlorine exist free except in ionic electrolytic dissociation so that it can migrate.

The reactions might be written in two installments.

6. $2\ CaCO_3 + 4Cl = Ca\ O_2\ Cl_2 + CO_2 + CaCl_2$.

7. $CaCO_3 + CO_2 + H_2O = (H_2\ CO_3 + CaCO_2)$.

8. $3\ CaO_2\ Cl_2 + 4\ Fe\ Cl_2 = 2\ Fe2O_3 + 4\ C1_2 + 3\ CaCl_2$.

Now since it would be strange if there were not more or less carbon dioxide in the original lavas and buried waters and more or less calcite also in the sediments, we may expect to find, as we do, native copper and calcite which may have been formed earlier and dissolved and driven ahead of the chlorine.

While therefore generally speaking the copper is earlier than the alkaline zeolites. I have seen one specimen, said to come from the Osceola amygdaloid in the Centennial mine, which seemed to have copper moulded around rectangular needles of natrolite.

Such reactions are entirely explicable on the hypothesis of migration and removal downwards.

They also give a chance for oxygenation *whenever chlorides are formed from silicates*.

These reactions 6 to 8 are only ideal ones to show how the chlorine may he pushed on as the iron oxidizes.

If we attack the bi-carbonate product of reaction 7 we have:

9. $(H_2CO_3\ CaCO_3) + 3\ FeCl_2 + 2\ CuCl_2O_2 = FeCO_3 + CaCO_3 + Fe_2O_3 + 2\ CaCl_2 + H_2O + 6\ Cl$

But in the presence of a large amount of chlorides and very little CO_2 according to the principle of mass action the CO_2 is more likely to go into solution.

10. $(H_2CO_3, CaCO_3) = CaCO_3 + CO_2 + H_2O$.

Such reactions may suggest the method of formation of the red calcite and red ankerite, which are as we know relatively early products of alteration, and also show how acid ions are continually shoved ahead to find new affinities.

The copper is readily dissolved by the chlorine and in any such reaction will be dissolved to be precipitated, as in Fornekes' experiments, in presence of a stronger neutralizing agent.

In these experiments, sodium carbonates, calcium carbonate $CaCO_3$ and silicate $CaSi\ O_3$, wollastonite, prehnite $H_2Ca_2\ Al_2\ Si_3O_{12}$ and datolite H Ca B SiO_5 were used. Judging from what we see in nature, and the minerals copper replaces we may be sure that chlorite and epidote very often, even laumontite and quartz sometimes, should be added to the list, and in fact *almost any rock*, for great masses of trap and solid pebbles of conglomerate may be changed to copper. The reactions are ones of equilibrium with a large number of ions. Take the simplest:

11. $CaCO_3 + FeCl_3 + 2\ CuCl + H_2O$. ?

The products are:

in solution + ions Ca (comes in), Fe, Cu (goes out), H; -- ions CO_3, Cl?OH, FeO_3. Besides this there are at various temperatures and concentrations, various amounts of undissociated salts, and possibilities of ions like OCl and FeO_3. Besides this there are at various temperatures and concentrations, various amounts of undissociated salts and possibilities of ions like OCl and

Fe O_3. The general effect of dissolving $CaCO_3$ it to add a strong + ion and a weak negative ion. One way to keep balance in the solution is to eliminate some other + ions, which may be and is accomplished by precipitating the copper, and also by converting the + ions Fe into negative FeO_3. If it were not for the possibility of using the O of the—ions Co_3 and CH in converting the + ions Fe into a – ion FeO_3 which is the kind of change needed to restore equilibrium, the copper ion might take CO_3 or the O of the OH with it. This is what presumably happened in the Allouez conglomerate at the Allouez mine where cores of native copper are surrounded with oxides and carbonates of copper and chrysocolla for quite a depth. This is exceptional, however. The zone of carbonates is extremely shallow generally and native copper often occurs "at the grass roots".

The same principles apply if for CO_3 we write SiO_3*, and so with the attack on prehnite.

12. $H_2Ca_2\ Si_3O_{12} + CaCl_2 + FeCl_2 + CuCl + H_2$ will result in a solution of
+ ions Ca, Fe Cu H, (AlO_3?) (Si?)
-- ions SiO_3 (FeO_3?) (AlO_3?) Cl OH

*Though there is the possibilty of the formation of compounds like $SiCl_4$ and $SiFe_4$ which account for the solution of pure quartz, though, rarely, with difficulty, and as a last resort. There must he a relatively large amount of cuprous chloride and little silica in solution to order to favor this reaction.

As the Ca comes in the Cu drops out. It is not certain just why the laumontite does not precipitate the copper so readily as the prehnite, though the fact is clear both naturally and artificially. That it has less of the stronger bases + ions like Ca and H and more the – ions (even though weakly) like SiO_3 and AlO_3 is significant. The formulae are:

Prehnite $H_2Ca_2\ Al_2\ Si_3\ O_{12}$
Laumontite $Ca\ Al_2\ Si_4\ O_{12}$ + 4 Aq

The solutions obtained in dissolving laumontite would be much richer in alumina and silica and thus in oxygen in proportion to lime. This might tend to favor the direct oxidation of the ion. Red colors are associated with laumontite.

With the very common feldspar (Ab_2An_3) or labradorite the change to prehnite and epidote is very simply written.

$Ab_2An_3 = 2(Na_2O\ Al_2O_3\ Si_6O_{14}) + 3(Ca_2Al_4\ Si_4O_{16}=2Na_2O\ 6CaO\ 8Al_2O_3\ 24SiO_2$

add $8H_2O$ + 10Ca and subtract $2Na_2$ and we have prehnite: $8H_2O$ 16 CaO 8 Al_2O_3 24 SiO_2. So that this would mean simply the replacement of Ca by Na in the mine water, and its concentration.

The formation of the *epidote* is of considerable importance. Its formula is:

Epidote $H\ Ca_2\ (Al\ Fe_{1\ 6\ to\ 2\text{-}3})\ Si_3O_{12}$ 2

Prehnite $H_2Ca_2\ Al_2\ Si_3O_{12}$

As compared with prehnite the difference is that there is less hydrogen, considerable ferric iron (about 10%). There is no reason why it might not act as a precipitant of the copper just as we know prehnite does, but less readily as there arc fewer + ions.

There are two kinds of epidote, -- a pale colored zoistic kind which is formed in the decomposition of the feldspar and a deeper colored epidote* which is the commoner variety and no doubt is richer in iron. The epidote is very commonly associated with chlorite in sharp crystals. The chlorite takes in magnesia and ferrous iron, but not willingly or to any great extent lime and ferric iron. Therefore in the hydrous decomposition of the augite, the lime, alumina and ferric iron of the same are precipitated in epidote as the solution gets over loaded with lime. This early epidote is formed before the copper and is very wide spread where there is no copper, and is almost as wide spread if not quite as abundant as the chlorite.

*Thallite or pistazite, yellow in thin section, deep yellow green. Volume VI, Part 1, p. 166.

Epidote also, however, occurs replacing the whole mass of the rock. In this case the feldspar and glass of the amygdaloid are also decomposed. It we compare the formula of epidote with that of feldspar we see at once that there will be silica left over* in its formation. And if we take the trap as being roughly** CaO, MgO (Na_2O FeO) $(FeAl)_2\ O_3\ 4SiO_2$ and suppose it decomposed into

chlorite = ($2FeSiO_3$), Al_20_3, 3 SiO_2, 3 Mg $(OH)_2$, Fe $(OH)_2$ and epidote = $(AlFe)_2O_3$ 3 SiO_2, CaO, CaOH we see clearly that there must also be as in the Calumet & Hecla pebbles. Silica (quartz) SiO_2 and soda Na_2O to be accounted for. We do as a matter of fact find quartz commonly associated with epidote and chlorite but often later, the sodium silicate being quite soluble, but precipitated by calcium chloride, giving calcium silicate for epidote.

In the lower part of the lava flows, the hanging of the lodes, there is an accumulation of the lime and iron, while at the top, which is the foot of the amygdaloid lodes there is more sodium (feldspar). Nevertheless generally speaking the hanging is chloritic, the foot and the amygdaloid itself more epidotic.

* $HCa_2\ (Al\ Fe_{13})2\ Si_3O_{12}$ epidote
$Ca_2\ (AI_4\ Si_4O_{16}$
$Na_2\ Al_2\ Si_6O_{16}$

**Proc. L. S. M. I., XII, p. 85.

The lime and silica are always abundantly present and the more important conditioning factors seem to be the presence of alumina, and the accumulation of oxygen to oxidize the iron.

This might very well go hand in hand with the formation of copper, and indeed it does, if only the physical conditions were such (as in Fernekes' tubes) that the oxygen derived from the decomposition of silicates by chlorides was preferably employed in building epidote. On the whole, however, epidote is vastly more

widespread than copper, that is in the attack of silicates the oxygen was in most cases provided for change from the ferrous iron of traps and chlorites to the ferric iron of the red amygdaloids and epidote without reducing the copper.

Of especial importance is the role of the chlorite family for they are so widespread and often replaced by copper. They have had a great many formulae assigned* but the essential thing to remember is that they are a hydrous alumo magnesian silicate with the magnesia always largely replaced by ferrous ferrous.

The chlorite naturally forms first in the hydration of ferrous minerals like olivine and augite. But that is only the beginning of the story. Chlorite is attacked by chlorine and H Cl, and as soon as corrosive chloride solutions reach a delessite, that bears ferrous iron, they will readily attack it. It is not uncommon to find amygdules that look like solid copper but are a fraud. They were coated with delessite and then this has been attacked and replaced by a thin film of copper that coats around the outside of the amygdule as though it were the first formed.

*Besides the chlorites proper, mainly a combination of a serpentine molecule $H_4\ Mg_3\ Si_2O_9$ with $H_4Mg_2\ Al_2\ SiO_9$ we have delessite $H_4\ (MgFe)_2\ Al_2\ Si_2O_{11}$ and diabantite $(H_2O)_{57}\ (MgO)_{53}\ (FeO)_{38}\ (Al_2O_3)_{11}\ (SiO_2)_{51}$. A common type of analysis would be SiO_2 30, Al_2O_3 13, FeO 25, MgO 20, H_2O 10.

So the early chlorite is very apt to be attacked by the migrating mine waters. But the mineral brought into solution cannot remain in solution. Hunt has remarked that magnesium chloride is precipitated by calcium silicate and carbonate quite completely, and there is very little magnesium chloride in the mine water—barely a trace. It seems, therefore, that the magnesium chloride is thrown out again as chlorite as fast as it is brought into solution, but with this difference, that if there is copper chloride present a proportionate amount of ferrous iron remains permanently in the form of ferric iron, either as, hematite or epidote, while the copper takes the place of that much of the chlorite.

This may be written (remembering that all the magnesian part of the chlorite and most of ferrous remains chlorite), for the fraction of the chlorite that reduces the copper, and the fraction of the epidote which has ferric iron.

$$3\ H_4Fe_8\ Al_2SiO_{11} + CaCl_2 + 5\ CaCl_2 = H_2\ Ca_4\ Fe_6\ Si_6\ O_{26} + 6\ AlCl_3 + 5\ Cu + 5\ H_2O.$$

The aluminum chloride shown in this transformation from chlorite to epidote has probably been used in making more chlorite out of relatively not aluminous minerals like augite and olivine.

The latter seems to be the reaction at lower levels, and may be the source of much of the chlorite on veins, joints and fissures.

We have now it seems to me reactions enough to account in principle for all the phenomena of the copper lodes, without supposing anything unlikely in the course of circulation, the elements previously dissolved, the character of the country rocks or the temperatures, while there is yet very much to be learned with regard to the relative solubility of the ions concerned.

Pumpelly's theories seem to be altogether confirmed except that chlorine rather than sulphuric anhydride was the acid radical.

It is perfectly possible to conceive a formation of copper with no surface waters concerned.

Take a glass with an ophite composition in the presence of water, say

$$CaO,\ MgO,\ (aNa_2O\ bFeO\ cCuO)\ (dAl_2O_3\ eFe_2O_3)\ 4\ SiO_2$$

$$a + b + c = 1$$

$$d + e = 1$$

add enough water $\times\left(=\frac{7}{6}+\frac{8}{6}\ d\right)\ H_2O =$

We have:

$$d(H_4Mg\ (Al_2O_3)\ SiO_4)\quad \text{(chlorite molecule).}$$

$$\frac{1\ (1-d}{3}\quad (H_4\ Mg_3\quad Si_2O_9)\quad \text{(serpentine molecule).}$$

$$\frac{1}{2}(H_2\ Ca_2\ (2e + b\ \ Fe_2O_3)\ \ Si_3O_{12})\quad \text{(epidote).}$$

$$+\ a\ (Na_2O,\ \ 4\ SiO_2)\quad \text{(water glass in solution.)}$$

$$+\ ?\ \ (d\ \ 2/3\ \ 2d/3\ \ 3/2\ \ 4a\ )\ \ SiO_2\quad \text{(quartz).}$$

$$+\qquad c\ Cu\qquad \text{copper.}$$

if c = ½b and if not, we can simply leave a certain amount of the iron in the chlorite molecule.

The accumulation of sodium silicate in solution as in the change of the Calumet & Hecla pebbles is noteworthy. This will in turn react with calcium or ferrous chlorides, leaving sodium chloride in solution. But to have valuable accumulation of copper there must be not merely the decomposition of the rock and the concentration of the copper near by but a considerable migration, since the rocks on the average run only something like 0.02% of copper. Unless, therefore, there was a migration of the water it could only take a little from the rocks or add a little to them until equilibrium was established.

But it is probably true that in nature the chlorine waters act not merely locally but on a large scale in their slow migration tending to sort and collect the different ingredients, the arrangement being similar laterally and vertically, but differing somewhat according to the temperature and pressure in exact composition. For instance epidote might be formed in depth where in the presence of a water of corresponding concentration near the surface the oxidation of the iron oxide would lead directly to hematite and red clays. Nearer the surface too there might be more CO_2 and the lime go into carbonates.

Thus the surface lateral alteration from the main channel of porosity and the downward succession are *not* exactly the same and the zones of formation of the minerals do not run exactly parallel everywhere. Cross fissures, sliding and slipping, the varying chemical character of the different flows, the varying amount of water originally in the beds,—all these are factors of which account may be taken in explaining the general trend of events, which may be summarized in the following diagram.

The main purpose of this rather long discussion is however to show that in the secondary changes of the mine waters and in all the reactions leading to the deposition of copper there is an accumulation of *sodium* in the mine waters, the same accumulation which we find actually has taken place in the upper part of the lower waters.

After the copper is formed the sodium accumulates to such an extent that sodium minerals are precipitated.

FOR CONVENIENCE THE DIP IS TAKEN AS VERTICAL.

Generally feldspathic footwall.	Surface previous lode	Generally augitic hanging wall
Ferric zone. Surface decomposed zonefull of fractures and of water coming from the surface only a few feet deep. Red colors—amygdaloids, hematite formed. Soda zeolites may be formed.	Water largely circulating fresh Na : Cl more than .65 chlorine less than 200. Carbon dioxide from surface form carbonate. Chlorine increases by diffusion, but sodium both by solution and diffusion of feldspars.	Much like the foot but more chlorite and augite less epidote and feldspar,
Ferrous zone. Copper is formed or accumulated in a zone laterally and downward where the tendency of the copper to be attacked is neutralized by the supply of decomposible silicates, chlorite, prehnite, etc. ferric iron present built into epidote.	Copper dissolved and carried down by the chlorine released in the formation of hematite and soda zeolites.	
Early alterations, water absorbed, feldspar and augite and olivine changing into epidote, chlorite, and serpentine. Glass decomposed, partial amygdaloid filling, original CO_2 gives carbonate,	Water, almost stagnant, gets stronger. The proportion of sodium falls as with depth it approaches the original water down to Na : Cl (.07). Chlorine soon measured in per cents, maximum 17.6 grams per liter. Generally augite Hanging wall.	

IRON COUNTRY WATERS.

The iron country waters are on the whole fresher. I think though they are so much less deep that it is hard to make comparisons. This may be due to more profound downward circulation, but I think also to the fact that the associated rocks are not so subject to hydration as the Keweenawan traps. Yet they are more or less hydrated, the dikes on the Gogebic changed to Kavlin and the Ishpeming diorites or amphibolites to “paint rock” and chlorite schists.

Years ago I suggested* the derivation of iron ores directly from these altered igneous rocks, very much as the iron has accumulated in the Calumet conglomerate pebbles whose analyses were above cited. But while it is generally accepted, for instance by Leith in the current volume of Economic Geology, that the iron ores have been derived from the greenstones, it is altogether likely as he holds that the larger deposits have been formed by the accumulation of these teachings in the water, whence they precipitated, most likely, according to the analogies of present happenings with the assistance of some lowly forms of living matter. But in some cases the iron ore directly leached from the greenstone formation (Kewetin) may have replaced some limestone or chert.

Finally these beds have in some cases been leached again, and still farther enriched by waters circulating from the present surface. How important this enrichment from the present surface is remains to be seen, so far as one can judge it is the dominant factor on the Mesabi, but it may not be so everywhere. If we should find iron ore deposits continuing in unimpaired richness to a depth where the strongly saline character of the mine water was such as to show that no great circulation of fresh water from the surface was now taking place we should have to infer that enrichment relative to the present surface was relatively unimportant, or that that there had been a diffusion of these salt waters into the ore bodies laterally or upward since, they were formed, or that we are entirely mistaken in our idea that chlorine is not readily leached from the rocks.

The pebbles of iron ore found in the Upper Keweenawan conglomerates, and in Huronian conglomerates as well, show that part of the iron ore formation took place at a very early date.

*Annual Report State Geologist of Michigan for 1892, p. 181.

THE HYDRO-ELECTRIC PLANT OF PENN IRON MINING CO., AT VULCAN, MICHIGAN.

BY THOMAS W. ORBISON, APPLETON, WIS., AND FRANK H. ARMSTRONG, VULCAN, MICH.

In 1877, the Republic Iron Co., installed a hydro-pneumatic plant on the Michigamme river, with transmission of about one mile, to furnish power for the operation of the Republic mine. Five years later the water power at the upper Quinnesec Falls on the Menominee river was improved with the installation of an air compressor plant, the transmission being about 3½ miles to the Chapin, Ludington and Hamilton mines at Iron Mountain, Mich.

These plants have been in successful operation all this time. Up to and until about one year ago they were the only water powers in all the Lake Superior district being utilized for mining purposes, notwithstanding the abundant tributary water power on the one hand, and the enormous consumption of coal required for power, on the other.

Though there are many reasons for the slow development of these water powers, the chief one has been the lack of a satisfactory medium of transmission, applicable to the successful operation of mining machinery, and economical in cost. Compressed air, as a medium of transmission meets the first of these requirements and is indispensible in mining operations. The cost, however, is great under favorable conditions, and increases rapidly with the length of the transmission.

The mine operator, therefore, has been watching with great interest the wonderful progress made in the last few years in electrical transmission, and the application of the power to his requirements.

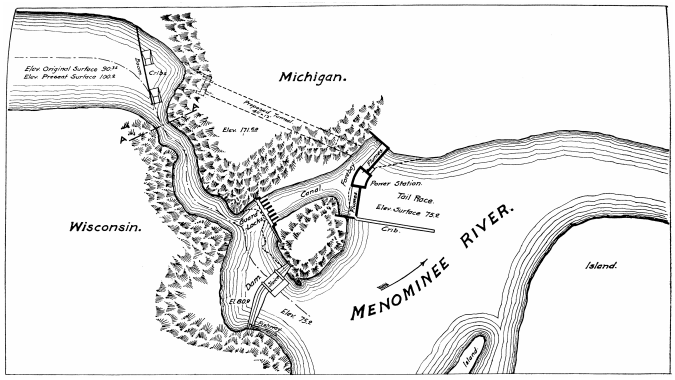


FIG. 1.

FIG. 2

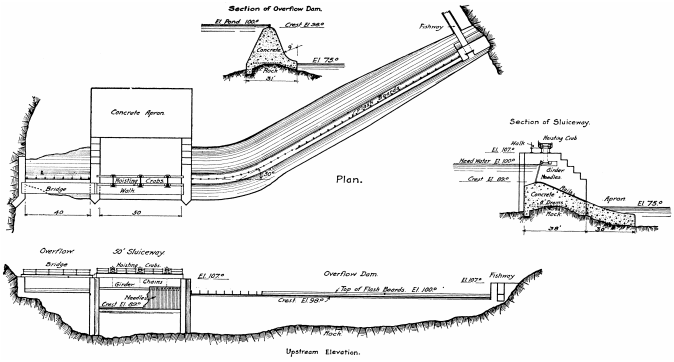


FIG. 3

In the fall of 1904 the Penn Iron Mining Co. Vulcan, Mich., began an investigation of their water power at Sturgeon Falls on the Menominee river, Mich., to ascertain the amount of power available, the possible plans for its development and transmission by means of compressed air or electricity, and the application of the power to the operation of the mines, at Vulcan, about three miles from the falls.

AMOUNT OF POWER.

The Menominee river has a drainage area at Sturgeon Falls of 2929 square miles. The average annual rainfall is 31.15 inches. The run-off, in ordinary low water, is estimated at 1266 second feet. The available head is 25 feet. Therefore, at ordinary stages of water, there is 3600 theoretical horsepower, or 2880 horsepower delivered by the turbines. For a large portion of the year the flow is very much greater, and this fact was taken into consideration when the capacity of the machinery installed was decided upon.

PLANS OF DEVELOPMENT.

Figure 1 shows the river at the falls, and two general plans for the improvement. One is for a dam at AA, with a tunnel through the bluff to the forebay at the power house; the other is for a dam located further down stream on the top of the last pitch in the rapids, with a canal through a depression, leading the water to the forebay. The latter plan was adopted, because the

estimates showed that its cost would be less, even with the longer and higher dam, and the longer dam would provide more spillway for the disposal of flood water, and facilitate the handling of the saw-logs that are floated down the river.

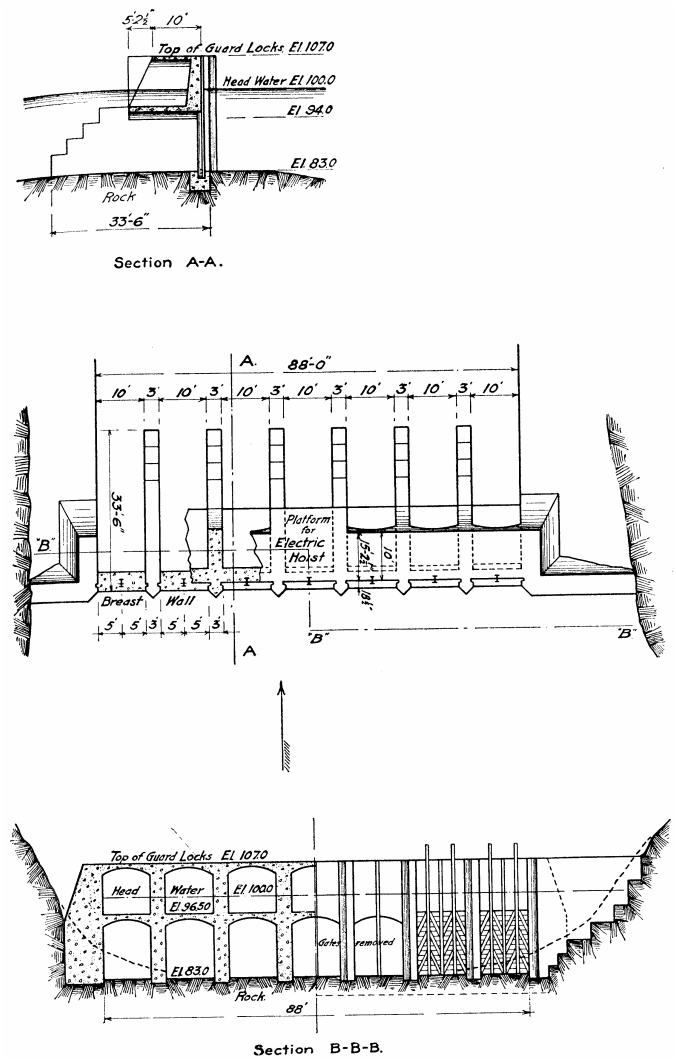


FIG. 4.

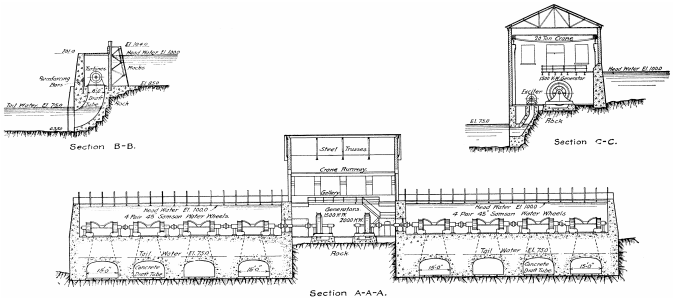


FIG. 5

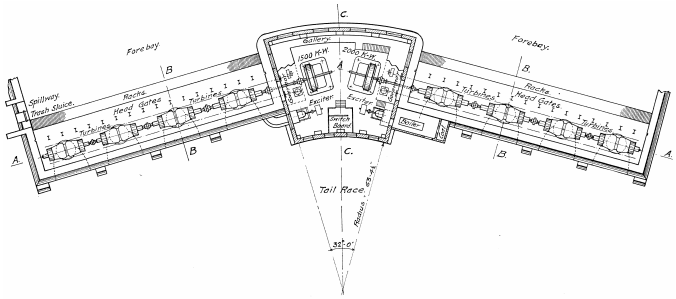


FIG. 5

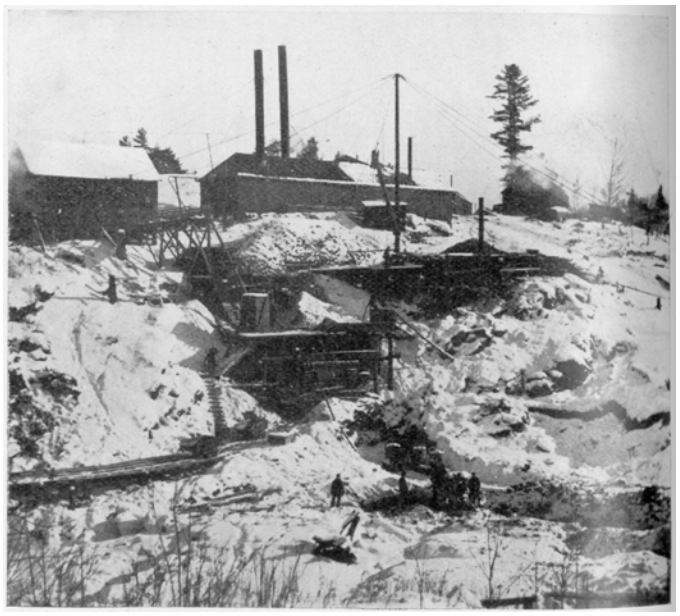


FIG. 6

FIG. 7

THE MEDIUM OF TRANSMISSION.

In discussing whether to transmit by compressed air or electricity, four things were considered: First cost, efficiency, net saving, and reliability.

First Cost: Carefully prepared estimates showed that the installation by compressed air would cost 14 per cent more than the electrical installation, including all changes for the mining machinery.

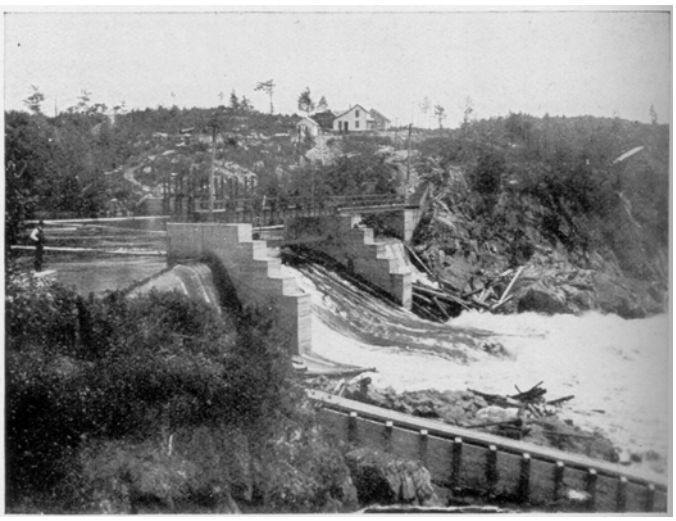


FIG. 8

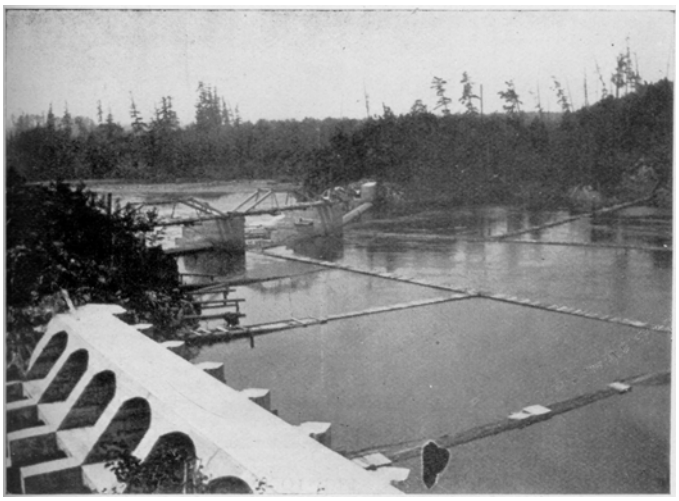


FIG. 9

In a new installation, requiring the purchase of all the machinery at the mine, the percentage in favor of electricity would be very much greater.

Efficiency: The divison of power used at the Vulcan mines, at the time of the investigation was,

For pumping water, 74.4 per cent.
For compressed air, 12.2 per cent.
For hoist, etc., 13.4 per cent.

Three manufacturers of electrically driven turbine pumps made propositions guaranteeing an efficiency of over 60 cent., and in our investigations, we assumed that efficiency.

It was estimated that it would require 54 per cent. more power to do the required work with compressed air, than if electricity was used.

Net Saving: The saving in fuel, labor and maintenance was estimated to be sufficient to warrant the expenditure. The estimate showed that there was very little difference in the saving in the two methods of transmission, except in the efficiency as stated above.

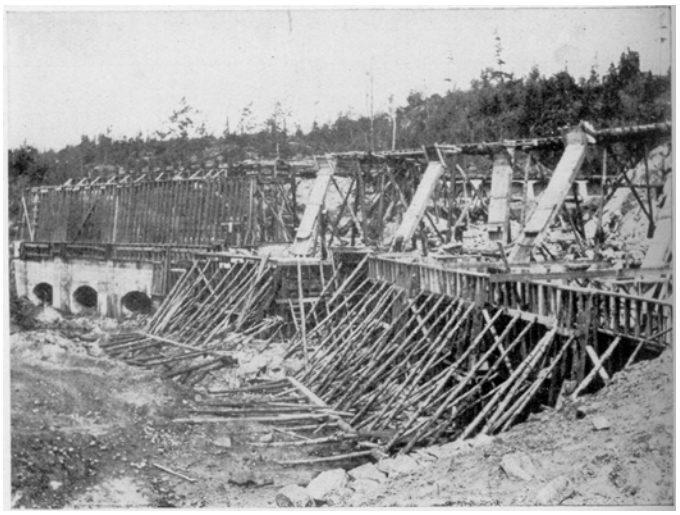


FIG. 10

Reliability: The experience of the last few years has proven that in its manufacture by water power, electricity is even more reliable than compressed air. In the application to the operation of mining machinery, compressed air had been proven to be very reliable, while on the other hand electricity had been almost untried.

At East Vulcan there was 700 gallons of water per minute to be raised 1000 feet. At West Vulcan 1800 gallons per minute to be raised 1200 feet. The inquiry failed to locate an instance where such volumes of water had been taken care of with turbine pumps under like heads, or an installation of sufficient size to establish a precedent. Although confident that the turbine pumps would eventually do the work, the question was, would it pay to undertake the experimental stage that seemed unavoidable.

There was also some apprehension as to the reliability of electricity applied to the operation of hoisting engines.

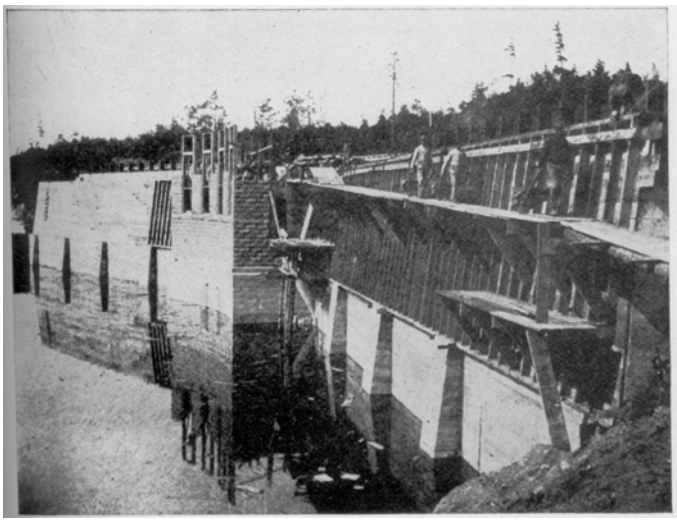


FIG. 11

The facts as above stated, were submitted to the engineers of the company in the East, in July, 1905. At this conference, for the reasons above cited, and for the

reason that at times of low water the mines would require the full power with a most efficient installation and transmission, it was decided unanimously to recommend the improvement of the water power electrically, and that it be applied to all departments of the work, including turbine pumps and geared hoists.

CONSTRUCTION.

In August the work was authorized and operations were commenced at once. Little was done, however, until September, except in the improvement of the road leading to the falls, and the building of camps for the laborers.

Figure 2 is a photograph of the river on September 28, when the first cribs for the coffer-dam were being located. This shows in the immediate foreground the location of the dam, in the upper right-hand corner the concrete mixing plant, and in the center of the picture, the entrance to the depression through which the canal was excavated.

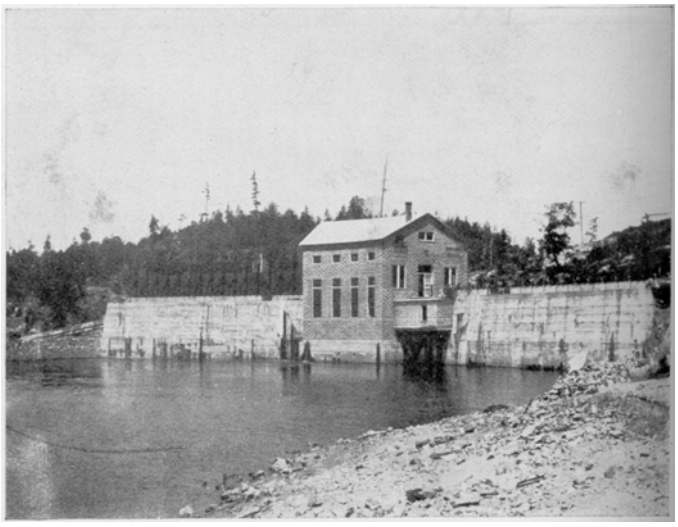


FIG. 12

Figure 1, already referred to, shows in heavy lines the general lay-out of the dam, guard locks, canal, forebay and power house.

Figure 3 is a plan of the dam with elevation and sections; it also shows the log sluice and fishway.

Figure 4 is a detailed plan of the guard lock, by means of which the amount of water let into the forebay is regulated or entirely cut off.

Figure 5 shows the plan and sections of the power, house and flumes, and the location of the machinery installed.

Figure 6 is a picture taken December 4, 1905, showing the derrick by which the rock for the concrete work was raised from the cut for the canal to the crusher; the concrete mixer; the boiler plant; the cement house, and in the foreground the track for the cars, by which the concrete was delivered to the dam.

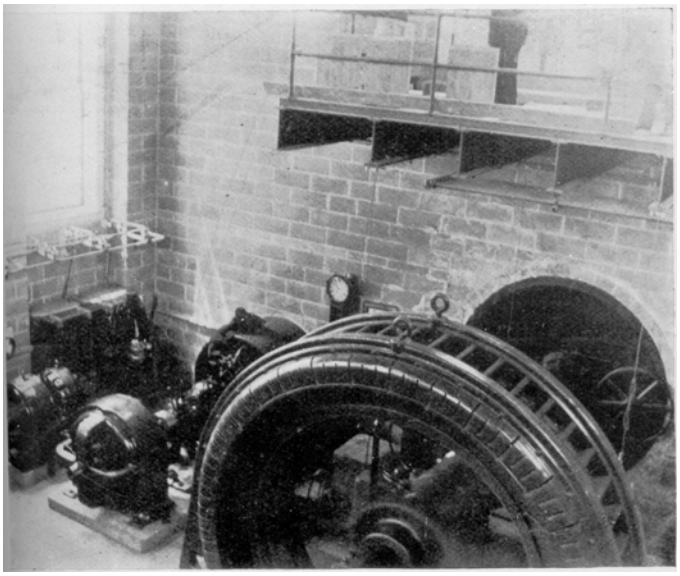


FIG. 13

Figures 7 and 8 are photographs of the dam taken January 6, 1906, and after it was entirely completed.

Figure 9 shows the river above the dam, and a portion of the guard lock at the entrance to the canal.

Figures 10, 11 and 12 are photographs of the power house; the first showing the forms soon after the concrete work was started; the second, when the flumes were nearly completed; and the third after the work was finished. It will be noticed that there is an angle in the power house. The reason for this is that the power house and flumes are founded on solid rock, and this line was adopted to conform with the natural contour, and thereby save a large quantity of excavation.

Figure 13 is an interior taken recently.

The dam was completed in the latter part of January, 1906, the power house late in the fall of the same year, and the machinery for the first unit was installed in the winter of 1906 and 1907. This first unit was started on March 22nd, 1907, and the first power used at the mines April 27th, and the plant has been in continuous operation ever since,

GENERATING MACHINERY.

The generating plant consists of a line of four pairs of inch horizontal turbines in tandem, furnished by The James Leffel & Co., of Springfield, Ohio, direct connected to a 1500 kilowatt, 3-phate, 60 cycle, 6600 volt alternating current generator, at 180 revolutions per minute, furnished by the General Electric Co., also two 30 kilowatt, direct current exciter units, direct connected to two single horizontal, 20-inch turbines. Of the two commercial cycle systems used in this country, 25 and 60, the latter was adopted because the pumps had to be run at about 1200 revolutions per minute.

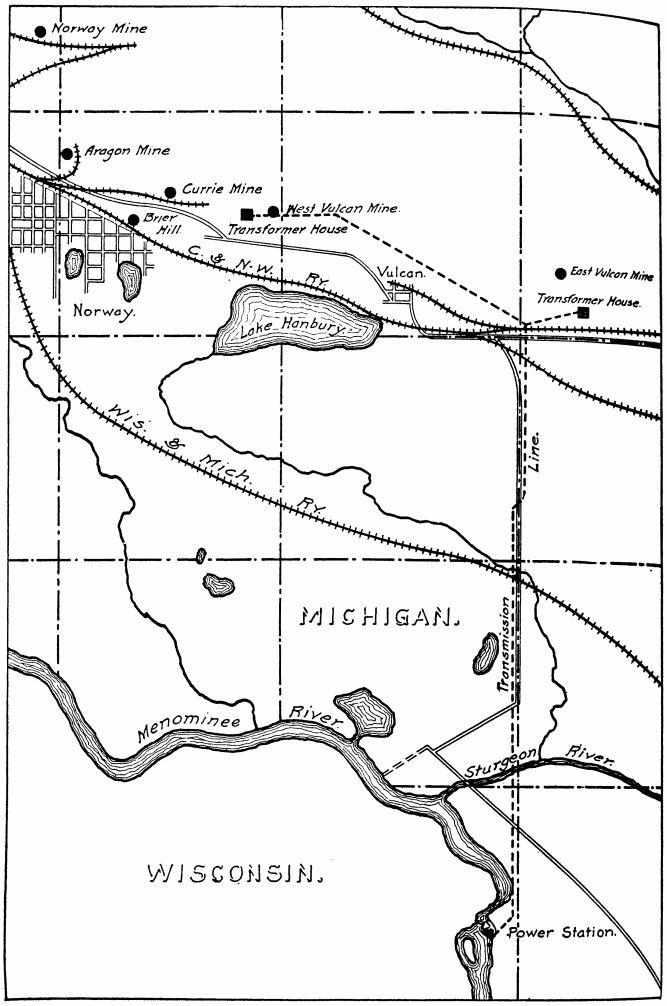


FIG. 14

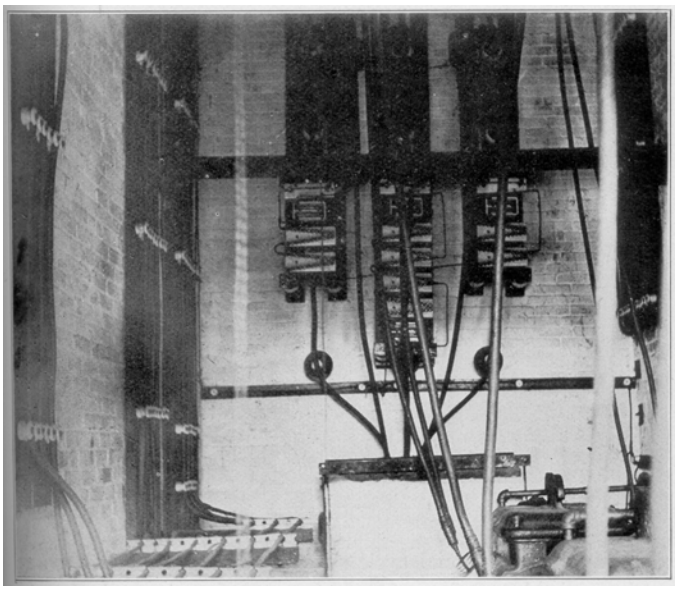


FIG. 15

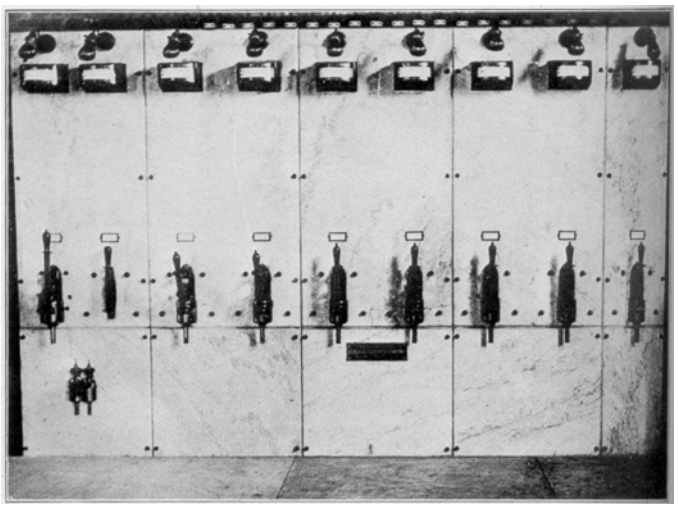


FIG. 16

Since starting the first unit there has been installed a motor driven pump for delivering water to the three dwelling houses, provided for the operatives, a small motor compressor for cleaning the generators, and a motor driven exciter.

The 1500 K. W. generator built by the General Electric Co. is rated at 132 amperes with 660 volts. This machine has been run for ten hours with a current load of between 200 and 250 amperes and voltage up to 7300. At times the load was 275 amperes. It has carried these heavy overloads without giving any trouble whatever. The water-wheels have worked perfectly and the Lombard governor holds the speed as constant as could be desired.

There has been no trouble with “frazil”—or “anchor ice.”

Recently the second unit has been installed, consisting of a duplicate line of water wheels, direct connected to a 2000 kilowatt generator, furnished by the Westinghouse Electric & Manufacturing Co., which will be operated in synchronism with the first unit.

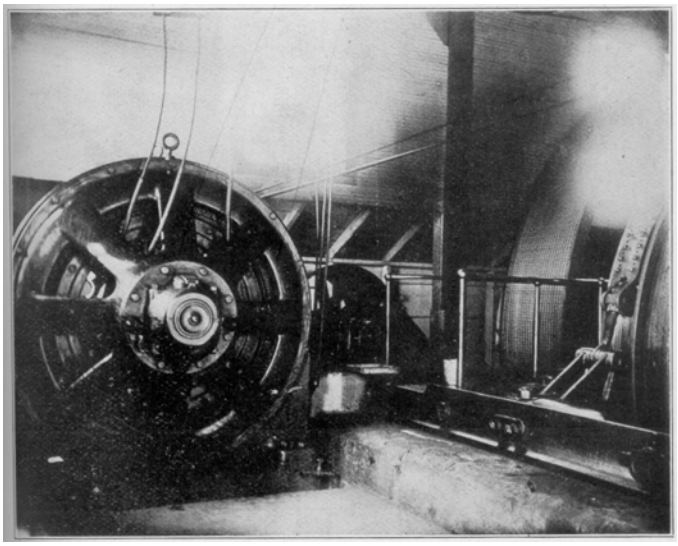


FIG. 17

TRANSMISSION LINE.

Figure 14 is an outline map showing the river, the transmission line to the Vulcan mine, and the location of the substations.

For the transmission line No. 000 Brown and Sharp guage stranded copper wire is used from the power house to the junction pole, 00 stranded wire from the junction pole to West Vulcan and number four solid from the junction pole to East Vulcan.

The poles are seven inch tops, 35 feet long except at few places across depressions where longer poles are used.

Locke porcelain insulators are used. These are tested to 60,000 volts, and are good for a line voltage of 23,000 volts, three and one-half times the voltage now in use i. e., 6600. The wires are spaced three feet apart.

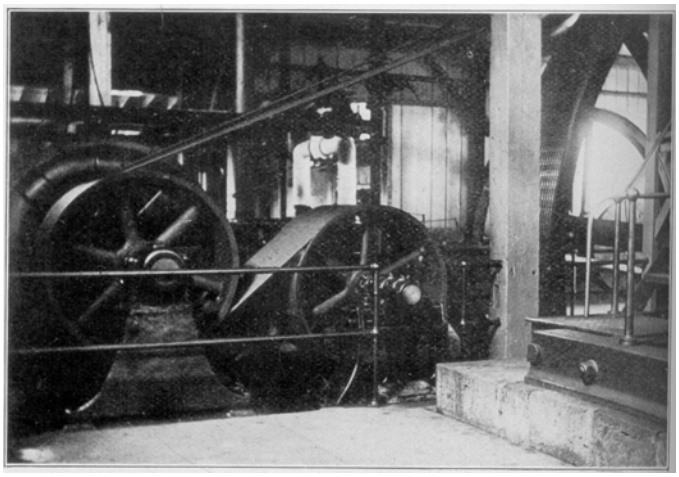


FIG. 18

SUB-STATIONS.

There are at present two sub-stations practically the same; one at East Vulcan and one at West Vulcan. They are built of brick, approximately 20 feet long, 9 feet wide and 20 feet high. The following describes the West Vulcan station.

The transmission line enters at one end through three Locke porcelain insulators which are supported by slate panels one and one-half inches thick, 19 inches square, built into the brick work of the end wall. From these insulators the line is led through disconnector switches and choke coils (which are shown at the top of Fig. 15) to a high tension switch the current is carried to three step down transformers, which reduce the voltage from 6600 to 2200. Three 500 K.W. transformers are used at West Vulcan, three 300 K. W. transformers at East Vulcan.

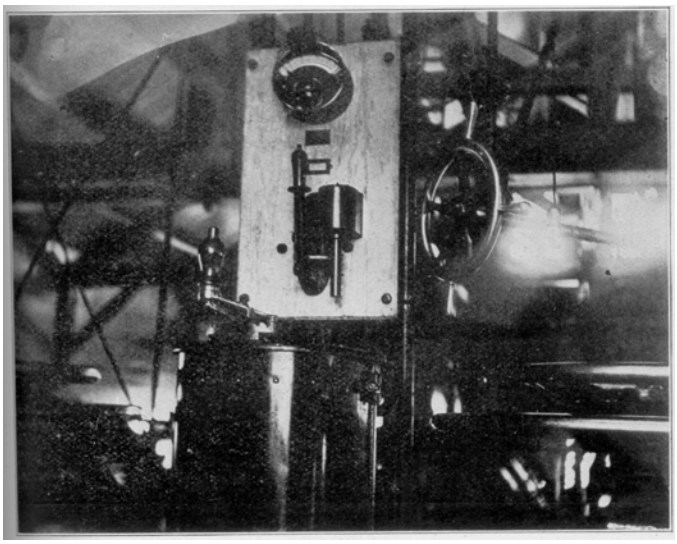


FIG. 19

The 2200 volt current is carried to the switch board shown in Fig. 16. The panel on the left is the sub-station panel. The larger handle on this panel operates, by a system of levers, the high tension switch in the sub-station. The smaller switch on this panel operates an oil switch through which all the 2200 volt current flows. Below these switches is a time limit relay which will open the first switch in case of a prolonged heavy overload. The two instruments on this first panel show the voltage and amount of 6600 volt current used at this sub-station. The other seven switches are feeder switches each supplying a certain motor or set of motors. Each feeder circuit has an ammeter showing the amount of current used on each line and an automatic release which will open the switch in case of a heavier overload than is desired. The point of release is adjustable. A ground detector hangs on a bracket to the right.

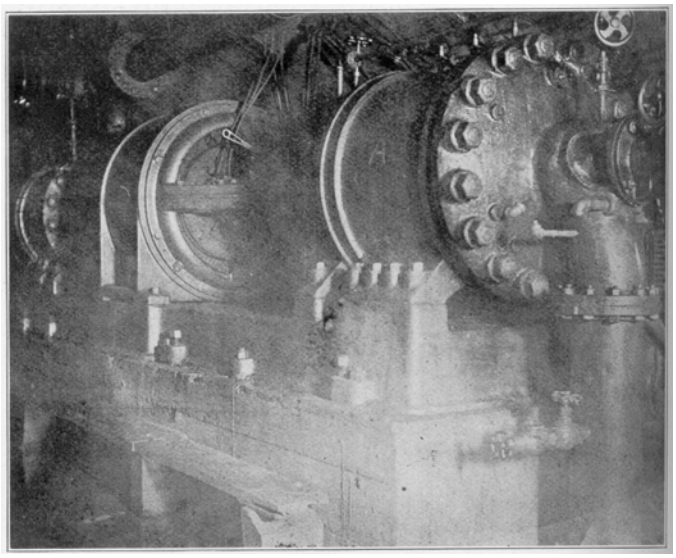


FIG. 20

The switch board at East Vulcan is the same excepting that it has one less panel.

HOISTS.

One hoist at each mine is motor driven. They are of the double drum geared type. The hoist at West Vulcan has drums 12 ft. in diameter. The pinion shaft runs at 56 revolutions per minute, the drums at 17.3 revolutions per minute with a hoisting speed of 652 feet per minute. The motor is connected to the pinion shaft by a rope drive built by the Dodge Manufacturing Co. The large rope wheel is 22 feet in diameter and the motor rope wheel 42 inches in diameter using 24 turns of one inch rope, American system. It was impossible to get more than 25 feet between the centers of the motors and the pinion shafts, which necessitates a deflector pulley as shown in figures 17 and 18.

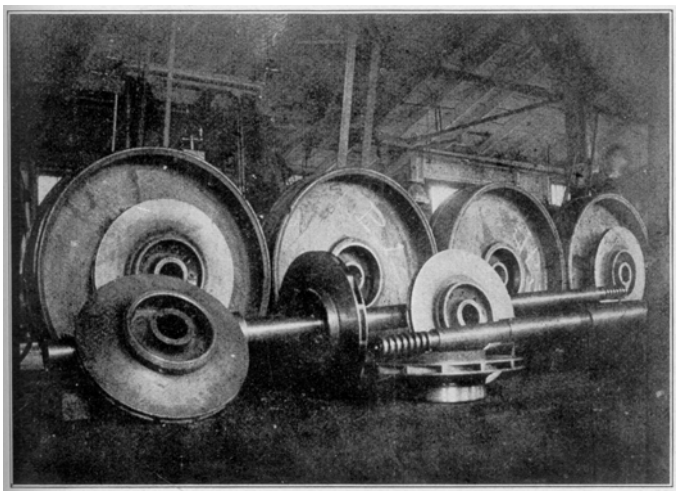


FIG. 21

The motors are General Electric company's 2200 volt, 200 H.P. three phase, form M, induction motors running at a synchronous speed of 360 revolutions per minute. The fly wheel of the engine was taken off and the connecting rod of the engine disconnected from the crank pin. To change back to a steam driven hoist, it is only necessary to put on the connecting rod—fifteen minutes work.

The energy of the revolving parts, varies with the weight, the square of the diameter and the square of the revolutions per minute. The amount of energy in these parts i.e. rotor, deflector pulley, 22 foot pulley, pinion and two gears, is such that it requires as much current to get them up to speed in 30 seconds as is required to do the hoisting. These revolving parts are gotten up to speed before the clutch is thrown in, which is done gradually. The energy given out by these revolving parts in slowing up from full speed to slip speed or full load speed, (which is 4 per cent less) is enough to accelerate the drum, skip, rope and load, thus giving no peak load in starting. At East Vulcan the skip carries 5800 pounds of ore with a total load of 14,400 pounds and the length of hoist is about 1250 feet of which1050 feet is in a vertical shaft.

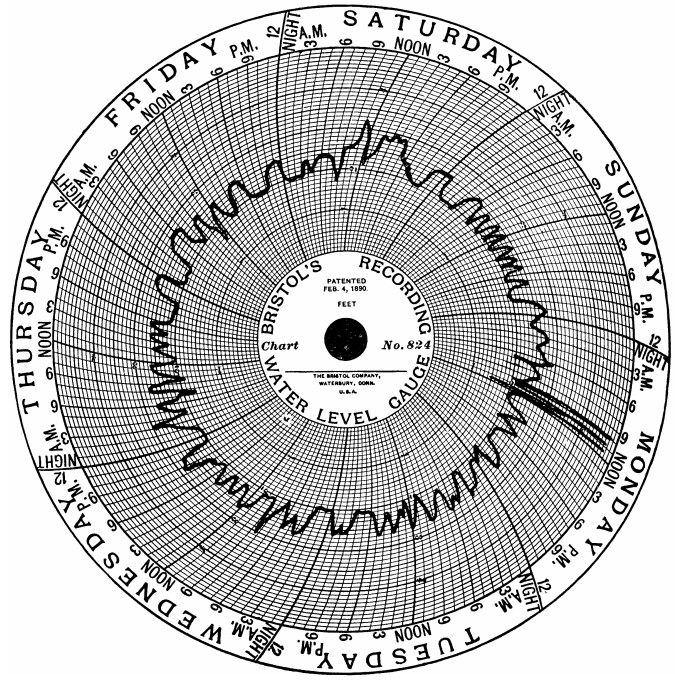


FIG. 22

These hoists have been running over a year and the same fibre hand on the friction clutch is still in service and in good condition.

Figure 19 shows the panel, with the oil switch and the ammeter, and below it, the controller. At the right and left of the controller are the hand wheels operating the friction clutches and the brakes. At the right of the oil switch is the hand wheel operating the throttle valve of the engine when using steam.

In new hoisting plants the steam engine would of course be omitted.

Back balance drums are to be used to counter-balance the weight of the skip or cage and the rope. There are to be two tapered drums for each skip or cage to be balanced, the rope from one leading to the hoisting drum, and the rope from the other leading to a counter weight in the shaft. By the use of tapered drums the varying weight of the rope is balanced so that the unbalanced load at any point is only enough to pull the drums around. Back balance drums on this principle are in use at the Republic mine.

PUMPS.

For pumping, three eight-inch turbine or centrifugal pumps are in use. Two are at West Vulcan and one at East Vulcan. They run about 1200 revolutions per minute and were designed to deliver 900 gallons of water per minute but they have a range of from 500 to 1250 gallons per minute each. The suction lift is about 20 feet and the discharge head including friction about 1275 feet. The pumps were built by the Henry R. Worthington Co. and are driven by 450 H.P. General Electric Co. 2200 volt induction motors.

These pumps are divided into two parts with four stages on each side of the motor as shown in Fig. 20. The suction is at the right from whence the water passes to the center of the first impeller (shown in Fig. 21) is thrown out at the circumference into a channel ring (not shown) and led by diffusion vanes (shown in Fig. 21) to the center of the next impeller. It travels thus through the first section of the pump toward the motor from which it is led by a pipe to the further or left end of the second section. Here it travels the same course through four impellers, channel rings and diffusion vanes, again toward the motor. In other words, the water travels in opposite directions in the two sections of the pump. The motor shaft is connected to the pump shafts by split sleeve couplings, making a rigid connection between the pumps and the motor. This allows one section of the pump to help balance the end thrust of the other section. On the suction end of the pump the shaft is fitted with a marine thrust bearing (shown in Fig. 21.) On the other end is fitted a water step bearing. The impellers are of bronze and the channel rings and diffusion vanes of cast iron. The casings are of cast steel. The shaft is nickle steel 3¾ inches in diameter. Where it goes through the pump heads it is packed with a fibrous packing. At these points the shaft is protected by a steel bushing which can be renewed when worn, and there are brass bushings where it goes through the diffusion vanes. The hubs of the impellers are also bushed where they enter the diffusion vanes.

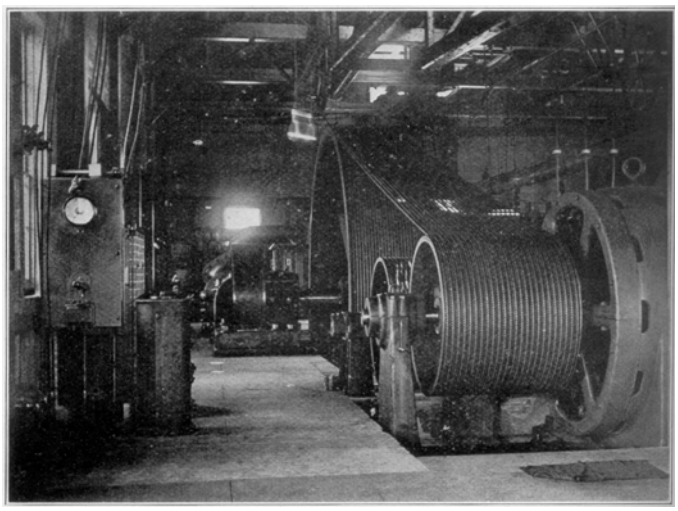


FIG. 23

The quantity of water is varied by simply closing or opening a gate valve on the suction of the pump. The pumps when in good order with 900 gallons of water per minute have given efficiency tests as high as 66 per cent. This is from the current delivered to the motor to the water delivered at the top of the shaft.

The water is measured by means of a vertical knife edge orifice. At West Vulcan this is seven inches in diameter. The quantity of water flowing through an orifice varies as the square root of the head of water above the center of the orifice. For recording this head a Bristol recording water level guage is used, which records with very great accuracy a variation in head of one-tenth of a foot. The chart is a weekly one, 7 inches in diameter, so that every chart shows the actual amount of water pumped for that week. (Fig. 22). The water at West Vulcan has decreased from 1800 to 900 gallons per minute since the original estimate three years previous.

COMPRESSORS.

At West Vulcan two Ingersoll-Sergeant piston inlet, rope driven duplex compound compressors are installed—size 35¼ inches and 22¼ inches by 42 inches. The rated capacity is 3110 cubic feet of free air per minute. The rope wheels are 18 feet in diameter grooved for twenty-four one and one-fourth inch ropes. The motor pulleys are fifty-two inches in diameter. Deflector pulleys were required here also because of the short centers between motors and crank shafts.

One of the motors is a General Electric Co. 450 H.P., 2200 volt form L. M. induction motor running at 300 revolutions per minute synchronous speed. The compressors run at 70 revolutions per minute. The other motor is a Westinghouse Electric & Manufacturing company's 450 H.P., 6600 volt form H. F. induction motor at the same speed. This is the motor shown in Fig. 23.

These compressors have 10-inch gate valves in the low pressure discharge and 5-inch gate valves on the high pressure discharge both opening to the atmosphere below check valves, so that the compressors can be started with less than full load current even when one is already running and the air pressure is up in the receiver. After getting up to speed these valves are closed. The quantity of air is regulated by an automatic valve which closes the intake. This valve is moved gradually sometimes remaining in a partially closed position for a considerable length of time.

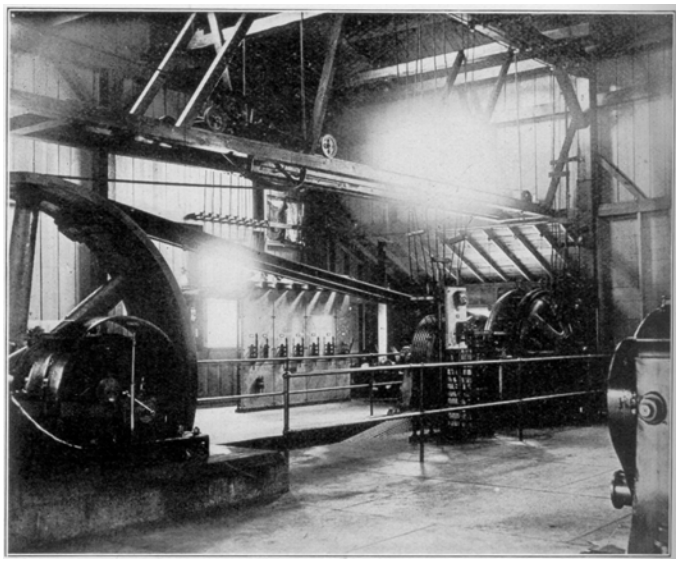


FIG. 24

The East Vulcan compressor is a Laidlaw-Dunn-Gordon 18 inch and 29 inch by 24 inch duplex compound rope

driven machine. The rated capacity is 2200 cubic feet of free air per minute. The rope wheel is 12 feet in diameter grooved for eighteen one and one-fourth inch ropes. The motor pulley is 50 inches in diameter. As the compressor wheel is only 12 feet in diameter it was not necessary to use a deflector pulley in this case.

The motor is a 350 H.P., 2200 volt, General Electric Co., form L. M., induction motor, running at 360 revolutions per minute synchronous speed. The compressor runs at 120 revolutions per minute.

The quantity of air is regulated by a choking controller which closes the intake entirely, but by the use of a dash pot it does it gradually. Ten to fifteen seconds are used to open or dose this valve. The action is automatic and is controlled by the air pressure.

The motor rope drive and a part of this compressor are shown in Fig. 24, which also shows the East Vulcan switch board.

MISCELLANEOUS.

Surface tramming is clone by 220 volt motors. The one at East Vulcan is geared to the tram plant. The one at West Vulcan is belted. The plants move the ropes to which are attached the cars that run between the shafts and the pockets or stockpiles. There is no power tramming underground as there is not enough ore on any one level to justify the expense of the installation,

The shops are run by 15 H.P. motors. On surface 220 volt motors, varying in size from 5 H.P, to 50 H.P., are running laboratory crusher and pulverizer, concrete mixers, cord wood saw, lagging saw for splitting lagging, boiler tube cleaner, rock crusher, 40 H.P. hoist, and triplex geared pumps. A one horse power motor runs a horse grooming machine at the stable. The pump and principal shaft stations underground and all the surface buildings at the mines are lighted with a current of no volts.

The results of the application of electricity to the mine machinery has fully realized its expectations.

AUTOMATIC THROTTLE CLOSING DEVICE FOR HOISTING MACHINERY.

BY SPENCER S. RUMSEY, DULUTH, MINN.

Ever since the application of steam power to mine hoisting machinery, there has been a continuous line of accidents caused by over-winding. These accidents are always of a serious nature and owing to damage to shaft house or machinery. Generally cause a cessation of mining operations for a longer or shorter period, and often result in loss of life.

Over-winding is caused sometimes by defective machinery, sometimes by the inattention or confusion of the brakeman, and often, where skips or cages are operated in balance, by the brakeman neglecting to reverse the engines, before opening the throttle for the next trip.

The means of automatically preventing over-winds has long been a subject which has received the most thorough consideration from mining operators and manufacturers.

One of the earliest devices was the automatic disengaging hook. This hook was fastened to the draw bar of the skip or cage and to it was attached the hoisting rope. In case of an over-wind, the hook would strike an iron plate held by timbers in the shaft house which would release the hoisting rope, and at the same time the hook would engage with, the plate, thus preventing the skip or cage from falling down the shaft when the rope was released.

Another device, and one which is furnished with many of the larger hoisting engines, is a powerful brake which is automatically controlled by a gear or sprocket attached to the drum shaft, and is instantly applied when the skip or cage has reached a certain position in the hoist, usually just above the skip dump, or top landing of the cage.

This device is a step in the right direction, but should the brakeman be suddenly confused or disabled and not close the throttle, the sudden application of the brake when the engines were working under a full head of steam, would tend to seriously strain the shaft house and the machinery.

The head room above this skip dump is usually so low that the application of the brake occurs so near the danger point as to render its reliability somewhat in doubt and especially so should it be a little out of adjustment due to expansion or stretching of the rope, or should there be condensation in the brake cylinder tending to make its action sluggish.

Attention was next turned to perfecting a device which would automatically close the throttle at a point during the hoist so that the momentum of the rising skip or cage would be just sufficient to bring it into the dump or to the top cage landing. If this device were perfected the skip

or cage would not rise to the danger point, and overwinding would be practically impossible.

A great many different designs have been submitted during the previous years, but inasmuch as none of them would prevent overwinding from all causes and that most of them interfered with the rapid handling of the machinery, they never came into general use.

In the latter part of the year 1900 some time after the formation of the Oliver Iron Mining company, it was necessary for that company to purchase a new first motion hoist to operate the cages in “A” shaft. Pioneer mine, and the specifications required that this machine be equipped with an automatic device which would be a part of the hoisting engine and which would close the throttle at a point during the hoist so that the momentum of the rising cage would carry it to the top landing, thereby making it impossible for an over-wind to occur.

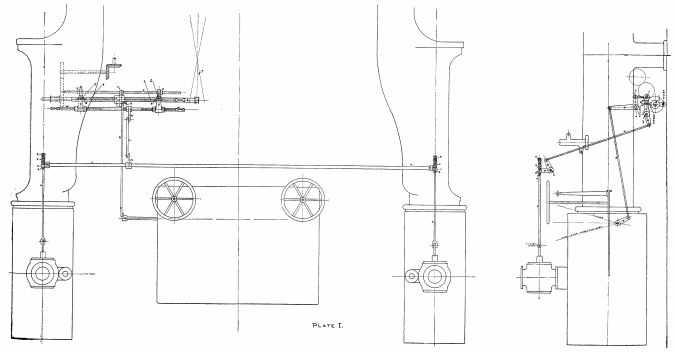
It is apparent to all that a number of devices could be designed which would be operated by the drum shaft and which would close the throttle at any point desired; the difficulty was to provide for unlocking the throttle so that the engine could be run in the opposite direction and still keep the device absolutely automatic; and even if the above were accomplished, it still left the machine liable to an over-wind in case the engines were not reversed, after a hoist, before steam was turned on for the next trip.

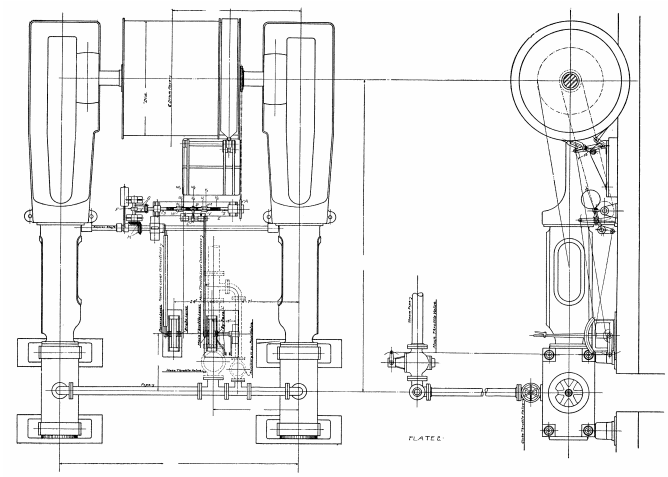
While the manufacturers were studying over these complications, a new hoist was ordered for the Savoy and Sibley mines. This hoist was first motion and had two drums; one operating two cages with attached skips in the Sibley shaft and one operating two cages with attached skips in the Savoy shaft was to be equipped with an automatic throttle closing device. This still further complicated the problem.

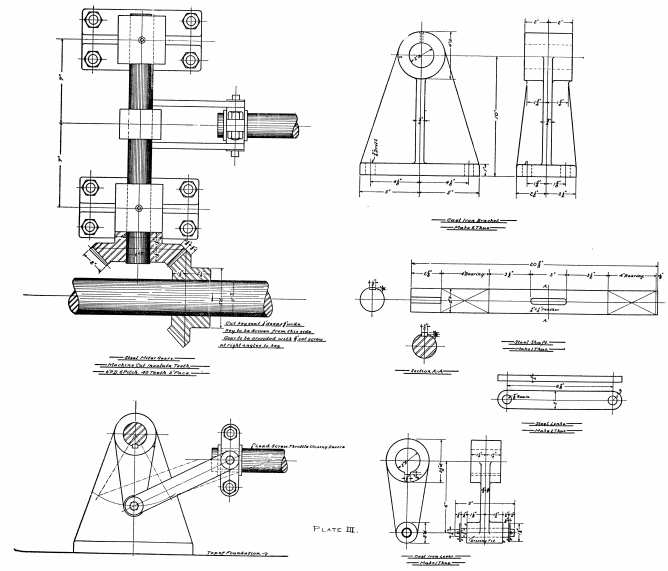
The solution was provided by Mr. H. J. Wessinger, then mechanical engineer for the company. He planned to attach the throttle closing device to the reversing gear on the engines, which made it possible to open the throttle after the engines were reversed. Accordingly, the drawing, shown in Plate I was prepared, in which the designs of the manufacturers were rearranged and Mr. Wessinger’s idea was embodied. In Plate 1 there is shown a screw shaft “I” which is rotated by a set of gears operated from the drum shaft. It is also given a movement of translation by the lever, 7, which is operated by the reversing gear.

“A” is a nut and wedge which engages the rollers “B” & “B.” The nut is moved from positions 2 to 5 by means of the screw, but it is prevented from revolving by a guide shaft; the wedge lifts the rollers “B” & “B”, thereby moving the roller-lever “C” & “C”, closing the throttle through the connections.

At the beginning of a hoist the nut and wedge “A” is at position 3. During the hoist it is moved to position 5, raising the roller-lever “B” “C” which closes the throttle and locks it, making it impossible to open the throttle until the engine is reversed. When the engine is reversed the nut and wedge is moved from the position 5 to 4 which releases the throttle. The throttle is opened and the return hoist is made, and the nut and wedge travel to point 2, where the throttle is again closed. When the engine is reversed the nut and wedge is moved to point 3, releasing the throttle, and the process begins over again as above described.







The manufacturers were provided with this drawing and the throttle closing devices which were furnished for the Pioneer “A”, Savoy-Sibley, also Pioneer “B” and Aragon No. 5 hoists were the same in principle as Plate 1, but differed somewhat in the details. The arrangement of

shafts and drive was altered and two wedges were used instead of one and one roller-lever instead of two. These hoists are also provided with small auxiliary throttle valves, which are operated by treadles and are independent of the throttle closing device. They are used to aid in raising the skip into the dump should its momentum be insufficient. The size of these valves is purposely small to prevent the engines being operated except at a very low speed.

The hoists mentioned above have been in operation several years and the throttle closing devices have worked very satisfactorily. They are regularly tested and have always been found reliable, and in several instances are known to have prevented accidents.

They have given such general satisfaction that it is the intention of the Oliver Iron Mining Co. to install them on all new plants and also on a large number of old ones.

The devices furnished for the above hoists are complicated and the design has since been simplified. The throttle closing device as designed, and now used by the Oliver Iron Mining Co. is described below and illustrated by the following plates: Nos. 2, 3 and 4.

Plate 2 shows the general arrangement of a throttle closing-device as applied to a direct acting hoist for the Mesabi range. In this plate you will note the lead screw "S" which is supported by boxes cast on the sole plate "E". The lead screw is revolved by a sprocket wheel "A" which is driven from the drum shaft by a sprocket chain. This screw is given a movement in the direction of its axis when the engines are reversed by means of the mitre gears "H" which are operated by the reverse shaft, lever "F" and connections "G". The screw has a feather key at the driven end which causes it to revolve with the sprocket wheel but permits it to slide in the hub of the sprocket wheel whenever the engines are reversed. "M" & "N" are shoes which are moved backward or forward with the revolution of the screw but are themselves prevented from turning by a guide on the sole plate.

The wedges "W" & "V" are fastened to the shoes and engage the roller "B", which is attached to lever "C", raising the latter and closing the throttle through the connections. To illustrate the operation of this device, we will consider the reverse lever in a position so that the engines will run under. The left hand or over wound rope is hoisting and the right hand or under wound rope is lowering. The wedges are at positions "W1" & "V1", the throttle valve is unlocked and may be operated by the hand lever.

The throttle is now opened and when the skip has been raised to the point where the steam should be completely shut off, wedge "W" has moved to position "W2", raising the roller "B" and lever "C" which closes the throttle. The throttle is now locked closed and cannot be opened until the engine is reversed. Wedge "V" has moved to position "V2".

When the reverse lever is thrown over it operates gears "H", lever "F" and connections "G", pulling the lead screw and shoes until wedge "V" is in position "V3" and wedge "W" in position "W3", which releases the roller and unlocks the throttle. Steam may now be turned on for the return trip in which wedge "W" moves to position "W4" and wedge "V" to position "V4'' which closes and locks the throttle.

The engine is again reversed and the wedge "W" moved to position "W1" and wedge "V" to position "V1" which unlocks the throttle and the process may begin over again as above described.

If for any reason the momentum of the skip should not carry it into the dump the by-pass or auxiliary throttle may be opened by the hand lever "L".

The size of the auxiliary throttle is such that it will admit only enough steam into the cylinders to operate the hoist slowly until the desired point is reached.

Plates 3 and 4 illustrate the details of construction of the various parts of the above device and are sufficiently clear as to need no further explanation.

The throttle closing devices which are being prepared for deep mines are identically the same in principle and differ only in the length of screw and sole plate.

STRUCTURES OF THE MESABI IRON ORE.

BY N. H. WINCHELL, MINNEAPOLIS, MINN.

After such a strenuous day as we have had I do not feel sure that I shall be able to say anything as to the structures of the ores of the Mesabi range which will keep your attention. I have, however, a paper which was written about a year ago which I will give in abstract.

It is nearly sixteen years since I visited Virginia, or rather the spot on which Virginia was destined to be built. My party camped in this vicinity somewhere. Some of the first openings were then being made in the ore bodies. After a careful review of the field-facts at this place and at other points further east bearing on the nature and origin of the ore formation of the Mesabi range, I reached the following conclusions, which I published in my report for that year:*

1. The ore is not explained satisfactorily by any theory that has been proposed.

2. The ore has resulted from a profound alteration of some pre-existing rock.

3. The rock was of a peculiar composition, or

4. It has passed through a peculiar and unusual physical history.

Since then other work has prevented me from visiting again the mines of the Mesabi range.

*Twenty-first annual report of the Minnesota Geological Surrey, for 1892, p. 134.

Prior to the opening of the great mines on the Mesabi iron range it was rather difficult to form opinions as to the grand structures that the ore possesses. Some of the great pits are now about 200 feet in depth and extend in a direction parallel with the strike of the rocks, something more than an eighth of a mile, affording a magnificent opportunity to study the ore and the structures, and the relations that it bears to the associated rocks. On the occasion of the late (1907) proposed meeting of the Lake Superior Mining Institute at Duluth (which was abandoned on account of the miners' strike) the writer enjoyed a revisit to the Mesabi range, which he had longed for ever since the close of the Minnesota Geological Survey. Not aware that the meeting had been postponed until his arrival at Duluth, he resolved to continue his trip alone to the mines on the Mesabi range. Owing to the great strike everything was quiet, and the dust and smoke which usually rendered such a visit unpleasant were wanting. It had rained copiously the previous night. The ore structures were washed clean. Three days of leisurely examination were given to the open pits at Hibbing, Virginia, Eveleth, Biwabik and Mountain Iron. This paper is designed to present some of the facts observed at those places.

HIBBING.

The celebrated Mahoning open mine was examined only along the north and northeasterly sides. The average grand dip is to the south. At the west end, on the third bench, in the face of the pit,* the ore section is composed of ore in two different structures; these structures alternate in strata that are evidently such as would be formed by water deposition: (1) fine grained ore in strata that are mostly continuous and from half an inch to fourteen inches in thickness, (2) harder, i.e. firmer, ore, in lumps and broken layers which are about four inches thick. These are not strictly continuous, but are made up of smaller constituents mingled with much fine ore presenting a conglomerate aspect. When closely examined the harder layers prove to be mainly composed of ore, which, however, is apt to be lean, and to pass to a kind of taconite, or a gray massive and limonitic ore.

*In excavating the ore with steam shovel the work proceeds by benches, separated from each other vertically about 20 feet, that being the depth which the shovel can easily excavate. The railroad tracks run into and about the mine on these benches. In some of the open mines these benches succeed each other to the number of six and eight, if the ore is firm; if the ore is uncemented a single course of the steam shovel may excavate, as at the Mountain Iron mine, a vertical depth of a hundred feet, as it crumbles naturally to the bottom of the pit.

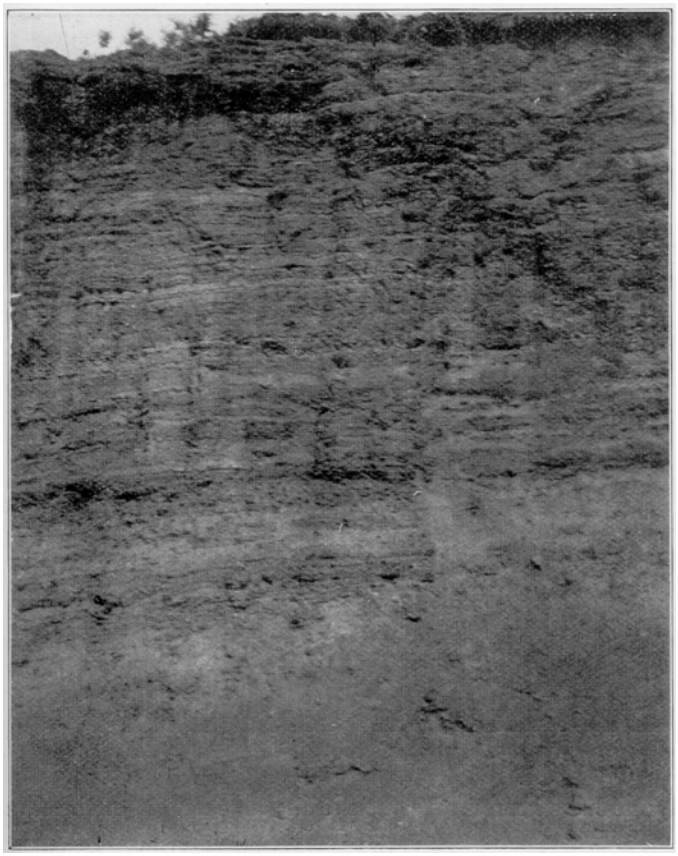


FIG. 1. Stratification at the Mahoning Mine.

Ropy Structure. Passing eastwardly along this bench the writer observed and picked up a piece of ore which on one side presents a parallel series of ridges or convolutions that resemble the ridges formed on the upper surface of a lava flow designated “ropy structure”. (Fig. 2). It is about six inches long and about five inches wide, a fragment, evidently, of a larger surface. It shows ten or eleven of the ropy elevations running parallel with the length of the piece. Such ridged upper surfaces of lava flows are seen in the trap beds of the Keweenawan and have been represented in the final report of the Minnesota Survey (Vol. V, p. 237)

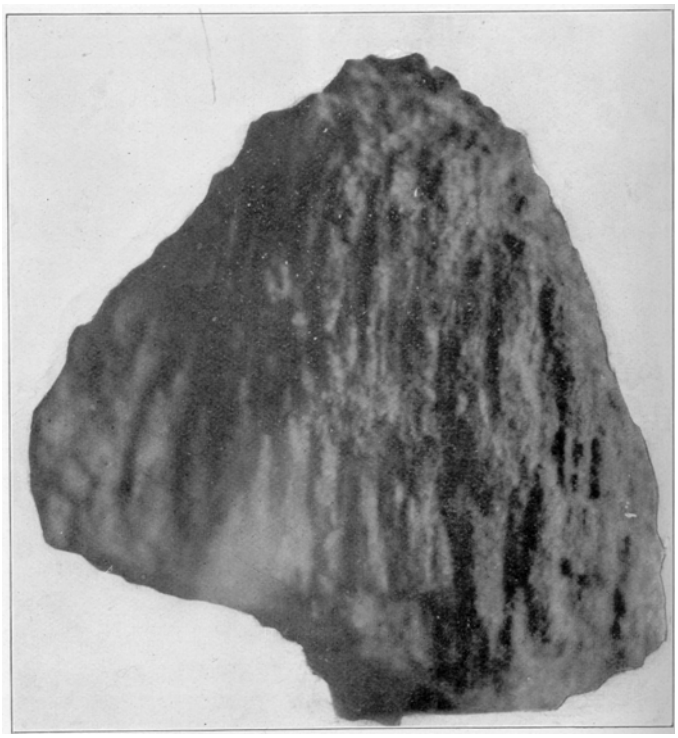


FIG. 2. Ropy Structure.

Sedimentary Shale. At the eastern end of the Mahoning pit the rock (and ore) grades into red shale which is very plainly sedimentary. This is in some of the highest of the strata exposed at this mine, so far as observed. Some of it might be called a low grade ore. Similar red shale is a common feature in the Keweenawan formation.

Volcanic bombs? Near the same place, but further west, in walking along the railroad track on the second bench, I observed several roundish masses, rolled down the talus to the foot of the cut. They were from three to ten inches in diameter, somewhat flattened. They appeared to be volcanic bombs. On being broken one was found to be composed of impure taconitic ore, but about one-half of it was spongy, or vesicular. Time was short. From about a half a dozen that were visible within about 30 feet one of the smaller ones was taken (Fig. 3). It had been broken away on one side disclosing a hollow centre.

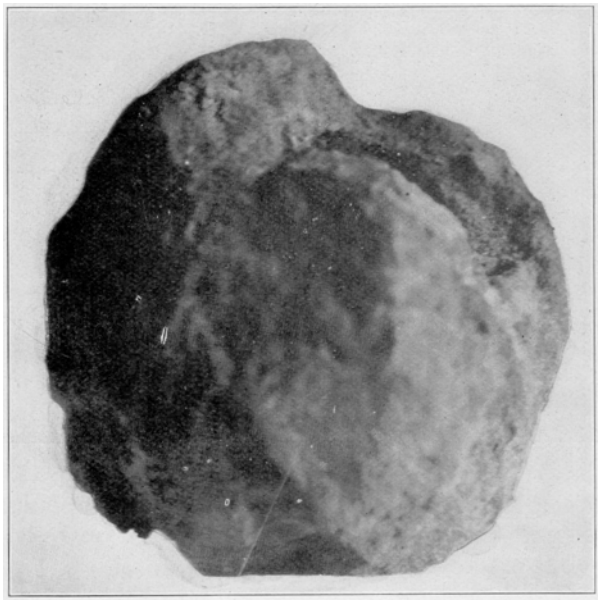


FIG. 3.

Globular Forms. Further west was noted a structure that appeared to be similar to that seen and described on Grand Portage island in the trap composing the upper portion of that island and described in Vol. V of the final report of the Minnesota Survey. This is characterized by *balls* due to the manner of solidification and subsequent disintegration of the trap flow (Fig. 4.) On weathering these globular masses are made apparent and can be gathered in considerable numbers on the level surface of the lava. At Grand Portage island they are about as large as a rifle ball, and smaller, but at the Mahoning mine the analogous masses are as large again, and consist entirely of ore. They are often adherent by a cement which crumbles out leaving the balls projecting. This globular structure was seen at other mines.

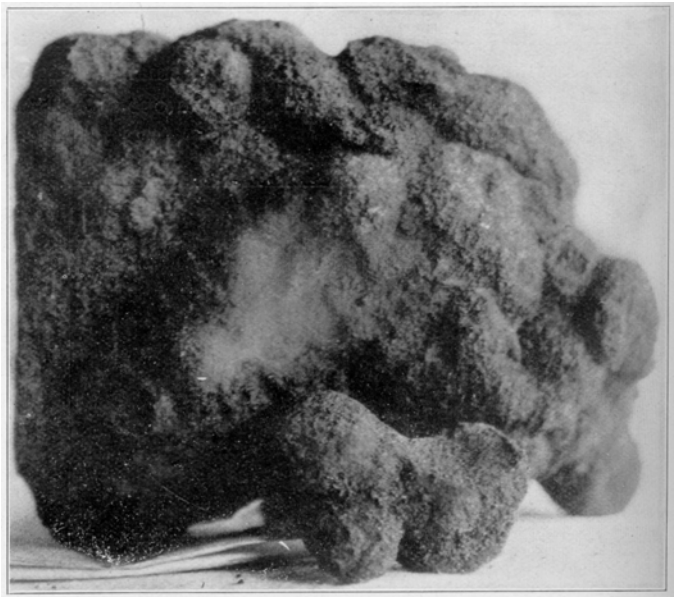


FIG. 4.

VIRGINIA.

Conglomerate. The Buffalo mine (also known as Oliver mine) is the only open pit at Virginia. At the west end is a lot of breccia or iron ore, a part of the mine formerly called Lone Jack. The writer has assigned this conglomerate to the bottom of the Cretaceous but he does not now feel satisfied entirely with that conclusion. From what is now known of the origin and structures of the Mesabi ore it is more reasonable to expect that this breccia-conglomerate is a constituent part of the Mesabi formation. Without having made any new observations on this ore worthy of being mentioned here, one or two features already published may be recalled.* (1) It is entirely made up of ore like that of the region, but some of it is of low grade and apparently results from a rock like taconite. (2) Some of the pebbles have an irony crust harder than the interior and from the crust toward the centre there is an increase of coarseness of texture, even becoming spongy, or somewhat layered with imperfect concentric shells. Some of the larger pebbles are of taconite.

This entire absence of quartz and granitic materials shows that the rocks of the nearby Giant's range did not contribute to its formation, thus differing remarkably from the conglomerate that lies at the bottom of the Animikie, and from all known conglomerates at the bottom of the Cretaceous. The structure of the individual pebbles, which indicates a progressive change from the surface to the centre, is like that of the individual grains of fine ore which have resulted from a similar progressive alteration from the green substance later called greenalite. Except that the ore of the Lone Jack is of lower grade this conglomerate is similar to that of the Mountain Iron mine.

*Twenty-first annual report of the Minnesota Survey, p. 128.

Jointed alike-like mass. Directly north from this breccia, the iron and its accompanying beds of impure ore are tilted almost to verticality. In the midst of these fine grained, nearly vertical, strata is a conformable sheet which is coarser grained and firm, from which the soft ore crumbles away allowing it to stand out conspicuously, presenting the outward aspect of a jointed dike, with an exposed face toward the south which extends about 30 feet, and about four feet high. Its lower part runs into the talus. Its thickness is about two feet, but at each end it becomes thinner and grades into the surrounding ore. The grain of the ore on the north side is immediately fine and dense and in thin sheets about half an inch thick, easily broken. The jointed southern face is represented below. (Fig. 5.) The sudden appearance of this curiously jointed mass, contrasting with the crumbling strata of ore above and below it, seems easily explicable on the supposition of a surface lava flow cracked by shrinkage in the midst of sediments accumulating by the ordinary methods of oceanic forces, the whole subsequently highly tilted—and that is apparently the only plausible explanation.

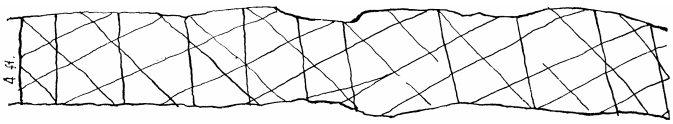


FIG. 5

Purgatories and Amygdaloidal Structure. Eastward from this jointed mass, the clip continuing about 60 degrees toward the south, there is a confused mingling of heavy taconitic beds with thin beds. At a casual glance the appearance suggests a line of fault and its breccia, the thin beds being mostly on one side, but having a steeper dip than the massive beds. The structure is probably due to the shrinkage of the rock which has been most altered, away from parallelism with the rock less altered, making an apparent non-conformity. The same appearance might be produced by the flow of a mass of lava over a cliff, becoming porous, thin bedded and non-conformable on the rocks of the cliff, and dipping at a higher angle. These irregularities appear extensively along the north side of this mine, the whole formation becoming twisted and crumpled, the heavy beds fading out, and in some cases also having crumpled, thin layers between them. Underneath all this, which has a thickness of 50 feet more or less, is a lot of good purple soft hematite, having the same steep southward dip, which is mined extensively. The face of the bluffy viewed at a distance, has the suggestive appearance structurally, of the trap bluffs along the north shore of Lake Superior, even to the *purgatories*. Some lumps of the best ore seem to have been originally *amygdaloidal*. They are pure and purple ore now, but porous and varied with blotches of ore that is plainly somewhat hydrated.

Remnants of Fluidal Structure. Along the north talus large blocks have fallen since the cut was made, most of these are joint blocks of taconite, but some of them, while firm taconite within are covered at the ends where the structure has been broken or rotted away, with a bristling lot of thin scaly projections which grow out from the rock itself. These stand parallel with each other and with the bedded structure of the mass. They are evidently remnants of the more durable parts of a structure which once penetrated not only the taconitic blocks themselves but also the rock surrounding them, passing into the general ore body, and can be referred to the former existence of a fluidal structure in the whole rock, the projecting sharp scales, or sheets, being the result of variation in the original obsidian. This supposition is perfectly concordant with another structure seen on these same scaly blocks, namely the bullet-structure in the form of irregular balls and small shapes which are on the upper sides of these masses, supposed to be analogous to the globular structure already mentioned, due to the disintegration of the surfaces of lava flows, such as seen on Grand Portage island in the Keweenawan.

EVELETH.

Fayal Mine. The ore in general structure resembles that of the Mahoning mine. At the west end it is approximately horizontal, much stained with limonite and thin bedded, but with taconite "horses" which seem to be simply more silicified conformable patches in the iron mass. These "horses" change horizontally rather abruptly into the surrounding ore, becoming thin bedded, the rock then sagging down a little by reason of shrinkage. The general dip is toward the S.E. and is most distinct at the east end of the pit. The bottom of the pit at the east end is in a great mass of purple ore which is pure, fine and cheaply taken out. There are distinct colors of the mass of the ore at different points, vis: yellowish (mixed with black, red and purple) : hematite red; and purple. The yellow color is most frequent along the upper portion, and is probably due to atmospheric hydration.

The smooth, wavy, upper surfaces of some of the fallen taconite blocks suggest the contact surfaces of trap layers seen along the Lake Superior shore, say, of the "Two Harbor rock". A thin scale, or two or three of them, somewhat more ferruginous, usually, or uniformly, cover the upper and lower surfaces of such fallen masses. The upper surfaces are not crosscut by joints but are simply undulatory or broadly mammillated. They do not indicate lava-flow surfaces but a deep seated sheeting. "Purgatory" holes in the bluffs are not uncommon, eight being visible from one point, looking west.

Biwabik Mine. Several quartz veins which are crumbling cut the ore, running nearly vertical, the width in one instance reaching ten inches. Balls of disintegration are here seen, like those already mentioned under globular forms. Some of them are detachable, and some of them run deep into the ore. There is here also a peculiar breccia which seems to be the same as that described long ago by me at the Cincinnati mine. Later this breccia was seen again on the old dump of the Cincinnati, where also was seen the ball structure already mentioned.

The bulk of the ore of the Biwabik is apparently not from a sedimentary rock, although it grades into a sedimentary structure. The yellow ore extends to the very bottom of the pit, but appearing in patches, somewhat alternating with red. The quartz veins probably antedate, or are coeval with, the formation of the ore. White kaolinic deposits were later than the ore. They embrace angular pieces of ore.

Igneous Sheeting Planes. The heavy fallen blocks, which consist of ferruginous taconite or lean ore, present a remarkable common and very suggestive feature which, though noticed before, did not appeal to me with such force as here. A large number of rough blocks, from 1½ to 2½ feet thick, lie on the sixth bench. (There are nine benches, each about 20 feet high). These blocks are sometimes four feet across along the extreme diameter, but vary to all sizes downward. When they have not been split in quarrying or in falling, their upper and lower surfaces are wavy and continuously coated over with a thin scale of fine-grained ore, though the mass is generally composed of taconite, or a coarse-grained, brown impure ore. These thin scales are sometimes two or three in number, indeed usually are, and are from ½ inch to 1 inch thick each, the whole scale portion grading into the general mass. They generally are denser and better ore than any other part of the blocks on which they occur. These are probably not the rapidly formed contact surfaces of successive flows of trap rock when molten but deep-seated bedding planes. It is these fine grained scales that constitute the undulating or coarsely mammilated surfaces already mentioned, and which crack by a fine jointing into small angular bits ½ inch square or less, and so become loosened from the parent slabs. Sheets of trap rock in the Keweenawan are thus characterized at several places on the north shore of Lake Superior.

Remnants of Green Stone. Associated with some of the kaolinic deposits at the Biwabik, or at least in the dump of the mine, are pieces of green original rock much altered toward kaolin. Some of it is stained with iron oxide but a noticeable amount of it still retains what was probably its original color, indicating that it was at first of a basic nature and igneous origin.

MOUNTAIN IRON.

Oliver Mine. Here is an immense open pit, second, so far as I have seen, to the pit of the Mahoning. It runs about east and west and probably includes several of the original "locations" noted by me several years ago.

Amygdaloid. Along the south face, near the top, just under the stripping, is found much taconite, rather evenly bedded and jointed in angular blocks so as to come out in pieces six inches to ten inches in diameter. The blocks have the smooth scales of more pure iron separating them and coating their bedding surfaces when separated horizontally, already mentioned at the Biwabik mine. On searching here for amygdaloidal parts I found but little. But instead I found beneath these thin scales of iron a blotched irregular taconitic belt, sometimes coarser, about two inches thick. This passes toward the centre of the block, into the unusual gray taconite. Sometimes this irregular belt is wanting and the iron scale is cemented upon taconite.

Some of the talus pieces are plainly pieces of amygdaloid, converted to ore and kaolin. The amygdules now being hematite and the rock mass itself being kaolinitic.

Indeed, many of the taconite blocks show, under the iron scale, a prevailingly white color, which on closer examination appears to be due to a pisolitic distribution of white kaolin; and this kaolin also sometimes is sprinkled more or less through the iron scale, and it goes deep within much of the taconite. It forms sometimes thin sheets both in the red ore, by which it is not stained, and in the taconite.

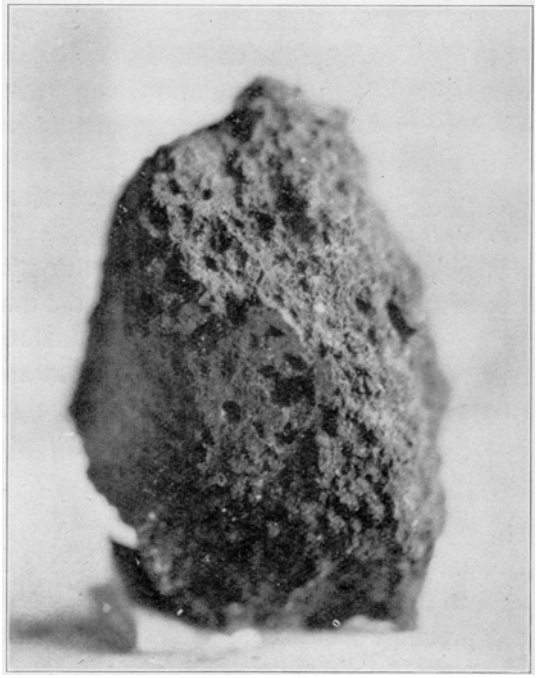


FIG. 6. Amygdaloidal Structure. Mountain Iron.

At the dump, near town, south side of the pit, has been thrown very much amygdaloidal rock. The mesh is here spongy quartz, passing to light colored taconite. It is associated with pisolitic taconite and with brown-gray limonitic taconite. Some of the masses of this amygdaloidal rock are more than a foot in thickness. They have the iron scale on at least one side. The dump extends about 75 feet, and is 18 feet high, the largest pieces having rolled to the foot. On looking all over this pile not a piece of amygdaloid was found with the iron scale on both sides. Either they have no such scale or they show it on only one side. The former condition being most frequent. This is in keeping with the well-known fact that in case of a lava flow the amygdaloidal structure is formed on cooling mainly in the upper part of the mass, and that it fades out downward into the body of the non-amygdaloidal rock. It is also in keeping with the supposition, already stated, that the iron-scale expresses the plane of contact of deeper internal sheeting, rather than lava surfaces.

In order to explain the prevalence of quartz forming the mesh in some places and kaolinic rock in others it seems necessary to allow that in a chemical transformation such as that which has formed this ore, the circumstances of environment must have been such that, while the alkaline earths and alkalies were being entirely removed in solution, quartz and alumina were not wholly removed, but were accumulated, now here, now there, in accordance with the demands of physical and chemical conditions. The iron ore, therefore, is no more a concentrate from the original rock than are the kaolin deposits and the quartz veins and the quartz-filled vugs. Of the last many large masses are seen at Mountain Iron in the form of crystals and coatings in cavities from a foot to four feet loner-the longer diameters lying in the direction of the structure and sometimes as much as a foot in thickness.

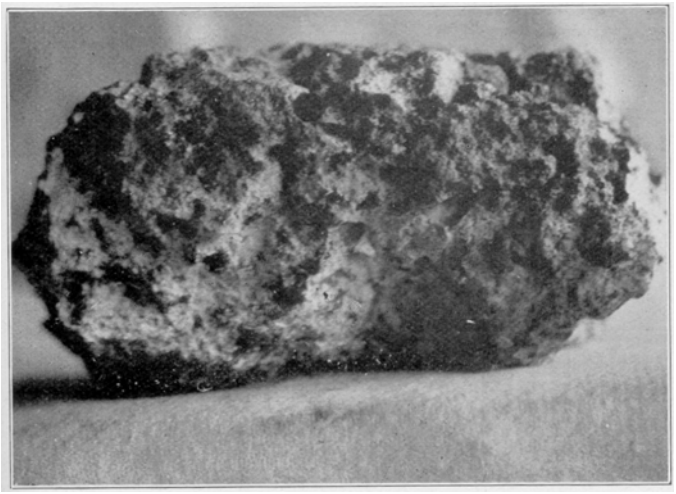


FIG. 7. Quartz Mesh. Mountain Iron.

Conglomerate. The peculiar conglomerate occurring at the Lone Jack mine, at Virginia, has already been mentioned. When this iron range was first examined by the writer, and this conglomerate was encountered, it was presumed that the Lone Jack conglomerate was probably a part of the basal beds of the Cretaceous; but in the light of what was seen lately at Mountain Iron mine it is allowable to refer it to the age of the iron ore formation. From limited field examinations, and from microscopic study of samples collected by the Minnesota survey, it was shown that a breccia and even a conglomeratic structure is found to be the extreme end term of the fragmental materials of which an obsidian sand was the other. At the Mountain Iron mine this broad generalization finds unequivocal confirmation. Here a conglomerate stratum estimated at about 200 feet in thickness, (so far as observable) constitutes a principal part of the ore as now mined. It rises, with a gentle dip, from below taconite and other kinds of rock and ore, at the eastern end of the pit, to the drift stratum lying on the top, and it extends at least to the bottom of the mine. It is nearly all composed of fragments, more or less rounded, but still cemented by occasional patches or layer-like masses of iron not conglomeratic. It is all loose and easily mined. The original pebbles are from half an inch to two inches in diameter, and their forms are obscured by alteration and by cementation. I The ore is ochreous. It is easy to imagine that by a reduction in the size of these pebbles we would have the “soft ore” proper, i. e., the sandy ore.

If the iron formation was originally a mass of trap rock, constituting a great formation analogous to the Keweenawan, as believed by the writer, it appears to have embraced large strata of conglomerate made up of rock of its own kind. Such conglomerates are a well known feature of the Keweenawan.

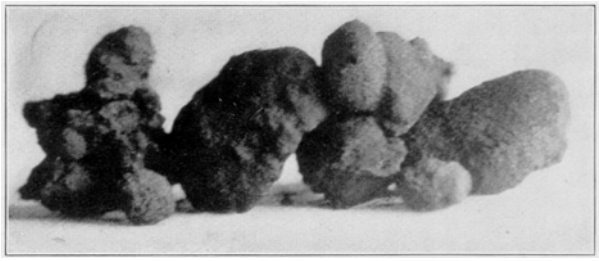


FIG. 8. Pebbles from the Conglomerate. Mountain Iron Mine.

To recapitulate: The iron formation of the Mesabi range embraces many of the structures that are easily referred to volcanic action and to igneous eruption, such as: ropy structure, volcanic bombs, globular forms of weathering, jointage identical with that formed in the cooling of trap rock, purgatories, amygdaloid, fluidal structure, contact planes, remnants of original basic greenstone and thick beds of conglomerate composed of the same rock as that of the associated strata.

To a person who is familiar with the Keweenawan along the north shore of Lake Superior, it is the most obvious inference that these structures can be formed only by igneous extrusion.

In conclusion I wish to say that I present these suggestions tentatively. I may be mistaken as to the interpretation of the structures described. Having already, in earlier publications, explained the Mesabi iron ore on the theory that it has resulted from a change in igneous rock, I may be more inclined to see igneous features than a disinterested observer. Whatever may be the final conclusion of geologists, however, whether from igneous rock or from—I do not know what kind of rock—I shall be satisfied when the problem is settled.

If opportunity and time permit it is my intention to make further microscopic examination of the minute structures of the Mesabi ore.

ACETYLENE AS AN UNDERGROUND LIGHT.

BY WILLIAM F. SLAUGHTER, REPUBLIC, MICH.

Up to the present time, acetylene has been a failure as an underground light. This failure has been due, I believe, to the inconvenience caused by the size of the lamps used. The lamps were too large and too heavy to be worn on the hat, so it was necessary either to carry them in the hand or hook them to a button hole in the front of the coat, both of the latter means being inconvenient at times; as, for instance, in going through low openings, or climbing ladders.

I have been using "Baldwin" lamps for six months in my surveying work underground, and find them very satisfactory. The lamp consists of a water tank on top into which is screwed the carbide container. A small pipe projects from the bottom of the water tank into the carbide container, and a wire of a size to permit just the required amount of water to flow down the pipe and onto the carbide, passes through the pipe, projecting above the top of the lamp. If the tube becomes blocked, it can be cleaned by rotating the wire. When the burner gets blocked, it is cleaned out with a small wire which is carried on the lamp. There is an extra bottom or carbide container furnished with each lamp. This bottom has a screw cap to keep the carbide dry, and when wanted, can be exchanged for the one in the lamp.

When water is added to the carbide, the reaction gives calcium oxide, CaO, and acetylene C_2H_2. The acetylene, when ignited in contact with the air, changes with the oxygen in the air to carbon dioxide and water. $C_2H_2 + 50 = 2CO_2 + H_2O$.

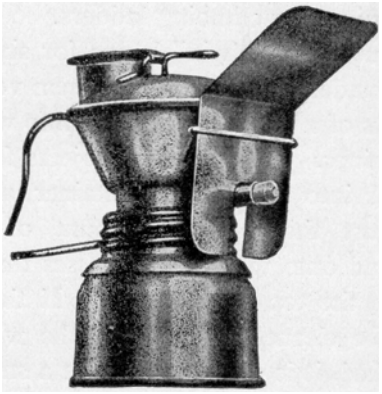
I compared the light with a mine candle, one of the kind known as "eights", and find the light about equal to that given by one candle. A test was made to see which consumed the most oxygen. The candle was placed in an inverted carboy, capacity about one and one-half cubic feet, the neck being under water, thus giving a water seal. Not being able to get the lamp in the carboy, the gas was conducted through a rubber tube to a burner inside. From several trials, it was ascertained that the acetylene uses about one-fifth as much oxygen as does a candle.

COMPARATIVE COST.

Candle at 9 cents per pound cost 2.81 cents for ten hours.

Carbide at 5 cents per pound costs 1.95 cents for ten hours.

This means that the acetylene saves one-third the cost of the candles.



ACETYLENE LAMP.

DISCUSSION.

MR. DICKINSON: I believe the lamps are now used in the Saginaw mine, on the Menominee range, for lighting instead of candles.

MR. LANE: In my use of the lamp the flame has been regular from the start to the time the carbide is consumed; the water is fed through the bottom of the carbide.

MR. UREN: How much carbide is used per shift in the lamps at the Saginaw mine? Mr. Dickinson stated that he had no figures.

MR. MCNAIR: My experience during the last fifteen months, I making tests of lights shows that where there is a deficiency of 16 or 17 per cent. less oxygen than normal atmosphere, where the miners' candle will burn low, the acetylene lamp burns as brightly, as far as ordinary observation goes, as it does in open air, which confirms Mr. Slaughter's statement.

Mr. Cole asked Mr. Hearding to give his experience in connection with lamps.

MR. HEARDING: We used quite a number at the Adams, in drifts, on account of bad air; we find the lamp will burn free where you cannot use a candle, and remain lit; they require a little attention by the miners in seeing that the water feeds properly to the carbide and outside of that there is no difficulty; they seemed to be satisfactory in lighting drifts where the air is particularly bad.

MR. SIEBENTHAL: I might say that we expect to use these lamps instead of candles in close places; we have none in use at present. The carbide costs about 5 cents per pound and about 2 cents per shift will provide carbide for one of these lamps.

MR. STOCK: They are used to some extent in the anthracite mines of Pennsylvania. The objection given by Mr. Hearding is the same there; the lamp requires to be picked out and kept clean. As soon as the men learn how to use them there does not seem to be any trouble.

MR. YUNGBLUTH: What is the cost of the lamp?

MR. SIEBENTHAL: About 75 cents each; of course you can get them in all sizes. This lamp will run about a shift, making allowances for the noon hour.

MR. VOGEL: At the New Jersey Zinc company they use these lamps. We went up in a 350 foot raise where the air was bad and the lamps gave good satisfaction. I was informed by the management that it costs them about 2 cents per shift for carbide.

THE STANDARD BOILER HOUSE OF THE OLIVER IRON MINING CO.

BY A. M. GOW, DULUTH, MINN.

Before considering in detail the plans of the standard boiler house of the Oliver Iron Mining Co. the conditions which it was designed to meet should be understood. In advance it was seen that a large number of boiler houses would have to be erected, and to avoid the labor and expense involved in a multiplicity of design it was important that some standard plan be adopted that would lend itself to the variety of conditions to be encountered at the various mines. In other words, while it was necessary to adopt a standard, the standard must have a great degree of elasticity and adaptability. The word "standard" as used in this connection does not mean "duplicate"; each separate installation presents its own peculiar conditions of location and size that must be taken into consideration, but certain features of construction and practically all matters of mechanical detail have been so standardized that the design of a new boiler house consists largely in assembling plans that have already been worked out. To begin with, it was necessary that the building should be such that it could be readily erected by available labor and be reasonably free from danger from fire; the boiler should be suitable for 150 pounds working pressure and of that type, which in the judgment of the chief engineer, was least liable to give trouble and could be maintained at least expense, while maintaining maximum efficiency; the setting should be adapted for use with from two to six) boilers in battery and capable of increase or decrease; the appurtenances must be as simple and as near "fool proof" as possible to make them; the entire plant must be of reasonable cost, thoroughly efficient and free from mechanical complications, and "frills," while fully able to bear criticism from the standpoint of good engineering.

At the outset, therefore, it is evident that the problem that confronted the engineer, Mr. H. J. Wessinger, was a very different one from that which presents itself when a central power station of from five to 20,000 horsepower is to be designed, with a lease of life supposed to be everlasting, the whole to be under the immediate supervision of a chief engineer with an abundance of skilled labor. The boiler house of the Oliver Iron Mining Co. is not to be judged by the standards applicable to such installations. It is essentially and primarily a boiler house adapted to the needs of the company. How well the plans have met the requirements may be judged from the fact that within the last six years about thirty boiler houses have been built, containing from two to six boilers each, and no essential changes made in the general designs. The members of the Institute will appreciate what a saving of time and labor in the engineering department has been effected by this system and how the work in the field has been facilitated.

This same system of standardizing working plans has been followed in the design of dry houses, oil houses, office and warehouse buildings, captain's offices, small machine shops and engine houses. As said before the word "standard" does not mean "duplicate." But in all these buildings a certain type of construction is followed, the details remaining the same, so that the work of designing a new building consists largely in assembling existing plans, already worked out, and adapting them to the new location.

The subject will be considered under the following heads: The boiler; the boiler setting; the fronts and appurtenances; the stack and breeching; the building, coal trestle and elevator; costs. All plates are reductions from working drawings.

THE BOILER.

The standard boiler is a 72"x18', horizontal tubular, with ½" shell, 9-16" heads, designed for 150 pounds working pressure. The specifications are practically those of the Hartford Steam Boiler & Inspection Co. somewhat condensed. The exact length over all is 17'-11-½" that 18' tubes may be used. Tubes are 4" Shelby steel, spaced wide in the center and away from the sides. A manhole is provided in the front head and four "4" through rods, upset at the front end and secured by inside and outside nuts, stay the heads below the tubes. The longitudinal seam is double butt strap, quadruple riveted, having an efficiency of 94 per cent. Upon the boiler are located three cast iron nozzles, faced and drilled for 1902 standard flanges; one 4" for feed and auxiliary steam connection; one 7" for main steam connection, and one 4" for safety valve. The blow off connection is a pressed steel flange threaded for 3" pipe. Special attention was paid to the matter of bracing the heads and 22 braces provided, carefully spaced, no brace to be less than 3'-6" long or less than 1" in cross section. Approximately 100 boilers have been built to these plans and specifications and no reason found to alter any of the details. The boiler is shown on Plate 1.

The question has often been asked why this type of boiler was adopted and not some approved type of water tube. It is not; within the province of this paper to discuss the relative merits of different types of boilers. Suffice it to say that it will not be admitted that, necessarily, a water tube boiler is a more economical steam generator than a horizontal tubular. The horizontal tubular can be set, removed and re-installed with much greater ease and economy than can a water tube, and this matter of removal is an important one, considering the life of the plants. The installations are, comparatively speaking, small, rarely exceeding four boilers to a battery and the matter of ground space is not one of serious moment. The objections raised to this type of boiler by the water tube advocates are the difficulty of cleaning, the liability to bagging and the danger from explosion. The water at the mines of the company is almost uniformly good; with good water and reasonable attention tubular boilers can be and are kept clean. As to bagging, the records show that with the hundreds of tubular boilers in use by this company, about one boiler, per hundred, per year, bags. Serious bags, which cannot be driven back and require either a new sheet or a patch, have amounted to less than one boiler in two hundred, per year. As to the danger from explosion, it will not be contended that this does not exist. Boiler explosions do occur and in the most unaccountable manner. By constant and careful inspection it is hoped to reduce this danger to a minimum. But the results from burst tubes in water tube boilers have been very serious according to the records of the insurance companies, which records do not show, by any means, that their losses are confined to horizontal tubular boilers. This company has in operation today about one thousand boilers. This includes firebox, marine, horizontal tubular and four different makes of water tube boilers. A fairly good opportunity is certainly afforded for judging of their relative merits. In all new plants the horizontal tubular is being installed.

THE BOILER SETTING.

The setting is shown on Plate II. Regardless of the number of boilers in battery this drawing is followed. It has been repeatedly used for batteries of from two to six. The boiler is supported upon lugs and is not suspended. This feature has been severely criticised, for as a rule, an advocate of the suspended setting can see no merit whatsoever in the supported setting. A first class, suspended setting is, no doubt, superior to a poor, supported setting, but it will not be admitted that there is anything inherently wrong in supporting a boiler upon lugs, resting upon the side walls. The claim that the walls of a suspended setting are less liable to crack and bulge than those of a supported setting is not borne out by experience. Walls that are heavy enough to reduce radiation to a minimum are abundantly strong to bear the weight of a boiler. Lighter walls are not desirable. Having provided heavy walls for the purpose of retaining the heat there is no reason why they should not serve the additional purpose of carrying the weight of the boiler. The advocates of the suspended setting place great stress upon the idea that it is almost impossible to make the four lugs bear equally, and as a consequence, unknown and torsional strains are introduced. There is some truth in this contention; but admitting that the weight on each lug is not equal it remains to be proven that the strains thus introduced are of any material consequence. The boiler is sufficiently strong to bear such torsional strains even if supported upon but two diagonally opposite lugs. The suspended setting does not lend itself readily to increase or decrease in the number of boilers in the battery, and this is an important consideration with the company. Take it all in all, the introduction of columns into the side walls and overhead supporting beams involves elements of cost and inconvenience which are wholly unnecessary and do not give adequate returns.

It will be observed that the distance from the grate bars to the boiler shell is 36"; that the bridge wall is low and merely serves to prevent fuel being pushed off the grates; and that there is no filling back of the bridge wall. It is not desirable that the flame should "hug" the boiler. The effect of the relatively cold boiler shell is to retard combustion and what is desired beneath the boiler is the most complete combustion obtainable. The heating surface of the shell is but 11 per cent. of the total heating surface. It is in the tubes that the heat must be absorbed and not through the shell. Combustion must be complete before the gases enter the tubes. Complete combustion is furthered by a large combustion chamber, a low bridge wall and a considerable distance between the grates and the shell. Rather than contract these dimensions it would be preferable to increase them.

The side walls are made heavy not with the expectation that all cracks may be avoided but that the loss of heat from radiation may be reduced to a minimum. The air space in the walls to a limited extent, allows the inner wall to expand independently of the outer wall. But a certain amount of cracking of the outer wall is to be expected; if the cracks are kept pointed, so that no air is drawn in, no harm is done.

In place of putting a single course of brick over the shell the masonry is leveled off to the top of the side walls, making the top of the battery as smooth as a ball room floor. This floor can then be kept clean and free from the rubbish that is so prone to accumulate on the top of boilers. The fire hazard is materially reduced thereby. Furthermore, when the fireman has occasion to go there he does not fall over loose planks. Valves and manholes are accessible. In addition, this mass of brick work reduces heat losses. As a matter of fact it is never uncomfortably hot on boilers set in this manner. It is not advisable that a space should be left between this brick covering and the boiler. In fact such a space is decidedly objectionable, so the first course is laid immediately against the shell thus effectually preventing the short circuiting of the gases with the consequent corrosion of the shell. The bottom of the ashpit is finished water-tight with cement below the level of the floor, and firemen are instructed to keep water therein. The evaporation serves to keep the grate bars cool. The use of live steam beneath the bars is considered as extremely wasteful and wholly unnecessary.

The boiler is set level. This is in direct opposition to the general practice of setting boilers high in front. The reason for settng level is that the flanges may come horizontal and taper joints be avoided. The only argument in favor of setting high in front is that scale and mud may drain to the rear. But the advocates of this practice only ask for an inch or an inch and a half in eighteen feet. It is not supposable that a slope of about one-sixteenth of an inch per foot, especially when the rear sheet makes a dam half an inch high at the center, can, to any appreciable extent, effect the currents of circulation along the shell. It is well known that the circulation establishes a current along the bottom of the boiler from the rear head forward. This frequently results in a deposit of mud and scale at the point where the heat is most intense, just forward of the bridge wall. That this current can be reversed and caused to flow in the opposite direction by so slight an inclination as one-sixteenth of an inch per foot is not reasonable. Owing to the expansion and contraction of the firebrick in the furnace there is a. slight tendency for a boiler to settle in front. That the boiler may eventually rest level there is no objection to a slight elevation at the start; but the idea that a boiler should be set high in front that scale and mud shall wash to the rear is believed to be erroneous and not borne out by experience. Even if it were so, the area that is effected when the blow off is opened must be a very limited one. Only the mud in the immediate vicinity is removed. Blowing off is necessary that the blow off pipe be kept open and also that a change may be effected in the water, but it is not and cannot be a substitute for cleaning, however high the boiler be set in front. The way to prevent bagging is to keep the boiler clean and it is not believed that this end is in the least hindered by setting the boiler level.

There are no air passages in the bridge wall; no attempt is made to pre-heat air before combustion; there is no “secondary air supply” to the combustion chamber. These are purposely omitted, because, while they are very pretty points to talk about it is not believed that they are of any practical utility. The question of the use of automatic stokers, shaking grates, and patented furnaces, has received due and careful consideration, but despite the claims of sales agents and reports of tests, with all of which the engineering department is very familiar, that department remains to be convinced that any economy, at all commensurate with the cost, would be secured by their adoption. It would have been an easy matter to complicate this setting; the attempt has been made to simplify it. The drawing has been used to set about 150 boilers and no reason found for changing it.

THE FRONTS AND APPURTENANCES.

The fronts are of the full flush type and considerably heavier than those usually furnished by manufacturers. Door joints are not planed but castings must be smooth and true. Grate bars are of the type known as the Kelly bar. They present the largest possible proportion of air space to surface. Two blow off valves are provided; a 3” asbestos packed plug cock and a 2½” brass angle valve. It is occasionally necessary to renew the brass seat but between the two valves no trouble is experienced from leaking at the blow off. The feed connection is somewhat novel; upon the front four inch nozzle is mounted the casting shown on Plate III, Fig. 1. The two inch feed line enters the top of this casting; a two inch nipple is screwed in from the underside and connects by an ell to a two inch pipe that runs immediately over the tubes to within two feet of the rear head; a tee is placed, on the end of this line that the feed water may be projected towards the side of the boiler and not against the back head. This casting is tapped at the side for a two inch pipe to supply steam to an auxiliary 4” line that furnishes steam to the pump and injector. This feature of an auxiliary steam line, independent of the main steam header, is a valuable one in mining practice in that it permits of repairs to the header without cutting off the steam to the mine pumps. The steam line leading to the shaft, in addition to being connected to the header, is always connected to this auxiliary 4” line. This arrangement of taking steam from the same connection that admits the feed water has been objected to on the grounds that the feed water has a tendency to cool the steam thus insuring a supply of wet steam to the pump. The condensing, or cooling effect of the few inches of pipe exposed cannot be but insignificant. Furthermore the steam to a feed pump is always throttled. The objection is not well taken. The arrangement is a most

convenient one and the feed pipe is much more accessible than if it entered the front head after the usual custom. To tap a feed pipe into the shell is not considered good practice as the breaking off of pipes so placed is abundant testimony. The desirability of feeding at the blow off will not be discussed here. We are not open to conviction on that point. The combination of feed and auxiliary steam line from one nozzle has proved very satisfactory. Plate IV shows the arrangement in plan.

The auxiliary steam line supplies the feed pump and injector which discharge into opposite ends of a cast iron manifold, having as many openings as there are boilers in the battery. The feed is regulated at the manifold and not at the boiler; but, in addition to the feed valve at the manifold, a 2" angle valve, for emergency, is placed on each boiler and the check valve located adjacent to it. This check is made flanged on one end so that it cannot be set to- open the wrong way. The feed water heater is of the open type and the large majority of those in use are of the Webster make. The only objection that can be raised to the open heater is the danger of getting oil into the boilers. The oil separator must be cleaned and care taken that the heater does not become foul. In none of the cases of bagged boilers was there evidence that the trouble arose from oil. Troubles from leaking tubes and deterioration of closed heaters are considered more serious than the clangers due to oil incident to open heaters.

It is the practice of the company to heat the mine buildings by the vacuum system, using exhaust steam. This effects an enormous economy in fuel. At many of the mines the power can be considered as costing nothing, for the buildings, if heated in the usual manner, would require as much fuel as, with the vacuum system, serves to supply both heat and power. Or to put it another way, the heating costs nothing, and were it not for this use of the exhaust steam it would cost as much as the power. The use of the vacuum system calls for a back pressure valve that shall release at a maximum of two pounds and at the same time prevent the inleak of air when the flow line is under vacuum. There are on the market a number of back pressure valves which will, presumably, answer the purpose fairly well with engines having a constant exhaust. But a hoisting engine has not a constant exhaust. At the beginning of a trip it may exhaust at sixty pounds and after a few revolutions at atmosphere. Under such conditions a poppet valve can do nothing but pound; and it pounds itself to pieces. It became necessary to design a back pressure valve that will not pound. The result was the Wessinger valve, that rotates on its seat after the manner of a Corliss valve. It does not pound or leak and the many in use are giving entire satisfaction. By means of a reducing fee, adjacent to the heater, a connection is always provided for the vacuum system. To supply the system and also insure a high feed water temperature a considerable quantity of exhaust steam is demanded. In a few installations it has been deemed advisable to disregard engine economy, to a certain extent, that the volume of exhaust might be sufficient to supply these demands. This is cited as an illustration of what was before mentioned, namely, that the criteria by which a large central power station might properly be judged are not applicable to the boiler houses of this company. This is in no sense an apology; merely an explanation.

With the exception of high and low water alarm on the water column, provided to conform to the state law and not because it is considered an essential, and an automatic float valve controlling the supply of water to the heater, there are no automatic appliances in the boiler room. Automatic pump governors, damper regulators, boiler skimmers and such like mechanical devices, designed to do the work of the firemen and water tenders, are not used. For those who like those sort of things no doubt those are the sort of things they like. The question of the use of superheaters has received some consideration and may receive more. Where line condensation, as in the case of underground pumps, is considerable, there is little doubt that initial superheating would effect an economy. But in connection with hoisting engines, where the flow of steam is intermittent, resulting in great variations of temperature in the superheating apparatus, the use of superheaters is something of a doubtful proposition.

Careful attention is given to the matter of steam pipe cov-vering. The only insulating material used is 85% plastic magnesia. It is applied two inches thick on all pipes up to seven inches in diameter and three inches on seven inch and over. This is expensive but the cost is materially reduced by having men at all the mines who can do a good job of covering. With this covering properly applied no hesitation is felt in running a steam line 1500 feet long, with expansion joints suitably located and pipes properly drained. It is an established rule, violated only in exceptional cases, that a steam line must pitch in the direction of flow. It is not conceivable that water can flow back along the bottom of a pipe against the velocity of the steam in the other direction. For this reason pipes pitch with the flow and to avoid water pockets it is the practice to use eccentric fittings where the diameter changes, that there may be no hindrance to the flow of condensation to the end of the line, where provision is made for trapping it off.

The size of the main header is determined by the number of boilers in battery but is always made larger than the total area of the pipes which it supplies. Thus it acts as a receiver and it is not the practice to use additional receivers on the lines. The header is connected to the boilers by curved pipes. Under no circumstances are stop valves placed next the boilers. They are invariably placed next the header. All valves, fittings and flanges, are extra heavy, cast iron, to the 1902 manufacturers' standard.

THE STACK AND BREECHING

The breeching is made from No. 8 sheet steel. A damper is provided in the smoke connection from each boiler but no main damper is provided in the breeching proper. That portion of the breeching which is exposed to the weather, between the boiler house and the stack, is most likely to need renewal. Consequently this section is made so that it can be readily removed by connecting it to the remainder of the breeching by an angle iron flange located just inside the boiler room wall. Upon the question of stacks the practice has, in general, been to use brick, where a long life was anticipated, and steel where the location was on ore or where the plant was, to a degree, temporary. The permanency of the brick stack and the fact that it does not need painting, are considerations in its favor. On the other hand the first cost of a brick stack is more than that of a steel stack, made from light tank plate and guyed. But the life of such steel stacks has been in many cases surprisingly short, not over six years. The question of the desirability of the two types is now receiving careful attention from the Engineering Department. It is not impossible that some design of concrete stack may be adopted as standard, but as yet none have been built for this Company. The self-contained steel stack, brick liked, "blast furnace style" as it is sometimes called, has been considered in place of the brick. It requires as much foundation as the brick stack and must be kept painted. These brick stacks are contracted, erected in place, upon foundations, all labor and material being furnished by the contractor. In two cases these stacks have been struck by lightning, but the damage was not material. Recent installations have been equipped with lightning rods. Plate III, Fig. 2, shows the stack in detail. Please note that there is no knob on the top. The primary purpose of a stack is to make draft. A knob does not assist the draft. That is why it is left off. Knobs are a matter of taste. No quarrel will be instituted with those whose tastes differ.

THE BUILDING.

The building is shown on Plates V and VI. The standard construction consists of a frame skeleton covered with sheeting, building paper and corrugated, galvanized iron, and veneered inside with one course of brick, between the studding. This construction is followed on nearly all the mine structures such as engine houses, dry houses, small machine shops, warehouses and captain's offices. Because of the fact that, winter or summer, buildings of this type may be erected by labor available at the mines and from material always readily obtainable, the construction has proved itself eminently adapted to the requirements. The wooden superstructure can always be framed and erected by the mine carpenters and then the work inside may be proceeded with regardless of the weather, and the corrugated iron and brick veneer put on when most convenient. The brick veneer materially reduces the fire hazard, makes the building much warmer and presents a neat and finished appearance. The brick are laid flush with the studding, so that the wall is smooth. Sheeting is laid diagonally, covered with building paper and finished with corrugated iron. The same weight of corrugated iron is used on roof and sides. It is customary to use heavier iron on the roof than the sides on most buildings but it was found that when the bundles of iron were opened the sheets were almost certain to get mixed. This is merely cited as one of the many small details that have been considered. As to the relative merits of galvanized and painted iron there is a difference of opinion among engineers. The experience of the Oliver Iron Mining Co. favors the use of the galvanized sheets and as yet the pitting of the sheets has not rendered painting necessary.

Plate VIII shows the design of the wooden roof truss. The wooden roof truss in a boiler house has been objected to on account of the fire risk. The members of this truss are heavy and the bottom chord is always placed well above the breeching. To reduce the fire hazard to a minimum the truss is kept well whitewashed. Steel construction has been considered for such buildings and may later, supplant the wooden standards followed up to this time. Considerations of first cost and convenience in the matter of erection, from the standpoint of both labor and material, led to its adoption. With the constantly increasing cost of timber and the constantly increasing facilities for obtaining and erecting steel structures it is possible that the design may be changed to steel construction. Plans and estimates have already been made on certain buildings that comparison may be instituted between the two types of construction. For all large buildings steel construction is used. In fact, the use of steel is constantly increasing in the mining business. Steel tram cars are taking the place of wooden ones. Steel head frames are being used more and more and on deep, permanent shafts, steel shaft sets and stuttles are in many cases substituted for wood. But for small mine buildings, where the necessity of following some standard practice is urgent, this brick veneered construction has proved itself to be very desirable.

The roof of the boiler house is always hipped parallel to the battery that extensions may be made if desired. For ventilation a monitor with wooden louvres is provided and upon recent Installations wire screen is put over the openings for the industrious sparrow finds the top of a warm boiler house a suitable place for nest building, using all the inflammable rubbish in the neighborhood.

The best way to get the coal within easy reach of the firemen is something of a problem. Overhead bins, filled by elevators and discharged by spouts, while admirable for large plants, present cost considerations out of the question in plants the size of these. At the same time coal storage for the winter months is absolutely necessary. The plan as adopted and in use on all new plants is shown on Plate VII. A coal trestle is erected alongside of the boiler house and in this connection it is well to remark the site of the boiler house is usually considered in connection with the possibility of getting a

trestle to it at proper grade. Upon the side of the boiler house are built bins that discharge coal within reach of the fireman's shovel. In summer time, when coal is being regularly received in drop bottom cars, the bins are kept full directly from the cars. The winter supply is stored between the bents of the trestle. At one end of the boiler house is a coal elevator, simply a platform raised and lowered by means of a steam cylinder within the boiler house. A coal buggy having been filled is run on the elevator, raised to the level of the bins, run into the house and emptied directly into the same bins that in summer receive their coal direct from the cars. There is no wheeling in of coal and dumping it on the floor. Having filled the bins the laborers are available for work elsewhere until the bins need to be filled again. The records of cost show a notable saving per ton by this method of coal handling.

At the back of the boilers is provided a trench, covered with cast iron plates, to receive the blow off pipe and exhaust pipes leading to the heater. It is considered very bad practice to locate the blow off pipe underground, or where it is not accessible. Furthermore the end of it should be visible. Steam and water coming from this pipe is the surest indication of leaking blow off valves.

Where the battery consists of but two or three boilers the engine room is, usually, built as part of the same building that houses the boilers, the two being separated by a brick partition wall. On larger plans the engine house is a separate building, of the same general construction that has been described.

COSTS.

A boiler plant, built to these designs, containing four boilers, brick stack, coal hoist, and everything complete, ready to raise steam, costs about $20,000.00. This does not include the coal trestle. From the estimates and actual costs on several installations the following cost sheet is made. It is assumed that the location Is such that convenient delivery of material can be made by rail; both labor and material are higher than they were a few years ago, when the same Installation could have been made for $19,000.00.

Excavations	$ 250.00
Foundations	2,200.00
Building	3,200.00
Boilers, grates, fittings	4,700.00
Setting, complete	3,000.00
Chimney	3,200.00
Pump, injector, heater	1,000.00
Piping and valves	1,800.00
Pipe covering	350.00
Coal hoist and car	700.00
Total	$20,400.00
Water tank, erected	700.00
	$21,100.00

An examination of many boiler houses might lead an observer to the conclusion that a boiler house was of necessity a dark, dirty, hot place, a sort of an inferno, where life for the fireman was a foretaste of the orthodox future. It is to be hoped that in going over the Mesabi range you will not receive this impression from an inspection of the boiler houses of the Oliver Iron Mining Co.

THE SAMPLING OF IRON ORES.

By L. S. Austin, Houghton, Mich.

Since iron ores are purchased according to their grade, that is according to their contents in iron, silica and phosphorus, it is necessary, in order to determine that grade, to obtain a sample representing the exact average of the lot or cargo which is to be purchased. This, accompanied by its gross weight and its percentage of contained moisture, enables us to determine its value. Since the grade of the ore depends upon the analysis of the dried sample, the percentage of moisture gives us the actual dry weight from which is estimated the net returns on the cargo, shipment or lot.

The literature on the subject of sampling is extensive and easily accessible,* and the subject has been thoroughly developed upon its theoretical or mathematical side. It would seem necessary in sampling the ores of iron, to consider simply the application of these principles to a mineral easy to accurately sample, and, the substitution in the general formulae of the known variations, would give the approximation to perfection which we would have a right to expect.

*Reed, School of Mines Quarterly III, p. 253, VI 351.
Brunton, Trans. A. I. M. E., XIII, p., 639.
Hofman, Metallurgy of Lead.
Peters, Modern Copper Smelting.
Richards, Ore Dressing.

It would be an exaggeration to say, as I have heard it said, that the older way of cargo sampling consisted in taking portions at the will of the sampling men, who would take them as they felt like it, and between the periods of rest needed to smoke a comfortable pipeful of tobacco. Were such a method followed it might even then chance to come out exactly, or in a correct average for that period. Still, why go even to that expense, and why not take a handful from each cargo under the idea that the true amount would be arrived at in accordance with the doctrine of averages. If the ore were in all parts of uniform grade, such a way might be good enough, but since iron ores can greatly vary, especially in phosphorus, such a method of taking might easily be wide of the truth.

In a paper, contributed to our proceedings four years ago by Mr. Separk,* and in a more recent one brought out by W. J. Rattle & Son** on cargo-sampling at lower lake ports, one is struck by the fact that the methods then used were defective in principle, since they did not represent the entire body of ore uniformly, and since, especially under the conditions which Mr. Separk described, the mixing of the ore from which the sample

was taken was imperfect. So far as mixing is concerned I will note the experience in the copper country in the sampling of their mineral. Here the South Range copper mines send their mineral, while in an imperfectly mixed condition to the Michigan Smelting Works, which, in their earlier experience, had trouble in getting duplicate samples to agree. Later, the method of receiving the material was modified by dropping the contents of the hopper-bottom railroad cars into a receiving hopper, this into a smaller hopper-bottom transfer car, and finally from this into the storage bin at which point the sample was taken. The railroad car was also loaded at the mill from a receiving hopper. Thus the mineral was mixed four times before the sample was taken, and this overcame the difficulty.

*Volume X, pages 103-126.

**Volume XI, pages 173-180.

One may infer from this, that by the time the ore is sampled at lower-lake ports the mixing has been well performed, and so true is this that the methods of W. J. Rattle & Son, imperfect in principle as they then were, still gave results which were not called in question.* In that method so much of the ore had been removed as to leave) what might be supposed to represent it on each side or face of the cavity. As the ore is shot into the hold it piles up, forming concentric layers, the lumps rolling to the exterior, and it is this portion that was not properly represented. We come finally to the conclusion, that if iron ore is to be sampled at all, it must be correctly sampled, and until we come to this there will always be uncertainty and dissatisfaction, both on the side of the buyer and of the seller. As Mr. Separk brought out the matter in his paper read before the Institute in 1904; "Sampling is the most important feature of this work."

When at Escanaba three years ago, the Institute witnessed the method of crushing the hard ore of the range through a large gyratory crusher, the product being delivered by a troughed conveying-belt to a receiving pocket and thence to cars which transfer it to the ore-docks, that is, it is crushed in transit.

Now let us suppose we desired to sample the ore: It would be at the point where it was about to be delivered to the receiving hopper, and where the ore has been spread out uniformly on the troubled belt, that it would be possible to take a sample so as not to interfere with the ore-handling and yet give a regular and reliable sample. To do this it would be easy to cut out by an automatic sampler, one-tenth of the ore-stream at the discharge end of the belt, the nine-tenths entering the receiving pocket. The sample would now be fed by a feeding shoe to another crusher, being there crushed and mixed, and then to a second sampler, which again takes out one-tenth; the rejected portion being at once returned to the receiving hopper. The running sample thus taken, in no way interrupts the delivery of the ore and its shipment as fast as crushed. The sample could now be treated in one of two ways: It may be allowed to fall upon the sampling floor in a heap (which mixes it) and may be put through crushing rolls, then through another sampler taking out one-tenth. This would give us, to complete according to any of the finishing methods, but one ton of sample from 1,000 of ore. Otherwise the ore, coming from the second sampler, may be sent over a feeding-shoe to rolls and then to a third automatic sampler. In either case this portion, a thousandth part of the whole is completed by the ordinary finishing methods.

*For the more recent method of sampling see Mr. Oscar Texor's description at the conclusion of this paper.

One would say, that while such a system of automatic sampling as above described, would be applicable to hard ore where the ore is to be crushed, it would hardly do for soft ores which need no crushing, and where one would wish to avoid the additional expense of so handling. On the other hand I do not doubt that such a plant, if carefully designed, could take care of the ore at but little additional expense per ton of ore handled, and above all both shipper and buyer could be sure of the precision of sampling, and the chances of uncertainty and disputes would be lessened.

Of sampling methods, coning and quartering, as commonly practiced, is defective. In this the ore is wheeled to and dumped in a ring upon the floor within which it is afterwards coned up. This ensures a mixing, but at the same time a segregation occurs owing to the coarser material (which may be of lower grade) finding its way to the perimeter of the forming cone. If it were possible to keep the apex of the cone truly vertical, and to spread it out symetrically from the center when completed, the opposite quarters would be truly representative of the whole, but, since this spreading or distribution is irregular, so is the consequent sample. A more accurate way is to reserve every fourth shovelful of the sample when shoveling it. This smaller amount, again crushed finer, can be worked down by means of a riffle until its quantity is so small that it may be finished upon the grinding plate.

The requirements for correct sampling ore

(1) Frequent taking.

(2) Progressive crushing.

(3) Proper mixing.

These conditions are fulfilled in the automatic sampling just described. It will be noticed that throughout the process all parts of the ore are equally represented; that the proper proportionate amounts of coarse and fine ore are taken; that the ore is sampled independently of the judgment or discretion of the men who do the sampling, and by which the personal equation is eliminated; and that it is done without interrupting the movement of the ore as it comes in. If experience should show that a smaller aliquot portion of the ore can be taken, the automatic sampling can be modified to suit the new conditions.

I would recommend that at first the sampling should be done in duplicate until the requirements for its exact

performance are known. This having been accomplished, the duplicated sampling can be omitted. This policy was pursued at one of our Western ore-treatment mills, where the ore was quite uneven or spotty, and where nevertheless the duplicate samples had to agree closely with one another.

In theory the moisture sample is to be taken at the instant of weighing and we are generally satisfied to take out a portion from time to time for a moisture determination as the weighing! proceeds. Several of these determinations combined give a fair average value of the moisture present. This sample is, however, less important than the one from which the chemical determinations are made. For all that, less attention is given to moisture determinations than should be. A result in moisture reported several tenths of a per cent. too high, makes just that much to be deducted from the returns on a cargo.

This brings one to the more radical idea, that is to one which would affect the arrangement and construction of ore docks and the handling of ore at them. Take for example the case of ore docks costing $600,000, and whose life even with constant repair would be some 12 years. The alternative, which I have known a certain engineering firm to propose, was to put in a more permanent structure involving the storage of the ore in stock-piles, and the reclaiming of it for delivery to comparatively light but permanent shipping pockets, the installation to cost but half as much, for the same capacity, as the present docks. Under such a system where the ore is being rehandled to go to the pockets it may be automatically sampled as already specified. While to me this method seems feasibe, it is quite possible that it has been, so far as the storage method is concerned, gone over and rejected. The general methods involved are not in themselves new, and they have elsewhere been put in practice. Whether they would do well on the large scale here demanded is a question. There is a natural conservatism and the desire of working along well-tried lines, which is against a radical change. Still one of the large companies could begin in a tentative way after the study of existing methods already worked out, and with the aid of those who have solved the problem under different conditions.*

The engineer engaged in construction keeps busy at his works and has (or thinks he has) but little time to leave it to (observe methods elsewhere. He should make the effort and take the time to see what is being done. The yearly trips of the Institute illustrate the benefit of so doing.

*I would note among reclaiming plants
The Garfield plant of the American Securities Co. at Garfield, Utah.
The Greene-Cananea plant at Cananea, Sonora, Mexico.
The South Chicago plant of the Illinois Steel Co.
Stocking and reclaiming systems of the Semet-Solay Co. at Milwaukee and South Chicago.

(Through the kindness of Mr. Oscar Textor, of Cleveland, Ohio, the secretary is enabled to add to this paper a brief description of the standard methods for sampling cargoes of iron ore at lower lake ports as adopted by the independent chemists for the season of 1907. This is published herewith in order to give the members all the information possible in preparing for discussion on this subject).

STANDARD METHOD FOR SAMPLING CARGOES OF IRON ORE AT LOWER LAKE PORTS, 1907.

A continuous sample shall be taken from all cargoes, thus insuring a large mechanical sample, the weight of the sample varying with the size of the cargo.

The samplers shall begin sampling as soon as the vessel begins unloading, and shall continue sampling until the cargo is unloaded. The sampling of each hatch shall be begun shortly after its unloading has begun, and the ore in each hatch shall be sampled as the unloading progresses at such intervals of time as to correspond with at least four distinct stages of unloading, and the ore shall be sampled at regular measured intervals over the surface exposed so as to represent practically all the ore in each hatch. The sampling shall be done in the hold of the vessel, except at times when conditions make sampling in the hold dangerous and unsatisfactory, in which case no more than one-fourth (34) of the total sample may be taken from the cars. No sampling shall be made from the original outside surfaces of the ore nor from the stock-pile.

Beginning at a convenient point, one full scoop of ore shall be taken in a standard trowel at each point sampled, and these points shall be at regular measured intervals, which shall be of a length eventually to be determined by our experience in the early part of the season. When a lump is encountered at the point from which the scoop of ore should be taken, a portion shall be broken off equal in amount to the fine ore taken in the scoop. As in sampling hard lump ores a scoop cannot be used, small pieces must be broken off with a hammer. Although the number of points sampled will remain the same, the amount taken at each place sampled will be so much less that the total amount taken from the cargo as a sample will be necessarily smaller than in the case of soft ores.

This method of sampling shall be continued at regular intervals of time during the process of unloading, i. e., the samplers shall work continuously. The sample must be carefully protected during the sampling and must not be quartered until the sample is complete, but it may be prepared for quartering by breaking up the lumps. The sample may be quartered down on the vessel or may be taken to some other suitable place for that purpose. Samples must be shipped to the crushing plant in standard cans.

In sampling cars, the sampler shall sample from one end of the car to the other, taking full scoops of ore at regular intervals not less than one yard apart as described above.

The moisture sample shall be a separate sample and shall be taken when the vessel is half unloaded. It shall

be taken on lines midway between the side and center of the boat on both sides of the center line of the vessel by the same spacing method. This sample must be taken wholly from fresh surfaces of ore that have not been exposed to sun or rain. It must be thoroughly mixed at once after it is taken, quartered down, and twenty pounds placed in a standard moisture can with tightly fitting cover and shipped without delay, or the moisture may be determined at the port where sampled, where proper facilities are provided. Every hatch must be represented in the moisture sample. The total moisture sample shall be weighed accurately, dried at 212°F., till the weight is constant, weighed again, the loss in weight representing the moisture in the cargo on arrival.

The above directions must be adhered to, day and night during the unloading of each cargo.

The following references are given to previous papers which have been presented to the Institute and to which reference may be made in the preparation of discussion:

Subject.	Vol.	Page.
Distribution of Phosphorus and System of Sampling at the Pewabic Mine, Michigan, by E. F. Brown, 1895...	III	49
Methods of Sampling Iron Ore, by C. T. Mixer, 1896....	IV	27
Some Aspects of the Analyzing and Grading of Iron Ores of the Gogebic Range, by Edward A. Separk, 1904..	X	103-126
Methods of Iron Ore Analysis Used in the Laboratories of the Iron Mining Companies of The Lake Superior Mining Region, by W. A. Siebenthal, 1905.....	XI	71-138
Cargo Sampling of Iron Ores at Lower Lake Ports—Including The Methods Used in the Analysis of the Same, by W. J. Rattle & Son, 1905.....	XI	173-180

BIOGRAPHICAL NOTICES.

The following paragraphs comprise such information as your biographical committee has been able to obtain concerning the lives of prominent men, now deceased, who have taken an active part in the development of the Lake Superior country. The data here given has been secured from sources which we consider reliable,

J. H. HEARDING,
W. J. OLCOTT,
GEO. A. NEWETT,
J. B. COOPER,
Biographical Committee,

JOHN HARRIS FOSTER.

Born at Erie, Pa., May 29th, 1822. Studied engineering, and went to work as civil engineer in 1844. Came to Lake Superior region in 1846, and left there in 1849, to go as assistant engineer on survey of Mexican boundary. After finishing this work he went to Alta, California, remaining there until 1855, when he returned to Detroit, and entered employ of United States government on survey of great lakes. Was married in 1855 to Martha Mullitt. In the fall of 1860, he was appointed superintendent of Pewabic and Franklin mines in Houghton county, and managed these institutions for five years. In 1864-5, was chosen to represent the upper peninsula in state senate. In 1874, on account of poor health and a crippled leg, be returned to his farm near Lansing, Mich., where he remained until his death, June 15th, 1894. He was a member of the Michigan Pioneer society and contributed a number of papers to its publication.

SILAS W. GOODALE.

Born in 1844 at Olean, N. Y. Entered army during latter part of civil war and was wounded. Was admitted to bar at Detroit about 1868. Practiced law first at Detroit, and then at Saginaw, Mich. Later he became court reporter, and was occupied as such for 32 years on the upper peninsula. He died May 4th, 1908, at Houghton, Mich. Though not connected with the mining industry, he was widely known and highly esteemed by the mining men of the upper peninsula.

WILLIAM H. HEARDING.

Born in 1827 at Adderbury, England. Came to United States in 1847, settling at Pontiac, Mich. On survey of great lakes from 1857 to 1864. Went to northern peninsula of Michigan in 1864, and acted as engineer for Quincy, Franklin, Pewabic, and South Pewabic, (near Atlantic) mines. Returned to the employ of United, States government in 1867, and remained on harbor improvement work until his death in 1893. Mr. Hearding was engineer for Edwin Hulbert in locating surface outcrop of Calumet & Hecla mine.

GEORGE HAYDEN.

Born in Charlotte, Eaton Co., Michigan, October 23rd, 1850, was educated in this state and graduated from the law department of the Michigan university in 1871. In 1873 he came to Ishpeming where he resided until his death, during this time building up a lucrative practice in his profession, representing some of the largest interests in the district and taking prominence in educational and other public institutions. It was largely due to his efforts that the Lake Superior & Ishpeming railway was built and at the time of his death he was president of the Fort Smith and Western railway, a line running westward from Fort Smith in Indian Territory. Mr. Hayden at the time of his death was a member of the board of school trustees of Ishpeming, a position in which he was of great help to the schools and where he worked faithfully to improve the tone of Ishpeming's educational interests. He served Marquette county as its prosecuting attorney in 1885-6, making a record for good service which is still well remembered by the people. He was also city attorney of Ishpeming for several years. He was a 32nd degree Mason and a member of the local Blue lodge, the Commandery and Mystic Shrine of Marquette, and the Consistory of Grand Rapids. Mr. Hayden's death occurred in Chicago on Wednesday, July 23rd, 1902, where he had gone to undergo an operation for some internal trouble. He was of a happy disposition, fond of out-of-door sports, took great delight in accompanying his children on long walks over the hills and sharing the pleasures of the camp fire with his family and friends.

DOUGLAS HOUGHTON.

Born in Troy, N., Y., Sept. 21st, 1809. Graduated from Van Rensselar school, N. Y., 1828. Soon appointed professor of chemistry and natural history in the same school. In 1830 he was appointed by General Cass and Major Whiting of Detroit to lecture on chemistry and geology in Detroit, thus bringing him to Michigan. Appointed surgeon and botanist for Schoolcraft's expedition to source of Mississippi in 1830, by secretary of war. During the next 15 years was elected mayor of Detroit twice and was offered the presidency of Michigan university before he was 30 years old. Appointed state geologist in 1837. As such he made many discoveries concerning the mineral bearing formations of the upper peninsula and especially those of the copper bearing series. On such an expedition he lost his life while attempting to get to Eagle river in an open boat on Oct. 13, 1845. His distinction lies in being the first scientific investigator of geological conditions in the tipper peninsula.

WALTER M. JEFFERY.

Born in Humboldt, Michigan, April 12th, 1871. When 2 years old the family moved to Negaunee, Michigan. In June, 1889, he graduated from the Negaunee high school. In the fall of 1889 he started to work in the office of the Queen mines, under Mr. Cole's management,

mines being owned by Schlessinger. In 1891 the mines were purchased by Corrigan, McKinney & Company. He was with them until the spring of 1894, when upon Mr. Cole's advice, he went to Hibbing to take a position at the Mahoning mine with Mr. Agnew, staying there until September, 1894, when Corrigan, McKinney & Co. again wanted him to enter their service in the home office at Cleveland, which he did in the fall of 1894, staying with them until December, 1897, when he again acted on Mr. Cole's advice and went to Milwaukee for the Oliver Iron Mining company. He remained in the Milwaukee office as chief clerk until December, 1899, when he went to Pittsburgh as assistant auditor for the Oliver people. In June, 1900, he was made auditor of this company. Died in May, 1906.

SAMUEL MITCHELL.

Born in Devonshire, England, in 1844. Came to America in 1862 and began working at the Phoenix copper mine and later with the Madison Copper company. After which he worked successively with the Calumet & Hecla, the Cliff, the Saginaw, and many other mines both iron and copper, advancing gradually to positions of importance. He sank the first sand shaft in the Lake Superior district at the Negaunee mine, which property was operated under his personal supervision several years. During the years intervening between 1886 and 1890, he was chief factor in the development of the Montreal River Iron Mining Co., on the Gogebic range, and in 1887 he also became largely interested in the Jackson Iron Mining Co., becoming' its president and general manager. He was interested in a number of banking institutions, including the First National of Negaunee, the Miners of Ishpeming, and at various times was interested in the First National of Marquette, First National of Hurley, First National of Escanaba, and Lincoln National of Chicago. He was also interested in some of the mining ventures on the Vermilion range. He died in Chicago, May 12th, 1908.

DONALD M'VICHIE.

Born in 1847 at Lanchester, Glengarry Co., Ontario, Canada, where he passed his boyhood days, coming to the upper peninsula of Michigan when 21 years of age and settling at Munising where he secured employment in the old Munising furnace, then in operation. In 1871 he came to Ishpeming, securing employment at the old New England mine under S. S. Curry, who had charge of the property at the time, remaining in Ishpeming for a couple of years. In the early days Mr. McVichie gave some attention to politics, holding several offices of trust. In 1878 he was chosen marshal of the city, filling the position most efficiently for six years. Upon the election of Graver Cleveland to the presidency for his first term, he appointed Mr. McVichie revenue collector for this district. During Cleveland's second administration, he was made postmaster, holding the office for four years. Mr. McVichie was a staunch gold democrat, one who firmly believed in the principles of his party and would listen to none of the isms of the later day illusionists. Besides being the active head of the Marquette County Telephone company and the Anthony Powder company, he was also vice-president of the Miners National bank and also held a seat on the directorate of the institution. Mr. McVichie was also a 32nd degree Mason. He was taken ill in the fall of 1905 with dropsy of the heart in a mild form but his condition gradually grew worse until his death September 14th, 1906. He was a true friend, a fair fighter and a man in the strictest sense of the term.

HARLOW OLCOTT.

Born in Hunts Hollow, N. Y., December 2nd, 1821. Educated in Nunda Valley college, N. Y. In 1842 he came to Salena, Mich., and studied medicine for two years. In 1843 he married Elizabeth Fifield. From 1844 to 1867 was principal of schools in Salena and Detroit, Mich. In 1867 he came to Marquette, Mich., as superintendent of schools, remaining until 1877 when he took a similar position at Ishpeming, Mich., resigning from that place in 1894. He then removed to Ann Arbor, Mich., where he died in April, 1901. Though not connected directly with the mining industry, his influence as an educator extended throughout the entire upper peninsula, where he was very widely known and greatly respected.

AMOS SHEPHARD.

Born at Linden, Wis., May 5, 1861. During his childhood he had limited advantages, working during the summers hauling lead and zinc ore from Linden to Mineral Point, from where it was shipped. He worked in this way until 1878, when he applied and received a teachers' certificate, W. A. Jones, who afterwards was commissioner of Indian affairs was county superintendent at the time. He again entered school, going to the State Normal at Plattville for ten months, which ended his educational advantages. On his return home he again labored in the mines at Linden, until the fall of 1879, when he taught school in a district near Linden. In the spring of 1880, he went to Quinnesec, Mich., and secured employment in the mine at that point as a miner. Being a good penman, he was soon made timekeeper by Capt. N. Cowling. By hard and efficient work, he arose from timekeeper to head accountant at the Quinnesec mine, where he remained until 1884, when he moved to Tower, Minn., taking the position of head accountant for the Minnesota Iron Co., under Capt. E. Morcome, superintendent. This position he held until January, 1889, when he was elected register of deeds, St. Louis Co., and moved to Duluth. He continued in office for six years, at the end of which time, he refused re-election and accepted the position of under sheriff for two years. During the years 1897-8, he traveled extensively in old Mexico; and the western states. He was then appointed, by Jos. Sellwood, superintendent of the Cuff mine at Iron Mountain, Mich. He remained there for about two years and was then transferred by Mr. Sellwood as superintendent of the Atlantic mine at

Iron Belt, Wis. About January, 1902, he entered the employment of Corrigan, McKinney & Co., with headquarters at Hibbing, Minn. Subsequently the old range mines of that company were put under his charge. He remained in this position until his death, June 6th, 1905. His jovial disposition, keen sense of humor, and fund of anecdote made him one of the most popular members of the Mining Institute.

JOHN STANTON.

Born in Bristol, England, February 25th, 1830, came to Pennsylvania in 1835. Studied engineering and managed his father's iron mines at Dover, N. J., up to 1852, when he became interested in copper mining in Tennessee, Maryland and Virginia. In 1861 he turned his attention: to the richer Lake Superior mines and particularly the Atlantic mine, then the South Pewabic, which he developed to a paying mine though the ore was considered very low grade. He was connected with several mines opened at a later date and especially with the exploration of the newer and successful South Range mines. At his death he was president of the Baltic, Michigan, Mohawk, Winona and Wolverine companies and director of the Atlantic and Copper Range Consolidated companies and the Michigan Smelting company, and was interested in some properties in Arizona and British Columbia. He was one of the founders of the old New York Mining Exchange in 1876. Executive officer and statistician of Copper Producers association about 1890, remaining as such until its abandonment, also connected with the Trimountain Mining Co. He died in New York, February 23rd, 1906. Mr. Stanton was greatly admired and respected by all his associates as being an honest, conscientious and able man.

WILLIAM THOMAS.

Born in Cornwall, England, April, 1858. He came to America and settled at Negaunee, Michigan. Moved to Ironwood, Mich., in 1886. Was a miner, shift boss, and night captain, in succession at the East Norrie mine. Later he was appointed captain of the Aurora mine, and while acting in such capacity he was shot and killed by an Italian whom he had refused work, Jan. 6th, 1908.

JAMES H. TREBILCOCK.

Born on the 21st of May, 1848, at the village of Ashton, parish of Breage, in the county of Cornwall, England. He was the third son of Mr. and Mrs. William Trebilcock. He came to Ishpeming direct from his native country in the summer of 1868 and resided at Ishpeming continuously until his death. In 1880 he was appointed mining captain of the Lowthian mine, one of the properties owned by the Lake Superior Iron company. Later he took charge of the Lake Superior Hematite and Section 16 mines as mining captain and held that position for about 20 years until a short time before his death. He was one of the best informed men on mining matters in the upper peninsula and was a most conscientious and careful mining captain in the care of those in his employ. In politics Captain Trebilcock had always been a faithful republican and took a deep interest and part in local and national affairs. He served the city of Ishpeming as supervisor, alderman, member of board of education, and mayor, filling these offices with conscientiousness. He was an active member of the Knights of the Golden Eagle, the Sons of St. George, and of the Independent Order of Odd Fellows and of the Lake Superior Mining Institute. He died October 19th, 1901.

WILLIAM TREBILCOCK.

Born on April 24th, 1845, at village of Ashton, parish of Breage, Cornwall, England, and died October 15th, 1905, at Falmouth, England. He commenced working in the mines of his native place at a very early age and continued to do so until the spring of 1866. In April of the year 1866 he decided to go to the United States and in the early part of May left his native land and went direct to the copper country where he found employment at the Cliff mine, remaining there for about a year; he then came to Ishpeming and worked at the Cleveland mine for about three years; leaving Ishpeming he went to the mines of New Jersey, later going West to the mines of Idaho and Oregon; after an absence of a year or two he returned to Ishpeming and was employed at the Lake Superior mine where he did considerable contract work and held other important positions. In the year 1872 he accepted the position of mining captain at the Norway mine, Norway, Mich. The following year, on account of a change of management, he resigned and accepted a similar position with the Lumbermen's Mining Co., and was mining captain of the Ludington and Stephenson mines of the above company. He was next induced to take charge of the operations at the Curry mine and remained there until influenced by the late Jeff Day, then superintendent of the Metropolitan Iron & Land Co., resigned and accepted a position under him at the Metropolitan mine on the Felch Mountain range which position he held until operations were practically suspended. In the spring of the year of 1885 he went to the Gogebic range and took charge of the mining operations which developed the Norrie, East Norrie and Pabst mines of the last named company and continued in the employ of this company until it sold its interests to the Oliver Iron Mining Co. Many important mining positions in different parts of the country were offered the captain after this but he could not be induced to accept any of them, he having made up his mind to retire from active mining pursuits. He returned to England in the year 1900 where, a year or two later, he met with an accident which developed a complication of diseases to which he succumbed Oct. 15th, 1905.

FRANCIS W. ANTHONY.

Born at Stockton, Mass., May 2nd, 1827. Came to lower peninsula in 1845 and to upper peninsula in 1847. Located at Ontonagon river. Was superintendent of

surface at the Michigan mine for a time„ and subsequently built a military road for the United States government from Green Bay to Copper Harbor, receiving land grant for same. In 1882 settled on a farm about a mile from Hancock, Mich., and died there March 29th, 1908.

GIDEON TREVARTHEN.

Born in Cornwall, England, 1859. Came to America in 1869, settled in Humboldt, Marquette county, attended public school there and worked in the old Edwards mine as a miner, from there went to the Champion mine, and following the same occupation, from there went to Florence, Wis., and worked in the foundry then run by the Marinette Foundry & Machinery Co. Then served his time at the machinists trade, from there went with the Florence Mining Co. as master machinist. He remained with them until 1896, when he met with an accident in removing some machinery, and from the effects of the same he died, leaving a wife and three children, one son and two daughters. His son is now with the Tennessee Coal & Iron Co., as mining engineer, at Birmingham, Ala.

DANIEL D. BROCKWAY.

Born at Morristown, Vt., May 2nd, 1815. In childhood he moved to Malone, N. Y. He moved when a child to lower Michigan and as far west as Chicago, finally settling in Washtenaw county, Mich., in 1831. He was married at Galesburgh, Mich., Jan. 21st, 1836, to Miss Lucena Harris and then returned to Malone, N. Y., with his bride. His brother, W. H. Brockway later secured him the position of mechanic in the Indian reservation at Keweenaw bay, which position he at once accepted and started for the northern peninsula April 14th, 1843. From the Soo Portage they took the brig "John Jacob Astor" on August 4th, arriving August 8th, 1843, at L'Anse mission. Their first mail was received eleven months later by the schooner Chippewa. Mr. Brockway remained for three years at Keweenaw and leaving the Indian mission left by canoes with his wife and three daughters for Copper Harbor, arriving there May 3rd, 1846. During Mr. Brockway's stay at Keweenaw, a daughter was born and given the name of Sally, (now Mrs. S. L. Scott of Lake Linden), who was the first white child to be born and reared on Lake Superior. Two other children born on the Indian reservation died or left the country at an early age. Mr. Brockway immediately settled permanently on Copper Harbor and opened an hotel at which place almost all of the early explorers and settlers stopped and by whom he was well known. In 1849 he was placed m charge of the old North West mine, later the Delaware. In 1851 he forsook a small salary and returned to the hotel, and was appointed postmaster of Copper Harbor the same year. In 1863 he sold his boarding house and erected a private dwelling for his own use, doing some prospecting on his own account until 1858 when he went to the Isle Royal mine on construction work. In 1859 he was appointed state road commissioner by Governor Wisner, and was reappointed in 1861 by Governor Blair, commissioner for Mineral Range state road. In 1862 he moved his family into the Phoenix hotel at Eagle River and contracted for the hauling of copper and supplies from the Cliff mine. In 1863 he returned to Copper Harbor and entered the mercantile business for about three years. In 1867 he returned to the Harris, near Kalamazoo, in an attempt to retrieve his fortunes. Not meeting with success he returned in 1872 to the Cliff mine and again engaged in the mercantile business with his son Albert. In 1878 he bought a controlling interest in the Atlas mine and operated it in company with others. In 1879 with John Senter, Capt. Dick Uren, and Wm. and John Edwards, he made a trip to the Black Hills and acquired the Bismarck and Fairview claims, suffering a great deal of hardship on account of meeting with a severe blizzard. On the death of O. A. Farwell in 1881, he was appointed agent of the Cliff mine and remained as such until its sale to the Tamarack company in 1892. In 1895 Mr. Brockway bought a home at Lake Linden and retired from active life, after 50 years of activity in the Lake Superior region. His wife died on March 2nd, 1899, and blind and helpless he followed her on May 9th, the same year. Thus for 56 years, Mr. Brockway had been almost a continuous resident of the northern peninsula and had done much towards its development in many ways. His hospitality was well known by almost all of the early men on the peninsula.

WILLIAM A. BURT.

Born in Worcester county, Mass., June 13th, 1792. Moved to New York in 1792. With but little education he mastered surveying, as then known. Moved to Erie county, New York in 1809. Served in the war of 1812. In 1813 married Phoebe Cole. Came west in 1817 to St. Louis, and to Auburn, Michigan in 1822. In 1833 he was appointed United States deputy surveyor, and commenced work in lower peninsula. In 1835 he invented the solar compass. In 1844 he discovered iron ore in town 47-27 West in E. line. In this party were Jacob Houghton, Wm. Ives, H. Mellen, R. S. Mellen, James King and two Indians named John Taylor and Michael Doner. Mr. Burt was a man of high inventive faculties and almost completed his equatorial sextant previous to his death on August 18th, 1858. His discovery of the iron bearing formation was really the beginning of the iron ore mining in the upper peninsula.

WILLIAM EDMUND DICKINSON.

Born in New York city, May 31st, 1824. Admitted to bar of state of Connecticut in 1844, and practiced law until 1846. For the next three years, he sailed on a whaling vessel, returning in 1849, at which time he married Delia E. Welch, of Litchfield, Conn. Owing to his wife's ill health, he decided to locate in the northern peninsula of Michigan. He located at Ontonagon, and had charge of the Bohemian and other mines in that county, and in Houghton until 1865. During this time his wife died. In 1865, he moved to Rockey Bar, near Boise City, Idaho,

to develop a gold and silver claim for Jos. Hanna and others. In 1867, he returned to New York and married Elizabeth S. G. Sargent, of Boston, Mass. In 1870, he returned to Lake Superior and took charge of the New York mine at Ishpeming, Michigan, for Samuel J. Tilden and others. In 1881, he moved to Commonwealth, Wis., and was superintendent of the Comomnwealth mine for Tuttle Bros., until 1889, at which time he moved to Bessemer, Mich., to take charge of the Colby mine for Charles Colby. In 1892-3 he went to Daquire, Cuba, to develop the Spanish American mines near Santiago, for the Colbys, under Mr. S. P. Ely. He left this place on account of the unsettled conditions of the government and returned to the United States in 1896, settling in Florence county, Wis. From that time until his death, June 15th, 1899, he was general agent for the Aetna Powder Co. Mr. Dickinson's connection with the mining industry was long and varied, and he won the esteem and affection of all who were brought in contact with him, by his many sterling traits of character.

JEFFERSON D. DAY.

Born in Chatauqua county, New York, March 15th, 1840, and died at South Lake Linden, Houghton county, Michigan, December 5th, 1895. He came to the copper country of Michigan in 1864, being employed as a surface foreman at the mines in the vicinity of Hancock for two years, followed by two years' service at the Calumet & Hecla mine. In 1868 he went to Marquette county, and for eleven years held positions of trust and responsibility with the Lake Superior Iron company, resigning the position of assistant superintendent in 1879 to go with the Menominee Mining company as assistant superintendent for Dr. Hulst. Mr. Day became identified with the Metropolitan Iron & Land Co. in 1882, when the company was operating at Felch mountain, in what is now Dickinson county, Michigan, and remained with that company until his death. In 1885 lie was appointed superintendent, and when the company transferred its operation to the Gogebic range he was appointed general superintendent of its extensive interests at Ironwood, which included the Norrie, East Norrie and Pabst mines. His connection with Ironwood dated from the beginning of the town and he was prominently identified with, the movements which resulted in the creation of the county of Gogebic out of territory detached from Ontonagon county and the incorporating of the village and finally city of Ironwood. Mr. Day was married to Miss Jennie Hague at Hancock, Mich., in 1868, whose father, Thomas Hague, was one of the early pioneers of that place. An interesting occurrence in his life was his driving with Capt. Nat Moore from Ashland, Wis., to the exploration, now the Colby mine, in the spring of 1884 or 1885. On his recommendation Mr. Chas. L. Colby began the development of the mine.

JOHN DUNCAN.

Born in Argyleshier, Scotland, in 1835, and came with his parents to Canada in 1842, at the age of 7. Learning the carpenter trade, he was employed on railway construction work in southern Michigan up to the age of 23, when on account of contracting malaria, he moved to the northern peninsula. He obtained employment first at the Quincy mine in 1859, as carpenter foreman, then as surface captain, and worked as such for nine years. He then went as surface captain and assistant superintendent to the Calumet & Hecla mine in 1868, in charge of all surface work and also of all lands owned by the company, which position he held until his death, June 5th, 1904. Mr. Duncan was one of the best known men in the Lake Superior region. His charity, patriotism and unselfishness won him the esteem of all who knew him, and made him one of the prominent figures in the upper peninsula for years. He was an active worker in fraternal societies and an ardent republican in politics. His prominence as a mining man won him the presidency of the Mining Institute in 1895.

PETER WHITE.

Born at Rome, N. Y., October 31st, 1829. His family moved to Green Bay, Wis., in 1841, and he ran away from home in 1842 at the age of 13, going to the Island of Mackinaw. Here he worked for two years for Edward Kanter, a storekeepeer, and also on vessels coming into Mackinaw. On one occasion he fell, breaking his arm badly while unloading a boat at Bay City, Mich. In 1844 he was employed by Capt. Augustus Canfield as timekeeper on the government work constructing Waugoshance lighthouse. In 1849 he went with Robert J. Graveraet to the present site of Marquette, and felled the first tree when the first clearing was done. In 1850 he was in charge of the store for the Marquette Iron Co., and in the winter of 1850 and 51, he carried the mail to L'Anse, making nine trips on snow shoes. In 1852 he was appointed postmaster of Carp River, it being the first postoffice of Marquette, and which was afterwards changed to Marquette, holding the office until 1864. In July, 1852, he wrote the first bill of lading for six barrels of iron ore, the first shipment of ore made from the northern peninsula. During the year 1855 he was placed in charge of the management of the lands of the Marquette Iron Co., and from that beginning he became interested in the real estate business and remained more on less interested until his death. In 1856 he was elected to the state legislature, and walked most of the way to Lansing to attend the session. He was appointed collector of customs and also studied law, and was admitted to the bar in 1857. In 1857 Mr. White married Miss Ellen S. Hewitt of Marquette. He also named the town of Ishpeming. He had been interested in a private banking enterprise which in 1862 he incorporated into the First Nation-al bank of Marquette, Samuel P. Ely, of Marquette, being elected president and he cashier. In 1872 he built at his expense the public library of Marquette and dedicated it to the city. He was elected in

1875 to the state senate. He also secured the passage of the measure in congress that gave to Marquette the beautiful public park at Presque Isle. In 1900 the University of Michigan conferred the degree of LLD. upon him, and in 1902 the same institution made him one of its regents. In 1904 a new library building was erected in Marquette and named after him. He died June 7th, 1908. The history of the iron ore industry of the Lake Superior region is written in his biography, "The Honorable Peter White" and he stands as the foremost character developed in the northern peninsula of Michigan.

PHILO MARSHALL EVERETT.

Born in Winchester, Conn., October 21st, 1807. When a young man he moved to New York state and lived for a number of years in Ulster and Oneida counties. He was married in Utica, N. Y., and lived for a time afterward in Kingston. During the time he lived in New York he had a contract for making cement for the original Croton water works project, and later had a contract for the construction of a section of the Erie canal. In 1840 he moved to Michigan and with his wife and one child drove from the then end of the Michigan Central railroad at Ann Arbor to Jackson, Michigan, where he settled. He lived at Jackson, Michigan, until about 1845, conducting a mercantile and wheat commission business. As was the case with most of the early settlers in Michigan, he suffered a great deal with ague and chills and fever, which very seriously affected his general health and resulted in a long fit of sickness which affected his eyesight to such an extent that for about a year he was totally blind. He finally recovered his eyesight, however, so that he could get about and do ordinary business, but for the balance of his life his eyesight was very poor. In 1845 he and his brother-in-law, Charles Johnson, were both in poor health and their physician advised them to go to the upper peninsula. At this time the village of Copper Harbor was attracting much attention as a great mining town and wonderful stories were told of the richness of the country. They finally concluded to go to this place. While at Sault Ste. Marie looking for guides and boats to proceed up the lake, he met an old squaw, a member of the Chippewa or Ojibway tribe, who told them of a rock or mineral, which was too hard for the Indians to use, but which she thought the white men, with their wider experience, might make use of. She described the place where to look for the rock, which was near the Carp river, which empties near the city of Marquette, and gave them the directions and distance from the mouth of the river they should go, to a place where they would find some pieces of copper buried under the leaves at the foot of a large pine tree, and near this pine tree they would find the hard rock. They finally got their guides and boats and coasted up the shore in a so-called mackinac boat. On reaching Marquette they found that the spot described by the old squaw was on the hunting ground of Marji Gezicks, who happened to be then at L'Anse for the payment of the government bounty or assistance which was given to the Indians. After a few days he returned and they got his permission to go to the place. They had no trouble in finding the place and found it just as the old squaw had described it. Near the foot of this pine tree was a boulder of jasper and iron, and this was the discovery upon which was made the location of the Jackson Iron company. This old pine tree stood for many years until the company found it necessary to mine under and around it, when it was cut down. The stump remained there for many years, but within the last five or ten years has been destroyed by fire. After Mr. Everett found this he concluded that it was better than to go further to look for copper, so went back to the land office at Sault Ste. Marie and made a mineral location of the land. The point where this discovery was made is about the center of section 1-47-27. This entire section was located and finally a mineral lease was secured of this land, and later when the land was opened for entry this section 1 was purchased for the benefit of the Jackson Iron company. After this discovery Mr. Everett returned to Jackson and interested sufficient of the prominent business men then there to form a company of thirteen members. He returned to the upper peninsula the next year with some men to open up the deposit and finally built a bloom forge on the Carp river just below Negaunee, which was operated a few years, and it was at this point that the first iron manufactured in the upper peninsula of Michigan was made. He returned in 1846 and 1847, and again in 1848 and 1849, and finally moved to what is now the city of Marquette with his family in the fall of 1850. Test cargoes of this iron were sent to Sharon, Pennsylvania, and also to Pittsburgh, where it was found to be of a very valuable character. The original boulder of jasper and iron is now in the Smithsonian Institute in Washington and was sent there by Mr. Everett. He was the first and only supervisor of Marquette county originally elected, and was also the first judge of probate. He and his wife were members of St. Paul's Episcopal church of Jackson, and when they settled here were very anxious to start a church, but as they and one other were the only communicants, it was not until 1855 that they could get a church started. They worked hard and constantly, and in 1856 the first Episcopal church building was put up and was called St. Paul's. From the institution of the church for many years he was senior warden, and from the time when he was unable to actively fulfill the duties of this office until the time of his death was senior warden emeritus of the church. He died September 15, 1892, at Marquette, Michigan, at about the age of eighty-five years.

PAST OFFICERS

PRESIDENTS.

Nelson P. Hulst	1893
J. Parke Channing	1894
John Duncan	1895
William G. Mather	1896
William Kelly	1898
Graham Pope	1900
W. J. Olcott	1901
Walter Fitch	1902
George H. Abeel	1903
O. C. Davidson	1904
James MacNaughton	1905
Thomas F. Cole	1906

(No meetings were held in 1897, 1899 and 1907.)

VICE-PRESIDENTS.

	1893.	
John T. Jones. F. P. Mills.	J. Parke Channing.	Graham Pope. M. W. Burt.
	1894.	
John T. Jones. F. P. Mills.	R. A. Parker.	Graham Pope. W. J. Olcott.
	1895.	
F. McM. Stanton. Geo. A. Newett.	R. A. Parker.	Per Larsson. W. J. Olcott.
	1896.	
F. McM. Stanton. Geo. A. Newett.	J. F. Armstrong.	Per Larsson. Geo. H. Abeel.
	1898.	
E. F. Brown. James B. Cooper	Ed. Ball.	Walter Fitch. Geo. H. Abeel.
	1900.	
O. C. Davidson. T. F. Cole.	M. M. Duncan.	J. H. McLean. F. W. Denton.
	1901.	
J. H. McLean. M. M. Duncan.	Nelson P. Hulst.	F. W. Denton. William Kelly
	1902.	
William Kelly. Nelson P. Hulst.	Fred Smith.	H. F. Ellard. Wm. H. Johnston.
	1903.	
H. F. Ellard. Fred Smith.	James B. Cooper.	Wm. H. Johnston. John H. McLean.
	1904.	
M. M. Duncan. Fred M. Prescott.	F. W. McNair.	John H. McLean. James B. Cooper.
	1905.	
M. M. Duncan. Fred M. Prescott.	F. W. McNair.	J. M. Longyear. F. W. Denton.
	1906.	
M. M. Duncan. J. M. Longyear.	Fred M. Prescott.	F. W. McNair. F. W. Denton.

MANAGERS.

	1893.	
John Duncan. Walter Fitch.	William Kelly.	James MacNaughton. Charles Munger.
	1894.	
Walter Fitch. John Duncan.	M. E. Wadsworth.	C. M. Boss. O. C. Davidson.
	1895.	
F. P. Mills. Ed. Ball.	M. E. Wadsworth.	C. M. Boss. O. C. Davidson.
	1896.	
F. P. Mills. Ed. Ball.	C. H. Munger.	Graham Pope. William Kelly.
	1898.	
M. M. Duncan. J. D. Gilchrist.	T. F. Cole.	Graham Pope. O. C. Davidson.
	1900.	
E. F. Brown. Ed. Ball.	James B. Cooper.	Walter Fitch. George H. Abeel.
	1901.	
James B. Cooper. James MacNaughton.	(One Vacancy.)	James Clancey J. L. Greatsinger.
	1902.	
James Clancey. J. L. Greatsinger.	Amos Shephard.	Graham Pope. T. F. Cole.
	1903.	
Graham Pope. Amos Shephard.	Wm. J. Richards.	T. F. Cole. John McDowell.
	1904.	
John McDowell. Wm J. Richards.	John C. Greenway.	William Kelly. H. B. Sturtevant.
	1905.	
John C. Greenway. H. B. Sturtevant.	Felix A. Vogel.	William Kelly. J. R. Thompson.
	1906.	
John C. Greenway. Jas. R. Thompson.	William Kelly.	H. B. Sturtevant. Felix A. Vogel.

TREASURERS.

C. M. Boss	1893
A. C. Lane	1894
Geo. D. Swift	1895-1896
A. J. Yungbluth	1898-1900
Geo. H. Abeel	1901-1902
E. W. Hopkins	1903-....

SECRETARIES.

F. W. Denton	1893-1896
F. W. Denton and F. W. Sperr	1898
F. W. Sperr	1900
A. J. Yungbluth	1901-....

LIST OF PUBLICATIONS RECEIVED BY THE INSTITUTE.

American Institute of Mining Engineers, 99 John St., New York City.

Canadian Mining Institute, Ottawa.

American Society of Civil Engineers, 220 W. 57th St., Newt York City.

Institution of Mining Engineers, Neville Hall, Newcastle-upon-Tyne.

Massachusetts Institute of Technology, Boston, Mass.

Chemical, Metallurgical and Mining Society of South Africa, Johannesburg, S. A.

Western Society of Engineers, 1734-41 Monadnock, Blk., Chicago.

The Mining Society of Nova Scotia, Halifax, N. S.

Canadian Society of Civil Engineers, Montreal.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne.

State Bureau of Mines, Colorado, Denver, Colo.

Stahl and Eisen, Dusseldorf, Germany, Jacobistrasse 5.

Reports of the U. S. Geological Survey, Washington, D. C.

Geological Survey of New South Wales, Sydney, N. S. W.

Geological Survey of Ohio State University, Columbus, O.

The Mexican Mining Journal, Mexico City, Mexico.

Mines and Mining, 1824 Curtis St., Denver, Colo.

Engineering-Contracting, 355 Dearborn St., Chicago, Ills.

[Ore Shipments from the Lake Superior District for 1907 and Previous Years]

LAKE SUPERIOR IRON ORE SHIPMENTS FROM THE DIFFERENT RANGES FOR 1904, 1905, 1906 AND 1907, AND GRAND TOTAL, FROM 1855 TO 1907, INCLUSIVE:

(Complied from tonnage as published by Iron Trade Review.)

		1904	1905	1906	1907	Grand Total.
Marquette Range	(Tons	2,843,703	4,210,522	4,057,187	4,388,073	85,245,874
	(Per ct.	13.	12.2	10.5	10.3	22.41
Menominee Range	(Tons	3,074,848	4,495,451	5,109,088	4,964,728	63,641,213
	(Per ct.	14.1	13.1	13.3	11.8	16.71
Vermilion Range	(Tons	1,282,513	1,677,186	1,792,355	1,685,267	26,785,426
	(Per ct.	5.9	4.9	4.7	4.	7.04
Gogebic Range	(Tons	2,398,287	3,705,207	3,641,985	3,637,907	54,107,342
	(Per ct.	11.	10.8	9.4	8.6	14.2
Mesabi Range	(Tons	12,156,007	20,153,699	23,792,882	27,492,949	150,235,558
	(Per ct.	55.7	58.7	61.7	65.1	39.5
Miscellaneous	(Tons	67,480	111,391	128,742	76,146	*401,672
	(Per ct.	.3	.3	.4	.2	.14
	Total tons	21,822,839	34,353,456	38,522,239	42,245,070	380,417,085
		Decrease from 1903 10.2 p.c.	Increase over 1904 57.4 p.c.	Increase over 1905 12.1 p.c.	Increase over 1906 9.8 p.c.	

*Iron Ridge, Wisconsin....Tons....143,039
Illinois, Wisconsin .....Tons....258,633

Tons....401,672

Increase for 1907 over 1902, 53 p. c.