

STATE OF MICHIGAN
MICHIGAN GEOLOGICAL AND BIOLOGICAL SURVEY

Publication 16. Geological Series 13.
MINERAL RESOURCES OF MICHIGAN
WITH
STATISTICAL TABLES OF PRODUCTION AND
VALUE OF MINERAL PRODUCTS
FOR
1913 AND PRIOR YEARS.

Prepared under the direction of
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Published as part of the Annual Report of the Board of
Geological and Biological Survey for 1913.
Lansing, Michigan
Wynkoop Hallenbeck Crawford Co., State Printers
1914

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LETTER OF TRANSMITTAL.

*To the Honorable, the Board of Geological and
Biological Survey of the State of Michigan:*

Gov. Woodbridge N. Ferris, President.
Hon. Wm. J. McKone, Vice-President.
Hon. Fred L. Keeler, Secretary.

Gentlemen:—Under authority of act number seven,
Public Acts of Michigan, Session of 1911, I have the
honor to present herewith Publication 16, Geological
Series 13, the third of a series of annual statements of
the production and value of the mineral products of
Michigan.

Very respectfully,
R. C. ALLEN,
Director.

PART I. METALLIC MINERALS

THE MICHIGAN COPPER INDUSTRY IN 1913. BY REGINALD E. HORE.

Michigan made a poor record in copper mining in 1913.
During the first half of the year production was fairly
good; but after June 23, the production was small and
the cost high. In previous years the production was
about 220,000,000 pounds per year; but in 1913 it was
only about 150,000,000 pounds.

In previous years the Michigan copper mining district,
the "Copper Country" as it is often called, was noted as
the location of a thriving industry which supported, and
supported well, a large population. To mining men of all
classes the Michigan copper mines are known to be well
managed. The low grade nature of much of the ore calls
for exceptional skill and repeated improvements in
methods of mining, milling, and smelting.

PROFITS FROM COPPER MINING IN MICHIGAN.

Fortunately one of the deposits, the Calumet
conglomerate, yielded exceptionally rich ore for many
years and the profit from mining in the district has
consequently been large, the Calumet & Hecla company
alone paying to the end of 1913, \$123,250,000 in
dividends and investing several millions in other
properties. Of the many other companies operating in
the district few have been successful. Those which have

paid dividends are the Ahmeek, Atlantic, Baltic, Calumet & Hecla, Central, Champion, Cliff, Copper Falls, Franklin, Kearsarge, Minnesota, Mohawk, Osceola, Quincy, Tamarack, Trimountain and Wolverine. Of these several have long since ceased to pay dividends, the mines having been abandoned. Only seven companies were able to pay dividends during each of the five years 1908-1912.

LOSSES IN COPPER MINING.

While the Calumet & Hecla has paid large dividends in 1912, a very large number of companies have operated at a loss. Omitting the Calumet & Hecla, the profits and losses of all the operating companies about balance. The companies paid in dividends up to the end of 1913 about \$206,000,000; \$123,250,000 is credited to the Calumet & Hecla, leaving a balance of about \$85,750,000 which may be compared with assessments amounting for the same period to \$87,000,000. It is perhaps surprising to some that mining companies should spend such large amounts instead of closing the unprofitable mines. The reason is simply that the deposits are so low grade that very large sums must be spent to determine whether they can be profitably mined. One or two pounds of copper per ton may make all the difference between profit and loss. One cent per pound rise or fall in the price of copper means profit or loss in some cases. A large body of ore that allows a very small margin of profit when the price of copper is good has a very doubtful value. No one can foretell with certainty what the price of copper will be when the ore has been mined and treated. Those who engage in mining such ore take a chance. They hope that the price of copper will be good, that they will find better ore as the mine openings are extended and that they will be able to cut down the costs of mining. Needless to say there have been many disappointments as well as some realizations.

THE COST OF MINING.

While the price of copper necessarily varies and the mine openings disclose ore of varying value there is a more regular change in the costs of mining. The men who have been in charge of Michigan copper mines have been able to record from time to time great improvements. In spite of the fact that much of the ore is now being mined at great depth the actual cost of mining a ton of ore is now much less than it was years ago. In 1913 costs were unusually high owing to the strike. The costs for several preceding years will be found in the accompanying statistical tables showing summary of results obtained by the producing companies and in previous reports. To the credit of the mine managers it should be stated that decrease in cost has not been brought about by decrease in wages, but rather by improving methods and machines. While costs have gone down wages have been increased.

WAGES PAID.

Enormous sums have been paid in wages. During 1912 the employees of Michigan copper mining companies received over \$1,000,000 per month. The Calumet & Hecla company alone has paid about \$200,000,000.00 in wages. A complete statement of wages paid is not available but the accompanying statement of wages paid by companies in 1912 will show that the mining industry in this district is a means of livelihood to thousands of people. The list is by no means complete, as large amounts were paid by several companies not therein mentioned, but it contains all the profitable companies and most of the producing ones.

The wages paid to miners and trammers are shown by the following tables prepared by a committee of the Copper Country Commercial Club:

SHIFTS WORKED AND EARNINGS OF MINERS AND TRAMMERS AT VARIOUS COPPER COUNTRY MINES, FOR A PERIOD OF SIX MONTHS, JANUARY 1, TO JUNE 30, 1913.

Mine.	Miners.			Trammers.			Miners and trammers.		
	Days.	Amount.	Average wages.	Days.	Amount.	Average wages.	Days.	Amount.	Average wages.
A.....	19,447	\$60,224.78	\$3.06	17,769	\$50,581.62	\$2.85	37,216	\$110,806.40	\$2.98
B.....	13,472	48,533.81	3.60	15,844	45,008.28	2.73	29,317	93,542.09	3.15
C.....	12,027	115,280.62	9.59	20,620	97,901.29	4.74	32,647	213,181.91	6.53
D.....	72,241	364,584.87	5.05	50,790	153,216.35	3.02	123,031	517,801.22	4.21
E.....	1,859	4,609.94	2.48	1,043	2,400.99	2.30	2,902	7,010.93	2.42
F.....	4,767	16,615.39	3.49	4,504	12,181.10	2.70	9,271	28,796.49	3.11
G.....	367	933.53	2.54	460	420.01	0.91	827	1,353.54	1.64
H.....	30,009	94,003.73	3.13	20,000	54,382.59	2.72	50,009	148,386.32	2.97
I.....	106	425.19	4.02	207	587.54	2.84	313	1,012.73	3.24
J.....	873	2,846.42	3.26	30	11.12	0.37	903	2,857.54	3.16
K.....	17,104	61,319.73	3.58	20,311	31,645.06	1.56	37,415	92,964.79	2.51
L.....	12,002	36,290.82	3.02	13,005	35,858.44	2.76	25,007	72,149.26	2.89
M.....	11,002	39,520.34	3.59	10,924	27,762.13	2.54	21,926	67,282.47	3.07
N.....	1,692	5,274.84	3.12	1,603	4,602.45	2.87	3,295	9,877.29	3.00
O.....	6,701	23,708.71	3.54	4,642	14,564.16	3.14	11,343	38,262.87	3.38
P.....	17,417	58,617.22	3.37	14,692	40,614.45	2.76	32,110	99,231.67	3.09
Q.....	9,865	4,549.15	0.46	1,114	3,858.44	3.46	11,000	8,407.59	0.76
R.....	39,591	115,881.59	2.93	19,327	44,586.35	2.31	58,918	160,467.94	2.72
S.....	15,023	45,023.65	3.00	21,643	69,992.45	3.23	36,666	114,916.10	3.14
T.....	26,268	77,140.80	2.93	11,041	25,617.35	2.32	37,309	102,758.15	2.75
U.....	16,139	44,629.67	2.77	10,528	25,690.84	2.44	26,667	70,320.51	2.65
V.....	9,843	19,890.40	2.01	1,701	5,244.90	3.08	11,544	25,135.30	2.18
W.....	35,779	8,724.00	0.24	24,215	5,267.01	0.22	60,000	13,991.01	0.23
X.....	1,708	5,088.55	2.98	1,000	2,400.00	2.40	2,708	7,488.55	2.76
Y.....	20,000	22,000.00	1.10	20,000	24,000.00	1.20	40,000	46,000.00	1.15
Z.....	14,072	43,669.77	3.12	13,709	32,694.03	2.38	27,782	76,363.80	2.76
AA.....	13,064	40,666.66	3.12	14,091	35,769.00	2.54	27,155	76,435.66	2.82
Total.....	541,869	\$1,735,766.07	\$3.20	309,210	\$944,509.38	\$2.62	851,079	\$2,680,275.45	\$3.08

Mine.	\$5.00 and over.	\$4.75 to \$5.00	\$4.50 to \$4.75	\$4.25 to \$4.50	\$4.00 to \$4.25	\$3.75 to \$4.00	\$3.50 to \$3.75	\$3.25 to \$3.50	\$3.00 to \$3.25	\$2.75 to \$3.00	\$2.50 to \$2.75	Under \$2.50	Total per cent.	Average wages.
Ahmeek.....	4.95	0.49	2.98	7.54	7.54	7.54	7.54	19.23	3.40	8.42	2.77	100.00	83.64	\$3.64
Algonquin.....	8.61	2.15	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	100.00	82.64	\$2.64
Calumet and Hecla.....	0.72	0.53	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	100.00	82.64	\$2.64
Central.....	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	100.00	82.64	\$2.64
Ida Royce.....	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	100.00	82.64	\$2.64
North Keweenaw.....	8.52	0.97	1.82	9.64	5.87	0.77	14.66	0.69	0.70	0.00	0.00	100.00	83.60	\$3.60
South Keweenaw.....	3.05	5.95	4.94	5.58	5.76	4.94	13.38	10.38	65.78	0.00	0.00	100.00	83.60	\$3.60
Osceola.....	8.52	3.84	3.90	4.45	1.07	0.41	5.53	69.77	45.57	0.74	3.96	100.00	83.60	\$3.60
Superior.....	5.15	3.37	1.71	1.91	6.31	8.88	18.09	45.57	14.75	0.00	0.00	100.00	83.60	\$3.60
Tamarack.....	2.54	1.39	1.76	3.62	4.85	8.02	9.75	39.30	14.33	12.84	1.29	0.31	100.00	\$3.47
Total percentage.....	0.27	0.01	0.00	0.33	0.84	2.96	6.63	6.80	6.64	10.05	62.99	2.48	100.00	\$2.83

PERCENTAGE OF TOTAL SHIFTS WORKED BY TRAMMERS AT VARIOUS RATES, CALUMET AND HECLA AND SUBSIDIARY COMPANIES—MONTH OF MAY, 1913.

Mine.	\$5.00 and over.	\$4.75 to \$5.00	\$4.50 to \$4.75	\$4.25 to \$4.50	\$4.00 to \$4.25	\$3.75 to \$4.00	\$3.50 to \$3.75	\$3.25 to \$3.50	\$3.00 to \$3.25	\$2.75 to \$3.00	\$2.50 to \$2.75	Under \$2.50	Total per cent.	Average wages.
Ahmeek.....	2.90	0.09	0.83	0.06	1.60	11.19	8.36	12.21	2.56	59.38	0.22	100.00	82.63	\$2.63
Algonquin.....	0.01	0.66	2.15	6.81	13.24	11.78	11.24	6.24	41.26	6.31	0.00	100.00	82.63	\$2.63
Calumet and Hecla.....	0.01	0.66	2.15	6.81	13.24	11.78	11.24	6.24	41.26	6.31	0.00	100.00	82.63	\$2.63
Central.....	0.01	0.66	2.15	6.81	13.24	11.78	11.24	6.24	41.26	6.31	0.00	100.00	82.63	\$2.63
Ida Royce.....	0.01	0.66	2.15	6.81	13.24	11.78	11.24	6.24	41.26	6.31	0.00	100.00	82.63	\$2.63
North Keweenaw.....	0.01	0.66	2.15	6.81	13.24	11.78	11.24	6.24	41.26	6.31	0.00	100.00	82.63	\$2.63
South Keweenaw.....	0.01	0.66	2.15	6.81	13.24	11.78	11.24	6.24	41.26	6.31	0.00	100.00	82.63	\$2.63
Osceola.....	0.01	0.66	2.15	6.81	13.24	11.78	11.24	6.24	41.26	6.31	0.00	100.00	82.63	\$2.63
Superior.....	0.01	0.66	2.15	6.81	13.24	11.78	11.24	6.24	41.26	6.31	0.00	100.00	82.63	\$2.63
Tamarack.....	0.01	0.66	2.15	6.81	13.24	11.78	11.24	6.24	41.26	6.31	0.00	100.00	82.63	\$2.63
Total percentage.....	0.27	0.01	0.00	0.33	0.84	2.96	6.63	6.80	6.64	10.05	62.99	2.48	100.00	\$2.83

Compared with wages paid in some mining districts the wages are low. It should be borne in mind however that the Michigan miners enjoy many material advantages which such tables take no account of. The companies provide houses at very low rentals and in many ways relieve the employees of expenditures. Splendid schools, hospitals, libraries, etc., are at the disposal of employees at very low cost.

It will be noted from the tables that there is great variation in the earnings of miners. Some receive very good wages, but the general average is low. The wage paid varies at the different mines, being highest at the Calumet & Hecla. At each mine there is a variation which is fairly indicative of the relative amounts of work done by the individual miners. According to the mine managers the miners who receive the highest wages are

the most profitable to the companies. It will be seen from the tables that a number of miners earn over \$4 per day. Most of these men use the light-weight one-man machines, to which the anti-labor-saving device agitators object.

EXPLORATION IN 1913.

In the early part of 1913 exploratory work was being carried on by a number of companies besides the producing ones. Diamond drilling was done at the Adventure, Algomah, Keweenaw, Mayflower, Naumkeag, Old Colony and Onondaga.

Exploratory openings were made at the Cliff, Indiana, Keweenaw, Naumkeag, New Arcadian, New Baltic and North Lake.

Development of lodes was continued at the Hancock, Houghton, Laurium, Lake, Ojibway, St. Louis, White Pine and Wyandot.

During the strike many of these companies continued their work without interruption. The diamond drilling was not stopped by the strikers. The White Pine continued operations; but most of the companies doing any underground work were forced to close down their mines and wait for more peaceful and less costly conditions for operation.

NEW CONSTRUCTION.

During 1913 there were several important additions made to the already extensive equipment of the mining companies.

The Calumet & Hecla company made a number of additions to plants, including some very notable ones. At the power house an enormous electric turbine generator has been erected to utilize the exhaust steam from the stamps. At the smelter the two large furnaces which were under construction in 1912 were completed and an electrolytic plant of large capacity was erected. This plant is a splendid one and has very few equals in the world. When it is in operation the Calumet & Hecla company will be able to ship all of its copper in the refined state. At present much of the copper is ready for the market when it leaves the smelter, but some is sent to the company's plant at Buffalo for electrolytic treatment. At the mill a large building has been erected to house a regrinding plant which is to be equipped with 64 Hardinge conical mills. At the end of the year some of the mills were in position and the plant will doubtless be in operation before the end of 1914. Experiments have been carried on to determine the advisability of leaching the tailings from the regrinding plant. It is stated that a successful process has been devised and that a large plant will be built.

The Copper Range Consolidated company has made many improvements at its mills. Regrinding apparatus has been erected and turbines have been installed to develop the increased power necessary. At the mines

the underground electrical equipment was extended and several motors are now in use to haul the ore to the shafts.

The Quincy Mining company installed a new hydraulic jig classifier devised by the company's staff and consulting metallurgists. The new apparatus, known as the Shields-Thielman jig classifier is giving great satisfaction.

At several of the mines new rockhouses were built and old ones improved. At the mills, especially those of the Calumet & Hecla subsidiary companies, there were many additions and improvements. At the Winona mill a new device known as the Lovett machine was found very successful in treating fine copper. It rolls the copper and makes its concentration easier.

During the year a company interested in power development did some preliminary work with the view to supplying the mines with power from the Sturgeon river.

EARNINGS 1913.

The first half of the year was a profitable one for several companies; but the last half was disastrous. In spite of the strike a few companies are able to report a profit on the years' operations. The statistical tables on another page show concisely the result of the year's business for the more active companies.

DIVIDENDS PAID IN 1913.

While the mines were idle for several weeks and short handed for some months the leading companies were able to pay out more than was earned during the year and consequently the amount paid was little less than in the previous year. Assets have however been considerably reduced.

ADVENTURE CONSOLIDATED COPPER CO.

Early in 1913 all work was discontinued at this company's property pending the result of operations on adjoining properties.

AHMEEK MINING COMPANY.

Until the strike occurred the Ahmeek was making a large production and promised to have a very successful year. The main ore deposit, the Kearsarge lode, yielded good ore and the fissure vein north of No. 2 shaft proved very rich. The vein has been opened up for 419 feet on the 10th level, 70 feet on the 13fch level, and 212 feet on the 14th level.

Owing to the satisfactory condition of the mine and of the treasury, the company was able to pay \$850,000 in dividends; but the balance of assets was reduced from \$1,379,209.34 to \$706,128.53.

There was treated in 1913, 383,749 tons of ore yielding 9,220,184 pounds copper, an average of 24.0 pounds

per ton.

Mr. R. L. Agassiz, President, says in his annual report that new openings at No. 1 and No. 2 shafts showed average values except at the 17th level. Comparatively little opening was done at Nos. 3 and 4 shafts on account of construction.

At the mill a four-stamp addition is in course of construction. A contract has been let for a 2,000 kilowatt low pressure steam-turbine, which will be supplied with steam from the exhaust of the steam stamps and will furnish all the necessary power for operating the washing and recrushing machinery in the mill.

ALGOMAH MINING COMPANY.

During the first half of the year the shaft was sunk 203 ft. and the crosscut at the second level was extended northwest 228 feet. No mining work was carried on after July 23. The president states that when work is resumed the shaft will be deepened.

ALLOUEZ MINING COMPANY.

The Allouez was making good progress before the strike and made a profit of \$155,728.21 on the year's operations. Openings were quite up to the average and a good profit from future operations is assured. The Allouez produced during the year 4,091,129 pounds of copper from 236,663 tons of ore treated, an average of 17.29 pounds per ton.

BALTIC MINING COMPANY.

The Baltic was making good progress when the strike interfered with operations. The mill was improved by the addition of regrinding apparatus and is giving very satisfactory results.

The Baltic produced in 1913, 7,736,124 pounds copper at a cost of 11.91 cents per pound. This was sold at 14.89 cents. Mr. F. W. Denton, General Manager, reports that openings at No. 2 and No. 3 shaft were good, while the openings at No. 4 were in poor ground. He anticipates rapid recovery to normal conditions.

CALUMET & HECLA MINING COMPANY.

The Calumet & Hecla, the largest of the Michigan copper mines, was operated very profitably until July 23. After being idle a few weeks the mine was reopened and at the close of the year there were as many men at work as before the strike. The company bore a large share of the expense of the strike.

The company made important additions to plant during the year. A second regrinding plant is well advanced and an electrolytic refinery is nearly ready for operation.

In the regrinding plant there will be 64 Hardinge Conical mills. The concentration will be done on Wilfley tables. With this plant in operation the company will begin to

recover the copper contained in the stamp mill tailings which have been accumulating for years.

The refinery will have a capacity of 65,000,000 pounds deposited copper per year. This plant will therefore be able to handle all of the company's product, as only a portion of the copper needs to be subjected to electrolytic treatment for the recovery of silver or the removal of harmful impurities.

The two large furnaces which were under construction in 1912 have been completed. Most of the copper treated in these will be cast into anodes.

At the power house a 7,500 kilowatt electric turbine generator which was being installed in 1912 is now in operation.

To raise the sands from Torch lake the company has had built an enormous steel dredge. Centrifugal pumps will raise the sand to settling boxes in a Shore plant. After draining, the sand will be hoisted on a traveling belt and crushed in the Hardinge mills referred to above.

During 1913 there was treated 2,035,625 tons of ore, which yielded 45,016,892 pounds of copper, an average of 22.11 pounds per ton. The total cost per pound was 14.25 cents and the price received for copper sold was 15.77 cents.

As usual the chief production was from the Conglomerate lode. This yielded 32,731,768 pounds copper at a cost of 12.67 cents. The Osceola lode yielded 12,051,238 pounds and the Kearsarge lode 233,915 pounds.

At the Manitou-Frontenac Branch three diamond drill holes were made. At the St. Louis branch the shaft was deepened and 1,237 feet of drifting was done.

The company estimates that the new regrinding plant, working at its capacity of about 3,000 tons per day, would retreat the available sands in Torch Lake in about 30 years and save five pounds of copper per ton at a cost of about six cents, giving a profit if sold at thirteen and one-half cents per pound of over \$10,000,000 less the cost of the mill and power equipment. An equal profit is expected from further treatment of the sands by leaching.

The Calumet & Hecla paid \$3,200,000 in dividends in 1913 and received from other mining companies in dividends, \$915,439. Dividends received exceeded interest paid on notes by \$716,379.

CENTENNIAL COPPER MINING COMPANY.

The Centennial did very well during 1913, considering the conditions, and made a profit of \$31,397.00. There was treated during the year 85,443 tons of ore, which yielded 1,612,262 pounds copper, an average of 18.87 pounds per ton. The total cost was 13.38 cents and the price received for copper sold was 15.358 cents per pound.

No work was done at No. 1 shaft. The openings north of

No. 2 shaft were according to Mr. Quincy A. Shaw, President, up to the average.

The balance of assets on December 31, 1913, was \$27,847.78.

CLIFF MINING COMPANY.

The exploration carried on from the temporary shaft proved unsatisfactory and was discontinued early in June. Since then the company has bored three diamond drill holes in the eastern part of the property.

CONTACT COPPER COMPANY.

Four diamond drill holes constitute the exploration done in 1913. All work was discontinued on August 2.

COPPER RANGE CONSOLIDATED COMPANY.

The company from the Baltic, Trimountain and one-half Champion produced in 1913, 18,767,359 pounds copper at an average cost of 11.71 cents. This was sold at 14.89 cents per pound.

Profits from the individual mines were: Baltic, \$230,211.37; Trimountain, \$113,363.24; Champion, one-half, \$252,383.30.

Mr. W. A. Paine, President, reports that extraordinary expenses, mostly in connection with the regrinding installation, amounted to \$230,835.97. Until the strike, operations had shown an improvement over the previous year. He states that the mines are in good condition and satisfactory results may be expected in 1914.

FRANKLIN MINING COMPANY.

The Franklin had a very unsatisfactory year owing to labor conditions. There was a shortage of trammers early in the year. After July 23 no mining was done.

Early in 1914 the Allouez conglomerate, which lies east of the Pewabic lode, was opened up at the 32nd level. The company reports that samples of four and one-half and eight tons representing 15 feet of the lode were assayed and found to contain 31.8 and 35.2 pounds copper per ton. This lode will now be developed.

The Franklin produced in 1913, 123,179 tons of ore which yielded 1,021,440 pounds of copper. There was a much larger tonnage of ore broken but lack of trammers prevented its being hoisted.

Receipts during 1913 amounted to \$164,556.45, while expenses totalled \$306,660.59. The deficit at the end of the year was \$100,264.87.

HANCOCK CONSOLIDATED MINING CO.

The company continued exploration of the deposits cut by No. 2 shaft by crosscuts and drifts; 12,612 tons of ore

from drifting on the several lodes and from stopes on No. 3 and No. 9 lodes was stamped and yielded 16.82 pounds copper per ton. After July 23 operations were suspended for the balance of the year.

Mr. J. L. Harris, General Manager, says, in his report for the year 1913 that development work on No. 9 lode at the 13th and 18th levels has been satisfactory, the ore mined being of good grade.

HOUGHTON COPPER COMPANY.

The company continued exploration by drifts at the 620 feet and 820 feet levels, and by a winze. After July 23 operations were suspended.

Mr. R. R. Seeber, superintendent, says in his report for the year 1913, that the north drift on the 820 foot level showed copper most of the way, while the south drift was in average ground.

INDIANA MINING COMPANY.

The company deepened its shaft to the level at which it was expected to find a deposit cut by diamond drill holes. The cores showed copper in felsite at a point believed to be close to the bottom of the shaft. The completion of the shaft showed, however, that the drill hole survey was incorrect as the shaft is bottomed in trap. As very considerable deviations are common in drill holes, it is thought that the deposit can be best developed by following the deposit exposed at the 600 foot level which is similar to that cut by the diamond drill.

No work was done at the property after July 23.

ISLE ROYALE COPPER COMPANY.

The Isle Royale had a serious set back in 1913, owing chiefly to the strike; but partly also to a decrease in the yield of copper per ton of ore stamped. There was a decrease of \$382,301.91 in balance of assets as a result of the year's operation; \$100,000 of this was due however to purchase of land and \$150,000 to dividend. The loss properly attributed to operation, including strike expenses, was \$128,313.04.

During the first six months good progress was made in opening up the mine for larger production. The openings made totalled 11,972 feet. Development work after July 23 was necessarily curtailed. The yield of copper per ton of ore was disappointing, being 13.2 pounds. The average yield in 1912 was 15.4.

The Isle Royale produced in 1913, 314,679 tons of ore which yielded 4,158,548 pounds copper. This cost 18.81 cents per pound.

Mr. R. L. Agassiz, President, reports that openings at No. 4 and No. 5 shafts were in average ground, while those at No. 2 and No. 6 were below average.

LAURIUM MINING COMPANY.

Development work at the No. 1 shaft was carried on without notable results; \$26,486 was expended and the company ended the year with a balance of liabilities of \$8,020.

LAKE COPPER COMPANY.

The Lake mine was operated under adverse conditions early in the year, and was closed by the strike. Later it was operated again; but again closed on account of the unusual high cost.

Mr. C. H. Hitchcock, the mine superintendent resigned and Mr. E. W. Walker, superintendent of the Mass mine, was appointed to take charge of the Lake mine also.

KEWEENAW COPPER COMPANY.

Diamond drilling was done during 1913 to explore the Ashbed lode east and west of Lake Medora. Fourteen holes giving a total of 7,911.5 feet were drilled. It is intended to continue this work.

On the property of the Phoenix Consolidated Company exploration was also carried on. See Phoenix.

LASALLE COPPER COMPANY.

Work was resumed at the property during 1913; but little had been done when the strike interfered with progress. The company's balance of assets was reduced to \$158,827. There was treated during the year 2,221 tons of ore yielding 43,906 pounds of copper.

LAKE MILLING, SMELTING AND REFINING COMPANY.

A number of improvements were made in plant during the year and more will be made in 1914. Regrinding apparatus is being provided and new concentration machinery is being installed.

MASS CONSOLIDATED MINING COMPANY.

The mine has been put in very good shape for production and with satisfactory labor conditions would have given a good account of itself. The superintendent found however that under the conditions existing in 1913 it was better for the company to close the mine.

The Mass produced in 1913, 1,213,545 pounds copper which was sold at 15.6 cents.

MAYFLOWER MINING COMPANY.

Exploration was carried on during 1913 without interruption.

Mr. Charles J. Paine, Jr., President, reports that the drilling operations have materially increased the area which is demonstrated as being underlain by the

Mayflower lode. In a number of places the lode has been found to be more or less displaced by faulting.

MICHIGAN MINING COMPANY.

The company has been doing no mining for some years. After operating for several years the company for some time carried on exploratory work. Some mining was done by tributors. During 1912 a shaft was started to explore the Ogima lode.

All operations have now been suspended.

MOHAWK MINING COMPANY.

The company suffered seriously from labor troubles during 1913. Early in the year the trammers went on strike. This lasted only a few days. After July 23 the mine was closed for some time. When it was opened again the small size of the working force resulted necessarily in high costs; \$500,000 was paid in dividends but the surplus was reduced from \$897,316 to \$521,156.

The Mohawk produced in 1913, 366,458 tons of ore which yielded 5,778,235 pounds copper. This cost 13.22 cents per pound.

NAUMKEAG COPPER COMPANY.

The company has 1200 acres in the western part of the copper bearing formation. This is being explored by drilling, trenching and small underground openings. Eleven holes have been drilled, totalling 13,913 feet. Work is now being confined to the Quincy-Pewabic horizon.

NEW ARCADIAN COPPER COMPANY.

Exploration was continued during nine months of the year. From August 1 to November 1, the work was suspended on account of the strike.

A crosscut east at the 750 foot level disclosed a promising copper bearing amygdaloid. This was drifted on with good results. Mr. H. W. Fesing, the company's engineer, reports that of 200 feet of drifting on this deposit all but 25 feet shows good ore.

NEW BALTIC COPPER COMPANY.

Exploration was carried on during the first half of the year, but after July 23 no underground work was done. Mr. H. W. Fesing, engineer, says in his annual report that the most important development during the past year, as affecting the New Baltic property, is the opening up of the amygdaloid lode on the New Arcadian property close to the boundary line of the New Baltic.

The treasurer's report shows a balance on hand on January 1, 1914, of \$23,956.13.

NONESUCH MINE.

During the year some work was done at the company's property in Ontonagon county. After the mine had been unwatered and examined, however, the work was discontinued.

NORTH LAKE MINING COMPANY.

Exploratory work was carried on until July 23, after which date all work was suspended. Mr. R. M. Edwards, President, says in his annual report that all plant and equipment necessary for the development of the property is completed. The shaft was sunk 282 feet during the year and the total depth is now 345 feet. At the 300 foot level a crosscut was driven northwest 112 feet.

The treasurer's report shows a balance of assets on December 31, 1913, of \$49,408.33, including unpaid assessments of \$31,724.

OJIBWAY MINING COMPANY.

The Ojibway mine was operated early in the year without very encouraging results. It is now closed down.

OLD COLONY COPPER COMPANY.

Exploration was continued during 1913 by diamond drilling. In a report dated December 10, 1913, Mr. H. H. Fay, President, says that 9 holes totalling 12,627 feet were drilled during the year and that the horizon of the Mayflower lode was definitely located in every drill hole.

ONECO COPPER COMPANY.

Exploration was continued by cross cuts and drifts until the strike occurred on July 23. After that date no work was done.

ONONDAGA COPPER COMPANY.

During 1913 exploration was carried on by diamond drilling on the company's lands in Ontonagon county. Mr. W. B. Smith, Superintendent, resigned and Mr. H. W. Fesing is now in charge of operations.

Mr. R. C. Pryor, President, in a report to stockholders says that diamond drilling has been carried on continuously since August, 1912. A geological and topographical survey of the company's lands has been made.

The treasurer's report shows a balance of \$74,675 on hand on January 31, 1914.

OSCEOLA CONSOLIDATED MINING COMPANY.

In spite of the very adverse conditions the company made a profit of \$381,967 and paid dividends of

\$721,125.

The report of the directors shows that there was stamped 735,044 tons of ore. The production of refined copper was 11,325,010 pounds or 15.4 pounds per ton. The cost was 12.30 cents per pound and 10,958,926 pounds was sold at 15.50 cents.

At the Osceola branch the cost per pound was 20.79 cents, at the North Kearsarge 12.46 cents, and at the South Kearsarge 8.11 cents. Of the 256,233 tons mined at the South Kearsarge branch, nearly two-thirds was mined from the footwall.

As a result of the small earnings and large distribution in dividends the balance of assets was reduced from \$1,888,458.05 to \$1,549,300.06.

PHOENIX CONSOLIDATED COPPER COMPANY.

After obtaining encouraging results by diamond drilling the company opened up an old shaft in the Ashbed lode. This old shaft has been unwatered and enlarged. In the work of enlarging the shaft some good ore was broken and the company intends to deepen the shaft below the old workings. In his report, Mr. T. F. Cole, President, says that an examination of the openings made on and above the first level of the old workings shows good copper values.

QUINCY MINING COMPANY.

This company which has been successfully mining low grade ore for many years made a profit of only \$76,160 in 1913 as compared with \$960,779 in 1912. There was produced 12,184,128 pounds of copper at a cost of about 15.3 cents per pound. This was sold at 15.59 cents.

During the year \$412,500 was paid in dividends and \$150,000 was paid on note given St. Mary's Canal Mineral Land Co. The balance of assets was decreased from \$1,233,278.15 to \$746,938.34.

Mr. Chas. L. Lawton, General Manager, reports that a new 90 pound drilling machine has been successfully tried out in the mine, and that the company has ordered 100 machines of this type. He says that there has been no particular change during the year in the average copper contents of the ore developed at No. 2 shaft, though the openings as a whole are looking better for stamp rock and heavy copper than years ago. He says that at the No. 6 shaft the bottom openings average about the same in stamp copper as for several years, but do not carry the old quantity of heavy copper. At the No. 8 shaft the average of the openings is below that of other years. but the bottom levels look well.

ST. LOUIS COPPER COMPANY.

Exploration was continued during 1913 by extending the workings at No. 1 shaft. The shaft was deepened and

drifting along the lode continued. Copper was found in places; but no large body of good ore has yet been found.

SOUTH LAKE MINING COMPANY.

Development was carried on by shaft sinking and cross-cutting until July 23. After that date no work was done, pending improvement in labor conditions. Mr. R. M. Edwards, General Manager, in his annual report says that the shaft has been sunk to a depth of 537 feet and a crosscut driven at the 300 feet level to open the lodes known as Nos. 1, 2 and 3 cut in the shaft between depths of 110 and 210 feet.

At 600 feet a long crosscut will be driven southeast to cut the lodes found by diamond drilling.

The treasurer's report shows a balance of assets on January 1, 1914, of \$46,606.36.

SUPERIOR COPPER COMPANY.

The Superior had a fairly successful year, being one of the first to resume large shipments after the strike began. Before the strike attention was devoted chiefly to developing the lodes. This was proceeding with fair results when the strike was called.

The company produced 2,992,765 pounds of copper, the ore stamped averaging 22.87 pounds copper per ton. A profit of \$93,912.93 was made, increasing the balance of assets to \$193,697.01.

In his annual report Mr. Quincy A. Shaw, President, says that no copper was developed in the Superior lode south of the shaft and that the ground opened on the 16th and 17th levels north of the shaft is below average. Good ore was opened south of No. 1 shaft on the 17th, 18th, 19th and 20th levels in the West lode; but development north failed to show anything of value except on the 20th level near the shaft.

TAMARACK MINING COMPANY.

The Tamarack mine has for the past few years been a high cost mine. In several recent years it was operated at a loss. During 1912 a profit was made. With plenty of good men available 1913 would also have been a profitable year. After the strike the mine was closed for the balance of the year pending improvement in the labor situation.

During 1913 there was produced 4,168,743 pounds of copper at a cost of 16.60 cents per pound; 3,852,040 pounds was sold at 15.45 cents. Considering the conditions the loss from operations was not very large. The balance of assets was decreased from \$1,120,861.88 to \$1,070,938.19.

Openings at No. 3 shaft, according to the report of President R. L. Agassiz, have shown fair copper values. At No. 2 shaft very little drifting was done on the conglomerate lode. A considerable tonnage of ore was

mined from the footwall side of the Osceola amygdaloid lode at this shaft.

The Tamarack company has a very large tonnage of mill tailings which is expected to yield a large profit when treated. Concerning this Mr. R. L. Agassiz says: "It has been estimated that a mill of a capacity of 1,500 tons a day will treat the available sands in 21 years, saving about four pounds of copper out of 12.4 pounds in a ton of sand, at a cost of about seven cents, giving a net profit, if sold at thirteen and one-half cents per pound, slightly over \$2,500,000, less the cost of the plant. Experiments that have been carried on at the Calumet & Hecla stamp mills indicate that a leaching process has been developed which, if applied to a portion of the tailings of this recrushing mill, will result in an additional profit from the sands of the same amount, or a total profit of \$5,000,000. The construction of the recrushing mill will not be undertaken until all details have been worked out at the Calumet & Hecla stamp mills.

TRIMOUNTAIN MINING COMPANY.

The company had a fairly good year in spite of the strike. The openings made were good and the yield of copper was unusually high. There was produced 4,990,938 pounds copper, the ore yielding 21.78 pounds per ton. The cost was 12.62 and the selling price 14.89 cents per pound.

During the year the installation of improved drilling machines was completed. Three of the four heads at the mill are now equipped with regrinding machinery.

Receipts for the year totalled \$746,529.86. Operating expenses were \$608,922.11. After paying taxes amounting to \$24,244.41 there was a net profit of \$113,363.34. As \$200,000 was paid in dividends the surplus was reduced and amounted on December 31, 1913, to \$444,757.68.

VICTORIA COPPER MINING COMPANY.

This company experienced in 1913 one of the best years in its history. The mine being far removed from the centre of strike disturbances, operations were carried on without interference. Early in the year there was a scarcity of men but the closing of mines in Houghton county was an advantage to the Victoria.

A large amount of development work was done and good results were obtained. The year's operations resulted in a decrease of \$16,938 in surplus but the outlook has been greatly bettered.

The production was 1,428,693 pounds copper.

Mr. Geo. Hooper, Superintendent, says in his report for 1913 that the ore developed during the past two years is better than that opened in preceding years. The average yield in 1913 was 2.4 pounds per ton higher than in 1912.

WHITE PINE COPPER COMPANY,

The company has been carrying on development work for the past few years with good results, and is now planning to erect a mill and begin production in 1914. During 1913 the openings were extended and a large body of good ore blocked out. The employees did not take part in the strike, and good progress was made.

The ore is quite different to that being mined in other parts of Michigan. It is a sandstone containing copper in small particles.

Mr. Quincy A. Shaw, President, reports that work on the building and machinery for a mill of a capacity of 1,000 tons per day has been started. The mill will be equipped with gyratory crushers, rolls, Woodbury classifiers, Wilfley tables, and Hardinge pebble mills.

WINONA COPPER COMPANY.

The company did fairly well during 1913, considering the labor conditions. Early in the year there was a shortage of trammers at the mine. After the strike was called the mine was closed until October. Slowly the force was increased and at the end of the year prospects were good.

There was produced during 1913, 1,448,737 pounds of copper, the ore yielding 11.99 pounds per ton. The annual report shows a balance of assets of \$74,508.16 compared with \$62,034.12 a year ago.; \$128,506 was collected by assessments.

Three Hardinge Conical mills were added to the regrinding plant during the year, and very good results were obtained.

Mr. A. L. Dickerman made a study of the extraction problem at the Winona mill during the year and recommended the use of the Shields & Thielman jig classifier and the Lovett grinding machine.

WOLVERINE MINING COMPANY.

The Wolverine's financial year ending June 30, 1913, was a fairly good one; but the last five months of 1913 was a very unprofitable period. It was not until some months after the calling of the strike that any considerable amount of ore was being mined. At the end of the year production was still small.

WYANDOT COPPER COMPANY.

During 1913 the company continued exploration of the No. 8 lode. The mine was closed for one month during the strike. The superintendent, Mr. F. L. Van Orden, recommends further development of the No. 8 lode.

THE IRON ORE RESERVES OF MICHIGAN.

BY R. C. ALLEN.

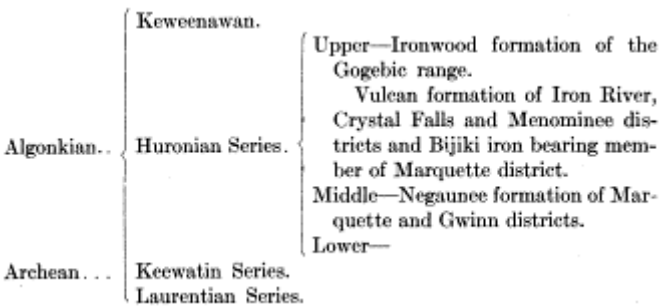
A BRIEF DESCRIPTION OF THE IRON BEARING FORMATIONS. CHARACTER OF THE IRON FORMATIONS.

The iron formations, in which the iron ore bodies are found, are sedimentary rocks composed, in an unaltered condition, chiefly of silica in the form of chert and quartz, and the iron bearing minerals, ferrous carbonate (siderite), ferrous silicate (greenalite) and iron oxide (mainly hematite). Oxidation has transformed most of the ferrous iron contents to iron oxide in the exposed parts of the formations producing ferruginous cherts ("soft ore jasper"), ferruginous slates and, by further metamorphism (anamorphism) jaspilites ("hard ore jasper"). If oxidation is complete and the silica content sufficiently reduced by leaching, ore bodies result.

RELATIONS TO OTHER FORMATIONS.

The iron formations are interbedded with other sedimentary rocks, mainly slate and quartzite, and in some places with basic igneous rocks of contemporary volcanic origin. In some areas they are cut by dikes and irregular masses of younger intrusive basic igneous rocks, notably in the Gogebic and Marquette districts, and to lesser extent in all of the other districts.

The names of the iron bearing formations and their age relationships are given below.



THICKNESS OF THE IRON FORMATIONS.

The iron bearing beds vary greatly in thickness in the different ranges. In the Gogebic district the maximum thickness is 800 to 1,000 feet, in the Marquette district from 1,000 to possibly 1,500 feet, in the Iron River and Crystal Falls districts not more than 350 feet to 400 feet, and in the Menominee district the combined thickness of the two productive beds varies on the average between 300 feet and 400 feet.

DEFORMATION AND ALTERATION OF THE IRON FORMATIONS.

Originally deposited in about flat lying or horizontal

position, the iron bearing beds and associated rocks were subsequently folded by compressive earth movements into synclines (troughs) and anticlines (arches). During deformation the formations were not only folded but fractured, and along many of these fractures faults or displacements occurred. Deformation of the iron formations was mainly accomplished while they were buried beneath overlying formations but erosion has since partially removed the overlying rocks.

FORMATION OF THE ORE BODIES.

The ore bodies are concentrations of iron oxide in exposed parts of the richer layers of the iron formation. They are further very largely limited in occurrence to places where structural conditions combine with other factors to render the agents of alteration exceptionally effective. The main agent of alteration is oxygenated and carbonated meteoric water. The waters descend from the surface oxidizing the ferrous carbonate and silicate to ferric oxide and leaching out the silica. Those parts of the iron formation most happily situated to receive a vigorous circulation of oxidized and carbonated waters are more apt to carry ore bodies than parts not so situated. Concentration of downward moving meteoric waters is favorably influenced by certain structural conditions such as (1) the occurrence of impervious foot walls of slate or other rocks, (2) pitching troughs with impervious basements, (3) an inclined position of the iron formation, (4) a brecciated or porous condition of the iron formation, (5) a large area of the iron formation exposed at the surface. Ferruginous chert and ferruginous slate are iron formation rocks which represent a part way stage between the unaltered phase and iron ore. In them the original ferrous carbonate and ferrous silicate minerals are partly or wholly oxidized to ferric oxide but the silica has not been removed. Rocks thus altered make up the great bulk of the accessible parts of the iron formations.

DEPTH TO WHICH IRON ORE OCCURS.

Nearly all of the ore bodies are exposed at the rock surface. Those deposits which are not exposed at the rock surface are connected with this surface by ferruginous chert or slate, that is to say, by rocks which have been altered by processes which if completed would result in ore concentration. Ore deposits may be expected to occur to depths to which an active circulation of oxidizing waters has penetrated. Obviously such depths will depend on factors of uncertain character which vary widely in different localities. For these reasons speculation as to the maximum depth at which ore will ultimately be found is hazardous to say the least. The ultimate maximum depth at which iron ores may be found and from which they may be profitably mined has not been attained.

IMPORTANCE OF THE MICHIGAN IRON MINING INDUSTRY.

For nearly a half century prior to 1901 the annual production of iron ore in Michigan exceeded that of any other state. Since the year 1900 the production in Minnesota has been greater than that in Michigan, and is now fully two-thirds of the tonnage annually mined in the Lake Superior region and more than half of the total production of the United States. Notwithstanding the overwhelming magnitude of the Minnesota production in recent years Michigan had shipped at the end of 1913, 40.6 per cent (255,565,856 tons) of the total tonnage mined in the Lake Superior region, and about 21.5 per cent of the entire tonnage mined in the United States in all years. Compared with nearly all of the other producing districts of North America the Lake Superior ores are high grade and were the figures in the following table expressed in weight of metallic iron rather than tons of ore the importance of the Lake Superior region would appear even greater, vastly preponderating as it is under any basis of comparison.

PERMANENCY OF THE IRON MINING INDUSTRY IN MICHIGAN.

Michigan iron mining dates from the year 1845 when 300 pounds of ore were carried out from the Jackson mine at Negaunee and made into a bar of iron in a blacksmith's forge at Jackson. Twenty years later the annual production had risen to 1,000,000 tons; in forty years to more than 2,000,000 tons, and in sixty years to between 11,000,000 and 12,000,000 tons; at the end of 1913 the total production had risen to 255,565,856 long tons.

If all of the openings which were excavated in ore in mining the total production of Michigan were thrown together to form a single void of cubical form each of its three dimensions would approximate 1452 feet, or a little over one-fourth mile. The available iron ore reserves of Michigan at the end of 1913 have in the ground in their natural condition a volume of about 2,424,000,000 cubic feet, which is equivalent to a cube whose dimensional index is about 1343 feet, or about one-fourth mile. For each 14 tons of ore mined since 1844, 13 tons still remain in the ground accessible for mining; in other words, the acceleration in production, rapid as it has been, has been fully counterbalanced by acceleration in discovery and development. There is now available for mining almost as much ore as has been shipped in all preceding years.

Were exploration and discovery to cease at once, production at the average rate for the year preceding 1914 would exhaust the known reserves in a little more than 17 years; corresponding figures for 1911 and 1913 are 15.2 years and 17.7 years respectively. Up to the present year the reserves have been maintained well in advance of production. Contrary to the popular notion, there seems to be no sufficient reason for believing that this condition will be reversed in the near future, barring of course the possible effect of free foreign competition

or other legislation unfavorable to mining and development of iron ore. The basis of this opinion rests on (1) the assured development of large ore reserves at deeper levels than have yet been attained in mining, (2) expected developments in unexplored and partially explored mineral lands, (3) reopening of abandoned properties, and (4) the future utilization of low grade ores.

MINING AT DEEP LEVELS.

The results of deep level exploration have in recent years been decidedly reassuring. This is especially true on the Gogebic and Marquette ranges. Large bodies of high grade ore have been opened under 2,000 feet in depth on the Gogebic range. The average depth of the mines on this range is now 1,385 feet, and so encouraging is the outlook for deep level mining that underground exploration at deep levels through expensively constructed shafts is no longer considered unworthy of serious consideration, as it was a decade ago. Recent drilling on the Marquette range has demonstrated that ore exists, probably in great volume, at depths near 3,000 feet. In Iron county exploration has not progressed below 1,800 feet, but ore bodies are known to occur near this depth with presumption in favor of still greater depths. Many years will elapse before deep level exploration will be generally necessary to maintain reserves for there still remains in drift covered areas and partially explored parts of easily accessible iron formations untested possibilities from which new tonnages are being annually developed.

DEVELOPMENT OF UNEXPLORED MINERAL LANDS.

At the end of the year 1913, 71,726,559 tons of ore, equivalent to about one-third of the total reserves, was available for mining in undeveloped properties. The amount of ore which will ultimately be produced from these properties is, on the whole, much greater than it is possible to measure with assurance in their present condition, although some of them have been so thoroughly developed by drilling that fairly close estimates may be made.

In addition to the acreages in which minable ore bodies are known to exist there are 2,392 separate descriptions of land comprising 94,951 acres wherein there are known possibilities for the occurrence of ore bodies. In the light of present information these lands may be divided into three classes which, in the order of relative probability for ore occurrence, may be denominated, class A, class B and class C.

CLASSIFICATION OF IRON MINERAL LANDS IN MICHIGAN
JANUARY 1, 1914, EXCLUDING ACTIVE MINES AND LANDS
KNOWN TO BE ORE BEARING.

County	Number of Descriptions.			Acres.		
	Class	Class	Class	Class A.	Class B.	Class C.

	A.	B.	C.			
Gogebic	71	45	93	2825.62	1781.31	3651.92
Iron	202	29	418	7673.98	1200.00	16992.25
Dickinson	153	21	221	6225.16	840.00	8924.78
Marquette	666	213	--	27902.15	6503.27	--
Menominee	--	--	228	--	--	9160.75
Delta	--	--	32	--	--	1270.08
Total	1092	308	992	44626.91	10324.58	39999.78

With the progress of information it is certain that the total acreage of mineral lands will be increased, but in the meantime a considerable acreage will be eliminated through exploration. A very long time will elapse before the mineral lands are adequately prospected, but exploration is annually demonstrating that large tonnages in these lands await discovery. They constitute a main source of future production.

OPENING OF ABANDONED MINES.

At the end of 1913 there were no less than 120 abandoned mines that had formerly made ore shipments, 80 iron mines were active and 21 temporarily idle. Of the 65 undeveloped properties containing proven ore bodies, 24 were active and 41 were idle. Of the 58 unfinished explorations 19 were in progress and 39 were suspended.

The changing conditions of the iron trade, gradually decreasing average tenor of shipments from the Lake Superior region, progress in beneficiation of low grade ores, demonstrated possibilities of deep level mining, the recurrence of periods of relatively easy finance, not to mention general advances in the science of mining engineering and in geologic knowledge, have made possible from time to time the resumption of activities on properties formerly abandoned. A number of such resumptions have occurred in recent years, some are in progress at the present time, and it is to be expected that a relatively large proportion of abandoned properties will in the course of time receive thorough exploration by modern methods. Many of the abandoned properties, particularly some of those which were abandoned in early years will be regenerated. No well informed person will fail to consider these properties, taken as a whole, as an important source of future production.

UTILIZATION OF LOW GRADE ORES.

The tonnage estimates which have been referred to above include only those grades of ore which are marketable under current conditions of the iron trade. In commercial practice the definition of iron ore varies from year to year with a well marked general tendency towards the inclusion of lower and lower grades of iron bearing rock. For any particular mine the definition of iron ore varies with the sale price of the available grades and cost of production. The grade of iron bearing rock that may be profitably marketed is not the same in a

given year in all districts, nor for all mines in any district. A year of lessened demand or of low prices, such for instance as 1914, always curtails the production of low grade ore and invariably forces the suspension of many mines which have only the low grades in reserve. But although demand and price, and consequently the tenor of the average output, fluctuate from year to year, the increasing ratio of iron consumption to available high grade ore reserves is gradually lowering the tenor of ore marketed from the Lake Superior region. A measure of this tendency is afforded in the following table compiled by W. L. Tinker, Secretary of the Lake Superior Iron Ore Association.

AVERAGE IRON CONTENT OF LAKE SUPERIOR IRON ORE SHIPMENTS 1902-12. ALL RANGES.

Year	Tonnage.	Per cent average (Natural.)
1912	44,365,100	51.9603
1911	30,255,438	51.8869
1910	41,172,143	52.0703
1909	40,552,405	52.1130
1908	24,774,568	52.9551
1907	38,574,136	53.4020
1906	36,179,170	53.8552
1905	32,353,475	54.6072
1904	20,529,719	55.5791
1903	22,357,876	55.5049
1902	24,930,701	56.2233

The average yearly decline in iron content for the period 1902-12 is .4263 per cent, or 4.263 per cent for the decade. It is obvious of course that this decline must cease at some future period.

There is no doubt among students of fundamental conditions that ores of very low grade will eventually have to be mined in the Lake Superior region. Experiments in the beneficiation of the various types of Lake Superior ores are already under way. From what has been accomplished it begins to be apparent that nearly all types of Lake Superior low grade ores will be subject to beneficiation at the mines. Wet concentration methods are now in use on tremendous scale by the Oliver Iron Mining Company near Coleraine, Minnesota, while other plants are located near Nashwauk and at the Madrid mine near Virginia, Minnesota, and also at the American-Boston mine at Diorite, Michigan. In Canada magnetic concentration is successfully operating at the Moose Mountain mine, near Sudbury, and at the Magpie mine, on the Michipicoten range, low grade carbonate ore is treated in rotary kilns. A number of other plants are planned on the Lake Superior ranges.

It is needless to remark that each decline of one per cent in the average iron content of ores mined adds millions

of tons to the ore reserves. How far this decline will be forced cannot be foreseen. An issue of immediate and growing concern refers to encroachment of foreign ore into territory which heretofore has been tributary to the Lake Superior mines. This question has a bearing on the matter under discussion, but its complexity does not admit of its consideration here. When the time shall come for general utilization of the low grade iron bearing rocks from the Lake Superior region the Michigan reserves alone will be ample for the needs of the country for generations. The supply is so enormous that estimates at this time have no significance.

RECENT ESTIMATES OF MICHIGAN IRON ORE RESERVES.

Careful estimates of the iron ore reserves of Michigan are made annually under the direction of the Board of State Tax Commissioners. The first estimate was made in 1911 by C. K. Leith; the estimates for 1913 and 1914 were made by the writer assisted by Mr. O. R. Hamilton.

The reserves are divided into two classes, viz.: developed ore and prospective ore. The developed ore is that which is expressed by mining engineers by the term "ore in sight" and is limited to ore blocked out above bottom levels in developed mines. The prospective ore is included in undeveloped properties, extensions below bottom levels, and in some cases lateral extensions of partially developed mine levels.

Inasmuch as each of the three estimates above referred to were made by the use of the same methods the resulting totals may be considered strictly comparable. The managers, superintendents and engineers of the various mines should be credited with the indispensable aid which they rendered in the work of each of these tonnage estimates.

ROYALTY AND OWNERSHIP.

The term royalty refers to payment by operators for the ore in properties of which they own a part or none of the mineral value. The royalty is proportionate to the number of tons of ore shipped and is calculated on a flat or a graded rate per ton, or a combination of the two. Nearly all of the modern leases provide for a graded royalty based on sale price of ore, or on its composition. The sum paid for the privilege of holding a lease is called the minimum royalty. The royalty paid by the operators on shipments is commonly charged against the minimum, but in the event that the amount is less than the stipulated minimum royalty the difference must be paid to the fee owner.

The ownership of more than three-fourths of the Michigan iron mines resides in fee holders in distinction from operators. In the period 1908 to 1913, 88 per cent of the producing mines paid royalties. There have been few recent transfers of title to minerals in undeveloped iron lands. Mainly because of the uncertainty of values, both owners and operators prefer to deal with these

lands on a royalty basis under the leasing system.

Royalties which were actually paid by producing Michigan mines for the period 1908 to 1913 range from .864 cents to .055 cents per ton. Average royalties are highest on the Gogebic range, then follows in decreasing order the Marquette, Iron River-Crystal Falls, and Menominee ranges. The figures in the table below take no account of the partial ownership of minerals by operators of some of the royalty paying mines and are consequently somewhat lower than the average royalties expressed in leases. The figures are obtained by dividing the total royalties paid by the total tons shipped, excluding the mines wherein full ownership of minerals is vested in the operator.

ROYALTIES PAID BY MICHIGAN IRON MINES. 1909-1913.

Range.	Number of producing mines.	Number of shipping mines paying royalty.	High.	Low.	Average per mine.	Average per ton mined.
Gogebic	26	26	.52723	.22374	.37633	.34765
Iron River--Crystal Falls	32	32	.54279	.08142	.28393	.23148
Menominee including Metropolitan & Calumet	15	15	.36077	.05494	.24198	.23605
Marquette--Gwinn	36	23	.86400	.02766	.44452	.19877
State	109	96	--	--	.34105	.25249

In the five years preceding 1914, 109 mines controlled by 64 operating companies including subsidiaries made shipments; of these 96 paid royalties. The Oliver Iron Mining Co. of the United States Steel Corporation is the largest shipper but does not hold the position of preponderance in Michigan as it does in the Lake Superior region in general, as shown in the table below. Of the total reserves in 1914, 46,547,454 tons, or 22.9 per cent, is controlled by the Oliver Iron Mining Company while 155,876,701 tons, or 77.1 per cent, is controlled by 16 other companies. The number of independent companies becomes 57 if the larger organizations are broken up into their subsidiaries.

VALUE OF MICHIGAN IRON ORE, 1913.

The figures annually reported to the Michigan State Tax Commission afford the means of ascertaining with accuracy the value of Michigan ore at any stage in the process of mining and marketing, from its natural location in the ground to points of delivery. The following table shows the calculation of value of Michigan ore by ranges f. o. b. mine in 1913.

TO ASCERTAIN VALUE OF 1913 IRON ORE SHIPMENTS.

Range.	Gross receipts.	"Beyond the mine" charges.	Net receipts (f. o. b. at mine.)	1913 shipment.	Value per ton.
Gogebic.....	\$15,966,386 61	\$4,117,877 71	\$11,842,508 90	3,836,739	\$3 08
Iron River and Crystal Falls.....	8,688,761 74	2,248,845 02	6,439,916 72	3,088,591	2 08
Old Menominee.....	5,306,965 51	1,227,781 23	4,079,184 28	1,708,847	2 38
Marquette.....	11,708,799 80	2,687,628 19	9,021,171 61	3,790,566	2 38
State.....	\$41,664,913 66	\$10,282,132 15	\$31,382,781 51	12,424,743	\$2 52

PART II. NONMETALLIC MINERALS. BY R. A. SMITH.

LIMESTONE.

A study of the following table shows that the limestone industry in Michigan has made an almost uninterrupted growth from 1899 to the present time, the total value increasing from about \$282,000 in 1899 to \$1,408,708 in 1913. Twenty-five quarries were in operation in 1913, located chiefly in Monroe, Charlevoix, Emmet, Alpena, Presque Isle, Schoolcraft and Mackinac counties. Other quarries are located near Menominee, Escanaba, Omer (Arenac county), Bellevue (Eaton county), Bayport (Huron county), and at Sibley near Detroit. A number of quarries are idle but some will be reopened in 1914. New developments are in progress on the D. N. McLeod property in section 31, T. 45 N., R. 8 W. and section 36, T. 45 N., R. 9 W. in Luce county. Other important developments are contemplated or are in progress at Rockport, Alpena county, by the Great Lakes Stone & Lime Co.; near Mackinaw City, Cheboygan county, by the Cheboygan Limestone Products Co.; and near Charlevoix by the Wolverine Lime Co.

The principal limestone formations in Michigan are the Trenton of Ordovician age, the Niagara and the Monroe of the Silurian, the Dundee and Traverse of the Devonian, and the Bayport of the Mississippian. The Trenton consists chiefly of limestone and dolomite, grayish buff to blue in color. Toward the base, the formation is blue and shaly or solid shale. In the Northern Peninsula numerous outcrops of the Trenton limestone occur along the lower courses of the Menominee, Ford, and Escanaba rivers, and in the valley of Rapid and Whitefish rivers. The stone varies in composition from high calcium to high magnesia, but the amount of argillaceous and silicious material renders most of the stone unfit for lime burning or chemical purposes. The stone is quarried near Menominee and Escanaba for road metal and rough building block.

Extensive outcrops of the Niagara limestone occur throughout a broad belt extending from the southern part of Garden Peninsula, Delta county, along the northern shores of lakes Michigan and Huron to the eastern part of Drummond Island. The outcrops generally occur in prominent ridges with precipitous northern slopes and

gentle southern ones and this affords most favorable conditions for quarrying. The formation is approximately 600 feet in thickness and consists of a great variety of limestones and dolomites. Some of the limestones are very massive and others very thin bedded. Many of the beds in the middle portion of the formation are very fossiliferous and cherty. In composition, the beds range from high calcium limestone to normal dolomite and unlimited quantities of limestone suitable for almost every purpose may be found in the belt of Niagara limestone even within a radius of a few miles.

Unfortunately in many cases, the valuable limestones are associated with cherty, "rotten" or low grade limestones unfit for any use, and the cost of removing these is prohibitive.

At or near the top of the Niagara, there is a massive bed of dolomite more than 50 feet in thickness. This bed is the cap-rock of the Niagara escarpment from Whitedale (Gulliver postoffice), Schoolcraft county, eastward to Point Detour, Chippewa county. The stone is a normal dolomite in composition, is free from clayey material and contains but little impurity other than chert or sand which is present in injurious amounts only locally. The stone, of which there is an inexhaustible supply, is said to be especially adapted to blast furnace or paper mill purposes. Mr. E. W. Hough has opened a quarry at Ozark in this bed.

In the lower part of the Niagara, there is a series of high calcium limestones interbedded with dolomites and dolomitic limestones. The most important high calcium bed is from 18 to 30 feet in thickness and consists of a massive very brittle lithographic limestone buff to buff gray in color. The lithographic texture and small disseminated crystals of calcite are characteristic of the bed. It has been traced from a point four miles north of Whitedale, Schoolcraft county, eastward through Blaney quarry, Gould City, Hendricks (Rex) and Fiborn quarries into the western part of Trout lake township, Chippewa county. Drift specimens were found near Pittsburg Landing and on Lime Island, St. Mary's river. This limestone is quarried on a large scale at Fiborn, Hendricks (Rex), and Blaney quarries for blast furnaces and sugar factories, and for road making.

When wood was abundant many small lime kilns were operated along St. Marys river, and the Duluth, South Shore and Atlantic and the "Soo" railroads. The difficulty of burning many of the Niagara limestones and dolomites and the exhaustion of suitable wood for fuel caused the early abandonment of most of these small kilns.

A middle portion of the Niagara consists of a large series of dense to crystalline light colored dolomitic limestones and dolomites, some of which are fossiliferous and cherty. Some of the dolomites and magnesian limestones make very good lime and have been developed on a considerable scale by the White Marble Lime Company at Manistique and Marblehead, Schoolcraft county. The stone in certain beds at Manistique is unsuitable for lime burning, but most of it is

hard and and tough and is crushed for road material.

The bluffs near Drummond, Drummond Island, consist chiefly of very massive, dense to fine grained dolomites which are divided into very large rectangular blocks by two systems of joint planes approximately at right angles. The hardness of the stone and the favorable quarrying conditions have led to the extensive quarrying of block stone near Drummond for use in the locks of the ship canals at the "Soo." At present the quarries are idle.

In conclusion it may be said that the Niagara formation contains an enormous amount and a great variety of commercial stone. There are unlimited supplies of magnesian stone suitable for blast furnace and paper mill purposes, and there are at least twenty sections of high calcium limestone favorably situated for quarrying operations and adapted for use in the manufacture of sugar, carbide and soda ash.

The Monroe formation outcrops in the St. Ignace Peninsula and in eastern Monroe county. The Upper Monroe in southeastern Michigan consists of dolomites and the intercalated high calcium Anderdon limestone. In general the dolomites are fit only for road metal, concrete material and building block. The Anderdon limestone is quarried at Sibley, Wayne county in connection with the overlying Dundee limestone and is used chiefly in the manufacture of soda ash. The Lower Monroe is essentially a dolomite formation and the stone has been quarried mainly for road metal, concrete and building block. In Monroe county and in the St. Ignace peninsula, a peculiar brecciation is locally characteristic of the Monroe dolomites and the stone is practically worthless for any use. Many small quarries were formerly operated in Monroe county, furnishing crushed and block stone to Detroit, but the great amount of limestone secured from dredging operations in Detroit river have forced most of these quarries out of business. The present quarries furnish crushed stone for the local markets and for road building.

In the northern part of the Southern Peninsula, the Dundee limestone outcrops near the lake shore four miles southeast of Mackinaw City, Cheboygan county, near Rogers City and Thompson's Harbor, Presque Isle county and on Middle Island, Lake Huron. In southeastern Michigan, the Dundee outcrops at Sibley, Wayne county and in the vicinity of Dundee, Monroe county. The Dundee is essentially a true limestone formation and contains much high calcium stone of great purity, some beds averaging 98 to 99 per cent calcium carbonate. Unfortunately the formation is generally deeply buried by glacial drift.

Large quarries are operated by the Michigan Limestone & Chemical Co. at Calcite near Rogers City and by the Solvay Process Co. of Detroit at Sibley. A new quarry is being opened by the Cheboygan Limestone Products Co. about four miles southeast of Mackinaw City, and considerable drilling has been done in the vicinity of the Mary R. Bullock (formerly the Macon or Christiancy)

quarry two miles northeast of Dundee on Macon river. The available stone in the old quarry back of the National Hotel in Dundee has been exhausted.

The Traverse formation consists of a series of shales and limestones, a heavy shale always being found at the base of the formation. Numerous outcrops of the Traverse, especially of the hard limestones, occur along the south shore of Little Traverse Bay and in Presque Isle and Alpena counties. In southeastern Michigan, it is deeply buried beneath glacial drift.

Some of the beds of limestone are locally very pure, containing 97 to over 99 per cent of calcium carbonate. The purest portions are in the vicinity of the coral reefs which characterize some of the limestone beds. Certain of the limestones contain a large amount of shaly material and gradations from shale into limestone and vice versa are characteristic of the Traverse formation.

The high calcium beds of the Traverse have been more extensively developed than the limestones of any other formation. The principal quarries are along the south side of Little Traverse bay near Charlevoix, Charlevoix county, Bay Shore and Petoskey, Emmet county; and near Alpena in Alpena county. Important quarries are also located near Afton, Cheboygan county. The quarry at Onaway has been idle for some time but new quarries are being opened at Rockport, Alpena county, by the Great Lakes Stone & Lime Co. and by the Wolverine Lime Co. near Charlevoix.

The high calcium stone of the Traverse is chiefly used in making Portland cement, soda ash, bleach, sugar, and chemical lime. The lower grade stone is crushed for concrete and road material, ground for agricultural purposes, or burned for commercial lime.

The Bayport limestone of the Grand Rapids series consists of light colored to bluish limestone, dolomite and sandstone. Some of the limestone is high calcium but the formation is locally very cherty and sandy, rendering the stone unfit for lime burning or for use in making soda ash, Portland cement, sugar, etc.

The formation has been heavily eroded and in Jackson county it forms the cap rock of some of the hills. At Bellevue, the Burt Portland Cement Co. operates a large quarry, utilizing the limestone and associated shale in the manufacture of Portland cement. At Bayport, Huron county, the Wallace Stone Co. have operated a quarry for many years. Formerly the stone from an upper high calcium bed was used for lime but this bed is now exhausted. The lower beds in the quarry are hard, dolomitic and very silicious or sandy. The siliceous material is largely present in the form of a cement, and this probably accounts for the exceptional hardness and toughness of the stone which make it especially adapted for road building.

In Arenac county, there are a number of outcrops of the Bayport limestone. Some of the stone is high calcium but it is cherty and requires more or less careful sorting. At the McDonnell quarry, three miles south of Twining,

the stone is utilized chiefly for burning lime. The M. J. Griffin quarry two miles northeast of Omer has been idle for the past six years.

In brief it may be stated that Michigan has enormous supplies of limestone of almost every variety, but most of the available supplies are in the Northern Peninsula and in the northern part of the Southern Peninsula far from the manufacturing and commercial centers.

In 1913 Mr. R. A. Smith of the Geological Survey of Michigan made an investigation of the limestone resources of the Northern Peninsula. The work upon the limestones of the Southern Peninsula will be completed in 1914, and the results of the investigations are to be published in a report on the limestone resources of the state. This report will probably be available before the close of 1915.

LIME.

The lime industry in Michigan has made but a relatively small growth in the last 10 years in comparison with the limestone industry. This is largely due to several factors, viz: (1) the growing scarcity of suitable wood for burning lime, (2) the introduction of the era of concrete, (3) the poor location of suitable limestones, and (4) the invention of gypsum plasters and other plaster substitutes. The supplies of cheap wood fuel are nearing exhaustion and much of the limestone suitable for making lime is used for other purposes or is located far from large markets. No lime is produced in the southern half of the Southern Peninsula. Concrete has largely replaced stone and lime mortar in construction work and gypsum plasters and plaster-board, sand-lime mortar for plastering. Most of the lime produced is of the "hot" variety, there being but little of the mild magnesian lime burned. The production of hydrated lime, produced by only two companies, shows a material increase. The use of lime as a fertilizer or soil rectifier has opened a new field for the disposal of the lime product.

SANDSTONE.

The value of sandstone annually produced in Michigan has decreased from about \$188,000 in 1902 to less than \$13,000 in 1911, but the years of 1912 and 1913 show slight increases, the total value being \$19,220 in the latter year. The decline of the sandstone industry may be ascribed, (1) to the poor quality of most of the sandstone in Michigan, (2) to the substitution of concrete in construction work, and (3) to the greater use of brick and artificial stone.

Sandstones belonging to the Coal Measures were formerly quarried near Ionia, and quarries in the Marshall sandstone were operated in Jackson, Calhoun, Hillsdale, and Huron counties. Most of the sandstone from these formations, upon exposure to the weather for a few years, alters in spots or uniformly to an unsightly yellow color. Some of the sandstone at Ionia, though locally

soft and friable, is streaked and mottled by various tones of yellow and red which give a pleasing appearance in structures. No quarries are now operating in the sandstones of the Coal Measures or of the Upper Marshall, but some rubble and riprap are produced in connection with the quarrying of grindstones from the Lower Marshall in Huron county. Most of the present output of sandstone is derived from the Lake Superior or "Eastern" sandstone, which is quarried extensively by the Portage Entry Quarries Co. and the Portage Entry Redstone Co. at Jacobsville, Houghton county. The "redstone" or "brownstone" of the "Eastern" is well cemented, permanent in color and has a pleasing appearance, but the great distance of the deposits of the better grades of "Eastern" sandstone from ready markets has been and will continue to be an effective obstacle in the way of their development.

SHALE.

Shale is quarried in Michigan chiefly for use in making Portland cement and vitrified brick and tile. Near Coldwater and Alpena and in Charlevoix county, shale has been quarried at several places for use in the manufacture of Portland cement. At Grand Ledge and Jackson soft shales, so-called "fire clays" of the Coal Measures, are quarried or mined on a large scale in making vitrified sewer pipe, tile, conduit and stove lining. Vitrified brick are made from Coal Measure shales at Corunna, Shiawassee county, Frankenlust, Bay county and Flushing, Genesee county.

Excellent exposures of the Coldwater shale occur at Richmondville and along the shore of Lake Huron from Forestville to White Rock in Sanilac and Huron counties and numerous outcrops occur in the vicinity of Coldwater, Union City, Quincy and Bronson, Branch county.

A number of exposures of the Antrim shale occur in Charlevoix and Antrim counties near East Jordan, Norwood and Ellsworth, and a prominent exposure is found on Sulphur island in Thunder Bay and also at Paxton, Alpena county. The Antrim shale, when fresh, contains much organic matter, but when weathered, it is very suitable for use in making Portland cement, common and vitrified brick and tile.

TRAP ROCK.

Trap rock is quarried on an extensive scale in the vicinity of Marquette and large quantities are taken out in connection with copper mining in Houghton and Keweenaw counties. The trap rock from Marquette is harder, tougher, and much less altered than the amygdaloid trap produced by the copper mines. The inferior wearing qualities of the latter for road making are partly compensated for by most superior cementing power.

Most of the quarry product is crushed for concrete and

road making. On account of its hardness, toughness, and high cementing power, it is unexcelled as a road metal. Unfortunately the great distance from thickly settled communities and the high cost of quarrying are serious obstacles in preventing the development of the trap rock industry.

GRINDSTONES AND SCYTHESTONES.

Large quantities of grindstones and scythestones are produced in Huron county by the Wallace Co., at Eagle Mills near Point Aux Barques, and by the Cleveland Stone Co. at Grindstone City. The grindstones vary in size from very small ones up to those seven feet in diameter with a 14 inch face. The broken stone is worked up into scythestones.

The sandstone, a grit stone, occurs in low lying ledges near the shore of Lake Huron. The rock after being stripped of a thin veneer of drift is cut up into square blocks by channelling machines.

As there are but two producers no tables of production and value can be given.

**THE MICHIGAN SLATE INDUSTRY.
BY O. R. HAMILTON.**

The slate quarries at Arvon were abandoned 10 years ago and the property, which is in a general state of dilapidation, was recently acquired by the Marshall Butters Lumber Co. operating mills at L'Anse. The earliest work was done by the Huron Bay Slate & Iron Co. organized in 1872. Preparatory work was started in the fall of the same year. A tramway was built to Huron Bay where a dock was later constructed to load the slate from the quarries on section 28, T. 51, N., R. 31 W., directly into lake steamers of 14 foot draught. By 1877 the company had exhausted its resources after making meager shipments. Previous to 1878, 5,100 squares of roofing slate had been shipped and during the year 1878, 1,535 squares were sent out.

In 1874 the Clinton Slate & Iron Co. began work in a small quarry on section 33, T. 51 N., R. 31 W. The resulting success is best shown by the shipments:

1875	405 squares of roofing slate.
1876	1,045 squares of roofing slate.
1877	1,034 squares of roofing slate.
1878	<u>600 squares of roofing slate.</u>
Total	3,084 squares of roofing slate.

These companies ended their operations in ruin and their holdings were acquired by the Michigan Slate Co. formed by Jackson and Lansing capitalists in 1881. The officers were James Turner, W. K. Prudden, S. F. Seager and S. L. Smith of Lansing, Mich. With a capital

of \$500,000 the new company started extensive improvements, of which we now see the ruins, the dock on Huron Bay with connecting railroad, engine house, saw mill, blacksmith shop, carpenter shop, stable, 14 dwelling houses, a two story hotel which cost \$10,000, all now going to decay except one dwelling occupied by a caretaker.

Following is a table of the production of slate for the state, which means for the quarries at Arvon since slate has been quarried from no other section in Michigan. The production for the United States is given to show relative values of the Michigan slate and that of other regions.

Michigan production of slate from Bulletin 275, U. S. Geological Survey. Shipments for years previous to 1883 not reported:

1883	5,000 squares of roofing slate valued at \$18,250 or \$3.65 per square.
1884	7,000 squares of roofing slate valued at 35,300 or 5.04 per square.
1885	10,000 squares of roofing slate valued at 40,000 or 4.00 per square.
1886	12,000 squares of roofing slate valued at 46,000 or 3.83 per square.
1887	7,000 squares of roofing slate valued at 25,000 or 3.57 per square.
1888	7,000 squares of roofing slate valued at 24,000 or 3.43 per square.
Total	48,000 squares of roofing slate valued at \$188,550 or \$3.93 per square.

No mention is made of any milled stock being shipped although sample blocks from which slabs three and one-half by five and one-half feet could be machined were sent to Chicago and Detroit for the inspection of billiard table and mantel manufacturers.

During the same period the production for the United States was 3,296,793 squares of roofing slate valued at \$10,764,709 or at an average of \$3.26 per square in addition to which \$18,000 value of milled stock was produced. Since 1888 milled stock has amounted to 15 per cent of the total production of the United States. Prices given above are f. o. b. at the quarries.

The slates suitable for roofing are found on the northwest side of the Huron Mountain Range in the vicinity of Huron Bay. The thickness of the strata is uncertain, but great, while only locally is the slate of fine texture and sufficiently free from fracture planes to be of commercial value. The roofing slate which was sent out from the quarries at Arvon is of an agreeable black color and of uniform quality. The grain is fine, silky, homogeneous and combines durability with smoothness, bearing favorable comparison with the product from the Eastern quarries.

Cleavage or splitting planes of the slate in the quarries dip very uniformly to the south, but the bedding plane is in broad anticlinal and synclinal waves which trend east and west with a consequent dip to the south or north as the case may be.

In the Huron Bay quarry (located S. W. $\frac{1}{4}$ of S. E. $\frac{1}{4}$ of sec. 28, T. 51 N., R. 31 W.) the formation dips 15 degrees to the north while the cleavage dips 30 degrees

to the south; in the Clinton quarry, which is close to the section line in the N. W. $\frac{1}{4}$ of section 33, T. 51 N., R. 31 W., the bedding dips 12 degrees to the south, nearly conforming to the cleavage which dips at a slightly steeper angle of 30 degrees. The strike is N. 85° W.

The process of quarrying was attended with great waste and the management of the early quarrying has been criticised by Dr. Rominger and other writers. However, it is true that the output was comparatively small and in absence of accurate data it is reasonably sure that the work in the quarries was hindered by many natural difficulties. The early companies exhausted their capital and left the property littered up with refuse, which placed an added burden on the later management.

A. P. Swineford, Commissioner of Mineral Statistics, in his report for 1884 says of the slate industry: "The time is near at hand when the slate interest of Baraga county will come to the front and take rank as one of the most important of our Michigan industries. Indeed all that is now needed to make it a permanently profitable industry is the employment of the capital (backed by intelligent management) necessary to its thorough development."

Occurrence of workable slates has been reported in various localities. Among these are, sec. 19, T. 51 N., R. 29 W., and sec. 24, T. 51 N., R. 29 W., in Marquette county; sec. 14, T. 48 N., R. 34 W., sec. 6 and 7 in T. 50 N., R. 32 W., and sec. 16 and 17 in T. 50 N., R. 33 W., all in Baraga county.

Literature on the Slate Industry of Michigan includes, Volume III, 1873-1876, Dr. C. Rominger's report to the Board of Geological Survey, pages 159-166.

Michigan Mineral Statistics, beginning with the year 1878, particularly volumes 1878, 1881, 1882, 1884.

Bulletin 275, United States Geological Survey, by T. Nelson Dale and others. Table of Production of Slate by States.

SAND AND GRAVEL.

The present era of concrete in the United States dates from about 1895, the production of Portland cement growing from less than 1,000,000 barrels in that year to over 92,000,000 barrels in 1913. Sand and gravel are the chief materials used in concrete aggregates hence the sand and gravel industry has grown in importance hand in hand with that of cement. In 1904 the former industry in Michigan had become of such importance that statistical data were collected by the U. S. Geological Survey. A further impetus has been given to the industry during the past few years through the inauguration of the state wide propaganda for good roads.

Owing to the large number of sand and gravel pits, their short life, the desultory manner in which most of the smaller ones are operated, the difficulty of obtaining a directory of the producers in rural communities and of securing returns, the statistical data have been more or

less incomplete and unsatisfactory. Up to 1913, the sand and gravel directory contained only about 125 names and these were chiefly of operators in the vicinity of cities and towns, hence the tabulations represent chiefly the status of the industry as developed in urban communities. In 1912, in co-operation with the State Highway Department, an effort was made to obtain a more complete directory of the producers especially for the rural districts with the net results that the location of about 3,000 sand and gravel deposits and the addresses of nearly 2,000 new producers were secured. A large part of the apparent increase in production in 1913 is due to the much larger number of reports received from the producers.

Michigan has enormous sand and gravel resources. Only a small portion has been developed and this is chiefly in the vicinity of towns and cities, or favorable means of transportation. The most extensive developments have been made in Berrien, Kalamazoo, Calhoun, Kent, Ingham, Oakland, Washtenaw, Macomb, and Huron counties. Extensive dredging operations are carried on in St. Clair river and along the shore of Lake Huron.

GRAVEL FOR CONCRETE AGGREGATES.

During the past year, numerous tests have been made upon sand and gravel by the Universal Portland Cement Co. of Chicago to determine the fitness of such material for use in concrete work and the results of these tests have been furnished the Geological Survey through the kindness of Mr. C. W. Boynton and Mr. E. F. Smith of the Information Department of the company. Further tests were conducted on the sand and gravel deposits of Ingham county by F. W. Schmidt, a student engineer in the Michigan Agricultural College, who kindly presented the Geological Survey with a copy of his investigations and tests.

The results of the investigations and tests show that, in general, pit run material in Michigan is unfitted for use as a concrete aggregate. The reason for this lies in the facts (1) that the natural material is not properly graded and (2) that various injurious impurities are present in most sand and gravel.

Concrete aggregates are usually classed as fine and coarse, according to the size of the particles. The dividing line generally accepted is one-fourth inch diameter. The air spaces between the particles are termed the voids and are generally referred to as a percentage of the whole. Tests upon nearly 200 different sands show that the percentage of voids ranges from 29 to 44 per cent, the smaller percentages predominating. If the aggregate consists of grains of nearly uniform size, the percentage of voids approaches a maximum and is generally too large for the cement to fill, consequently the concrete made from such material is porous and lacks the necessary cement bond to give it

strength. This is especially true in coarse aggregates having but little fine material to fill up the large voids. The failure of much concrete pavement can be traced to poorly graded aggregates, the concrete crumbling and cracking to pieces under ordinary traffic. An ideal mixture should consist of material grading from coarse to fine in such proportions that the percentage of voids would be reduced to a minimum. This insures a more perfect bond between the individual grains with a minimum amount of cement. The finer the aggregate, the greater is the total amount of surface. This surface must be covered by cement, if a perfect bond between the grains is to be secured, therefore fine aggregates require a greater amount of cement than coarse ones, other things being equal. Pit run material generally does not consist of a proper mixture of the finer and coarser aggregates, hence it should be screened and then mixed in the proper proportions. Experience and tests have demonstrated that the mixture should consist of about half as much fine as coarse aggregate. In pit run gravel, generally the fine material makes up half or more than half of the total bulk. Tests show that, in general, with a given proportion of cement, concrete made from screened and properly graded gravel develops greater strength than that made from unscreened and poorly graded gravel.

Nearly all sand and gravel contains impurities in the form of clay, silt, oxides or organic matter. The effect of clay or silt on concrete has been investigated by many students of concrete aggregates and widely different conclusions have been drawn. It appears, however, that clay, when present even in small amounts as a coating on the particles of sand, is undoubtedly injurious, because it prevents the adhesion of the cement to the sand particles. When it exists as separate particles scattered throughout the mass of aggregate, it appears to be harmless, and, in case of poorly graded aggregates, it may be of value in filling up the voids. Clay, when present in amounts more than four or five per cent, may dilute the cement to such an extent that the cement bond is soft and friable.

Organic matter is unquestionably injurious and generally exists in the form of roots and as a dust coating on the particles. This organic dust gives a "dead" appearance to sand when dry and its physical effect is similar to that of clay, but, in addition, it appears to have a deleterious chemical effect on the aggregate. The organic matter and clay, when present in considerable amounts, may cause the concrete to harden so slowly that constructive operations are interfered with. In many cases such concrete never develops any great strength and the use of material with much organic matter or clay should be prohibited.

Clay, silt and organic matter may be almost completely removed by washing and the tests show that in general the strength of the concrete is greater with washed than with unwashed material, provided properly graded material is used.

SALT.

The production and value of salt in Michigan for 1913 were greater than for any previous year. The total amount of brine and rock salt was 11,528,800 barrels valued at \$3,293,032. This was an increase in quantity of 582,061 barrels and, in value, of \$318,603. The average price per barrel was \$0.285, the highest since 1901, excepting in 1904 when the average price was \$0.309 per barrel. Since 1905, the average price per barrel has gradually risen from \$0.196 to the present figure.

Thirty years ago most of the salt was produced in Saginaw Valley, chiefly along Saginaw river from Saginaw to Bay City. The industry was carried on in connection with the lumber industry, utilizing the waste steam and fuel of the saw mills to evaporate the brines, which were obtained from the Marshall sandstones at depths varying from about 600 feet at Saginaw to nearly 1,000 feet at Bay City. With the decline of lumbering in the Saginaw Valley, the salt industry along Saginaw river has become relatively unimportant, only about 3% of the total output of the state coming from this region in 1913.

The chief salt producing districts are at Ludington and Manistee and along Detroit and St. Clair rivers, where artificial brines are utilized in the manufacture of salt. Rock salt is also mined at Oak-wood, a small suburb of Detroit. Over 96% of the total production of the state comes from these two districts. The most remarkable growth of the salt industry has occurred in Wayne county. Salt was first produced in this county in 1895, the total output being 13,077 barrels. In 1906 the production exceeded 1,000,000 barrels and in 1913 the total output was approximately 6,385,000 barrels. Most of this production is in the form of brine, which is used in the manufacture of soda ash, bleach, caustic, etc. The Solvay Process Co. of Delray, the Michigan Alkali Co. at Ford City and Wyandotte, and the Pennsylvania Salt Co. at Wyandotte use great quantities of brine in the manufacture of such products.

St. Clair county produces only about 15.5% of the quantity but nearly 39% of the value of the salt output of the state. The explanation of this lies in the fact that much of the salt produced in this county is of the finer grades, over 45% being table and dairy salt.

Bromine and calcium chloride are made at Mt. Pleasant, Midland and Saginaw.

The rock salt beds are encountered at about 1,900 feet below the surface at Manistee and 2,300 feet at Ludington. The total observed thickness of the salt beds in the Ludington-Manistee district is from 20 to 44 feet. In the Detroit-St. Clair rivers district, the first salt is struck at depths varying from 730 feet at Wyandotte to 1,500 and 1,600 feet, respectively, at Port Huron and St. Clair. The average aggregate thickness of the various beds appears to be about 400 feet along Detroit river, but at Royal Oak, Oakland county, salt beds aggregating 609 feet were penetrated without reaching the bottom of the

Salina or rock salt bearing formation.

Drill holes at Alpena, Grand Lake, and Onaway in Alpena and Presque Isle counties show that the salt beds have a great development in the northeastern part of the Southern Peninsula. The salt beds penetrated at Grand Lake aggregate over 300 feet and at Onaway over 800 feet in thickness. The Ludington-Manistee, the Detroit-St. Clair rivers, and the Alpena-Presque Isle county rock salt districts are probably but parts of one and the same great rock salt area.

CEMENT.

The present era of cement concrete construction dates from about 1895, when less than 1,000,000 barrels of Portland cement were produced in the United States. From this date, until checked by the general depression in 1907, there was a phenomenal growth in the cement industry, nearly 48,000,000 barrels being produced in that year. This remarkable growth was resumed in 1908 and has continued to the present when the total production for the United States in 1913 was over 92,000,000 barrels.

The "boom" years of the cement industry in Michigan were between 1899 and 1901, the production growing from less than 350,000 barrels in 1899 to more than 1,000,000 in the latter year. By 1907 the production had increased to nearly 3,750,000 barrels, but the financial depression in 1907 caused a large decrease in 1907-08. Although low prices prevailed from 1907 up to the latter part of 1912, the growth continued until the total production in 1913 reached nearly 4,100,000 barrels, the largest in the history of the industry in Michigan. From 1907 to 1912 the average price of cement in Michigan was 85 cents or below per barrel with the exception of 1911 when the price was a little over 89 cents. During the latter part of 1912, the price of cement materially increased and this increase prevailed throughout the season of 1913, the average price being \$1.036 per barrel. During the period of low prices little or no profit was made by any of the companies and some experienced severe losses and went out of business, the number of plants decreasing from fifteen to eleven.

On account of freight rates and competition from extra-state cement, Michigan cement is largely confined to local markets. With the larger number of plants of prior years, the capacity for production was much greater than local consumption. Most of the plants were thus forced to be idle part of the time or to run at less than normal capacity. The decrease in the number of cement plants and the increased use of cement enable the remaining plants to work at or near their maximum capacity with consequent reduction in the average cost per barrel. The larger consumption and the higher prices of cement make the outlook for the cement industry in Michigan much brighter than since 1907.

A comparison of the following tables show that for 1913 Michigan produced 4,186,236 barrels of cement, or

nearly 692,000 barrels more than in 1912, but the shipments in 1913 exceed those of 1912 by only about 430,000 barrels. This was due in part to the fact, that, in 1912, there was a decrease in production on account of the large stocks held over from 1911 and that the high prices during the latter part of 1912 resulted in heavy sales and a consequent reduction of the stocks. Also, upon the advent of higher prices most of the plants made preparation for a large production in 1913, some plants being closed down in the fall of 1912 for a thorough overhauling and refitting. While the increase in sales was only 430,000 barrels, the increase in value was nearly \$1,084,000, a reflection of the higher average price of cement.

GYPSUM.

The annual production of gypsum in Michigan from 1868 to 1890 inclusive never reached 75,000 tons. During the next three years, there was a large increase, a total of nearly 140,000 tons being mined in 1892. The financial depression in the United States in 1892-3 caused a large decrease and only about 66,500 tons were mined in 1895. By 1899 the gypsum industry had recovered from the effects of the depression and nearly 145,000 tons were produced. Since the invention of gypsum wall plasters and other gypsum products, the industry has made a rapid growth and nearly 424,000 tons were mined in 1913.

From 1868 to 1887, more than half of the gypsum produced was ground and sold as land plaster. Since 1887, the grinding of land plaster has become of less and less importance, only 9,600 tons being ground in 1913. More than 85% of the gypsum mined in 1913 was calcined and sold as plaster of Paris, stucco, or used in the manufacture of wall plaster, plaster board, fire proofing, various cements, and calcimines. The mining or quarrying of gypsum has become relatively unimportant in comparison with the business of manufacturing gypsum products.

In 1913, seven mines and quarries and eight mills were operated. Six mines or quarries and seven mills are located near Grand Rapids and Grandville, Kent county. One quarry and mill is located at Alabaster in southeastern Iosco county.

Three gypsum beds are worked in Kent county. The two upper beds respectively 6 and 12 feet in thickness, are near the surface. The first is quarried and the second is both quarried and mined. The third bed about 60 feet below the second is 22 feet thick and is divided near the center by a shale parting a foot or less in thickness. At Alabaster, the gypsum bed is from 18 to 23 feet thick and is quarried on a very extensive scale. In Arenac county, another gypsum bed 50 to 100 feet above the Alabaster bed has been located near Turner and Twining and the deserted village of Harmon City on Lake Huron. This, bed, called the Turner, appears to be from 6 to 22 feet in thickness.

According to the records of test holes drilled north of Alabaster, there are a number of gypsum beds from 5 to 25 feet in thickness below the Alabaster bed. Coal drillers have reported the discovery of thick beds of pure gypsum in several places in the Coal Measures of Saginaw valley. While drilling test wells for the city of Ionia, E. E. Strobe and A. G. Lang of Mason reported the discovery of a bed of pure gypsum from 4 to 30 feet in thickness. The gypsum was struck above the depth of 105 feet which would indicate that the bed is in the Coal Measures. Further investigation must be made before a definite assertion is warranted. The sample of gypsum submitted to the Geological Survey by Mr. Strobe was of the selenite variety.

CLAY.

The clays of Michigan belong in general to three classes, viz. (1) boulder clays or till, (2) lake clays, and (3) river silts. No deposits of kaolin or china clay are known to exist in Michigan and the chances for the occurrence of kaolin appear to be small. The clays are generally highly calcareous except at the surface where the lime has been more or less leached out to the depth of a few feet.

The boulder clays contain stone and pebbles and, locally, lime concretions which necessitate screening. Screening and washing have been practiced in some instances to remove this coarser material, but the extra expense of washing is generally prohibitive, except in cases where the clay possesses exceptional burning qualities. On account of the high content of lime most of the clays burn white.

The glacial lake clays, though generally high in lime, are freer from pebbles and coarse sand. There are inexhaustible supplies of lake clays along the eastern portion of southern Michigan from Arenac county to the Ohio boundary and these have been developed on a large scale in the vicinity of Detroit. The river silts occur in small deposits more or less variable in character and their generally low lying position makes them difficult to work.

In summary, it may be stated that Michigan possesses unlimited clay resources but they are largely of low grade, being chiefly adapted for making common brick and tile. In Ontonagon and Chippewa counties there are large areas of lake clays and some of those in Ontonagon county are of the slip variety, suitable for glazing pottery. A deposit of slip clay is reported near Harrietta, Wexford county. Further exploration will probably reveal the presence of other deposits of high grade clays. Nearly all of the clay mined and sold as clay in Michigan is of the slip variety, and most of it is obtained from Ontonagon county. A very small amount of the total production is sold for medicinal purposes. The sale of brick clay is incidental to the business of brick making and generally amounts to only a few tons each year.

POTTERY.

The value of pottery in 1913 exceeds that of any previous year. There was a marked decrease in the value of red earthenware, produced, but this decrease was more than made up by the increase in the value of porcelain and electrical supplies, art tile and miscellaneous pottery products. But five firms were in operation and one, the Markham Pottery Co. of Ann Arbor, discontinued business in Michigan and removed to California.

Much of the clay used in Michigan in the manufacture of pottery products is imported from other states, few of the local clays being suitable for making the higher grades of pottery.

BRICK AND TILE PRODUCTS.

The quantity and value of brick and tile produced in Michigan in 1913 were greater than in any previous year, the total number of brick of all kinds being 282,664,000, valued at \$1,758,569. The average price per thousand for all grades except vitrified was slightly greater than in 1912. The noteworthy differences in the production in 1913 from that of 1912 are the great decrease in the amount of front brick and the relatively large increase in the production of vitrified brick. The value of tile and other clay products exclusive of brick was \$692,673 in 1913 as compared with \$623,644 in 1912.

The greater portion of the brick and tile produced in Michigan is of the common variety, most of the clays of Michigan being unsuitable for making higher grade products. (See Clay.) Nearly four-fifths of the total production of common brick is made in the vicinity of Detroit. Shale or "fire clay" is used in the manufacture of vitrified brick, tile, stove lining and fire-proofing at Grand Ledge, Jackson, Corunna, Bay City, and Saginaw.

SAND LIME BRICK.

The production of sand lime brick in Michigan has grown from 9,886,000 in 1904 to 49,373,000 in 1913, valued at \$321,245. In both production and value, the amount is more than twice that of any other state. The increase in production has been made not through an increase in the number of plants but by a larger output from each. There were the same number of plants in 1913 as in 1905, yet the total production in the former year was only half that in 1913.

The plants are located at Flint, Ripley (Houghton county), Sebawaing (Huron county), Rives Junction (Jackson county), Kalamazoo, Grand Rapids, Manistee, Menominee, Rochester (Oakland county), Holland, Saginaw, and Detroit.

MINERAL WATERS.

The production of mineral waters in Michigan is subject to large fluctuations from year to year, but since 1902 there has been a decrease from about 8,654,000 gallons to 885,000 gallons in 1913. The number of springs has not decreased in the same proportion, the number in 1913 being 20, or only 8 less than in 1902. Formerly the production and marketing of mineral water was conducted as an independent business, but now it is largely carried on in connection with other lines of business.

The great decrease in 1913 is chiefly due to the installation of new filtration plants at Grand Rapids and Marquette. The unsafe character of the municipal water supply of Grand Rapids for years past had given rise to a large industry in the vending of drinking water from springs and wells in the vicinity of the city. Similar conditions, though to a lesser degree, had prevailed at Marquette where the municipal supply from Lake Superior had been contaminated by the refuse from the wood kilns of the blast furnaces.

NATURAL GAS.

Natural gas is produced chiefly in southeastern Michigan from drift wells drilled for water. The gas, associated with water, occurs in sand and gravel beds and apparently its source may be ascribed to leakage from bituminous and oil bearing strata which underlie the drift in this portion of the state. The gas is usually in small volume and under small pressure. At Onkama, however, gas was struck in drift at a depth of about 437 feet under a pressure of 185 to 190 pounds per square inch. The gas wells generally last from 6 to 10 years but some "play out" in a few weeks or months, while others may last 20 years or more. When a well is exhausted, a new supply generally may be obtained by drilling deeper or sinking another well at some distance from the old one. Most of the gas wells are in Macomb and Oakland counties.

Considerable gas is associated with the oil in the Port Huron oil field and, in the Michigan Development Co. wells at Port Huron, it is sufficient to furnish motive power for pumping the wells.

PETROLEUM.

A small quantity of petroleum was produced in 1913 at Pt. Huron by the Michigan Development Co. The oil is a natural lubricant and is used by the G. B. Stock Xylite Grease and Oil Co. in the manufacture of lubricants for which the oil is especially adapted. The oil wells drilled at Saginaw in 1912 were abandoned in 1913 after producing a few hundred barrels of excellent oil.

GRAPHITE.

Graphitic slate is quarried about 9 miles from L'Anse, Baraga county, by the Northern Graphite Works of L'Anse and the Detroit Graphite Co. of Detroit. The graphitic material is ground and utilized in the manufacture of paint. The mines were not operated in 1913, enough material having been mined in 1912 to supply the needs for 1913.

QUARTZ.

Quartz is mined near Ishpeming by the Michigan Quartz Silica Co. of Milwaukee and ground chiefly for wood filler and paint. Some of the ground product is used for making polishes. The quartz is practically pure, containing 99.73% of silica with a trace of alumina, iron and calcium, and 0.27% of moisture.

MINERAL PAINTS.

A considerable quantity of iron ore, mined in Iron county by Pick-ands, Mather & Co. is sold for metallic paint. The Acme White Lead & Color Co. of Detroit manufactures a large amount and a variety of mineral paints, but the two firms noted above are the only producers, hence statistics of production and value are not given.



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