MICHIGAN GEOLOGICAL AND BIOLOGICAL SURVEY.

**Publication 8**
**Geological Series 6**

# Mineral Resources of Michigan with Statistical Tables of production and value of mineral products for 1910 and prior years

PREPARED UNDER THE DIRECTION OF

R. C. ALLEN

DIRECTOR, MICHIGAN GEOLOGICAL AND BIOLOGICAL SURVEY

CALIFORNIA
STATE MINING BUREAU
FERRY BLDG.
SAN FRANCISCO, CAL.

PUBLISHED AS A PART OF THE ANNUAL REPORT OF THE BOARD OF GEOLOGICAL AND BIOLOGICAL SURVEY FOR 1911

LANSING, MICHIGAN
WYNKOOP HALLENBECK CRAWFORD CO., STATE PRINTERS
1912

BOARD OF GEOLOGICAL AND BIOLOGICAL SURVEY, 1911.

---

EX OFFICIO:

THE GOVERNOR OF THE STATE,

HON. CHASE S. OSBORN, *President.*

THE SUPERINTENDENT OF PUBLIC INSTRUCTION,

HON. L. L. WRIGHT, *Secretary.*

THE PRESIDENT OF THE STATE BOARD OF EDUCATION,

HON. D. M. FERRY, JUNIOR.

---

DIRECTOR,

R. C. ALLEN.

---

SCIENTIFIC ADVISORS.

Geologists.—Dr. L. L. Hubbard, Houghton; Prof. W. H. Hobbs, Ann Arbor; Prof. W. H. Sherzer, Ypsilanti.

Botanists.—Prof. E. A. Bessey, East Lansing; Prof. F. C. Newcombe, Ann Arbor.

Zoologist.—Prof. W. B. Barrows, East Lansing; Prof. J. Reighard, Ann Arbor; Mr. Bryant Walker, Detroit.

## LETTER OF TRANSMITTAL.

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

Gov. Chase S. Osborn, President.
Hon. D. M. Ferry, Jr., Vice President.
Hon. L. L. Wright, Secretary.

Gentlemen:—Under authority of act number seven, Public Acts of Michigan, Session of 1911, transferring to the Board of Geological Survey the duties which formerly devolved on the Commissioner of Mineral Statistics as defined by Act number nine of the Public Acts of 1877, I have the honor to present herewith Publication 8, Geological Series 6, a volume on the Mineral Resources of Michigan containing statistics of production and value of mineral products for 1911 and prior years with outline of the present status and progress of the more important mineral industries of the state.

Very respectfully,
R. C. ALLEN,
Director.

# CONTENTS.


| | Page. |
|---|---|
| Letter of Transmittal | 5 |
| Introduction by R. C. Allen | 11 |
| The Copper Industry of Michigan by R. E. Hore | 15 |
| The Iron Mining Industry of Michigan by R. C. Allen | 117 |
| The Pig Iron Industry of Michigan by A. E. White | 221 |
| The Jones Step Process by A. E. White | 245 |
| Michigan Coal by R. A. Smith | 257 |
| Michigan Gypsum by R. A. Smith | 305 |
| The Salt Industry of Michigan by Chas. W. Cook | 315 |
| Michigan Cement by Chas. W. Cook | 337 |
| Michigan Gold by R. C. Allen | 355 |
| Oil and Gas in Michigan by R. A. Smith | 367 |
| Directory of the Mineral Producers of Michigan | 399 |
| Statistical Tables of Various Non-Metallic Products | 431 |
| Appendix | 443 |
| Index | 457 |

# LIST OF ILLUSTRATIONS.

## FIGURES.


| | | Page. |
|---|---|---|
| Fig. 1. | Map showing location of copper and iron districts of Michigan | 18 |
| Fig. 2. | Calumet conglomerate lode | 26 |
| Fig. 3. | Kearsage amygdaloid lode | 28 |
| Fig. 4. | Osceola amygdaloid lode | 30 |
| Fig. 5. | Sketch map of Menominee ranges showing distribution of iron formations | 146 |
| Fig. 6. | Magnetic fields in vicinity of Calumet mine | 147 |
| Fig. 7. | Magnetic fields in southwest extension of Calumet trough | 148 |
| Fig. 8. | Generalized section showing thickness and relations of iron formation on the Porter-Amasa property. Compiled from plats furnished by the E. J. Longyear Company | 152 |
| Fig. 9. | Magnetic belt in T. 43 N., R. 37 W. and T. 43 N., R. 38 W | 161 |
| Fig. 10. | Map of the Gwinn district compiled from plats of the Cleveland Cliffs Iron Co. and Oliver Mining Co | 175 |
| Fig. 11. | Production curves for Michigan iron ranges | 176 |
| Fig. 12. | Map of Michigan coal basin | 261 |
| Fig. 13. | Production and value curves for Michigan coal | 303 |
| Fig. 14. | Sketch map showing location of gypsum producing areas and gypsum deposits, | 306 |
| Fig. 15. | Graphic representation of the annual production of gypsum, gypsum products, and value, 1868-1910 | 314 |
| Fig. 16. | Map showing producing salt districts of Michigan | 322 |
| Fig. 17. | Production curve for salt in Michigan and the United States | 332 |
| Fig. 18. | Map showing location of cement plants in Michigan, 1911 | 340 |
| Fig. 19. | Map showing location and direction of anticlines in lower Michigan | 379 |


## PLATES.


| | | | | |
|---|---|---|---|---|
| Plate | I. | A. | Shaft houses Nos. 1 and 2 at Centennial Mine | 33 |
| | | B. | Rock houses, old and new types, Centennial Mine | 33 |
| Plate | II. | A. | Shaft house at Baltic Mine | 33 |
| | | B. | Isle Royale Mine | 33 |
| Plate | III. | A. | Adventure Mine, 1911. New vertical shaft | 33 |
| | | B. | Baltic Mine | 33 |
| Plate | IV. | A. | Copper ingots on dock at Houghton | 33 |
| | | B. | Copper ingots on dock at Houghton | 33 |
| Plate | V. | A. | Opening up at St. Louis Mine, 1911 | 49 |
| | | B. | Starting shaft sinking at St. Louis Mine | 49 |
| | | C. | Sinking shaft in overburden, South Lake Mine, 1911 | 49 |
| Plate | VI. | A. | South Lake Mine, 1911 | 49 |
| | | B. | Vertical shaft (in felsite) at Indiana Mine, 1911 | 49 |
| | | C. | New Baltic Mine, 1911 | 49 |
| Plate | VII. | A. | Installing new hoist at Lake Mine, 1911 | 49 |
| | | B. | Skips and man car at Red Jacket vertical shaft | 49 |
| | | C. | One of the Calumet and Helca hoisting engines | 49 |
| Plate | VIII. | A. | Tamarack Mine | 49 |
| | | B | Red Jacket rock house and power house | 49 |
| | | C. | Red Jacket shaft | 49 |
| Plate | IX. | A. | Timber at Tamarack shaft | 65 |
| | | B. | Rock house and storage bin at Ahmeek Mine | 65 |
| | | C. | Shaft house at North Kearsarge Mine | 65 |
| Plate | X. | A. | Mesnard shaft, Quincy Mine | 65 |
| | | B. | Rock house at Shaft No. 2, Quincy Mine | 65 |
| | | C. | New rock house at vertical shaft, Hancock Mine | 65 |

| | | | | Page. |
|---|---|---|---|---|
| Plate | XI. | A. | Drilling competition, Hancock, 1911 | 65 |
| | | B. | Drilling by steam in St. Louis lode, 1911 | 65 |
| | | C. | Shaft sinking on St Louis lode | 65 |
| Plate | XII. | A. | Ahmeek Stamp mill, Torch Lake | 65 |
| | | B. | Tailings conveyor, Winona stamp mill, 1911 | 65 |
| | | C. | Calumet and Hecla stamp mills, Lake Linden | 65 |
| Plate | XIII. | A. | East Jordan furnace | 241 |
| | | B. | Newberry furnace | 241 |
| Plate | XIV. | A. | Antrim iron furnace | 241 |
| | | B | Furnace and chemical works, Antrim, Michigan | 241 |
| Plate | XV. | | Plant of the Kloman Mining Company at Republic, Michigan | 254 |
| Plate | XVI. | A. | Salt plant of the R. G. Peters Salt and Lumber Company | 321 |
| | | B. | Anchor Salt Company plant, Ludington, Michigan | 321 |
| Plate | XVII. | A. | Grainer block. Saginaw Plate Glass Co., Saginaw, Michigan | 321 |
| | | B. | Chemical plant Saginaw Plate Glass Co., Saginaw, Michigan | 321 |
| Plate | XVIII. | A. | Plant of the Diamond Crystal Salt Co., St. Clair, Michigan | 337 |
| | | B. | Grainer block Diamond Crystal Salt Co., St. Clair, Michigan | 337 |
| Plate | XIX | A. | Plant of the Delray Salt Co., Delray, Michigan | 337 |
| | | B. | Plant of the Detroit Salt Co., Oakwood, Michigan | 337 |
| Plate | XX | A. | Plant of the Peerless Portland Cement Co., Union City, Michigan | 353 |
| | | B. | Plant of the Michigan Portland Cement Co., Gray village, Michigan. | 353 |
| Plate | XXI | A. | Plant of the Wolverine Portland Cement Co., Coldwater, Michigan | 353 |
| | | B. | Plant of the Wolverine Portland Cement Co., Quincy, Michigan | 353 |


## INTRODUCTION.

In this volume there is presented a general survey of the more important mineral industries of the state together with statistical data of production and value of the mineral products in 1911 and prior years.

Under a coöperative agreement with the U. S. Geological Survey, reports of production and value of mineral products and other items of information have been received directly from the producers except in the case of copper and pig iron. We take this occasion to express our thanks and appreciation to all who have thus contributed to this volume. The information received in this way is properly tabulated and kept on file in the Survey office. Statistics of production are published in such detail as is permitted by space at command with due regard to the interests of the various producers. Information, other than purely statistical material, which is received in confidence is not disclosed. Those reports of individual production which are not a matter of public record are tabulated in state, county or district totals.

The labor involved in the preparation of this volume has devolved on various members of the Survey and some special appointees, each of whom has some special familiarity with the subjects presented by him. A part of the information has been obtained by personal work in the field, a second part by correspondence and reports from the producers and a third by reference to the literature. In preparation of the articles on the copper and iron industries we have had special reference to two recent publications viz., "The Appraisal of the Mining Properties of Michigan" by J. R. Finlay and Monograph 52, U. S. Geological Survey by C. R. Van Hise and C. K. Leith. The former contains a closer estimate of reserves of copper and iron ores than heretofore attempted and the latter, accurate statistical and geologic data, especially of the iron districts, and complete revised maps of the mineral producing areas.

*Copper.* The main features of Mr. Hore's article on the Copper industry are the description of the copper lodes, a thing not heretofore attempted in such completeness of detail, and a review of recent developments in copper mining and exploration. Unlike the iron mining industry the copper industry is a quasi-public enterprise, financed by a very large number of stockholders in Michigan and other states. For this reason the description of particular properties and details regarding the various companies should be useful to a large number of people.

*Iron.* The inclusion of deails regarding the various iron mines and iron mining companies is omitted for a number of reasons among which are: lack of space; such details have been published in recent reports of the Lake Superior Institute of Mining Engineers; the general public is not interested in these details to the same extent as in the case of the copper companies; the desire to include more complete statistical data and a general account of the more important factors in the iron mining business.

The important recent developments on the different ranges have been noticed, particularly the bearing of these on the future of the iron mining industry, and special stress laid on developments of new properties and the extension of producing ground in the Iron River and Crystal Falls districts lying in the great Upper Huronian slate area containing probably the greatest undeveloped ore reserves of the state.

As bearing on the problem of the utilization of low grade ores, there is presented a special article by Mr. Albert E. White on the Jones Step Process, the first authoritative description of the experiments which are being conducted by Mr. John T. Jones of Iron Mountain and associates.

The status of the pig iron industry was made the object of a special investigation by Mr. White and is a valuable contribution to the literature of iron making in Michigan.

*Coal and Gypsum.* The Survey reports on coal and gypsum have been out of print for a number of years and, therefore, there has been given to these subjects more space than would otherwise have been done.

*Oil and Gas.* Drilling for oil and gas is somewhere in the state going on almost continuously. On no other subject does the Survey receive so many demands for information. In the article on oil and gas Mr. R. A. Smith presents the available information and the article is commended to all persons contemplating exploratory operations. Reports from drill men on indications of oil or gas and accurate well records, are earnestly solicited that the Survey may better keep in touch with the situation as it develops. Scattered bits of information of no significance when considered singly may when correlated have an important bearing on the matter of intelligently directed exploration.



*Salt and Cement.* Mr. C. W. Cook has made special studies on these subjects. The article on salt is partially a brief abstract of an extended treatise on this subject which Mr. Cook has had in course of preparation for the Survey for the past eighteen months and which will appear in print it is hoped before the end of the year. The basis of the report on cement is the information obtained by Mr. Cook in 1911 for the State Tax Commission under the direction of Mr. J. R. Finlay.

Miscellaneous Products: Lack of space in this volume precludes the inclusion of descriptive matter bearing on the minor mineral products. There is given, however, statistics of production and value for 1910 and 1911. Special reports on particular mineral industries will appear in subsequent volumes but all of them cannot be thus treated each year.

*List of the Mineral Producers of Michigan.* There is included a directory of the mineral producers of the state. There are doubtless some omissions in the list but it is complete so far as we have data. Its publication should aid dealers, miners, manufacturers and others interested in the mineral industry in getting in touch with each other. The Director will appreciate the receipt from any source of additions or corrections to the directory.

TO THE MINERAL PRODUCERS OF MICHIGAN.

The Survey invites criticism of this and subsequent annual statements of similar character. If you find inaccuracies of statement, let us know of them; if you can suggest an improvement, kindly do so. We want your coöperation in making the annual statement of development and progress in the mineral industry of maximum usefulness. A State Geological Survey should function in part as a bureau of natural resources; we hope that you will use the Michigan Geological Survey as such. If you want information that does not appear in our formal reports, write for it; the probabilities are that we have it if it exists or if we cannot give it to you we can direct you to sources where it may be obtained. Our information is public property with the exception of certain matters which are considered as a private business asset by the sources from whence it comes to us.

R. C. ALLEN,
Director.

Lansing, Michigan, February 15, 1912.

# THE COPPER INDUSTRY OF MICHIGAN.

BY

REGINALD E. HORE.

## PREFACE.

In the following pages will be found some account of Michigan's copper deposits and mines. In preparing this I have drawn on the writings of many authorities and desire to mention those I have consulted most frequently.

For geological descriptions I have made free use of the writings of Pumpelly,[1] Irving,[2] Hubbard,[3] Lane,[4] Seaman,[5] Wadsworth,[6] Wright,[7] Rickard,[8] and Gordon.[9]

For mine descriptions and company notes, the Copper Handbook published annually by Horace J. Stevens of Houghton, has proven of great assistance. Those who are intimately acquainted with the copper industry, know Stevens' Handbook to be carefully written and based upon information from reliable sources. It contains descriptions of the property of every copper mining company that operates or has operated in Michigan, and includes information on a number of subjects which are not mentioned at all in my report. I wish to acknowledge my indebtedness to Mr. Stevens, and to recommend the book to others.

For statistical data I have used especially the figures collected and published by the U. S. Geological Survey and the State Commissioners of Mineral Statistics; but I have also used figures published in Stevens' Handbook and in J. R. Finlay's report to the State Tax Commissioners. For individual mines I have accepted the

---

[1] Copper-Bearing Rocks of the Upper Peninsula, Raphael Pumpelly. Geol. Sur. Mich., Vol. I, 1873.

[2] The Copper-Bearing Rocks of Lake Superior, by R. D. Irving. U. S. G. S., Monograph V, 1883.

[3] Keweenaw Point, by L. L. Hubbard. Geol. Sur. Mich., Vol. VI, 1898.

[4] The Geology of Keweenaw Point—a brief description. A. C. Lane. Pro. L. S. Min. Inst., 1906, pp. 81-104.

[5] Notes on the Geological Section of Michigan. A. C. Lane and A. E. Seaman. Jour. Geol., Vol. XV, No. 7, 1907.

Native Copper Deposits, A. C. Lane. Quebec Meeting Canadian Mining Institute, 1911.

[6] Origin and Mode of Occurrence of Lake Superior Copper Deposits. M. E. Wadsworth. A. I. M. E., Vol. XXVII, pp. 669-696, 1898.

[7] The Intrusive Rocks of Mt. Bohemia. F. E. Wright. Mich. Geol. Survey, Sept., 1908, pp. 355-402, 1909.

[8] Copper Mines of Lake Superior. T. A. Rickard.

[9] A geological section from Bessemer down Black River. Mich. Geol. Survey, 1906, 99. pp. 399-507, 1907.

figures contained in the annual reports of the mining companies. Some figures have been specially collected from the companies for this report.

For a general description of the mines and the methods of mining, I would recommend T. A. Rickard's book on Copper Mines of Lake Superior, and a series of articles[10] by R. B. Brinsmade. Methods in use at individual mines and mills have been described by a number of writers in various publications, and references to some of these will be found in the footnotes. Mr. A. Carnahan[11] has published interesting accounts of the two largest properties.

Accounts of the early development of the copper district will be found in H. Steven's handbooks and in articles by H. V. Winchell and Graham Pope published by the L. S. M. I., in 1894, Vol. II, pp. 33-50 and 1901, Vol. VII, pp. 17-31.

To readers interested in a thorough discussion of the geology, I wish to recommend Dr. A. C. Lane's Monograph,[12] now being printed for the State Survey. A briefer account of the general geology and a discussion of the origin of the ores by Van Hise, Leith and Steidtman has been recently published by the U. S. Geological Survey, as part of a monograph[13] on Lake Superior geology. Both these reports are accompanied by numerous geological maps.

An excellent map showing company holdings has been published by R. M. Edwards, and recently revised by B. F. Sparks and W. R. Hodge of Houghton.

REGINALD E. HORE.

Houghton, Mich., January 10, 1912.

---

[10] Michigan Copper Mines and Methods. Min. World, 1910, Mar. 12, Mar. 26.
[11] Calumet and Hecla. Min. World, Oct. 13, 1906.
Copper Range Consolidated. Min. World, Dec. 1, 1906.
[12] The Keweenaw Series of Michigan. By Alfred C. Lane. M. G. S. In press.
[13] Geology of the Lake Superior District. By Chas. Van Hise and C. K. Leith. Mono. 52. U. S. Geol. Survey, 1911.

CONTENTS.

1. Introduction. Location of the mines.
General Geology of Keweenaw Point.
Structure and lithology of the copper-bearing rocks.
2. Mode of occurrence of the copper.
3. The ore deposits or lodes.
4. Character and value of the ore.
5. Methods of prospecting and developing deposits.
6. Methods of mining the ore.
7. Crushing and concentration of the ore.
8. Smelting ore and concentrate.
9. Costs and profits.
10. Present condition of the industry.
11. Copper mining companies.
12. Statistical tables. Production, costs and profits.

# CHAPTER I.

## INTRODUCTION.

*Location of the Mines.* The Copper Mines of Michigan are all located on Keweenaw Point, the prominent peninsula which extends for seventy miles northeasterly from the south shore out towards the middle of Lake Superior. As may be seen from the accompanying map, the mines are in the counties Ontonagon, Houghton and Keweenaw. In the early days the chief activity was in the vicinity of the Mass and Minesota mines in Ontonagon county, and in the Eagle River section of Keweenaw county, but in recent years nearly the whole production (86.2% in 1910) has come from mines in Houghton county. Most of the producing mines are in a 25 mile section of the copper range between Painesdale and Mohawk. In order from southwest to northeast are the following important mines: Champion, Trimountain, Baltic, Atlantic, Superior, Isle Royale, Hancock, Quincy, Franklin, Osceola, Calumet and Hecla, Tamarack, Centennial, South Kearsarge, Wolverine, North Kearsarge, Allouez, Ahmeek, Mohawk and Ojibway. All but the last four are in Houghton county, and these are in Keweenaw county. Further southwest in Ontonagon county, are the Lake, Mass, Adventure, Michigan and Victoria mines. Other active properties in

Houghton county are Winona, King Philip, Wyandot, Elm River, Houghton, New Baltic, LaSalle, St. Louis, Laurium and Oneco.

In the Porcupine Mountain District, further west, development work is being done on the White Pine property. In the vicinity of Lake Mine, Ontonagon county, there are being opened up a number of properties including Indiana, South Lake and Algomah. On some other properties diamond drilling or other prospecting work is being done. Among old mines once productive, but now long abandoned, are the well known Cliff and Central in Keweenaw county.

*General Geology of Keweenaw Point.* The Keweenaw peninsula has in its central part a plateau at an elevation of 400′ to 600 feet above the lake level. From this the ground slopes down on either side, gradually towards the west and more abruptly towards the east. A valley occupied by the narrow arm of Portage Lake cuts across this plateau, and gives ready access for lake ships. Further out on the point this plateau drops away, and there is a short gap of lower land followed by two long ridges which extend with occasional gaps well out to the end of the point. The northern ridge is called the Greenstone Range, and the southern is known as the Bohemian Range.

The plateau and ridges along the central part of the peninsula are formed by the copper-bearing, Keweenaw formation,—bedded igneous and sedimentary rocks dipping to the northwest, and striking with the general trend of the point. The western slope down to Lake Superior is formed by the upper members of the same series. The easterly part is underlain by gently inclined Upper Cambrian sandstone, separated from the Keweenawan by a great fault, which extends the whole length of the point. The fault is of the reverse type,[1] the older series slipping up and over on the sandstone.

STRUCTURE OF THE COPPER-BEARING SERIES. The Copper Range of Keweenaw Point is comparatively simple in its larger geological features. The outcrop shows but the eroded edge of one limb of a synclinal formation, which dips under Lake Superior and appears again on the north shore. The beds strike with the general trend of the shore line northeast. Near the extremity of the point the strike is almost due east, and at the very extremity the formation bends south of east. In following the range out towards the point, there is found a lessening of the inclination of the beds, and in going from lower to higher horizons, the same change in dip is found. On following down on the dip of a bed, there is found in

[1]For diagram by Prof. Seaman showing this relation, and for discussion by Dr. Hubbard, see Vol. VI, pp. 118-123.



ine the dip
own the in-
Hecla, the
n being 38°-
le. At the
21° in the
are few
re outlined.
n the neigh-
locality has
part of the
her west in
e the struc-

wan series.
parallel the
he Potsdam
y the fault
beds of the
re probably
ıctive lodes
e dip of the

lower beds
ement been
has moved
th from its
or "slide"
or, consider-

beds of soft
formed by

re the fault
throw has
t frequently
n the mines
short cross
f the series
the Baltic
rable small

Houghton co
Houghton, N
In the Po
work is bein
of Lake Mine
ber of proper
some other p
is being don
abandoned,
county.
*General G*
has in its ce
above the la
side, gradua
east. A val
across this
Further out
a short gap
with occasio
ern ridge is
as the Bohe
The plate
are formed
igneous and
ing with th
to Lake Sup
The easterl
sandstone, s
extends the
type,[1] the o
STRUCTUR
Keweenaw
features. T
synclinal fo
again on th
of the shor
strike is al
bends south
there is fo
going from
found. On

[1]For diagra
Hubbard, see



all deep mines a lower angle of dip. At the Quincy Mine the dip of the lode near surface is about 54°, while a mile down the inclined shaft, the dip is only 37°. At the Calumet and Hecla, the change in the same distance is very little, the inclination being 38°-39° at surface and 36°-37° at a depth of over one mile. At the Central Mine, the dip increases from 27° at surface to 21° in the lower levels. On the main copper range there are few marked divergences from the general structure as above outlined. Changes in strike and dip and thickness of beds occur in the neighborhood of some intrusive masses. Recent work in one locality has shown the beds there to be sharply folded, so that a part of the formation is dipping south instead of northwest. Further west in the Porcupine Mountains, folding and faulting has made the structure locally more complex.

*Faulting.* Faults are very numerous in the Keweenawan series. The most important line of movement is that nearly parallel the strike where the series has been brought up against the Potsdam sandstone. In the northern part of Houghton County the fault dips to the west at a much smaller angle than do the beds of the Keweenaw series. Beds at low horizons in the latter are probably cut off at no great depth; but none of the very productive lodes are very close to the sandstone here. Further south the dip of the fault is steeper.

There are instances where upper beds have slipped on lower beds great distances; but only in a few cases has the displacement been measured. Dr. Hubbard has estimated[2] that one part has moved on the lower part of the series about 2.7 miles north from its original position. In other cases a similar slide fault or "slide" has displaced the upper downwards on lower beds for considerable, but unmeasured distances.

Throughout the series there are frequently found thin beds of soft clay-like material or fluccan, which have probably been formed by beds sliding on one another in this way.

Besides these "slides" there are numerous faults where the fault plane cuts across the bedding. Where the amount of throw has been measured, it is usually less than 100 feet, and most frequently it is so much less, that displaced beds are picked up in the mines by a little widening of the drifts or by driving but short cross cuts. Faults are especially numerous in the parts of the series near the eastern sandstone. In some of the mines on the Baltic lode, which is at a low horizon, the rocks show innumerable small faults.

[2]Fault in Central Mine. Mich. Geol. Sur., Vol. VI., 1896. pp. 86-91.

*The Copper-bearing rocks.* The Keweenaw formation in Michigan is commonly divided into two[3] series, lower and upper. The lower is largely igneous, with occasional interstratified beds of sediment, and the upper largely sedimentery with some interbedded layers of igneous rocks. The copper bearing lodes are, with one exception, in the lower Keweenawan. The exception is a deposit in sandstone in the upper series.

*The Lower Keweenawan* of the Copper Range is chiefly made up of dark grey and brownish volcanic rocks in beds usually between 10 feet and 200 feet in thickness; but often thinner or thicker. With the dark colored volcanic rocks are imbedded reddish conglomerates and sandstones, ranging from mere seams up to beds of several hundred feet in thickness. In the horizon of the chief productive lodes, the sediments form only about 7 per cent of the total thickness of the formation. In addition to the dark colored volcanic rocks, there are much smaller areas of light colored felsitic and porphyritic types, and more basic coarse grained intrusive masses. The felsites do not occur in the immediate vicinity of the chief copper lodes; but are common at both lower and higher horizons. Distinctly grained intrusive rocks, such as gabbros, occur in the Keweenaw series but are not found in the copper mines.

The dark colored heavy volcanic rocks* range in composition from basic to intermediate, while those of lower specific gravity and light color are more highly siliceous. Dark colored dense effusives are commonly called *trap* and are mostly *melaphyres* or *porphyrites*, the former basic and the latter of intermediate composition. These are often partially amygdaloidal, and such portions are commonly designated simply as amygdaloids. The melaphyres are from their different textures classed as *diabases, ophites* and *dolerites.* Diabases show lathshaped feldspars enwrapped by augite, while ophites show lustre mottling on pyroxenes, and dolerities are even grained and lack the diabasic texture and lustre mottling. The light colored rocks are called *felsites* and *porphyry.* The felsites are composed chiefly of a fine felted mass of feldspar and quartz, and in some varieties have phenocrysts of feldspar. The typical porphyries show phenocrysts of quartz, and occasionally of feldspar, in a very dense ground mass, usually quite light colored and sometimes brownish red.

[3]A third division is sometimes, and notably in a recently published monograph by C. R. Van Hise and C. K. Leith of the U. S. G. S., made to include only the sediments found in some localities at the bottom of what is more commonly called the Lower Keweenawan. The rest of the Lower is then called Middle Keweenawan.

* Numerous descriptions of the melaphyres will be found in A. C. Lane's report on Isle Royale. The felsites of Keweenaw Point have been described by L. L. Hubbard in the report of the Geological Survey for 1898.



*Alteration of the rocks.* Almost all the Keweenawan rocks are much altered. Many have been almost completely changed by the development of new minerals. The melaphyres are usually of dull brownish or greenish color, due to secondary products, common colored ones being chlorite, epidote and a brown micaceous mineral resembling iddingsite. Very commonly a considerable portion of a bed below the true amygdaloid top is spotted with aggregates of chlorite and other secondary minerals, so that it resembles amygdaloid and is called *pseudamygdaloid.* The felsites usually show a devitrified ground mass, in which are abundant particles of secondary quartz and altered feldspars, while here and there are areas of calcite and epidote. The coarse grained intrusive rocks, such as gabbro, have commonly an abundance of chlorite or secondary hornblende from the alteration of the original ferromagnesian minerals. The two green colored secondary minerals, chlorite and epidote, are very abundant in the copper bearing rocks.

*The sedimentary beds* are chiefly coarse red *conglomerates,* red-brown and grey *sandstones* and grey or brown *shales.* The pebbles in the conglomerates are mostly reddish or brownish felsites, and in one locality quartz porphyry. The sandstones and the matrix of the conglomerates are very largely made up of small particles of rock as well as of mineral fragments. Many of the sediments have evidently been largely, if not wholly, derived from the igneous beds of the Keweenawan series itself. The upper Keweenawan is composed of thick beds of conglomerates, sandstone and shale, with comparatively few igneous beds.

## CHAPTER II.

### MODE OF OCCURRENCE OF THE COPPER.

Practically all the copper mined occurs as the native metal. Arsenides and sulphides are found in some small veins, but the tonnage mined is very small. One lode, the extent of which is not yet known, has copper in the form of oxide, silicate and carbonate minerals.

*The native copper* occurs chiefly in bedded deposits. It fills cavities and replaces mineral and rock constituents of conglomerates and amygdaloids. By far the richest lode is a conglomerate, but all the others now being worked are amygdaloids. Other types of deposits are fissure veins cutting across the formation, epidotic beds parallel or nearly parallel the formation and disseminated copper in sandstone. Recently copper has been found in a much altered and fissured mass of felsite.

*The bedded deposits* are long and continue to great depths. The most important ones are worked for a distance of two to five miles along the strike. Two of the lodes are still being worked at over a mile down on the slope of the beds, and it is probable that others will be worked to a like depth. Most of the lodes average over ten feet in thickness, and some over twenty.

*Conglomerate lodes.* In the conglomerate lodes the copper occurs chiefly in the matrix, and has irregular branching forms suggesting that it has filled cavities in the porous rock. In other cases, however, there is copper in forms which show that it has taken the place of other constituents in the rock, and in many cases it has partially replaced large pebbles.

*Amygdaloid lodes.* In the amygdaloid lodes the copper occurs partly with other minerals, filling the amygdules. Much of it, however, is not in the form of a filling. As a rule the rock carrying high values in copper is to a large extent made up of secondary minerals, and the metal is usually enclosed in masses of these, especially in calcite, epidote, chlorite, prehnite and quartz. The copper, like these and other secondary minerals, is in such cases evidently a replacement deposit.

*Fissure veins.* In fissure veins the native copper occurs in masses, very irregularly distributed. The most usual immediate associates of copper are epidote, prehnite and chlorite. Calcite is abundant in most veins, but calcite veins not showing these silicate minerals seldom show copper. The veins worked were narrow in the traps, but widened out where the fissure crossed more porous strata. Commonly there are numerous masses of country rock enclosed in these veins, all of which cut across the formation and are nearly vertical. None are now being worked, but a large quantity of metal was taken from such deposits at the Cliff and Central[1] Mines years ago.



*Epidotic beds.* Epidotic beds, yellowish green in color, and composed largely of epidote and quartz, are frequently found, and several contain disseminated copper. In only one mine, however, has an important tonnage been taken from deposits of this sort. At the Minesota Mine an epidote bed striking with the bedded traps, and dipping nearly parallel with them, yielded a number of exceptionally large masses of copper and made the mine a dividend producer for a few years.

*Deposits in sandstone.* Sandstone and conglomerate carrying particles of copper occur in the upper Keweenawan in a horizon far above that of any of the important lodes. The copper fills in the spaces between sand grains, and is in very small particles. It is sometimes in mere films, but most of it is in grains.

*Deposit in felsite.* Native copper has been found at the Indiana and adjoining properties in Ontonagon County in a type of rock that has not been found productive elsewhere in Michigan. The copper occurs with secondary quartz, calcite and epidote in a felsite that is badly decomposed and full of joints and calcite seams. The felsite has been much crushed, and in places is brecciated. The natural deduction, from examination of the drill cores, is that the copper has been deposited with the calcite and other secondary minerals in much the same way as in the other lodes.

*Arsenides in veins. Arsenides and sulphides* are found in some of the mines in veins a few inches wide cutting across the lodes.

*The arsenides* are of variable composition containing copper, arsenic, cobalt and nickel in many different proportions. Names have been given to several varieties, including keweenawite $(Cu, Ni)_2 As$, mohawkite, whitneyite, $(Cu_9As)$ domeykite, $(Cu_3As)$ algodonite $(Cu_6As)$. The usual gangue mineral in fissures is calcite. The veins often show calcite as the earliest deposit forming against the walls, while the arsenides fill the central portion, the resulting appearance of a vein in the dark traps is that of a white band with a dark streak down the middle.

[1]Diagrams of the vein at the Central mine are given in a paper by L. L. Hubbard in proceedings of the Lake Superior Mining Institute, Vol. 3, 1895; pp. 74-83.
[2]The crystal character of the arsenides have been studied and described by Dr. Koenig. L. S. Min. Inst., Vol. 7, pp. 62-64.

*Sulphides in veins.* Sulphides are found in veins similar to those containing arsenides, but are of even less commercial importance. The veins are very narrow, generally less than one inch wide. Chalcocite ($Cu_2S$) is the most common sulphide. Covellite ($CuS$), Bornite ($Cu_3FeS_3$), and Chalcopyrite ($CuFeS_2$) also occur.

*Copper oxide, silicate and carbonate.* A deposit of copper oxide, silicate and carbonate minerals has recently been opened up in an amygdaloid bed at the Algomah Mine. It shows black melaconite ($CuO$), green chrysocolla ($CuSiO_3+2H_2O$) and green malachite ($CuCO_3 . Cu(OH)_2$) in irregular masses, and also as minute veinlets, filling the crevices in a brown melaphyre. The deposit follows the bedding of the rocks, making bodies of varying thickness along the strike. Chrysocolla in felsite has been found in drill cores from other properties in the neighborhood.



## CHAPTER III.

### THE ORE DEPOSITS.

A large number of lodes are being worked. The most important producing lodes are the Calumet conglomerate and the Kearsarge, Baltic, Pewabic, Osceola and Isle Royale amygdaloids.

*The Calumet lode* is the cupriferous portion of one of the conglomerate beds in the lower Keweenawan series. This bed continues for a distance of several miles, but the ore bearing portion is confined to that part, about two miles long, which outcrops on the property of the Calumet and Hecla Mining Company, and which at depth crosses into the property of the Tamarack Mining Company. On other properties north and south, development of the conglomerate has not proven profitable. The best ore[1] was in two shoots at Calumet and South Hecla shafts pitching north at about 70°.

The conglomerate rock mined is made up largely of pebbles of felsites and quartz porphyries cemented together with small particles or rock, calcite and native copper. The cementing material contains also, in smaller amounts, other minerals such as iron oxides, quartz, epidote and chlorite. There are a few pebbles of melaphyres, amygdaloids and porphyrites.

The conglomerate is characteristically red, both pebbles and the cement being commonly of that color. Most of the constituents are of light tones; but a considerable portion is made up of pebbles that are dark reddish brown. Most of the lighter colored pebbles, light red or flesh colored, are dense felsites and quartz porphyries. The darker colored ones have usually a finely felsitic ground mass with phenocrysts of brown red feldspar. Other dark brown ones have a very dense ground mass with phenocrysts of quartz. Some are dark colored felsitic rocks with no phenocrysts. Many of the pebbles show an outer rim of lighter color than the interior. This results from alteration.

The small rock particles in the matrix are similar in character to the pebbles, but have been more extensively altered. The copper occurs chiefly as part of the cement, filling spaces between sand grains and pebbles, but some has replaced the rock constituents.

[1] P. Kirchoff, Eng. & Min. Jour., July 12, 1884, pp. 17-20.

It is a common occurrence to find large pebbles partially replaced by native copper,[1] and at some rock houses a number of these are picked out every day. While most of the copper is coarse, much is in very minute particles and the ore has to be finely ground to permit of its recovery.

When a large section across the lode is exposed, as in the drifts and stopes, there are usually to be seen rather distinct light and darker colored portions. The copper is chiefly in the light colored portions. The darker colored places are noticably more compact and less altered than the lighter. They heve evidently not been much influenced by the solutions which is more porous parts altered the rock and deposited native copper.

The thickness of the lode, as determined by mining operations, is from ten to twenty feet. There are some thicker and thinner parts. Near the surface at the Calumet Mine the lode is about thirteen feet, at some levels at great depths at the Tamarack Mine about twenty-two feet, and at similar depth further south in the Hecla mine only about ten feet thick. The average thickness of the ore still to be mined is said to be about 15 feet. The thickness sometimes varies considerably in short distances. According to Capt. Daniell, the thin portions "seems to occur in spots rather than in regular courses." As a rule the values are irregularly distributed from wall to wall. In places the poorest part of the lode is near the hanging wall, and there are places where the upper portion is the richest. In extensive workings tributary to one deep shaft the portion next the footwall was always the least productive.

At the Calumet mine the lode strikes N 33° E and near surface dips to the N. W. at an angle of about 38°. At the South Hecla mine the dip at surface is 39°. At depth the angle of inclination is slightly less than at surface. One shaft, following the lode closely, is inclined at 38° down to the 36th level, and below that at 37° 30′.

The copper content of the conglomerate in the upper levels averaged 2% to 5% for a large output. In 1888, when the C. & H. mine was about 3,000 feet deep the ore mined yielded 4.5% copper. In 1900 the ore mined averaged 3% copper; but the working below the 57th level in the northern part of the mine have yielded ore of much lower grade. The average for the Calumet and Hecla mine for 1910 was 30.12 pounds per ton, while the output of the Tamarack mine in the same year averaged 21.1 pounds copper per ton of ore.

[1]See Dr. A. C. Lane's paper, "A boulder from the Calumet conglomerate." Econ. Geol., Vol. 4, and pp. 158-173, 1909.



ing but
ally all
ıed.
y other
t which
roducer
also a

the con-
rield 26
Another
ount of
he lode

l upper
re near
ıocrysts
is com-
ygdules
copper
shaped
copper

l to the
rthwest

r a con-
arsarge,
Mines.
eca and
of the
r a mill
Calumet
copper
proven

Mohawk
portions
ıds, and
910-1911
At the
percent-
age of rock broken and not stamped is very small.

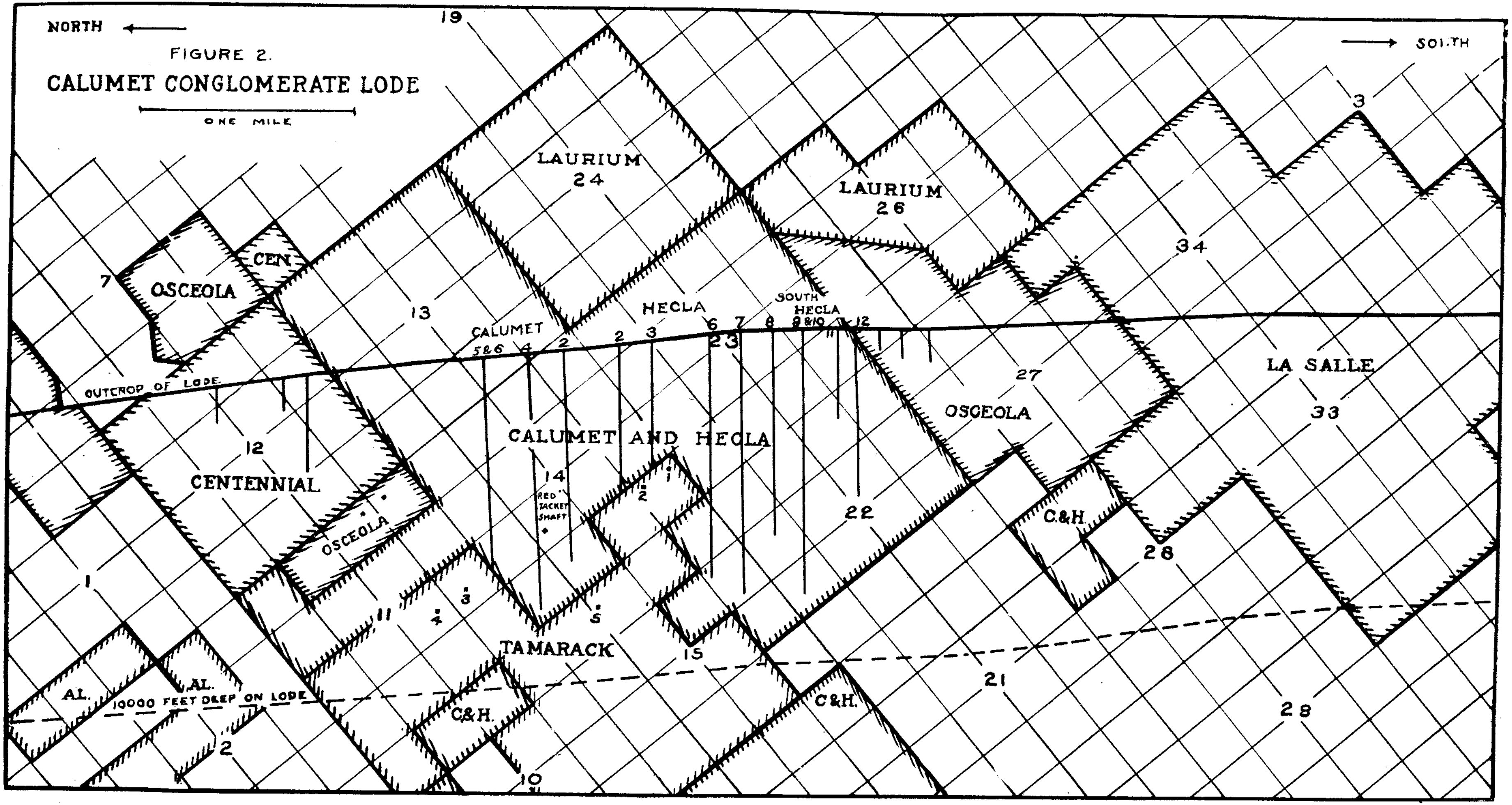

NORTH
SOUTH
FIGURE 2.
CALUMET CONGLOMERATE LODE
ONE MILE
LAURIUM
24
LAURIUM
26
OSCEOLA
CEN
CALUMET
HECLA
SOUTH HECLA
OUTCROP OF LODE
CALUMET AND HECLA
CENTENNIAL
OSCEOLA
RED JACKET SHAFT
TAMARACK
OSCEOLA
LA SALLE
C&H.
AL.
AL.
10000 FEET DEEP ON LODE
C&H.
C&H.
C&H.

FIG. 2.

It is a
by nati
picked
is in v
permit
Whe
and st
darker
portion
and les
influen
rock a
The
is fron
parts.
teen f
about
Hecla
the ore
someti
Capt. I
in reg
buted
near tl
is the
the po
At t
dips t
mine t
is slig
closely
at 37°
The
aged 2
was al
1900 t
the 57
much
1910 v
mine
ore.

[1]See Dr. A. C. Lane's paper, "A boulder from the Calumet
Geol., Vol. 4, and pp. 158-173, 1909.



In the mines blocks found to be low grade are left standing but aside from this there is little selection of the ore. Practically all the conglomerate broken in the stopes is hoisted and stamped.

The conglomerate lode has yielded more copper than any other on Keweenaw Point, and the metal has been won at a cost which has made the Calumet and Hecla the leading dividend producer among the mines of the world. The Tamarack mine has also a good record.

Mr. J. R. Finlay estimates that the C. & H. has still on the conglomerate lode about 27,000,000 tons of ore, which should yield 26 pounds per ton—a total of 702,000,000 pounds copper. Another estimate is 30,000,000 tons, 900,000,000 pounds. On account of great depth and lower values, the Tamarack portion of the lode gives little or no profit at present prices of copper.

*The Kearsarge Lode* is the copper-bearing amygdaloidal upper portion of a bed of porphyritic melaphyre. The melaphyre near the lode is a dark grey or brownish ophite, with large phenocrysts of feldspar, usually greenish labradorite. The lode itself is commonly a brownish amygdaloid, with numerous and large amygdules of calcite, quartz, red feldspar and green opidote. Some copper occurs filling amygdules; but much of it is in irregularly shaped forms, which have evidently replaced the rock. Much of the copper is closely and probably genetically associated with epidote.

At Calumet the Kearsarge amygdaloid lies about parallel to the Calumet lode, having a strike N 33° E and a dip to the northwest of 38°. Further north the lode curves off more to the east.

The lode is several miles in length, and is being mined for a continuous stretch of five miles at the Centennial, South Kearsarge, Wolverine, North Kearsarge, Allouez, Ahmeek and Mohawk Mines. Further north it has been opened up on the Gratiot, Seneca and Ojibway properties, and the latter, four miles northeast of the Mohawk, has since Nov. 1, 1911, been making shipments for a mill test. Further south the lode has been opened up on the Calumet and Hecla, Laurium, Osceola and LaSalle lands, but though copper has here also been found in the lode, no large body has proven enough to be mined profitably at present.

The ore mined on the five mile stretch from Centennial to Mohawk yields from 13 to 25 pounds copper per ton. The richest portions are at the Ahmeek, where the 1910 average was 22.3 pounds, and at the Wolverine, where the average for the fiscal year 1910-1911 was 24.75 pounds refined copper per ton of ore stamped. At the Wolverine the ore is unusually uniform in grade and the percentage of rock broken and not stamped is very small.

Mr. Finlay estimates that the five leading mines on the Kearsarge lode will produce 63,600,000 tons of ore, yielding 986,000,000 pounds of refined copper.

*The Baltic lode* is the upper portion of a melaphyre low down in the Keweenawan series. The amygdaloid has commonly grey or brownish groundmass, and amygdules of white calcite. The denser part of the bed, the footwall trap, is a brown melaphyre with abundant spots of green chlorite. The minable copper is not confined to the amygdaloid, and frequently makes well down into the trap, thus making the lode very wide in places. Narrow veins carrying sulphides and arsenides are found in the lode, but are of no consequence as ore.

At the Baltic Mine the lode strikes N. 60° E. and dips 73° N. W. The dip is much steeper than that on any of the other lodes, and consequently the method of mining is different, and will be described later.

The width varies commonly from 15 ft. to 60 ft. In some places the lode is mined for a width of 80 or 90 ft. The thickness is in most places greater than 20 ft. and averages about 24 ft.

Fissures are numerous in the lode, and at some of the mines faults and soft seams cut across it at short intervals. Many of the fissures are filled with calcite, which make conspicuous, though usually very narrow, white veins, running across the dark rock. Many others are filled with soft greenish and reddish material, chloritic, talcose or clayey. These soft seams have apparently resulted from crushing and slipping. Often in such ground, the lode is displaced many times in a short distance.

The main production of the Baltic lode is from a three mile stretch worked at the Champion, Baltic and Trimountain mines. Further northeast operations on the Baltic lode have opened up only one important ore body—that at the Superior Mine. At the Atlantic section 16 shaft the lode was found very badly fractured, faulted and crushed, and there was great difficulty in identifying horizons. The ore bodies found were cut off by faults at short distances, and the workings were generally in poor rock. After a thorough exploration the shaft was recently abandoned. At the Superior Mine the lode is also much fractured, but a large body of good ore has been blocked out at one shaft. Further north recent exploration work by the Houghton Copper Company has shown the extension of the lode. As at the Superior, the rocks are here much fractured and full of slips. Similar ground was found in exploration on the Isle Royale property, which the Houghton adjoins.



has evidently replaced the rock, and forms irregularly defined ploration on the Isle Royale property, which the Houghton adjoins.



At the Champion, Trimountain and Baltic Mines, the lode is comparatively firm. There are numerous fissures, but the ground has not been so severely disturbed as further northeast. In some places at the Trimountain and Baltic Mines the lode is more broken up. Between the Trimountain and Baltic mines there is a marked change in strike of the lode and possibly considerable faulting.

In all the mines on the Baltic lode, the system adopted is to break the rock for the full width and sort out the poor rock and use it to fill in the stopes. The sorted ore from the different mines in 1910 yielded 17.95 to 26.6 pounds copper per ton. At the Superior Mine much of the copper is unusually fine, and so disseminated that sorting is difficult. The ore mined at the Superior in 1910 averaged, however, 22.64 pounds per ton. At the other mines the ore is more readily selected from waste.

The lode has not yet been explored to any great depth, and its possibilities have yet to be determined. Mr. Finlay estimated that the lode will produce about 15,000,000 tons of ore, containing about 311,000,000 pounds of copper. In this estimate he does not assume that the deposits will continue to very great depth, and if the values persist to depths found on the other great lodes, this estimate will, of course, be far exceeded.

*The Pewabic Lodes* are the productive amygdaloids of the Quincy mine, and are now being opened up at the Franklin Jr.

Instead of a single lode, there is, at the Quincy, a zone about 300 feet thick in which there are several lodes. These vary considerably in different parts of the mine. For the most part they run parallel to one another and are separated by trap. In places they come together. There is commonly one of the lodes that is better than the other and is known as the "main" lode. As the workings are continued this main lode becomes in places quite subordinate in importance to one of the "east" or "west" lodes. What is known as the main lode in one part of the mine is not called the main lode in another part. In places there are four parallel lodes being worked at once.

The beds, of which the lodes are the amygdaloid portions, are a series of dark grey feldspathic lavas, porphyrites, known locally as the "Ashbed" series. The amygdaloid shows chlorite, calcite, epidote, quartz, prehnite and native copper in a dark brown or grey groundmass. The trap is a fine, but distinctly grained, dark grey, porphyrite, spotted with small patches of green chlorite. The copper occurs to some extent as a filling in cavities, but most of it has evidently replaced the rock, and forms irregularly defined masses, large and small. The larger masses, giving so-called "mass copper," are more abundant than in most of the lodes. While most of the copper is found in the amygdaloidal part of the bed, a large quantity is also mined from irregularly defined portions in the wall traps. The lodes are crossed by a number of persistent calcite veins, but these are usually barren and in parts of the lode that are poor.

At the Quincy Mine, the main lode is on the average about 10 feet thick, varying from 3 to 15 feet. The inclination, as with most of the lodes, becomes less with depth—at the surface being 54°, and at the lowest levels, over one mile down on the slope, about 38°. This low angle of dip is not found in the southern part of the mine, but only in the bottom levels of the northern part. At the Franklin Jr. Mine the dip varies from 49° at surface to 43° at the 32d level.

The lodes strike N. 30° E., and on the Quincy have a length of about three miles. Some of the lodes were not worked in the upper levels but were opened in cross cuts at lower levels and first worked extensively at a depth of nearly one mile down on the dip. They have since been worked for many levels above that at which they were first found to be good ore, and will be worked at comparatively shallow depth. Other lodes have shown copper where they have been encountered in cross cuts, but have not been extensively explored. The lower limit of the Pewabic series of beds seems to be the "old Pewabic" lode, and at the Quincy no copper is found in beds at lower horizon.

The Pewabic lode has produced at the Quincy about 600,000,000 pounds of copper. Some unusually rich ore was taken from the territory between No. 2, and No. 6 shafts, in the upper 20 levels. The ore mined in recent years has averaged about 16 pounds per ton. Mr. Finlay estimates that the Quincy will produce 200,000,000 pounds more. The Pewabic being a series of lodes, some of which have been developed to very slight extent, any very definite estimate of future yield is almost impossible. An important ore body on the lode has recently been opened up on the lower levels of the Franklin Jr. Mine. At the Hancock Mine a vertical shaft is being sunk to explore the Pewabic lode at depth, and the owners expect to find ore at least on that portion which immediately adjoins ore in the Quincy Mine. In November, 1911, the Hancock vertical shaft at a depth of 3,105 feet, struck good ore in a lode supposed to one of the west Pewabic lodes.

*Osceola Lode.* This is a brown amygdaloid, spotted and streaked



thomsonite. The foot-wall trap is a grey olivine diabase.

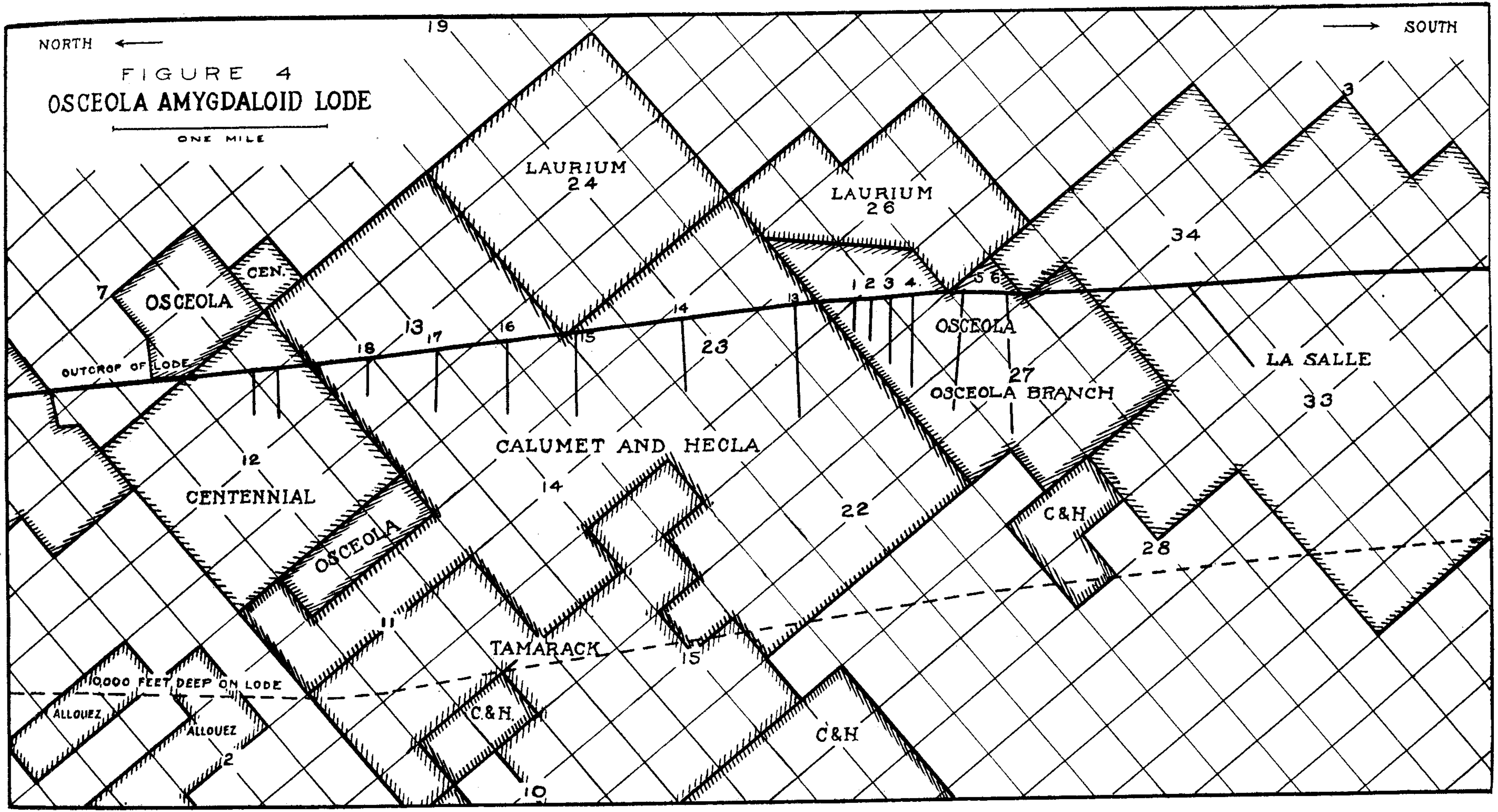

NORTH
SOUTH
FIGURE 4
OSCEOLA AMYGDALOID LODE
ONE MILE
LAURIUM 24
LAURIUM 26
OSCEOLA
CEN.
OUTCROP OF LODE
CALUMET AND HECLA
CENTENNIAL
OSCEOLA
OSCEOLA BRANCH
LA SALLE
C&H
TAMARACK
10,000 FEET DEEP ON LODE
ALLOUEZ
ALLOUEZ
C.&H.
C&H

FIG. 4.

with white calcite, which has been worked by the Osceola, Calumet & Hecla and Tamarack Mining Companies. On these properties it has a length of about 3 miles. It underlies and runs parallel to the Calumet conglomerate, striking N. 33° E. and dipping at the surface at Calumet at an angle of 38°. The width varies from 15 ft. to 100 ft., the ore coming from two horizons, designated as hanging wall and foot wall parts. The chief and most regularly shaped ore body is found at the upper part of the bed. This hanging wall lode averages about 9 ft. in thickness and is fairly persistent and well defined. Below it is commonly dense brown melaphyre of varying thickness, succeeded by another amygdaloid, in which are irregular shaped ore bodies. The footwall deposits are often richer and thicker than those at the hanging wall, but they are of more pockety character, and do not persist so regularly with strike and dip. In some places dip and hanging portions are continuous, and there the lode is very wide, 40 to 100 ft. There is usually 10 to 20 ft. of the so-called "*vein trap*" separating them. The amygdaloid encloses numerous lenticular masses of dense trap. Often a bar of trap cuts across the amygdaloid, and it has been frequently noticed that the amygdaloid on opposite sides of such bars is unusually rich in copper.

The copper in the lode is rather regularly distributed, and in good rock readily detected. Hence, a satisfactory selection can be made before breaking, and practically all rock broken is hoisted.

At present the lode is being mined only at the Calumet and Hecla mine. On the Osceola and Tamarack, work is temporarily suspended. Some other companies are exploring the lode, but as yet no new ore body of importance has been found.

Mr. Finlay estimates the future production of the Osceola lode on Calumet and Hecla property, at 23,000,000 tons, yielding 330,000,000 pounds copper. The production for 1910 averaged 15.82 pounds per ton. The Osceola lode is very easily milled and smelted and produces copper of exceptionally high grade. Most of the copper from this lode is treated electrolytically for the recovery of silver.

*The Isle Royale Lode* is the amygdaloid top of a bed of diabase. The amygdaloid has a grey or brownish-grey ground mass, which is commonly distinctly, though finely, grained. The amygdules contain many varieties of minerals, prominent among which are calcite quartz, epidote, chlorite, prehnite and laumontite. Cracks in the rock have in most cases been filled with chlorite, laumontite or thomsonite. The foot-wall trap is a grey olivine diabase.

The lode is worked at the Isle Royale Mine south of Portage Lake. A similar, and probably the extension of this, lode was opened up north of Portage Lake at the Arcadian mine; but without success. At the northern end of the Isle Royale property, the beds strike S. 38° W., but further south bend westward until the strike is S. 58° W. The dip is to the N. W., at an angle of 56°.

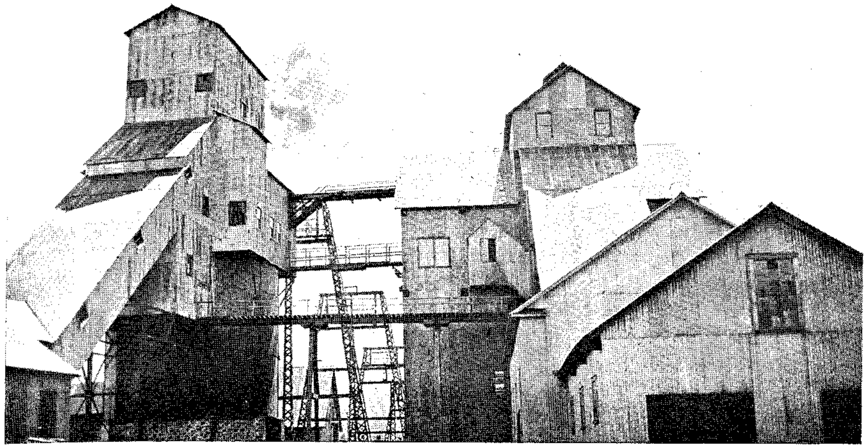
From the workings on the Isle Royale lode another very similar bed, known as the Grand Portage and lying a short distance to the west, has been mined but its product not distinguished. The lode (or lodes) is comparatively low grade, and until recently has been mined at a loss. The production for 1910 averages 14.5 pounds per ton. Mr. Finlay estimates that it will produce 112,000,000 pounds copper above the 4,000 ft. level. Another recent estimate is that the Isle Royale contains 435,600,000 pounds of copper in ore averaging 14 pounds per ton.

*The Atlantic Lode* is a comparatively low grade bed, which was worked at the Atlantic Mine. It differs from most of the lodes in having the copper more finely disseminated through the rock. The upper part of the lode is fragmental, and contains sandy and epidotic portions, so that it has the appearance of a conglomerate, and has been called a melaphyre conglomerate. The lower part of the lode is an ordinary amygdaloid.

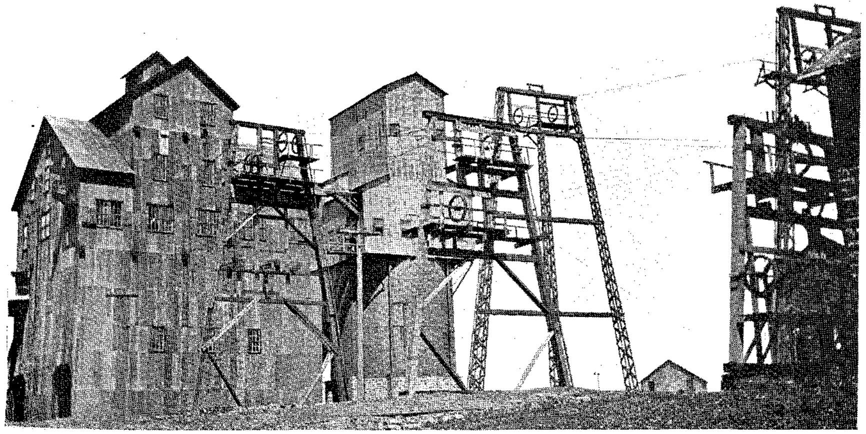
*The Lake Lode* is a wide amygdaloid the extent of which has not yet been determined. It is generally considered to be the best find in recent years in the district. In May, 1911, it had been opened up at the Lake Mine for a length of 2,100 feet, and a depth of nearly 1,300 feet on the dip. Where first found it strikes nearly north, but followed a few hundred feet to the north, it gradually turns to the westward, and at the end of some of the northern drifts, the strike is northwest. The dip is to the west and southwest. On the South Lake property, which adjoins to the westward, a similar lode strikes west and dips south. It is probable that this is a continuation of the Lake lode; but developement has not yet been carried on far enough to make this certain.

The lode at surface at the Lake Mine dips at an angle of about 36° A few hundred feet down it dips at about 34°. The South Lake drill holes give dips of beds to be to southward at angles of 55° to 58°. It is not unlikely that the discordance between the structure of the beds at the Lake Mine and the uniformly northwestward dipping beds of Evergreen Bluff has been partly brought about by faulting. No important fault has yet been definitely located however.

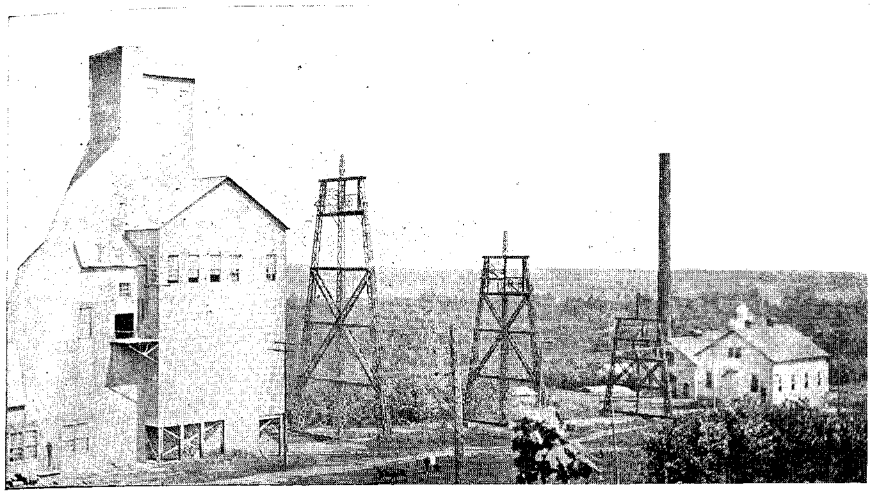




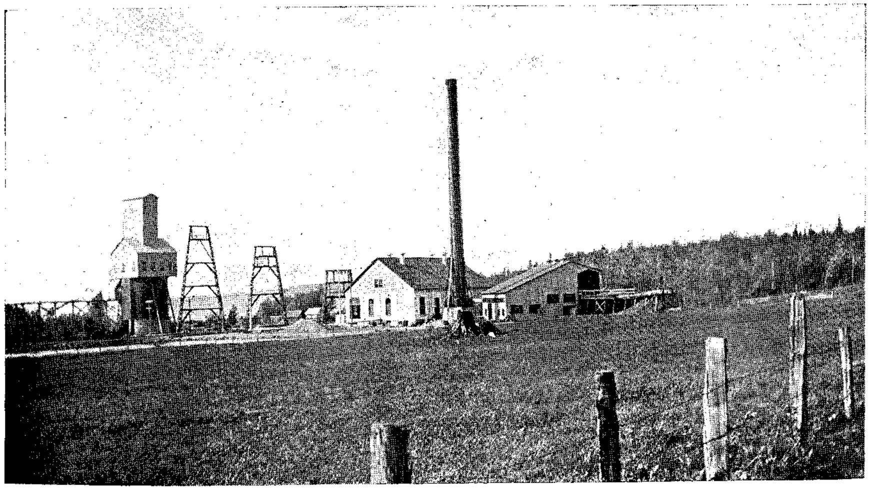
A. SHAFT HOUSES NOS. 1 AND 2 AT CENTENNIAL MINE.



B. ROCK HOUSES, OLD AND NEW TYPES, CENTENNIAL MINE.

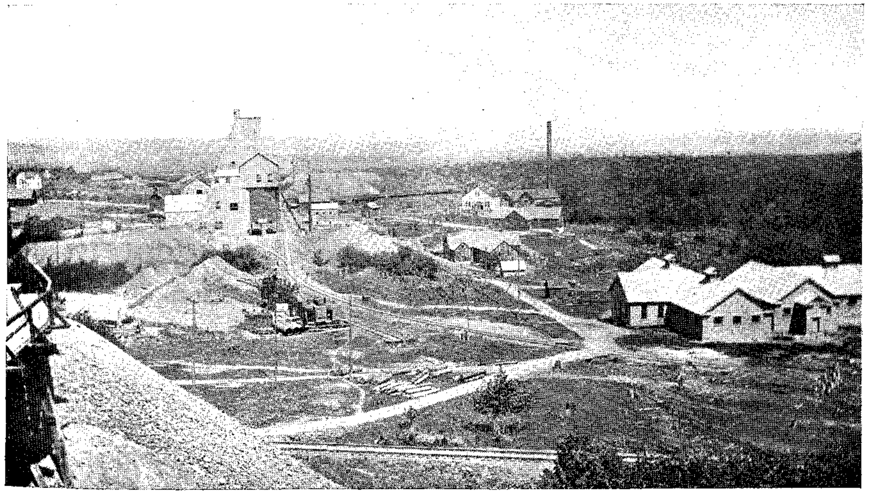


A. SHAFT HOUSE AT BALTIC MINE.

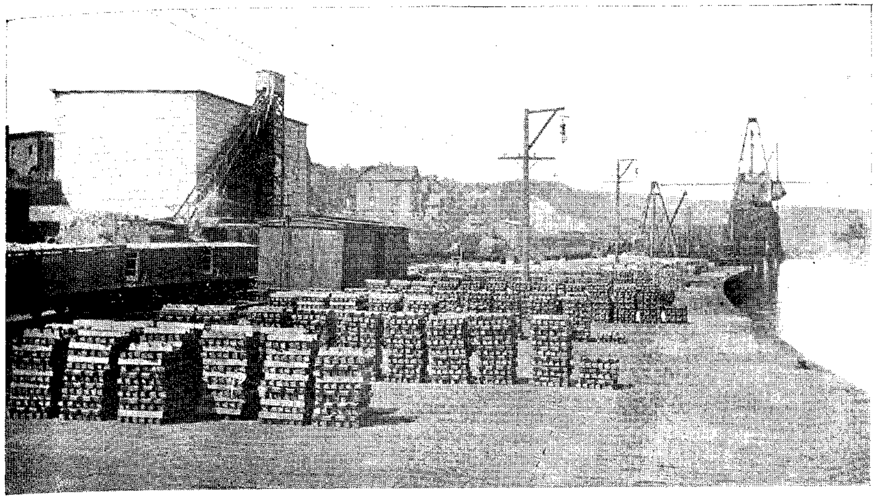


B. ISLE ROYALE MINE.

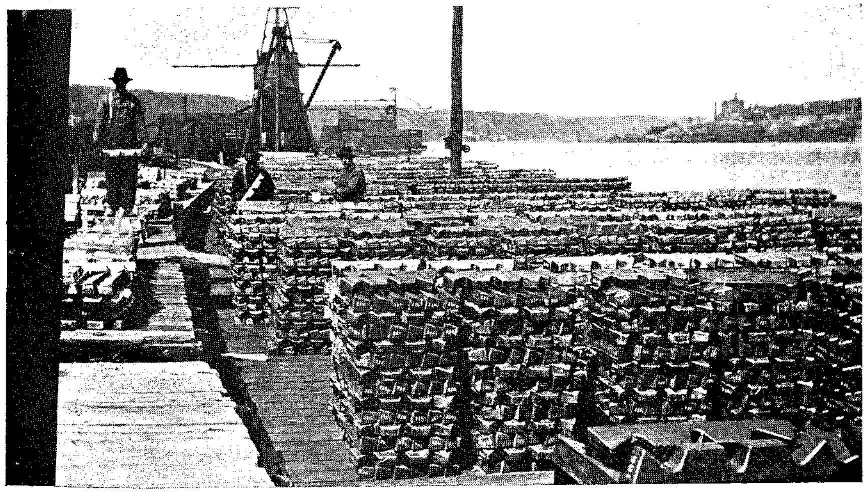
A. ADVENTURE MINE, 1911. NEW VERTICAL SHAFT.



B. BALTIC MINE.



A. COPPER INGOTS ON DOCK AT HOUGHTON.



B. COPPER INGOTS ON DOCK AT HOUGHTON.

The amygdaloid is commonly of red-brown color, and spotted with amygdules of chlorite, calcite and other minerals. In places it shows much heavy copper, and resembles good parts of the Baltic lode. The value of the lower grade portions is not very definitely known, as comparatively little stoping has yet been done. The richer portions have proved to be wide and have been in places cut out for 40 to 60 feet. East of the main lode, the Lake Mine has opened up a second, but much narrower lode, sometimes rich in heavy copper.

At the South Lake property, rich drill cores were taken up, but the lodes have not yet been further examined. Shaft sinking was recently begun, but is temporarily suspended.

In smelting the small amount of copper produced in testing the Lake lode it was found that the copper is comparatively free of arsenic, although the lode is in a very low horizon in the Keweenaw series.

*Mass Mine Lodes.* At the Mass Mine there are four parallel lodes which have been opened up from one shaft. These are in ascending order, the Evergreen, Ogima, Butler and Knowlton. The Evergreen is a greenish amygdaloid, which contains copper in irregularly distributed masses, acccompanied by much finely crystalline or granular epidote and coarsely crystalline calcite. The Butler is an amygdaloid of unusual reddish color, having abundant reddish feldspar along with the more common minerals in the amygdules. It carries more regularly distributed small mass and stamp copper. The Ogima is a grey amygdaloid, spotted with epidote and chlorite. It rarely has any masses, but in places carries good values in fine or "shot" copper. The Knowlton is a reddish amygdaloid, resembling the Butler.

*Forest Lode* is amygdaloid, worked at the Victoria Mine. The bed dips N. W. at an angle varying from 61° at surface to 55° at the 15th level. The ore mined is comparatively low grade, yielding about 12 lbs. copper per ton.

*Minesota Lode* is a vein rather than a bed. It strikes with the formations in which it occurs, but dips somewhat steeper. The chief mineral constituents are epidote and quartz, and from the former it takes a yellowish green color. Scattered through this epidotic lode are masses of copper, and many have been taken out that weighed several tons. The largest mass mined from the lode is said to have weighed over 500 tons and was one of the largest produced in Michigan.

*The Winona Lode* is an amygdaloid worked on the properties of the Winona, King Philip and Wyandot Companies. It has yielded considerable copper at the Winona, and will in the near future be worked on a more extensive scale. The ore is comparatively low grade. That which was mined during the past year yielded about 13 lbs. per ton.

*The Adventure lodes* are three amygdaloids which have been worked by the Adventure Mine.

*The Ashbed lode* is an amygdaloidal porphyrite, which has been worked in the Eagle River section. It has copper finely disseminated through the rock, as in the Atlantic lode.

*The Arnold lode* is an ashbed worked at the Arnold mine.

*Michigan Mine lodes.* There are on the Michigan property a large number of lodes, including those worked at the Mass Mine and several others. The amygdaloids, in addition to the Evergreen series, are the Calico, North Amygdaloid and South Amygdaloid. The veins are known as the Minesota, Branch and Contact veins.

*The Nonesuch lode* is a cupriferous sandstone and conglomerate in the Upper Keweenawan. The bed carries copper in small particles, filling spaces between, and sometimes forming a coating on the sand grains. At the Nonesuch mine the bed is 4 feet to 8 feet thick. The coarser particles of copper are found in a friable sandstone. The more compact sandstone shows some very fine copper.

*The Indiana lode.* This deposit was located by drill holes, and little is yet known of its shape and size. The ore is native copper accompanied by calcite, quartz and epidote in a much fissured and altered mass of felsite. The available records are not sufficient to determine the shape of the felsite mass, and still less the extent of the deposit in the felsite. Exploratory work in now being carried on to determine the nature of the deposit.

*The Algomah lode* is the upper portion of a brown amygdaloid bed and differs markedly from all the lodes mentioned above in carrying black oxide, green silicate and green carbonate of copper instead of the native metal. It has been only slightly developed, and little is yet known of its character at depth. Along the strike it shows masses of green colored ore more or less separated by stretches of brown amygdaloid. The shaft sunk at an angle of 60°, follows the dip of the lode, and is 200 feet deep. At the shaft there is a stock pile of several tons of green ore. Sixty tons of selected ore showed 24% copper. Some similar deposits are reported to have been found in one of the upper levels at the Lake Mine, which adjoins this property on the north, and chyrsocolla has been found in drill cores from other neighboring properties.



The copper minerals in the Algomah lode are chiefly chyrsocolla, melaconite and malachite. The oxide is usually dull black massive melaconite; but Prof. A. E. Seamen has found specimens showing black tetragonal crystals of paramelaconite in green malachite. This is the only known occurrence of paramalaconite other than that at the Copper Queen Mine, Arizona, where it was first identified by Dr. Koenig. Prof. Seaman has also found in the Algomah ore some minute green crystals which are thought to be dioptase.

*Hancock lodes.* At the Hancock Mine there are three parallel lodes, known as veins No. 1, 2 and 3. One of these, No. 3, has been extensively opened up recently. It is a chocolate brown amygdaloid, spotted with very abundant amygdules of green chlorite. It has a thickness of eight to ten feet, and dips at an angle of about 45° in the present workings. The copper occurs in this lode, more largely than in many other lodes, in the amygdules. Many of the green spots of chlorite show copper when the rock is broken. The rock is soft. The bed where now being worked is remarkably regular, and has a very distinctly marked off hanging wall.

*Hancock New No. 4 lode.* A lode struck in November, 1911, at a depth of 3,105 ft. in the No. 2 vertical shaft is as yet not definitely correlated with other lodes, but is generally thought to be one of the so-called "west Pewabic" lodes.

The lode is a brownish gray amygdaloid, with very numerous amygdules. A rather unusually large number of the amygdules are quartz. Most of the others are calcite. The white calcite and quartz are often greenish in appearance, owing to the presence of chlorite scales and occasional epidote grains. Many of the joints in the rock are coated with quartz and calcite. On some of the joints there are fine scales of copper. Most of the copper is in the amygdules with the calcite and quartz; but some is in grains scattered through the matrix of the rock and some in seams of calcite and quartz.

The lode where cut is seven or eight feet thick of uniform ore, and there is also some ore further in the foot separated from the main ore body by a few feet of trap.

*St. Louis Lode.* This is a brown amygdaloid, from which several copper bearing cores have been taken, and which is now being opened up at the St. Louis mine. Where cut by 9 drill holes it showed widths varying from 8 to 39 ft.

## CHAPTER IV.

### CHARACTER AND VALUE OF THE ORE.

The ore is native copper with small amounts of native silver, in a gangue of either amygdaloid or conglomerate rock. Large masses of the metal, often weighing from a hundred pounds to several tons, are called *mass copper* or simply mass. Smaller masses are known as *barrel work.* Ore showing copper in comparatively small particles scattered through the rock, is known as *stamp rock.* Ore is commonly known as *copper rock.* The term *copper ore* is by Michigan miners often used only for copper minerals other than native copper; but the term is never used in this sense in this report. The native copper ore is by miners and unfortunately also by the mining companies commonly called rock. This unusual terminology is not here adopted.

Most of the mines produce some mass copper, and in a few it forms a considerable percentage of the output. In all the mines, however, ore which must be crushed and concentrated is the chief product, the individual particles of copper being commonly less than one-half inch in diameter, and usually less than one-quarter inch. The ore is very low grade, much lower than any other copper ore being mined, and carries on the average only about 1.3% copper. The average yield of all ore mined in 1910 was only 20.5 pounds per ton, and yet this was mined at considerable profit, with copper selling at 12.7 cents per pound.

The conglomerate lode being mined is richer than any of the amygdaloids. The former in 1910 yielded 28.3* pounds of copper per ton, while the amygdaloids yielded 18.2 pounds per ton. During the year there was milled 2,474,356 tons conglomerate ore, yielding 70,036,097 pounds copper, and 8,395,205 tons amygdaloid ore, yielding 152,647,364 pounds copper. Of the ore, therefore, 22.8 per cent was conglomerate, which yielded 31.4 per cent and 77.2 per cent amygdaloids, which yielded 68.6 per cent of the total copper. While the conglomerate is richer it is more difficult to drill and stamp.

The ore mined several years ago was much higher grade. The falling off in copper content is due partially to the fact that in some of the deep mines the ore at very low levels is not as rich as in the upper levels, and partially to the fact that improved methods make it now profitable to mine low grade ore that would not have been broken years ago.

[1]These figures are from B. S. Butler's report in Mineral Resources of U. S., 1910.



Copper from the Michigan mines is unusually pure and commonly demands a somewhat higher price than copper from more complex ores. Some of the lodes give better metal than do others. Some are arsenical, due chiefly to presence of arsenides in viens cutting the lode. It has been noticed that the lodes in the lower part of the Keweenawan series are commonly higher in arsenic than those at higher horizons; but the newly found Lake lode which occurs low in the series is apparently an exception.

Native silver is commonly found in small amounts with the native copper, and in some few mines the silver is in commercial quantities. In 1910 the silver recovered from the ore mined in Michigan copper mines amounted to 330,500 ounces, valued at $178,-470.00. Only about one-seventh of the copper produced is electrolytically treated to save the silver. Some silver is picked out at the mills, but the amount obtained in this way is small.

The copper from concentrates carrying commercial quantities of silver is cast into anodes, and the silver is recovered electrolytically.

According to B. S. Butler the average ton of ore mined in 1910 produced copper valued at $2.54 and silver at 1.5 cents.

## CHAPTER V.

### METHODS OF PROSPECTING AND DEVELOPING DEPOSITS.

*The method of prospecting* in the Copper Country is now in almost all cases diamond drilling and trenching. The outcrops have long since been carefully looked over, but there still remains to be prospected a very extensive area, which is covered with glacial debris. The most notable new discoveries during the past few years have been made by drilling in such covered areas.

Exploration is also carried on underground at several mines. It is usual near an important lode to find parallel lodes which are not regular enough to be worked alone, but which carry at intervals copper in quantities sufficient to pay for extraction. In some mines prospecting for such deposits is carried on by systematic drilling into the foot or hanging from the workings on the main lode. In others, cross cuts are driven at less frequent intervals for the same purpose. In mines where a filling system is used, the rock cuts into hanging and foot are run far enough to explore other lodes.

In putting down the first drill hole in an exploratory campaign in drift covered areas it is the usual practice to set the drill at an angle normal to the dip as determined on neighboring properties. If the hole proves to be approximately normal to the bedding, other holes are bored at such distances that each will give a slight overlap over the section obtained in the next one. Many of the holes are drilled 1,000′ to 2,000.′ Where there is little known concerning the stratigraphy, the most satisfactory results are often obtained by vertical holes.

The cores drawn are closely examined for copper; and also for the purpose of correlating the various strata cut. Commonly all the core is kept regularly arranged in boxes. At intervals in the core-box a mark is made to indicate the depth from which the core was taken. After examination the cores are usually stored and kept for future reference.

*Development.* When a lode has been located, development is usually begun by sinking an inclined shaft in the lode or in the footwall. Exploration is carried on by drifts at levels about 100 feet apart. As a rule it has been found advisable in running these



drifts, to follow the hanging or the footwall rather than to take straight courses. On the Calumet conglomerate the drifts are on the foot, but on most of the amygdaloid lodes the hanging wall is followed. This practice enables the miner to keep to a definite horizon, as the contact of the hanging wall trap with the lode is usually rather distinctly marked. Moreover, a bed that is cupriferous usually shows most regular ore shoots close to the hanging, so in *keeping to the hanging* the miner is, most of the time at least, *following the ore.* In a few mines the hanging is not very closely followed, but this is largely because in these mines the contact is not easily recognized. In another mine thousands of feet of drifts run in regular courses in the copper-bearing bed disclosed very little ore, while subsequent drifts following the hanging proved up very large deposits. The wisdom of keeping to the hanging was early recognized, and with a few exceptions the best results are still obtained in this way. There are some cases, however, in which it is perhaps just as well to follow the foot. In wide lodes there is usually much copper close to the foot, as well as close to the hanging. If then, the footwall is more easily identified than the hanging, as sometimes though rarely happens, it may be preferable to follow the foot. In the conglomerate mines the foot is followed because it presents a good fact to draw the cut to, rather than on account of the values there. As a rule drifts run without following closely the foot or hanging, soon get away from the ore, and are of comparatively little use in estimating the value of the deposit. There are, however, a few cases where the broken nature of the ground makes it practically impossible to follow foot or hanging closely, and then courses are run along the strike of the bed.

When it is desired to explore at depth the underlay of a lode productive on adjoining property, vertical shafts[1] are sunk and at various levels cross cuts run into the lode, which is then developed in the usual way. At some mines similar "deep" ore is reached by starting the shaft down at an angle of about 80° and curving at depth into the dip of the lode.

There are in Houghton county three vertical shafts that are very nearly one mile in depth, and several shafts on the slope of the lodes that are down over one mile on the incline. The deepest vertical shaft is 5,308.5 ft. and the longest inclined shaft is 7,995 ft. measured on the dip.

The ore cannot be satisfactorily sampled in the mine. After

[1]A description by W. E. Parnall, Jr., of the No. 5 Tamarack shaft was published in proceedings of the L. S. M. Inst., Vol. VII, 1901, pp. 50-61.

considerable ground is blocked out it is tested by a mill run extending over a few months. The usual practice is to rent a stamp at one of the mills and test the ore thoroughly before erecting a new stamp mill.



## CHAPTER VI.

### METHODS OF MINING.

As all the deposits being worked are in the form of inclined beds there is a marked uniformity in the way in which the lodes have been opened up. The method of mining the ore, however, is by no means the same for all the mines. The method adopted depends chiefly on the geological conditions, especially on the dip and thickness of the deposit and firmness of the lode and wall rocks. As a rule the copper deposits are in unusually uniform and firm rock that is easily supported. There are, however, some mines in which the lode or hanging wall is full of seams and joints, and the necessity of providing support has then made it advisable to use a different method of mining. The greatest similarity in methods is found in mines working the same lode.

There are also, however, notable differences in method which do not result from the geological conditions, and which may be seen on the same lode and often in the same mine. Very often stoping has been started near the shafts and advanced toward the boundary, while in other cases stoping has been begun at the boundary and advanced to the shaft pillar. The latter makes less support necessary, thus making it possible to allow the ground to cave soon after a stope is cleaned out, and at the same time renders protection for levels necessary only under the one stope being worked.

In some mines drifts are run of ordinary size 7′ x 7′ while in others the opening is carried forward as a drift stope, by cutting the full width of the lode and taking a few cuts off the back. The drift stope method gives a better opportunity to follow sinuosities of a lode closely, thus making possible a more definite estimate of its contents; but unless the lode is very uniform in grade there is likely to be broken rock that might be better left standing. In long drifts the better ventilation in the large opening is a decided advantage.

In wide lodes the ore is not as a rule evenly distributed, and a considerable percentage of the lode is worthless. There is then to be decided whether it is better to break the full width of the lode and sort out the waste, or to make the selection before breaking, and as far as possible leave the poor rock standing. The mines on one lode use the former method, while on another wide lode the latter system is utilized.

Methods of handling the ore differ largely according to the nature of the deposit and also for other reasons. In some mines mechanical scrapers are used in stopes, while hand shovels are used in others under similar conditions. In one mine chutes are used to load tramcars, while in another mine where the dip of the lode is practically the same, the ore is allowed to run down to the track level and then shoveled up into the cars. In most mines the men themselves push the tramcars, while in others rope haulage or electric locomotives are used. In most mines the ore is dumped directly from tramcar into skip, while in a few, ore pockets are used. In most of the mines ore is hoisted from every level; but in some the ore from four or five levels is run down in chutes and hoisted from one level.

The methods of mining in use will be best understood from brief descriptions of the practices in individual mines. The variations dependent on the nature of particular deposits will be brought out by taking as examples mines that are on different lodes. For the conglomerate lode we can take the workings tributary to one shaft at the Calumet and Hecla Mine; for an amygdaloid 14 ft. thick and with dip or 40°, the Wolverine; for a narrow amygdaloid at a steeper angle (45°), the Hancock; for deeper workings on a narrow amygdaloid dip 38° to 45°, the Quincy; and for a wide amygdaloid of steep dip (73°), the Baltic.

*The Calumet and Hecla Mining Method.* The Calumet and Hecla conglomerate is now being mined at great depth from several shafts, one of which is vertical and the others inclined. The lode averages 15′ in thickness, and dips usually at an angle of between 37° and 38°.

The incline shafts are sunk in the lode, and levels established at intervals of about 100 feet. Drifts 8′x8′ are run each way from the shaft to the boundary. A raise is put through for ventilating, and to provide a stoping face, and stoping is begun first at the boundary. A cutting out stope is run for 100′ by cutting a slice off the back for the full width of the lode. Then heavy timbers are put in to support the hanging and protect the level. No square sets are used. Heavy timber is placed as stulls, three large sticks being placed close together and forming a so called battery. Batteries of stulls are placed about eight feet apart, leaving a space of about five feet. In this space a chute is built at sufficient height to deliver the ore into tramcars. Above the chute the foot



is covered with an iron plate 8′x4′ to enable the ore to run readily.

When stulls and chutes are in place heavy lagging is placed across the stulls, planks are placed over the timbers for the drillers, and regular stoping is commenced by breast cuts taking off 8′ to 12′ at a time. In each 100 ft. stope 2 or 3 drills work a short distance apart. As each cut is taken off the back, additional stulls are placed in line above the others. The broken ore falls down between the rows of stulls, and with some assistance from shovellers runs down to the chute and is loaded into tramcars. As the process goes on the ore is replaced by regularly spaced rows of stulls up to within a short distance of the next level. Stoping is carried on until all the ore is broken, no pillars being left anywhere in the stope. There are no arch pillars to support the levels above. The whole section of the lode is broken and swept down between the rows of stulls into the tramcars, mechanical scrapers being used to drag the ore down.

When the stope has been cleaned out, a solid row of heavy stulls is set across the foot of the stope, a considerable portion of the timber in the stope being robbed. The stope is then allowed to cave, the car tracks are taken up, and the thoroughly worked out part of the mine immediately abandoned. The 100′ block next towards the shaft is then attacked in the same way, and at the same time in the next lower level, stoping is begun at the boundary. Stoping is always done at several successive levels at the same time, and in any one level stoping is always being done in a block 100 feet nearer the shaft than the work in the next lower level. At the shaft a pillar 100 ft. wide is left on each side.

To work out a stope takes about eight months. Hence, stulls across the foot of the stope, while necessarily heavy, do not need to be of long lived wood. Consequently the heavy stulls are not of very valuable wood; but of timber common in the district—hemlock, birch and maple being generally used. The hardwood is used green and does not last long after it dries. Sometimes before a stope is worked out, caving starts in the level above, and small quantities of rock fall down onto the row of stulls. No damage is done, as the timber is still strong and the amount of caving slight. In a year or two the timbers have become weak, but by this time there are no miners in the stope below. At intervals there occur caves in the hanging and ultimately the stope is filled with the broken rock.

There is no sorting of the broken ore in the mine. Sometimes blocks of poor ground are left standing; but everything broken is hoisted. The tramcars are pulled to the shaft by air-engine rope haulage, and the ore emptied directly into skips. A seven ton skip makes seven or eight trips an hour to surface from a depth of 7,000 feet. At surface a little rock is picked out, as the ore is fed to the crushers.

*The Wolverine[1] Mining Method.* The Wolverine mine works a section of the Kearsarge lode, which here dips at an angle of 40.5° to 41.5° and averages 14′ in thickness. Shafts are sunk in the footwall and levels established at intervals of about 100 feet. Drifts are carried forward as drift stopes. The drift itself is about 6 by 7 ft. and the lode is cut out for its full thickness for a distance of 19′ from the foot rail. When the drift stope has been advanced a few hundred feet a block of ground 75′ long is marked off, and this is stoped out by four men on contract. The whole block is drilled by only one machine. A block is stoped out in about four months. The first block being raise and stope requires several weeks longer.

Owing to the dip there is no difficulty in rigging up drills on the foot, and at the same time the inclination is sufficient to allow all but the finest ore to run down to the level. No protection at the level is necessary, and no timber is used in the stopes. Rock pillars are left along the foot of the stope and a 8′ to 10′ floor pillar in the back. The ore runs onto a sollar beside the track, and is shovelled up into the cars. At the Mohawk mine where similar methods are used, the dip is in places not sufficient for the ore to run, and iron chutes are used in cleaning the stopes. A large number of cars are used at each level, and the trammers leave their loaded cars at the shaft. A special crew of workmen load all the ore into the skip, working their way down from level to level, and then riding up and going over the ground again.

*Hancock Mining Method.* At the Hancock Mine is illustrated an economical method of mining a narrow lode dipping at an angle of about 45°. In mining this lode use is made of a vertical shaft which is being sunk to open up the Pewabic lode at greater depth. In early workings an inclined shaft was sunk to the 13th level and three lodes opened up. The present method is in use below the 13th level on No. 3 lode.

A winze was sunk in the lode for about five hundred feet, and the lode worked from levels about 100′ feet apart. At the 18th level connection was made with the vertical shaft by a long cross

[1]A description of the Wolverine method will be found in Rickard's Copper Mines of Lake Superior and Crane's Ore Mining Methods.



cut. The winze was then no longer used for hoisting, but was converted into a chute, and all ore from upper levels brought down to this level.

Drifts are run 6′x7′. A cutting out stope follows enlarging the opening to 24′. A row of stulls 4′ to 6′ apart is set above the level and lagged over with cedar poles 4″ to 6″ diameter. At intervals of about 25 feet a hole 2′x4′ is left in the lagging, and a high sollar built about 4′ above the car rails. When the level is thus protected and provision made for handling the ore, stoping is commenced. In the first cut care is taken not to shoot the rock directly against the timbers. After a few feet of broken ore lies on the lagging, the remainder of the ore can be broken with wet holes. Enough ore is left in the stopes to support the miners and the rest drawn off. The ground is firm and no timber is used in the stopes. Rock pillars are left where poor rock is found, and an arch pillar, 6 to 10 feet thick, is left in the back of the stope to support the level above. The ore is drawn out of the stopes onto the sollars, and there sorted and loaded into tram cars. The cars are pushed by hand to the converted winze, which is now a chute having two compartments, one for ore and one for rock. At the bottom of the chute the ore is loaded into saddle-back tramcars, each holding about three tons, and drawn by electric locomotive to the vertical shaft. Here the cars are run over bins into which their contents are emptied. From the bin the rock is let into the skip by raising a heavy gate, and dropping an iron lipped chute over the edge of the skip.

*Quincy Mining Method.[2]* At the Quincy Mine narrow amygdaloid lodes, dipping at an angle of from 54° to 38°, are being worked at great depth. The conditions are somewhat similar to those at the Calumet & Hecla conglomerate mine, but comparatively little timber is used. Support is chiefly by rock pillars, and by heavy stulls loaded with broken rock. Drifts, 7x6 feet are run in the lode. Commonly the drifts are partly in the footwall. The miners driving the drift are closely followed by others cutting out the lode for a width of 18 feet from the foot rail. Following the miners making the cutting out stope, come timbermen who protect the level and make provision for drawing off the ore into tramcars. When a cutting out stope has been timbered and the levels ready, drills are started in the stope. The several groups of men are all

[2]The Quincy method has been described by T. A. Rickard in Copper Mines of Lake Superior, and by G. R. McLaren, Journal of the Canadian Mining Institute, 1907, pp. 399-417. The methods have been somewhat changed since their descriptions were written.

gradually working their way from the shaft to the boundary.

The level timbering was formerly of stulls placed about 4 ft. apart and covered with cedar poles. The present method differs in the absence of lagging consequent on close spacing of the stull timbers. This gives better protection from falling rock and is said to be cheaper. The stull are logs of peeled hemlock, maple and birch, averaging 15″ to 24″ in diameter— some are 3 feet in diameter. These are set in a row at the foot of the stope, and are only four or five inches apart. At intervals of 15 ft. a 5 ft. space is left and a high sollar is built. A 2 ft. hole is left so that the ore can be run out on to the sollar. In some parts of the mine the ore is run out on timbers over the level and dropped into the car.

In stoping there are numerous pillars left scattered irregularly in the stope wherever the lode is poor or where support is especially required. Many are in places where the hanging bellies down. In places stulls are set in the stope for support, either as single sticks or in batteries of three. In some stopes the workmen stand on rock covered platforms supported by stulls and work down the stope from either side of a raise.

A common practice is to have three drills working on the face towards the boundary. Each takes off a slice by five or six breast cuts in descending order, and then goes up in the stope and works down again, taking off another similar slice.

When the stope is mined out, the row of heavy stulls at the foot is heavily loaded with rock. This "poor rock" is commonly obtained by breaking into the footwall, as it is desirable to disturb the hanging as little as possible. Rock is piled onto the stulls to a depth of 30 or 40 feet. Later, as the hanging settles down, the stulls are compressed—often splitting longitudinally, and shortening 6 or 8 inches—and then the rock filling, wedged tightly into place, takes up the pressure.

The ore is drawn off onto the high sollars and loaded into tramcars. For short distances, 500 to 600 ft., the cars are pushed by men. After the distance becomes greater, electric locomotives are used to haul trains of 4 or 5 cars loaded with about 3 tons each.

The ore is not loaded from tramcars into skips, but is emptied into ore pockets near the shaft. From these pockets, some of which hold 100 skiploads, the ore is drawn off* at a lower lever into the skip.

*Diagrams illustrating arrangement for loading skip will be found in T. A. Rickard's "Copper Mines of Lake Superior," pp. 68 and 69.



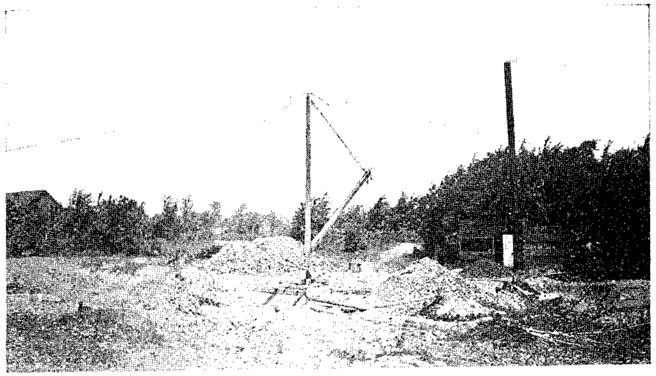
*The Baltic Mining Method.* The Baltic is one of several mines on the Baltic lode, which is wide, 15′ to 60′ and has an unusually steep dip—73°.

Shafts are sunk in or near the footwall, and levels are about 100 feet apart. Drifts are either run 8′x8′ and then cut out the full width of the lode, or else run the full width at once. Then another cut is taken off the back, the drills being mounted on broken ore. There is then an opening 16′ high for the width of the lode. The ore is drawn off, and the broken waste rock left in piles in the drift. The levels are now enclosed by "dry" walls built of rock, and a cover of lagging laid on heavy timber caps. Openings are left at intervals in the wall for chutes to draw off ore through mill holes. The mills are built up with a circular wall of rock, leaving an opening about 4 feet in diameter. Iron lips are placed at the chute, so that the ore can be drawn off from the flat bottomed mill holes into tramcars.

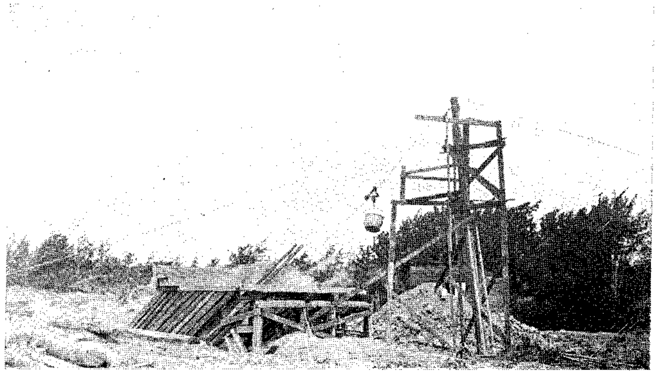
When walls are built and mill holes started, the remaining space is filled with poor rock. Then stoping is started, the drills being rigged up on the waste. Where the amount of poor rock broken is too small for the filling required, additional rock is broken from the foot or hanging in "poor rock stopes." The ore broken is sorted where it falls. The waste is left to fill in the stope, and the ore is thrown into, or carried in small cars to the mill holes. Stoping proceeds in this way, the mill holes being built up and the stope filled with waste while the ore is being drawn off.

When the stope has been carried up to within about 30 feet of the next level, a so called caving method is used to remove the arch. A raise is carried up to the level, and numerous holes drilled in the ground on either side of the raise. When the level is no longer needed, a wide opening is made by firing all these holes, and the waste rock filling in the stope above follows the ore down into the stope below. The ore is sorted out and thrown into the millholes and then drills are rigged upon the waste filling in the stope, and slices are taken off the arch. When only a few feet remain a large number of holes are drilled nearly through to the level, the stope is well cleaned of ore, and then the holes fired. The broken ore falls down into the stope, and is followed by a pile of waste from the stope above. As much of the ore as possible is sorted out and thrown the mill holes. When all readily reached is sorted out, the drills are rigged up on the side of the pile of waste and another cut is made across the lode. Then again the stope is well cleaned of ore, and the last few feet of back is drilled with numerous holes. These are fired, and another cave of waste takes place. In this way all the lode is broken and most of the ore is saved.

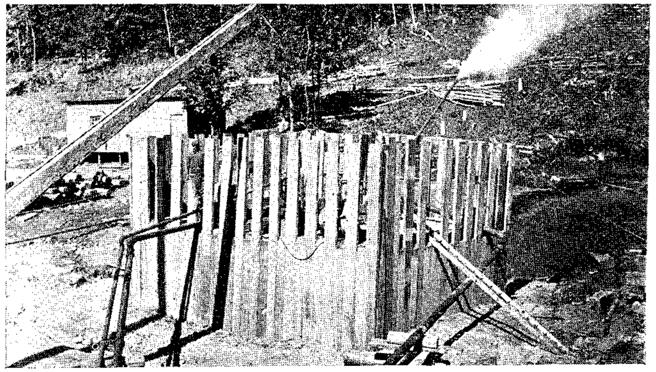




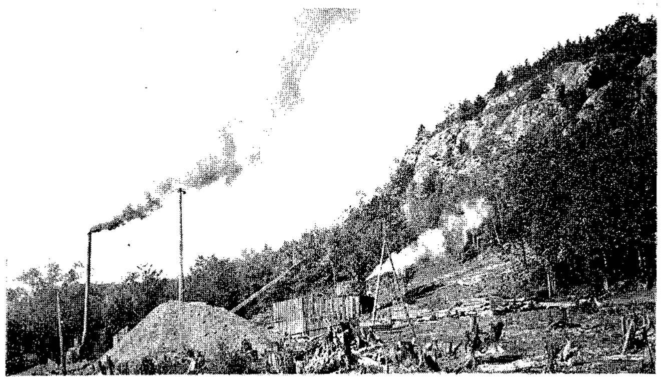
A. OPENING UP AT ST. LOUIS MINE, 1911.



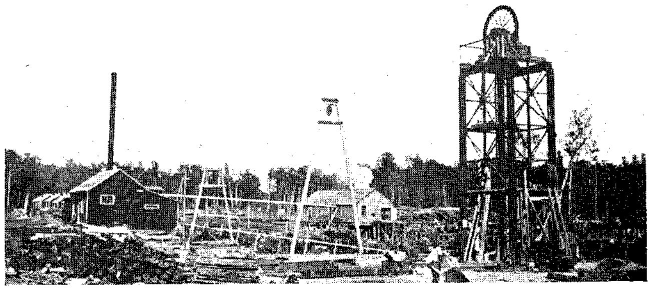
B. STARTING SHAFT SINKING AT ST. LOUIS MINE.



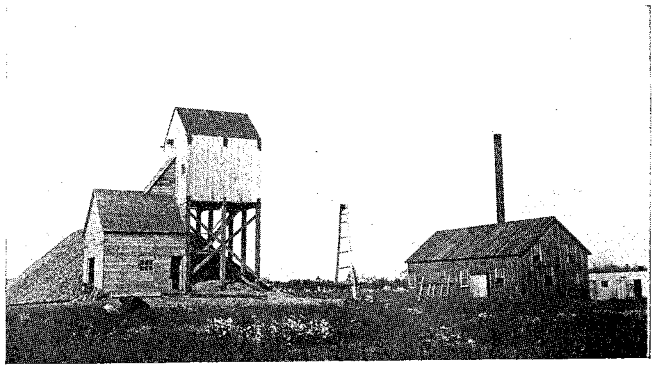
C. SINKING SHAFT IN OVERBURDEN, SOUTH LAKE MINE, 1911.



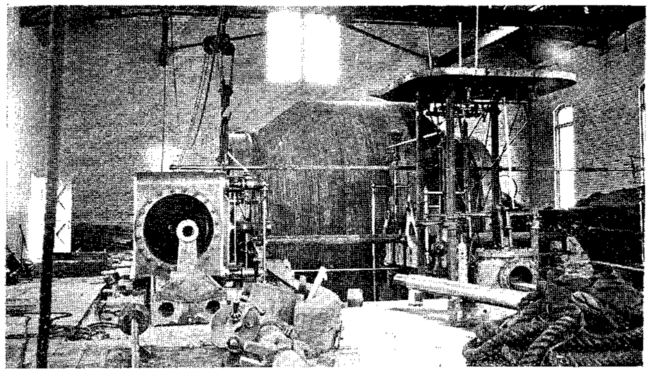
A. SOUTH LAKE MINE, 1911.



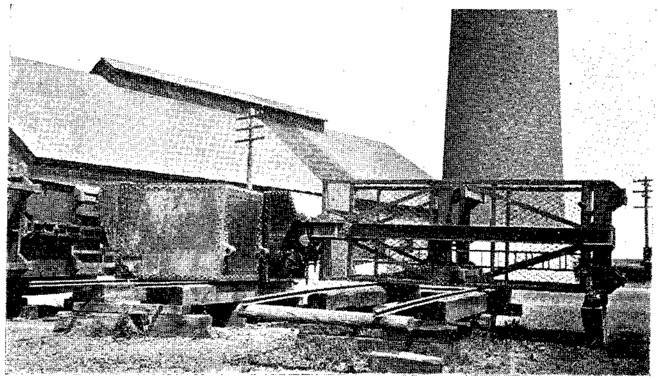
B. VERTICAL SHAFT (IN FELSITE) AT INDIANA MINE, 1911.



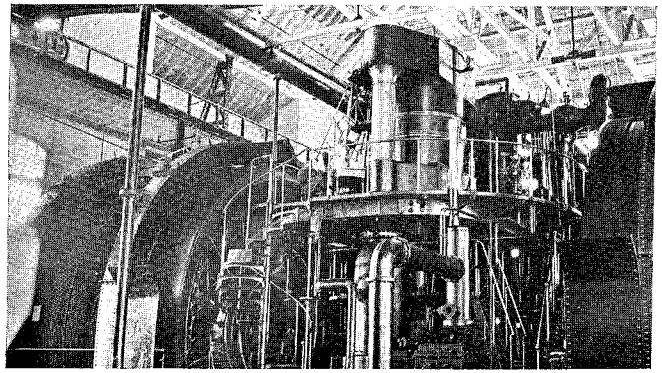
C. NEW BALTIC MINE, 1911



A. INSTALLING NEW HOIST AT LAKE MINE, 1911

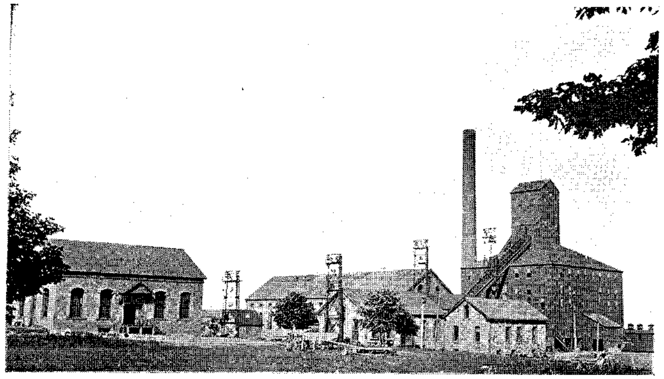


B. SKIPS AND MAN CAR AT RED JACKET VERTICAL SHAFT.

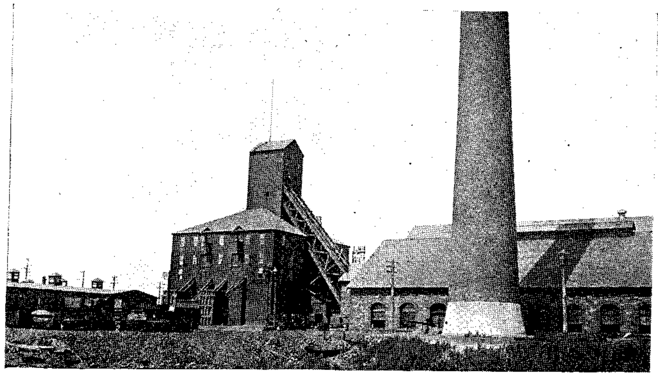


C. ONE OF THE CALUMET AND HECLA HOISTING ENGINES.

A. TAMARACK MINE.



B. RED JACKET ROCK HOUSE AND POWER HOUSE.



C. RED JACKET SHAFT.

# CHAPTER VII.

## CRUSHING AND CONCENTRATING THE ORES.

The ore in the mines when blasted commonly breaks for the most part into pieces that are readily handled by the trammers. Some large blocks are broken underground by hammer or powder. Some are broken by sledge or drop hammer at surface. The crushers[1] at surface are unusually large machines of the Blake type.

At surface the skips dump over grizzlies, small pieces of ore drop through and the larger slide down to the mouth of the crushers or into bins with chutes just in front of the crushers. There are numerous devices for handling the ore here. In some houses the ore is allowed to slide from the grizzly to a flat floor in front of the crusher. Workmen sort out the mass copper and waste rock, and feed the crushers entirely by hand. In several the ore is held back in bins, let into a chute by raising a gate, examined for waste rock or mass copper while in the chute, and then dropped into the crusher jaws by raising another gate. The gates are controlled by compressed air, and this power is also used in handling any large mass copper or waste rock which is not to go through the crusher. With the mechanical aids two men do easily as much work as six without, and as it is then only necessary to run the crusher one-half the time there is an important saving in steam. The method of handling boulders at the Calumet rock houses has been recently described in Engineering and Mining Journal, Jan. 20, 1912, pp. 159-160.

The rockhouses usually have large bins for storage purposes. Some of the newer ones, built of concrete and steel have a capacity of 700 to 1,000 tons. From these bins the rock is drawn off through chutes into railroad cars and taken to the mill. The masses which have been picked out are pounded by a drop or steam stamp until well cleaned of adhering rock and then shipped direct to the smelter. The mass as shipped averages 50% to 60% copper. The rock sorted out finds various uses. Much is crushed and used for railroad ballasting and for concrete. At some rockhouses the rock not crushed for other use is run down through chutes into the mine again and used to fill the stopes.

[1]For a description of the Calumet crusher by Claude T. Rice, see Eng. and Min. Jour., Nov. 25, 1911, p. 1026. An article on ore breaking methods written by W. R. Crane was published in Eng. and Min. Jour., Vol. 82, p. 768.

The mills of the copper country are remarkable for their enormous capacity. There are less than 100 stamps in the district, and yet the tonnage stamped daily is far greater than in any other copper district in America. In 1910 there was milled 10,869,561 tons, and a number of the stamps were idle. The recovery averages about 80%. The loss for most amygdaloids is 4 to 6 pounds copper per ton of ore. The loss in conglomerate ore is somewhat higher.

Steam stamps were early found to be well suited to crush the copper rock, and these have been improved until there are single heads which can crush 800 tons per day. Ordinarily the stamps average 320 to 700 tons per day, according to type of stamp, size of screen and kind of ore. The conglomerate is much more difficult to crush than is the amygdaloid, and considerable difference is found in the various amygdaloid lodes. Steeple compound heads have proven more efficient than simple heads, and most of the newer mills are thus equipped.

It has not been found advisable to crush the ore very fine with the stamps, as much of the copper is in coarse pieces and would be abraded by the stamps, and the fine crushing is done more effectively with other machines after the coarse copper has been saved. Conglomerate is stamped to pass 3/16″ screen; but amygdaloid only to pass ⅝″ screen. Chili mills are used for recrushing the coarser sands but these machines are being displaced by conical pebble mills. It is said that the latter not only do the work better, but are more cheaply and easily constructed, and will probably not spend such a large portion of their life in the repair shops.

From the stamps a product of heavy metallics is taken off by a hydraulic classifier or by a mortar jig. The pulp passes through a screen to jigs and tables. The jigs chiefly used are the Hodge and the Woodbury-Benedict. The tables concentrating sands are mostly Wilfleys and Deisters. For the slimes Evans round tables are commonly used.

The Calumet and Hecla stampmills,[2] the largest in the district, have 28 stamps, and in 1910 treated 2,795,514 tons of ore. The first product taken in the Calumet mill is heavy copper separated at the mortar. The conglomerate ore is crushed to pass a 3/16″ screen, but a slot at the bottom allows large pieces of copper to drop into the sieve box of a mortar jig, while the lighter gangue and finer copper is kept back by a current of water rising through the slot. The

[2]A description of these mills by Robert H. Mauer was published in the Mining World, May 2, 1908, pp. 705-708.



coarser part is taken out by removing a plug above the screen, and the finer copper in the hutch is removed occasionally by opening a gate below. The pulp from the stamp passes through the 3/16″ screen and is carried to the first of a series of five Woodbury-Benedict jigs. From the first jig, called a classifier jig, slimes run off to a settling tank, and thence the overflow runs into waste launders, while the heavier slime goes to round tables and thence to Wilfley tables for the final concentration. Sands from the first jigs pass on to the other four jigs. Metallic copper is taken from the first two. The next three jigs give coarse copper-bearing sand, which is recrushed in a Chili mill and then concentrated on Wilfley tables. The hutch product from all five jigs is concentrated on other Wilfley tables. Copper is taken from each of the tables, and middlings are collected on another table for final concentration, and the middlings from this last Wilfley go to the Chili mill for recrushing.

In the Osceola mill,[3] using Norberg steeple compound stamps, with a capacity of 750 to 800 tons amygdaloid ore per day, the rock is crushed to pass ⅝″ screen. The stamp is fitted with a hydraulic discharge and lump copper is removed at the mortar. All but these large pieces of copper pass through the screen into launders. The launders are fitted with a hydraulic discharge, which takes off a product of coarse copper. The launders lead to trommels with 3/16″ punched holes. From the trommels, oversize goes to rolls for recrushing. Undersize goes to trough classifiers, which distribute sands to jigs and slimes to settling tanks and round tables. Products are taken from jigs, and by hydraulic discharges on way from rough to finishing jigs. Heads from the round tables, after settling, are treated on Wilfley tables.

During 1911 the Osceola mill has been greatly changed, and there are now only three heads working on the system just described. The others are being replaced by apparatus of the Calumet and Hecla type. Two of the new heads were quite recently completed. Two others are in process of construction. In the new units a coarse product is taken at the stamp by a Krause discharge and another product by bull jigs. At one stamp a hydraulic discharge is used to take off a product after the oversize from the trommels is reground by rolls. Undersize from the trommels passes on to Woodbury jigs and Wilfley tables as at the Calumet and Hecla mill. Sands are reground in Hardinge conical pebble mills.

[3]An article on practice at the Osceola mill, written by Mr. Lee Fraser was published in the Engineering and Mining Journal, June 22, 1907.

The concentrates produced at the mills contain varying percentages of copper. Concentrates from the conglomerate average about 50%, and concentrates from the amygdaloids average 65% to 78%. Each mill produces concentrates of several different grades, and these are in some cases numbered No. 1, No. 2, No. 3, and No. 4, the latter being the finest. The concentrates are commonly called "mineral," but there is no special advantage in this unusual practice. The No. 1, largely lump copper or metallic, is naturally the highest grade, and commonly runs over 90%, while No. 4 is of fine particles and comparatively low in copper content. Different systems of classifying the product are in use at various mills. At the Calumet & Hecla the mill products are now classed as No. 0 containing 90 to 92% copper; No. 1 containing 65 to 75% copper; No. 2 containing 20 to 30% copper; and No. 2 regrinder containing 30% copper.

The active mills are, with two exceptions, located on Lake Superior, Torch Lake or Portage Lake. One mill, the Victoria, is located at the mine on the Ontonagon River. The Winona mill is located at the mine near a small stream. Enormous quantities of water are used in the mills, and consequently as the streams near the mines are very small, lake shore sites are generally necessary.



# CHAPTER VIII.

## SMELTING AND REFINING ORE AND CONCENTRATE.[1]

Michigan copper ores are comparatively easy to smelt. The operations are chiefly, (1) melting the concentrates and mass in reverberatory furnaces, (2) refining the copper and (3) recovering what copper goes into the slag.

The chief product of pure copper comes from the first melting. The concentrates and mass are melted without, (or in some cases with) fluxes in reverberatory furnaces, the slag formed by adhering rock is skimmed off as it forms, and the copper refined in the same furnace, or at one plant in a second furnace. The whole process takes one day for a small furnace, (capacity 30,000 pounds copper) and longer for larger charges (80,000-150,000 pounds). When one small furnace is used for both melting and refining, it is charged in the afternoon, melting and skimming continued over night, and refining done in the morning. In refining, the melt is rabbled by compressed air several hours to oxidize impurities, principally iron and sulphur, which then come up to the surface and are skimmed off. In the process a little copper is oxidized. Some of the oxide is skimmed off with the impurities. The completion of the rabbling operation is determined by observation of the texture (granularity) of the copper in test buttons. When the original impurities have all been removed, the copper still contains some cuprous oxide—as much as 7%. This is reduced by submerging wooden poles in the melt. Poling is continued until the copper is in the best possible physical condition. This point is determined by observing test buttons until a stage is reached at which they set flat on cooling. There is then still some cuprous oxide, but the metal is in its best physical condition, and without further poling it is poured into moulds. This is the final product ready for market, and unusually pure. In one plant the copper is tested for conductivity before pouring, and if the test proves unsatisfactory the

[1]An account of copper smelting practice in Michigan written by H. D. Conant was published in the School of Mines quarterly, June, 1912. In the description here given I have made free use of his article which contains descriptions of the several plants. I have incorporated information obtained from several other smelter men. R. T. White described the Michigan smelter in Eng. and Min. Jour., Vol. 79, p. 842.

An historical account of the smelting practice was given by J. B. Cooper in proceedings of L. S. M. Inst., Vol. 7, pp. 44-49.

melt is rabbled and tested again before pouring. The completion of the poling operation is checked by a copper assay.

A smaller, but important, quantity of copper is obtained by treatment of the reverberatory slag. This is allowed to cool in deep pots and the copper settles to the bottom. The buttons are broken off and returned to the reverberatory furnace, while the slag, containing 15 to 30% copper, is melted in a cupola furnace with suitable fluxes. Limestone is added for all slags. For the ferruginous slag from conglomerate ore, a siliceous flux is necessary, and for the siliceous slags from amygdaloid ore, ferruginous fluxes must be added. Anthracite is added as a reducing agent. The fuel is coke and the anthracite.

The charge is treated slowly under a low pressure blast. As the melt is inclined to chill, deep crucibles are used to allow the copper to settle, and there is no forehearth. The slag is allowed to flow off continuously. The copper is run off at intervals and cast into blocks. These cupola blocks, containing small amounts of iron, sulphur and arsenic, are refined in the reverberatory furnaces in the same way as the copper formed on melting the original charge of ore and concentrates, but on account of greater impurity must be rabbled much longer.

To obviate dust loss in treating fine slimes, one smelter has a briquetting plant. The slimes are thoroughly mixed with lime and pressed into briquetts. These are sealed up in a steel cylinder and highly heated. They are then smelted with the reverberatory slag in a blast furnace.

At one plant the fines are melted in a reverberatory furnace and the product run off into pots. It is allowed to cool and then broken up for treatment in the blast furnace.

Casting methods differ at the different smelters. In some cases the ladle is brought over stationary moulds, while in others the moulds are moved up to the ladle. At the Quincy smelter the copper is dipped by hand ladles suspended from beams, so that they can be swung over the moulds. At the Lake Superior smelting works the moulds are brought up to the ladle on an endless chain. At the Michigan smelter, the moulds are brought up to the ladle by a Walker casting machine rotating in front of the furnace.

The copper is cast into several shapes, the most common of which are known as ingots, ingot bars, wire bars, cakes, slabs, billets and anodes. The ingots weigh about 20 pounds each, and are much used in manufacture of alloys. Ingot bars consist of two or three ingots joined together endways for convenience in shipping. For wire drawing, the copper is usually cast into rectangular bars, weighing about 225 pounds. Cakes, square or round, and weighing from 120 to 6,000 pounds are used for rolling into sheets. Slabs. are thin cakes. Billets are for manufacture into seamless drawn tubes. Copper containing appreciable amounts of silver is cast into anodes for electrolytic recovery of the white metal. Some cupola blocks, containing considerable impurities, are recast into anodes for electrolytic refining. No electrolytic copper is produced by the Michigan smelters. The anodes are shipped to a plant at Buffalo.

## CHAPTER IX.

### COSTS AND PROFITS.

The ore produced by Michigan copper mines is lower grade than that of any other district. Costs must therefore be very low in order that any profit can be made. The ore produced in 1910 yielded 20.5 pounds copper per ton. The conglomerate ore averaged 28.3 pounds and the amygdaloid 18.2 pounds. Figures showing the actual copper content of the ores treated are not available; but the recovery is thought to average about 80%. The conglomerate ore treated averaged about 35 pounds and the amygdaloid ore about 23 pounds copper per ton.

This ore is developed, mined, hoisted, crushed, transported several miles to mills, stamped and concentrated, and the concentrates transported to smelting plants, smelted and refined. The copper produced is transported to eastern markets and sold for about 14 cents per pound.

That the industry should be a profitable one is remarkable. Fortunately, the mode of occurence and the character of the ore are such that mining, milling and smelting operations can be carried on at unusually low cost. The unusually favorable location of the mines gives comparatively low transportation rates.

Eleven leading producers of amygdaloid ore report for 1910 costs for mining, transportation and milling to be between $1.28 and $2.00 per ton of ore. Seven of these companies report for 1910 cost of smelting and marketing to between 0.89 and 1.81 cents per pound of copper. The thirteen leading producers of amygdaloid ore report total costs for 1910 to be respectively 11.05, 9.37, 11.57, 11.84, 14.48, 11.44, 8.32, 7.85, 12.17, 11.84, 10.53, 7.54 and 10.23 cents per pound of copper produced.

The conglomerate ore is much more difficult to mine and treat than the amygdaloid, and costs are consequently higher. For 1910 the Calumet and Hecla reports a cost of $2.11 per ton of rock mined, transported and stamped. The ore averaged 30.12 pounds copper per ton, and the total cost of production of refined copper was 8.55 cents per pound. The only other mine producing conglomerate ore was the Tamarack, and it made no profit in 1910 on ore averaging 21.1 pounds refined copper. The cost was 14.70 cents per pound produced.



Costs for each company for the years 1908, 1909, 1910 and 1911 will be found in the table in a later chapter of this report.

While the amygdaloid lodes and wall rocks are very firm and require little or no timbering, the conglomerate has a weak hanging wall which necessitates heavy timbering and increases greatly the cost of mining. The great depth to which the lode has been mined makes the cost of hoisting higher than in many of the amygdaloid mines. The conglomerate is much harder to drill and crush, and consequently the cost of mining and stamping must always be considerably greater than for amygdaloid ore. In spite of the greater costs per ton, the conglomerate is by far the most profitable lode, because of its higher values.

Many of the mines do not report costs of milling the ore. It probably averages in most cases over 20 cents per ton of rock stamped. The Osceola reported cost for 1907 to be 17.47 cents and for 1908 to be 15.78 cents. Transporation to the mills is an important item varying with length of haul. Smelting costs from one-quarter to one-half cent per pound of copper, and transportation and marketing takes another one-half cent per pound.

Owing to the low margin of profit, much attention is constantly given to devising cheaper methods. It is noteworthy that though the chief producers have to take their ore from ever increasing depth, and though the ore being mined is lower grade, yet during recent years a very steady improvement has been shown in the cost per pound of copper.

A very important feature of the past year has been the remarkably successful tryout of light weight one-man drills in competition with the heavy two-man piston drills of the ordinary type. Nearly all of the mines have been experimenting with the new drills, and in practically every case it has been found that they are preferable to the old type. In some cases one man with the light machine breaks fully as much ground as two with the old. There is good reason to believe that a considerable reduction in mining cost will result from the use of the light drills, and it will not be surprising if in a few years they displace the others altogether. In one mine using 40 drills the change has been made already. Two makes have proven especially successful. One of these is a piston drill and the other a hammer drill.

In the mills probably the most important saving in recent years has been made by the introduction of steeple compound heads. During the past few years much attention has been given to regrinding apparatus, and a considerable advantage is expected to follow the more general use of pebble mills. In addition to better recovery from new ore, large piles of tailings will probably be recrushed and concentrated at a profit.

Smelting methods do not change quickly. The chief changes introduced in new plants are the use of larger furnaces and more mechanical aids for the handling of charge and furnace products. By these means a considerable saving has been effected.

The copper mines have up to date produced about 5,345 million pounds of copper and paid dividends of $188,175,895 dollars.

Mr. Horace Stevens, who has made a special study of the situation states in his Copper Handbook:

"The average price received for all Lake Superior copper, from 1845 to 1910,, inclusive, was 14.19 cents per pound, with average dividends of 3.56 cents per pound, leaving an estimated cost of 10.63 cents for all years. While this may be accepted as an arbitrary figure, the cost might be figured much higher, or materially higher. By adding $60,000,000 to the cost of production, for money lost in unproductive ventures, the cost of copper produced would be made almost 11.5 cents per pound. By adding another $15,000,000 for assessments on mines that have since repaid in dividends the original assessments, the cost of copper would be increased to about 11.85 cents per pound, leaving a net margin of profit, for the entire production, of almost exactly two cents per pound, plus the present aggregate values of the mines, which would be about equal to total dividend disbursements to date, or about 3.5 cents per pound.

"Omitting the production of mines that have not proven profitable, the average cost of copper produced by dividend-paying Lake Superior mines probably has been about 9.5 cents per pound, for all years."

A discussion by J. R. Finlay of the costs at several mines is given in his book on "The Cost of Mining," pp. 127-164. Further notes on costs are included in his report to the State Tax Commissioners 1911.



## CHAPTER X.

### PRESENT CONDITION OF THE INDUSTRY.

During the past two years, and especially during 1911, the copper produced has been sold at unusually low figures. The domestic demand has been very unsatisfactory, and the price would have fallen still lower, but for a timely increase in demand by Europe. Foreign buyers took large quantities at around 12.5 cents per pound. Consumption during the year was greater than production, and in November the decrease in surplus stocks began to show marked influence on the price of the metal. Continued demand for large quantities soon forced the price up to over 14 cents, and the year closed with the market in very satisfactory condition. Good prices prevail and the surplus stock both in the United States and Europe has been considerably reduced. The improved price has prevailed too short a time to allow of very definite estimate of prices for the future; but it seems to have resulted directly from large consumption and low quantity of available stocks. If such is the case it seems likely that the price will be maintained, for the European consumption is expected to be very large, and the American consumers have comparatively small stocks on hand.

The following tables from statistics collected by the Engineering and Mining Journal shows the prices quoted for each month of the past five years, and the visible stocks in United States and Europe in each month of 1910 and 1911.

PRICE OF COPPER AT NEW YORK (in cents per pound).

| | Electrolytic. | | | | | Lake. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1907 | 1908 | 1909 | 1910 | 1911 | 1907 | 1908 | 1909 | 1910 | 1911 |
| January | 24.404 | 13.726 | 13.893 | 13.620 | 12.295 | 24.825 | 13.901 | 14.280 | 13.870 | 12.680 |
| February | 24.896 | 12.905 | 12.949 | 13.332 | 12.256 | 25.236 | 13.098 | 13.295 | 13.719 | 12.611 |
| March | 25.065 | 12.704 | 12.387 | 13.255 | 12.139 | 25.560 | 12.875 | 12.826 | 13.586 | 12.447 |
| April | 24.224 | 12.743 | 12.562 | 12.733 | 12.019 | 25.260 | 12.928 | 12.937 | 13.091 | 12.275 |
| May | 24.048 | 12.598 | 12.893 | 12.550 | 11.989 | 25.072 | 12.788 | 13.238 | 12.885 | 12.214 |
| June | 22.665 | 12.675 | 13.214 | 12.404 | 12.385 | 24.140 | 12.877 | 13.548 | 12.798 | 12.611 |
| July | 21.130 | 12.702 | 12.880 | 12.215 | 12.463 | 21.923 | 12.933 | 13.363 | 12.570 | 12.720 |
| August | 18.356 | 13.462 | 13.007 | 12.490 | 12.405 | 19.255 | 13.639 | 13.296 | 12.715 | 12.634 |
| September | 15.565 | 13.388 | 12.870 | 12.379 | 12.201 | 16.047 | 13.600 | 13.210 | 12.668 | 12.508 |
| October | 13.169 | 13.354 | 12.700 | 12.553 | 12.189 | 13.551 | 13.646 | 13.030 | 12.788 | 12.370 |
| November | 13.391 | 14.130 | 13.125 | 12.742 | 12.616 | 13.870 | 14.386 | 13.354 | 12.914 | 12.769 |
| December | 13.163 | 14.111 | 13.298 | 12.581 | 13.552 | 13.393 | 14.411 | 13.647 | 12.863 | 13.768 |
| Year | ........ | 13.208 | 12.982 | 12.738 | 12.376 | ........ | 13.424 | 13.335 | 13.039 | 12.634 |

VISIBLE STOCKS OF COPPER

| | United States. | | | Europe. | | |
|---|---|---|---|---|---|---|
| | 1909 | 1910 | 1911 | 1909 | 1910 | 1911 |
| January | 122,357,266 | 141,766,111 | 122,030,195 | 124,716,480 | 244,204,800 | 236,629,120 |
| February | 144,130,045 | 98,463,339 | 142,439,490 | 118,574,400 | 248,236,800 | 236,992,000 |
| March | 173,284,248 | 107,187,992 | 156,637,770 | 117,140,800 | 254,150,400 | 233,385,600 |
| April | 182,279,902 | 123,824,874 | 162,007,934 | 115,024,000 | 249,625,600 | 223,014,400 |
| May | 183,198,073 | 141,984,159 | 165,555,908 | 114,050,320 | 246,870,400 | 212,284,800 |
| June | 169,848,141 | 160,425,973 | 165,995,932 | 127,352,960 | 239,142,400 | 202,540,800 |
| July | 154,858,061 | 168,386,017 | 157,434,164 | 150,928,960 | 232,892,800 | 195,932,800 |
| August | 122,596,607 | 170,640,678 | 137,738,858 | 171,492,160 | 222,320,000 | 191,891,840 |
| September | 135,196,930 | 168,881,245 | 133,441,501 | 197,993,600 | 218,444,800 | 191,228,800 |
| October | 151,472,772 | 148,793,714 | 140,894,856 | 210,224,000 | 211,276,800 | 191,945,600 |
| November | 153,509,626 | 139,261,914 | 134,997,642 | 222,566,400 | 198,060,800 | 176,825,600 |
| December | 153,003,527 | 130,389,069 | 111,785,188 | 236,857,600 | 193,200,000 | 164,281,600 |
| January | ........ | ........ | 94,784,178 | ........ | ........ | 158,323,200 |



While the present price of copper is satisfactory and the immediate future is promising, it is the probably average price over a long period of years that most interests the mine owners. It is well known that there will soon be on the market a largely increased tonnage of copper produced by the comparatively new "porphyry" mines of the western states. If the "porphyry" copper is produced cheaper than that of Michigan, it is evidently of paramount importance to the stockholders of the older mines that this increase in output shall meet with a corresponding increase in consumption. If the increase in production is greater than the increase in consumption, then only those mines that can produce at low cost will be profitable and the others must close down. It has been claimed that the "porphyry" copper can be produced more cheaply than that of Michigan; but this remains to be proved. Mr. J. R. Finlay, a recognized authority on costs, has stated that it is highly doubtful if the average cost for the porphyry mines will be even as low as that in Michigan. In view of the fact that during the past there has been a fairly regular and large increase in the amount of copper consumed annually, it is reasonable to expect a large increase in the future. The larger market will probably readily absorb the copper from new sources, and the price will be quite as likely to rise as to fall. Mr. Finlay estimates 14 cents as a very conservative figure for the next ten years, and states that in his opinion the average price will be higher. It is interesting to note that Mr. Stevens' calculations show that the average price received for Michigan copper for all years 1845 to 1910 was 14.19 cents. Assuming a selling price of 14 cents, and consulting the production and cost sheet of this report it will be seen that large profits should be made in the future. It will be seen that in 1910 and 1911 over 99% of the total production is is made by 18 mines. It has been demonstrated that 13 of these the Ahmeek, Allouez, Baltic, Calumet & Hecla, Centennial, Champion, Isle Royale, Mohawk, Osceola, Quincy, Superior, Trimountain and Wolverine can make a profit with copper selling at under 14 cents. Four others Franklin, Mass, Victoria and Winona promise to show good results in 1912. The Tamarack has unusually high costs; but might show a profit on 14 cent copper.

Owing to the unfavorable market conditions, there has been during the past year no attempt to rush production. On the other hand there has been no great curtailment of output. The 1910 output was about 5% less than that of 1909, but the 1911 production is expected to be nearly the same as that of 1910, probably differing by less than one per cent.

One company, Ahmeek, paid an initial dividend in 1911. The eight dividend paying companies, Calumet and Hecla, Baltic, Champion, Osceola, Wolverine, Quincy, Mohawk and Ahmeek in 1911 distributed $5,376,125 to stockholders.

During 1911 the Franklin, Mass, Victoria, Winona, King Philip, Hancock and Ojibway called assessments for development work. The Adventure, Indiana, St. Louis, Old Colony and Mayflower called assessments for exploratory work, the first three for sinking shafts and drifting, the other two for diamond drilling. The Wyandot called an assessment to provide funds for the investigation of deposits found in a cross cut and for other exploratory work. The 1911 assessments totaled $2,086,299.

With copper selling at under 13 cents most of the dividend paying mines would probably produce in 1912 about the same amount as in 1911; but if a better price prevails an increase in output is to be expected.

The Ahmeek doubtless will show an important increase in any case, there being now a large tonnage of high grade ore available. The Mohawk has in the past few years developed at shafts No. 5 and No. 6 what is practically a new mine, and production can be much increased when desired. The Copper Range dividend producing mines, Champion and Baltic, are equipped to handle a large output, and if desired a considerable increase in production can be made. The Osceola output at present comes entirely from the Kearsarge lodes; but there is a large tonnage of ore on the Osceola lode that is developed, and which can be mined on short notice if the market warrants it. The 1912 production of Osceola, may therefore be about equal to that of 1911 or much greater, depending on operation on the Osceola lode. The Calumet and Hecla production from the conglomerate lode is not expected to fall off for several years, and when it does this can be partially offset by increasing production from the Osceola lode. The Wolverine mine has maintained a remarkably uniform production for several years, and the 1912 output will probably not differ much from other years. The Quincy, while maintaining a fairly uniform output in recent years, has made material additions to its reserves; and can greatly increase production when No. 9 shaft is sunk to the 22nd level and equipped for hoisting on a large scale.

Two mines not on the regular dividend list, Isle Royale and Trimountain, made profits during 1911, and are expected to make greater profits in 1912. The Isle Royale mine has shown considerable improvement in 1911, and is expected to show increased output in 1912. The Superior has one large body of high grade ore, but has not made a great production during the year, attention being chiefly devoted to developing the lode and improving methods of mining and handling the ore. The Centennial, which has been operated at a loss for several years, made a better showing in 1911, and is expected to about break even. An important additional source of copper for 1911 was the Winona, which produced no copper in 1908, 1909 or 1910; but came back on the list in 1911 with about 1,276,000 pounds. At the Hancock Mine in 1911, a mill test showed that the No. 3 lode can, by selection of the ore, be worked at a small profit, and the recent striking of a rich lode at the depth of 3,105 feet in the new vertical shaft, and the near approach of the shaft to the horizon of the Pewabic lode makes it probable that this mine will soon be an important producer. The Lake Mine, while not producing in 1911, is generally considered to be a very promising one. The ore body has been extensively developed during the year, and a hoist and rockhouse of large capacity are nearly ready for use. The Lake is expected to make a considerable output in the latter half of 1912. One large producer and former dividend payer, the Tamarack, has for some time been producing at a loss. During 1911 the working of the mine has been on a much smaller scale than formerly, and the year's production shows a falling off of about 3,500,000 pounds. The Michigan Mine, which was an important producer until two years ago, is closed down, but in 1911 was worked by tributors, and produced 327,773 pounds.



At the Mass and Franklin Mines, development work has during the past two years been far in excess of the production. These two mines have now large blocks of good ore developed and are installing hoists and rockhouses of increased capacity. They will in 1912 show a considerable increase in production.

More noticeable than at the mines is the cutting down of work on prospects. As elsewhere there is in this district always a desire to find copper in boom times; while comparatively little effort is made to find new deposits during a period of depression. During the past summer only very few diamond drills, in September seven, have been in operation exploring drift covered areas. Several of the properties on which copper beds were found by drills in 1909 and 1910 have been but little explored during 1911 because of the natural tendency of stockholders to hold back until brighter market conditions prevail. One property on which drilling showed exceptionally good cores is yet undeveloped, because the directors have not considered it advisable to do the necessary financing while there is so little enthusiasm. The drilling done in 1909 and 1910 showed conclusively how little is yet known of the possibilities of the Michigan copper district.

Of discoveries made in recent years, the most important are those in Ontonagon county at the Lake Mine and on neighboring properties. Exploration of the Lake lode was begun in 1906, and the work soon showed that an important new ore body had been found. Further development proved it to be rich, wide, and of considerable length and depth. The successful opening up of the new lode was naturally followed by exploration of the neighboring properties. There is a heavy overburden in the vicinity, and most of the prospecting was done by diamond drilling. It was found that the properties are well mineralized, and rich cores were taken from several holes, especially on the South Lake and Indiana properties. None of these deposits have yet been opened up.

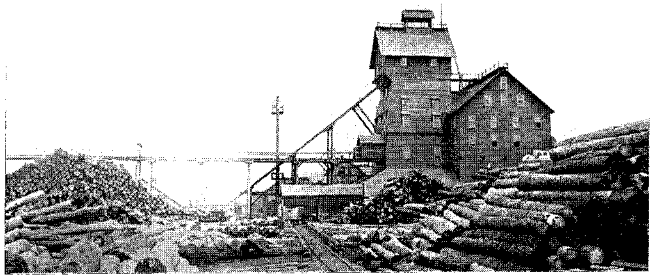
In the northern part of Houghton county diamond drilling disclosed a promising lode on the St. Louis property, and a recent discovery in a drill hole on the Mayflower property will doubtless lead to more thorough prospecting of this section.

If, as seems likely, copper producers in 1912 receive a more reasonable price for their product, there will be much greater activity on the so called "drill hole" properties. There are very large areas of ground on the copper range that are yet untested.

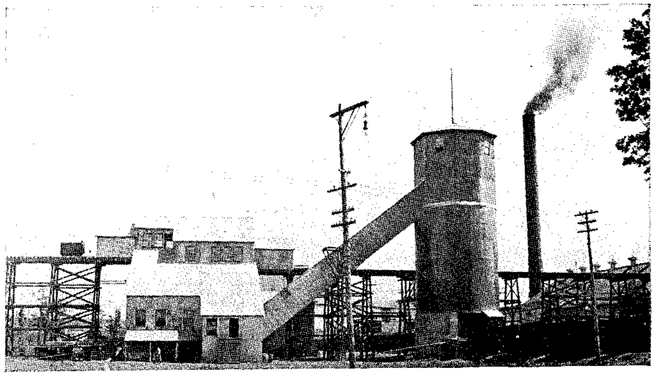
From this account of the work done at the mines during the recent past, and the expectations for the immediate future, it will be evident that the period of depression in the copper market has acted as a check; but has not by any means demoralized the industry. It is unfortunate for the mine owners that they have had to dispose of so much copper at comparatively small profits; but they will reap some benefit in the future from the marked reductions in costs which have been brought about partly by the necessity of keeping the mines on a paying basis while the price was low. The mines producing over 90% of Michigan's copper in the past few years, did so at a profit. During this trying period many improvements have been made and new standards set. With normal prices again established, the mines are making better profits than would have been the case if necessity had not demanded the reforms sooner than they would have come in a period of brighter market conditions.

The industry is therefore in a very satisfactory state. The mines are in good condition to produce large quantities of ore at low cost, and a good price is being received for the product. During

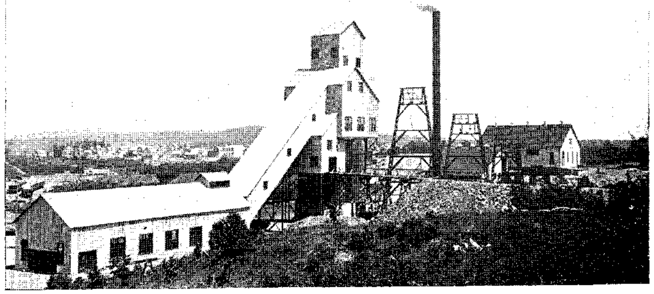




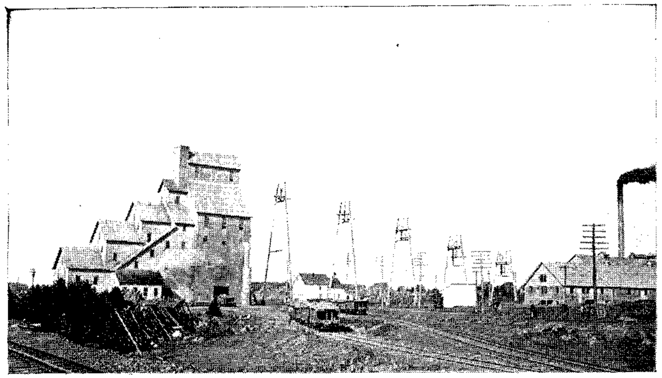
A. TIMBER AT TAMARACK SHAFT.



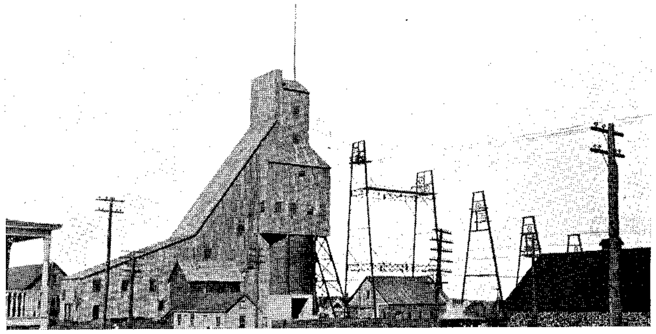
B. ROCK HOUSE AND STORAGE BIN AT AHMEEK MINE.



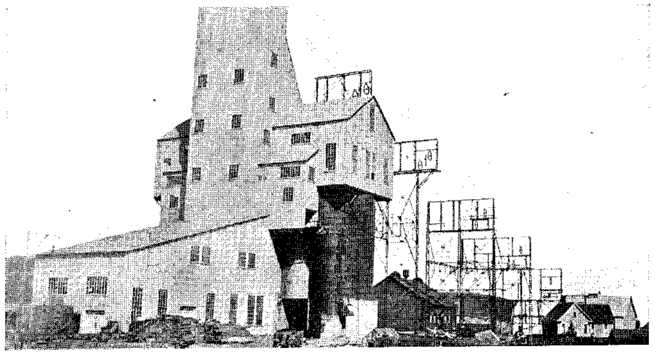
C. SHAFT HOUSE AT NORTH KEARSARGE MINE.



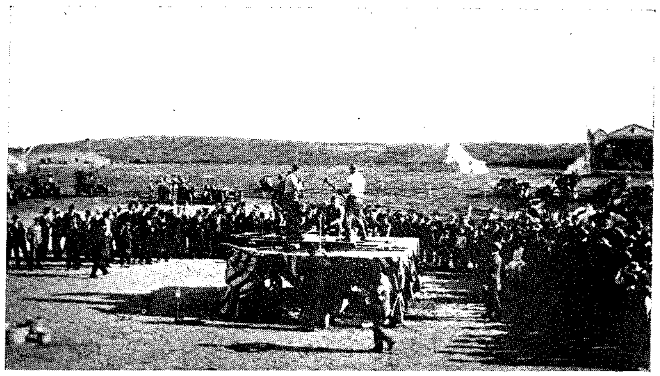
A. MESNARD SHAFT, QUINCY MINE.



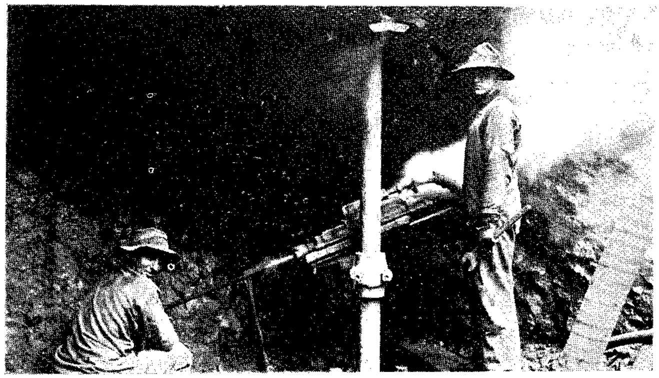
B. ROCK HOUSE AT SHAFT NO. 2, QUINCY MINE.



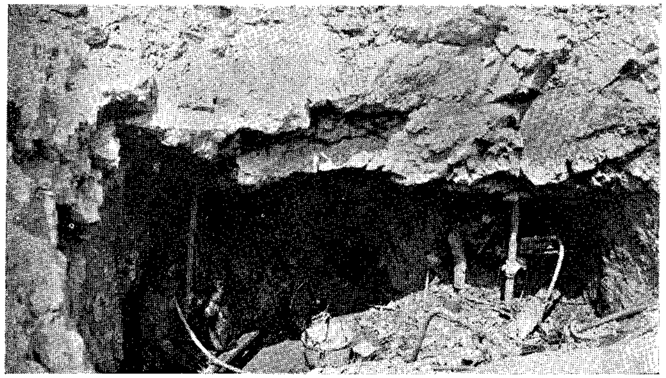
C. NEW ROCK HOUSE AT VERTICAL SHAFT, HANCOCK MINE.



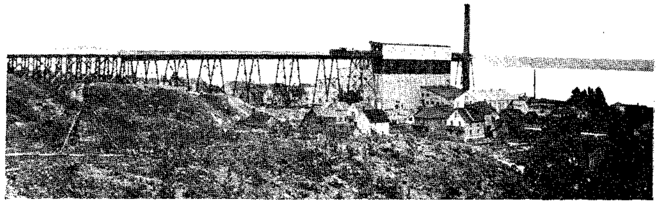
A. DRILLING COMPETITION, HANCOCK, 1911.



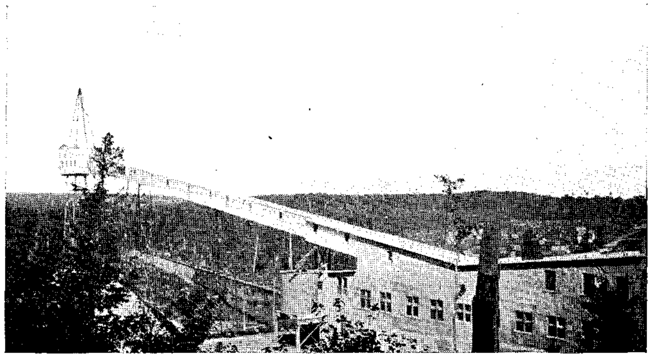
B. DRILLING BY STEAM IN ST. LOUIS LODE, 1911.



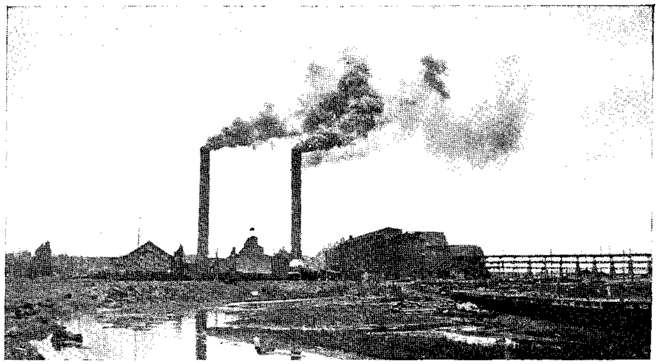
C. SHAFT SINKING ON ST. LOUIS LODE.



A. AHMEEK STAMP MILL, TORCH LAKE.



B. TAILINGS CONVEYOR, WINONA STAMP MILL, 1911.



C. CALUMET AND HECLA STAMP MILLS, LAKE LINDEN.

the past two years there has been a notable decrease in the number of miners[1] employed; but if present conditions continue more men will be put at work. There were many idle miners in the district during 1911. A considerable number have left for other mining camps or for Europe, and the remainder have a very good chance of finding employment. To both mine owner and miner the immediate future looks bright. Even though 1912 should not prove to be the prosperous year that it gives promise of being, there is very good reason to believe that the Michigan copper mines have a long and profitable life ahead of them. There are known bodies of ore which will take many years to mine, and there is a large area of unexplored territory in which ore is very likely to be found. It is scarcely to be expected that another bonanza like the Calumet and Hecla conglomerate exists in the district; but that many millions of pounds of copper will be taken from deposits yet undiscovered is a prediction that can safely be made. It will take many years to thoroughly prospect the drift covered areas, and it would be very remarkable if they should be found to contain no profitable deposits. It is also likely that much copper will be found in old workings by more thorough investigation of the wall rocks.

[1] Very few of the miners are American born. W. J. Lauck in the Min. and Eng. World, Nov. 18, 1911, pp. 1013-14, discusses the Michigan copper miner of today. He states that 27% are Finns; 14% English; 10% Northern Italians; 10% Croatians and 5% French-Canadians. Others are Southern Italians, Slovenians, Poles, Swedes and Germans. Mr. Lauck estimated the average weekly wage earned to be $13.86. The highest wages are earned by Cornish and Finish miners. Of the immigrants from southern and eastern Europe only 5% have had experience in mining before coming to America. There are about 18,000 men employed at the mines at present.

# CHAPTER XI.

## MICHIGAN COPPER MINING COMPANIES.

ADVENTURE CONSOLIDATED COPPER CO., 32 Broadway, New York.

Capital Stock, $2,500,000 in 100,000 shares of $25 each. Balance of assets Jan. 1, 1912, $72,375.27.

James L. Bishop, President.

Chester L. Dane, Vice President.

These officers and Charles J. Devereaux, James S. Dunstan, William R. Todd, Stephen R. Dow, and Charles D. Hanchette, Directors.

William R. Todd, Secretary and Treasurer.

W. A. O. Paul, Assistant Secretary and Treasurer.

Charles L. Lawton, General Superintendent.

Mine at Greenland, Ontonagon County, Michigan.

This Company has worked several lodes in the Evergreen belt in Ontonagon County without any marked success. Up to Dec. 31, 1910, there had been produced 8,727,512 pounds of copper, which with a little silver, was sold for $1,351,181.35. The cost of mining and construction during the period was $3,120,176.04.

The work now being done is of an exploratory nature. By diamond drilling in 1908 and 1909 three copper bearing beds were located, and a vertical shaft has since been sunk to explore these at depth. The first lode was cut in the shaft at 894′ but has not been extensively explored. The shaft was continued down to a little over 1,500′ and a cross cut is now being driven at this level to investigate the other two lodes. The cross cut at the end of the year was in over 200 feet. It is expected to cut No. 2 lode at about 450 feet and No. 3 lode at 850 feet. Recently 6 feet of good ore was encountered in the cross cut; but its relation to the lodes cut by drill holes is yet rather uncertain.

AHMEEK MINING CO. 12 Ashburton Place, Boston.

Capital Stock $1,250,000 in 50,000 shares of $25 each. Balance of assets Dec. 31, 1911, $1,013,812.45.

Rodolphe L. Agassiz, President.

Quincy A. Shaw, Vice President.

George A. Flagg, Secretary and Treasurer.

These officers and Francis W. Hunnewell, Francis L. Higginson, Thomas N. Perkins and James MacNaughton, Directors.

Clarence H. Bissell, Asst. Secretary and Asst. Treasurer.

James MacNaughton, General Manager.

Mine at Ahmeek, Keweenaw County, Michigan.

This Company, controlled by the C. & H. Mining Company, is mining a rich section of the Kearsarge lode. It is practically a new mine and has a long life ahead. The lode is opened up by four shafts, two, No. 1 and No. 2, following down on the dip from the surface, and two, No. 3 and No. 4, started in the hanging wall at an inclination of 80° and curving to the dip of the lode at depth. A large body of ore has been developed, and it is of unusually high grade, the 1910 yield averaging 22.3 pounds per ton, and that of 1911, 25.4 pounds. The production of earlier years was lower grade. During the past five years 1,722,281 tons of ore was stamped, yielding 35,911,797 pounds of copper, an average of 20.9 pounds per ton. This was produced at a cost of 13.3 cents and sold for 14.3 cents per pound. In 1910 there was stamped 530,365 tons of ore, yielding 11,844,954 pounds of copper. This copper cost 11.05 cents per pound. The 1911 production was 15,196,127 pounds copper from 548,549 tons ore. The cost per pound was 7.17 cents and the selling price was 12.78 cents. During 1911 the Company paid its first dividend, distributing $100,000 to stockholders. The net earnings for the year were $870,272.



The Ahmeek has been estimated to have a future production of 635,213,000 pounds copper to be produced from 80% of the lode averaging 18 pounds refined copper per ton. The probable cost for this production was estimated at 9 cents per pound.

Ahmeek has an enviable record, and has quickly taken an important place among the large producers. Ground was broken for the first shafts late in 1903. Since then two others have been sunk to reach the lode at depth, and a modern four stamp mill has been erected. In spite of the heavy items for construction, the company has accumulated a surplus and begun to pay dividends. With four shafts in operation, the mine is expected to make a much larger production in the near future.

The development at No. 3 and No. 4 shafts show a lower grade of ore than at No. 1 and No. 2 shafts and the copper is not so evenly distributed throughout the lode. During the year 38,450 tons of ore was produced from these workings.

At the stampmill Hardinge conical pebble mills were installed during the year to treat some coarse tailings from No. 1 and No. 2 heads.

ALGOMAH MINING CO. 60 Congress Street, Boston.

Capital Stock $2,500,000 in 100,000 shares of $25 each, $10 per share paid in. 70,000 shares issued.

Balance of assets Dec. 31, 1910, $36,696.24.

Stephen R. Dow, President.

Albert L. Wyman, Secretary.

Alvin R. Bailey, Treasurer.

These officers and John C. Watson, John H. Rice, David E. Dow and R. M. Edwards, Directors.

R. M. Edwards, Superintendent.

Mine at Lake Mine, Ontonagon County, Michigan. Property 480 acres.

The Algomah Mine, which adjoins the Lake, is opening up a lode that is unique in the copper country. It is an amygdaloid with practically no native copper. The ore is black oxide and green chrysocolla occurring in rather irregularly shaped bodies in a brown amygdaloid. A shaft was sunk in the lode and at a depth of 104 feet drifts run along the strike 1,200 feet north and 850 feet south. Similar ore was found in varying amounts. At 1,000 feet north the drift reached the Eastern sandstone and for 200 feet the contact was followed. The shaft was also sunk to second level and has now reached a depth of 210 feet. From the shaft a cross cut is being driven west at the 210 ft. level to explore a lode which was cut by drill No. 2. The cross cut is in 350 feet.

At the 104 foot level a cross cut showed the amygdaloid to be about 40 feet thick and to lie about 60 feet above the contact of the Keweenaw series with the Eastern sandstone.

In addition to the work at the shaft, exploration has been carried on during 1911 on other parts of the property by diamond drilling. Two vertical holes were put down as far as possible, No. 5 to 2,241 feet and No. 6 to 2,538 feet. There are several lodes cut in No. 6 hole, one at 2,090 feet, 2,090 to 2,119 feet being particularly promising.

An assessment of $1 per share, payable Jan. 22, 1912, has been called to provide $70,000 for continuation of the development work.

ALLOUEZ MINING CO. 12 Ashburton Place, Boston.

Capital Stock $2,500,000 in 100,000 shares of $25 each. $22.25 per share paid in. Balance of liabilities Dec. 31, 1911, $77,700.04.

Quincy A. Shaw, President.

R. L. Agassiz, Vice President.

G. A. Flagg, Secretary and Treasurer.

These officers and H. F. Fay, W. L. Frost, F. L. Higginson, F. W. Hunnewell, Thomas N. Perkins and James MacNaugton, Directors.

Geo. G. Endicott, Asst. Secretary and Asst. Treasurer.

James MacNaughton, General Manager.

This Company, controlled now by the Calumet and Hecla Mining Company, at first developed the Allouez conglomerate. The conglomerate workings were unsuccessful and finally abandoned. All work now is on the Kearsarge lode.

The Company does not own the outcrop of the Kearsarge amygdaloid, and the lode was reached, as at the Ahmeek, by steeply inclined shafts, which curve into the dip of the lode at depth. The ore is not nearly so rich as at the Ahmeek, but the Company is expected soon to become a dividend payer. During the past five years there was stamped 1,114,085 tons of ore, which yielded 17,355,301 pounds of copper, an average of 15.6 pounds per ton. It has been estimated that the mine will produce at a cost of 10.25 cents per pound, 282,317,000 pounds copper from ore yielding 16 pounds per ton. In 1910 there was stamped 247,119 tons ore, yielding 4,655,702 pounds copper, an average of 18.84 pounds per ton. This cost 11.57 cents per pound. In 1911 there was produced 288,160 tons of ore which yielded 4,780,494 pounds copper, an average of 16.56 pounds per ton. The cost was 13.30 cents per pound. The No. 2 shaft is now being equipped with a new hoist and rockhouse, so that the output can be greatly increased, and the latter half of 1912 should show a much larger production.

The drifting done during 1911 opened ground of average grade. The sinking at both No. 1 and No. 2 shafts showed only fair values. The No. 1 shaft is now 3,298 ft. and No. 2 is 3,228.5 feet deep.

ARCADIAN COPPER CO.

Succeeded by New Arcadian Copper Co.



ARNOLD MINING CO. 64-50 State St., Boston.

Capital Stock $2,500,000 in 100,000 shares of $25 each.

C. Howard Weston, President.

John Brooks, Secretary and Treasurer.

Capt. Wesley Clark, Superintendent.

Owns lands in Keweenaw County, including old Copper Falls mine and Arnold mine. The Copper Falls mine was an important producer years ago, but has long been idle.

ASHBED MINING CO. 64-50 State St., Boston.

Capital Stock $1,000,000 in 40,000 shares of $25 each.

John Brooks, Secretary and Treasurer.

Capt. Wesley Clark, Superintendent.

These officers and T. P. Farmer and W. C. Fiske, Directors.

Owns lands adjoining Arnold mine in Keweenaw County. Idle.

ATLANTIC MINING CO. 82 Devonshire Street, Boston.

Capital Stock $2,500,000 in 100,000 shares of $25 each.

Balance of assets Dec. 31, 1910, $190,050.52.

Wm. A. Paine, President, Frederic Stanwood, Secretary-Treasurer. These officers and John R. Stanton, J. Wheeler Hardley, Frank P. Son, John H. Blodgett, and Samuel L. Smith, Directors.

F. W. Denton, General Manager.

Mine at Atlantic, Houghton County, Michigan.

The Atlantic Mine, now closed down, was until May 1906 a large producer. Settling of ground in old stopes, producing so called "air-blasts," put the mine out of commission at that date. The Company then directed attention entirely to exploration for the Baltic lode on section 16, a portion of the Atlantic property. A lot of work was done from the section 16 shaft, but all efforts to find the Baltic lode were unsatisfactory, and in June 1911, this exploratory work was stopped, and the shaft abandoned. The directors decided not to reopen the old mine on the Atlantic lode, because from the results obtained in the last five years that the mine was operated, they could see no profit in taking out the limited amount of ore that remains. An offer of the Copper Range Consolidated Co., to take over the Atlantic on the basis of one share in that company for ten shares of the Atlantic stock was accepted, and the bargain was closed July 1, 1911.

The Atlantic lode is comparatively low grade, averaging 14 pounds per ton, but the metal is rather evenly distributed, and the mine made a splendid record for low cost per ton of ore mined. Apparently in a period of good copper prices the ore could be taken out at a profit, and it is likely that at some future time the mine will again be opened up.

BALTIC MINING CO. 82 Devonshire Street, Boston.

Capital Stock $2,500,000 in 100,000 shares of $25 each.

Balance of assets Dec. 31, 1911, $308,712.50.

Controlled by Copper Range Consolidated Company.

William A. Paine, President.

Frederic Stanwood, Secretary and Treasurer.

Wm. A. Paine, Samuel L. Smith, J. Henry Brooks, R. T. McKeever and Thomas S. Dee, Directors.