

1886

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Recommended Citation

Hall, C. W. (1886). A Brief History of Copper Mining in Minnesota. *Journal of the Minnesota Academy of Science, Vol. 3 No. 1*, 105-111.

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phyries undistinguishable from these, are seen in the *Cupriferous series* of Lake Superior, there associated with dark basic igneous rocks, the nature of which is not disputed.

If these fossils be taken as guides—and they are the only ones that have ever been found in these rocks—the age of the red quartzites of Minnesota seems to be the same as the so-called lower Potsdam, or St. Johns' group, and they at the same time indicate that the Cupriferous series of Lake Superior belongs to the same age.

October 6, 1885.

[Paper Q.]

A BRIEF HISTORY OF COPPER MINING IN MINNESOTA.—C. W. Hall.

I.

THE CUPRIFEROUS ROCKS.—The copper-bearing rocks in Minnesota are those comprised in the so-called Keweenaw formation or group of rocks. There are only one or two localities at present known where attempts at copper mining have been made, which are not referred to that group of rocks, and these attempts will be mentioned further on.

The Keweenawan rocks, frequently called the Cupriferous series, enter the state in its northeastern corner, a little to the west of Grand Portage bay, Lake Superior, and are continuous along the north shore of the lake to and beyond Duluth. Passing away from the lake shore, which by the way forms the southern and southeastern boundary of this northwestern Cupriferous, and we also see the northern and northwestern border passing from Grand Portage in an almost due west course for fifty miles, and then quite likely in a very regular curve to the southwest, closing in on the southeastern boundary just mentioned, to the west of Duluth, doubtless not far from Fond du Lac.*

Another area of the Keweenawan in Minnesota lies along the eastern border of the state, entering it from Wisconsin, and exposed along the Kettle, Snake and St. Croix rivers, and in the vicinity of Taylors Falls southward from these first two named streams.

*This portion of the state, owing to the difficulty of access on account of almost impenetrable forests, has not yet been explored.

This area is not large; it is the southwestward extension of the southern portion of the Lake Superior synclinal, that which presents its most typical exposures on Keweenaw Point. For many miles occasional exposures of these rocks may be seen along the St. Croix river, which forms the boundary line for a hundred miles or so, between the two states of Minnesota and Wisconsin. The exposures along the Snake and Kettle rivers, two Minnesota branches of the St. Croix, are somewhat scattered, and at the same time are fewer than those along the St. Croix. So far as is known to the writer these Keweenaw rocks in Minnesota die out completely on the east side of the St. Paul and Duluth railroad; not a single exposure is yet reported from the west side of that road, unless the numerous dikes of the granite area of Central Minnesota, in Stearns and neighboring counties, be regarded as of Keweenaw age. That these dikes are of this age is very possible, nay probable.

Other views than the one above given have been held by geologists, with reference to the age of these copper-bearing rocks; they have, in short, been relegated to positions from the Jurassic down to the Huronian. The opinion of Irving, above stated, is both the latest one and the one best and most completely supported by field evidence; for those two reasons the writer is willing to accept it until some competent person has reviewed the ground, and found grave faults in Irving's observations, arguments and conclusions.

The rocks which are included within this Keweenaw group are both sedimentary and eruptive. The sedimentary in Minnesota are red sandstones, such as occur on the north shore of Lake Superior, among other places at Good Harbor bay, in a bed upward of 200 or more feet in thickness, dipping southwesterly at an angle of 8 to 10 degrees, and conglomerates as those a mile or two below (east of) the mouth of Poplar river. Above and below these sandstone and conglomerate layers are massive flows of diabasic rocks, which in places are quite amygdaloidal with calcite, laumontite, thomsonite, lintonite, stilbite, etc. Further, sedimentary rocks appear in the St. Croix valley in the form of conglomerates associated with ash bed "trap" and amygdaloidal rocks of a diabasic type. Several localities can be mentioned.

At Taylors Falls melaphyre stands up thro' the cambrian sandstones and fossiliferous shales. In places, as along the bank of

the St. Croix at the head of the Dalles, this rock is quite porphyritic; elsewhere it is quite amygdaloidal; the amygdaloidal structure is the more prevalent, and at the surface the rock usually is much decomposed. At Duluth the huge masses of rock which Streng and Kloos first called hornblende gabbro comes in, very coarse grained and massive. Further down the lake, gabbro, diabases, both massive and of the ash bed type, felsite porphyries and quartz porphyries occur.*

II.

MIXING FOR COPPER.—Copper mining has never been prosecuted on a large scale in this state. The presence of the copper bearing rocks has led to a great deal of conjecture and to no inconsiderable amount of exploration: the frequent discovery of pieces of float copper, i. e. of pieces in the material of the glacial drift, completely isolated from all rock and mineral material which would indicate the presence of that metal, has also led to the careful examination of many localities which otherwise would never have been thought of as mining districts. I believe LeSueur was the first one to find one of these masses. His find was, according to Dr. Neill, near a small lake in the Mississippi valley, four leagues above the mouth of the river St. Croix. Among the numberless pieces which have since been found, the Academy owns one of the largest:—a mass of 75 lbs. weight found three or four years ago at Taylors Falls and presented to the Academy by Mr. Geo. H. Miller.

The first mining operations were also undertaken by Le Sueur. Copper had been found at some point now unknown in the valley of the Blue Earth river and had been assayed in Paris in 1696. LeSueur wintering in 1700-1701 near the junction of the Blue Earth and St. Peter rivers, as the spring opened worked out an enormous quantity of ore, and selecting 4,000 lbs. started with it down the St. Peter and the Mississippi in order to ship his treasure to France. Since that time a great many explorers have looked for the immense deposits said to have been found by LeSueur,

*A very interesting summary of the Minnesota Keweenaw rocks appears in a paper by Professor Irving, published as an "accompanying paper" in the Third Annual Report of the Director U. S. Geol. Survey, pp. 89-188 incl. Many of the facts here given are abstracted from that report recently published.

but to this day all efforts have been in vain. High, steep walls of Cambrian rocks have been found exhibiting a color which might be like that mentioned by LeSueur, but no copper lies behind them.

Passing northward we reach the St. Croix river valley, at Taylors Falls. Copper has been known to exist since before 1865, for in that year the legislature appropriated a sum of money, \$2,000. for exploring the mineral lands of the St. Croix valley. Professor James Hall came to the state and found at Taylors Falls a very distinct vein bearing copper.

This vein and several others in the neighborhood of Taylors Falls, one or two of them on the Wisconsin side of the St. Croix have been worked from time to time but never with paying results. The most noticeable working for copper at Taylors Falls was done by Mr. N. C. D. Taylor on the highest part of the melaphyr near the Lutheran church. A shaft from 40 to 50 feet deep was sunk. Some little quantity of leaf copper was found. Nearer the river a mining company, "the Taylors' Falls mining company" did some work in two or three places along what were designated veins. I believe silver as well as copper was found, the latter in even smaller quantities than on the hill.

Further up the St. Croix, near the mouth of the Kettle river, considerable exploring has been done especially by Mr. D. A. Canada, recently of Taylors Falls. This work has been chiefly in ash bed and amygdaloidal diabasic rocks. The product thus far has been a low grade ore which is unprofitable under the present condition of the market and the situation of the ore in an unsettled country and away from easy and rapid transportation.

Touching the locality at and below Chegwatona we read as follows:—"native copper occurs in these rocks on Snake river, both in the conglomerates and in some of the bands of altered amygdaloid, and in such quantity near the surface as to promise success to mining enterprise."* What effort has thus far been made has proved unprofitable although no little interest was recently aroused and no little work was done in exploring and testing the rocks. This was in 1880-1882.

Passing to the Lake Superior area of these Cupriferous rocks, there were found, according to Hon. H. M. Rice, in or about the

*Irving R. D. Monograph v, U. S. Geol. Survey, The Copper Bearing Rocks of Lake Superior, p 243.

year 1744, and north of Lake Superior, several large lumps of virgin copper; yet we note that the first mining of which we have definite record was done at French river 14 miles below Duluth.* Just when copper was discovered at this place cannot be told. The metal was first seen by Indians in the bed of the river at some distance away from the lake. In 1804 the Indians ceded to the government large tracts of land in northeastern Minnesota. In that year an association was formed by gentlemen for the most part residents of Cleveland, Ohio, for the purpose of securing possession of several locations then known. After four or five years title was obtained by R. B. Carlton & Co. In 1863, two companies were formed; one was the French River mining company, to which R. B. Carlton & Co., or their trustees conveyed the SW $\frac{1}{4}$ and lots 3 and 4, sec. 17, town 51, range 12 W; and the other was the North Shore mining company, to which the same parties conveyed the SE $\frac{1}{4}$, sec. 25, town 52, range 12 W. The first mining work so far as can be learned was done in 1864. Shortly after the mine was reopened by a Mr. Salisbury acting as foreman for the company of Cleveland capitalists, who worked for some time and succeeded in sinking a shaft of considerable depth but did not succeed in securing more than a few hundred pounds of copper. After Mr. Salisbury left the work, excavating was resumed by Mr. Tom Saxon, of Duluth, under a contract which he closed up in 1866. At this locality native copper occurs in amygdaloidal rock, partly in the form of nuggets up to 15 pounds weight and partly mingled with prehnite, forming amygdules in the decomposed and soft vesicular rock.

The mine has never been worked continuously since Mr. Saxon left it, although Mr. John Mallmann of Duluth has at different times done considerable work. Probably not more than a ton of copper in all has ever been removed from this mine.

*We learn however, from the Minnesota Historical Collections, that "In 1770, papers were issued in England, in company with a Mr. Baxter, for a company of adventurers to work the copper mines of Lake Superior. They opened veins on both the north and south shore. But the enterprise proved a failure. In one of their mineral expeditions a Russian gentleman picked up a piece of ore of eight pounds weight, took it to England, and it yielded silver at the rate of 60 pounds of silver to 100 pounds of ore. It was deposited in the British Museum and is the first recorded specimen of silver from Lake Superior." J. H. Baker, annual address, vol. III, p. 340.

Up the Knife river a mile or two from the lake, this same Mr. Saxon did some exploring work at the same time he was working the French river mine, i. e. in 1865-66; the excavation reached only a few feet in depth. While the rock was almost identical with that at French river, only two or three miles away, and scarcely a block could be removed without disclosing native copper, the amount was too small to make the work profitable. At both places, French river and Knife river, the early reports were most flattering and the owners always felt assured that the work was giving indications of valuable results.†

At Mr. Wakelin's, farm 10½ miles below Duluth, copper is also found. Here the rock is partly amygdaloid (commonly called ash bed amygdaloid) and partly conglomerate. The copper in small quantities is found everywhere, sometimes disseminated through the rock in fine threads and minute irregular masses, sometimes in leaves and bands and again in nodules and loose fragments. No veins have here been found; native copper can often be seen on the rock surfaces beneath the shallow water off the lake shore.

In Town 60, range 2 west, Mr. Henry Mayhew of Grand Marais did considerable work at mining for copper ore in 1868-69.

This location is on a vein of bornite which Mr. Mayhew found at the edge of the water on the lake shore, three or four years before. The vein is four feet wide; it dips slightly to the north and it carries the sulphide in seams or bands one-eighth inch and upwards in thickness. From where several veinlets unite quite a large piece of clear ore was taken out and shipped to the Vienna Exposition. The vein was followed but a short distance before it divided and work then stopped and has never been renewed. Probably 1,200 to 1,500 pounds of ore were shipped from this mine.

In Town 61, range 1 west, section 24, native copper has been found. This location is in the bed of the Rosebud river, one and one-half miles from the lake shore and three miles west from Grand Marais. In the year 1876 two men named Johnson and Maguire worked here and secured some hundreds of pounds of copper. The rock is a coarse grained, dark green gabbro or gabbroid. Since there is felsite or felsite porphyry both above and

†For details of these two early enterprises at French and Knife rivers, consult a paper by Hon. H. M. Rice of St. Paul, in the Minnesota Historical Collections, vol. 11, pp. 11 and 12.

below this exposure the copper bearing rock may be regarded as a dike. The copper is found in thin sheets and bands in the massive rock.

About the year 1870 the Minnesota silver and copper mining company did some preliminary mining work on a vein running across a small island off the south side of Pigeon Point. The vein carried a belt of copper ore, mingled bornite and chalcopyrite with a little silver which was penetrated by a shaft 50 feet deep. The country rock is a gray quartzite generally regarded as of Animike—Huronian—age. The general position of this formation along the south side of Pigeon Point is east and west with a southerly dip of 10 degrees to 15 degrees. Many barrels of ore were raised at the time of opening the mine but so far as the writer knows no systematic work has been prosecuted. Maj. T. M. Newson of St. Paul, has, I believe been the leading spirit in this enterprise.

The foregoing notes are the result of a recent attempt by the writer to discover the past results and a possible future of copper mining in Minnesota. Many efforts have been made, and particularly in the Lake Superior Keweenaw region from which the results are too meagre and futile to be mentioned here. Stratigraphically the first work was done in the Cambrian rocks (Le Saeurs' labors) but more recently investigations while largely carried on in the Keweenaw, the true Cupriferous series, have to some extent, been pursued down into the Huronian.

Finally the results have been meagre and the impression of the writer is that copper mining will never become a profitable industry either in the southwestern extension of the Keweenaw series around Chegwatona or in the larger area to the north of Lake Superior in Minnesota.

October 6, 1885.

[*Paper R.*]

THE LITHOLOGICAL CHARACTERS OF THE TRENTON LIMESTONE OF MINNEAPOLIS AND SAINT PAUL, WITH A NOTE ON THE BORINGS OF THE WEST HOTEL ARTESIAN WELL.—*C. W. Hall*

THE QUARRY STUDIED. —As a representative exposure of the Trenton limestone of this vicinity, the quarry at the foot of 6th avenue southeast was taken. From this quarry, rock has been