DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, Sheffield Scientific School of Yale University, New Haven, Conn. The full name of the author should be attached to all communications.

THE LOCALIZATION OF VALUES IN ORE BODIES AND THE OCCURRENCE OF CHUTES IN METALLIFEROUS DEPOSITS.

THE DECOMPOSITION OF A BOULDER IN THE CALUMET AND HECLA CONGLOMERATE, AND ITS BEARING ON THE DISTRIBUTION OF COPPER IN THE LAKE SUPERIOR COPPER LODES AS INDICATING THE TREND AND CHARACTERS OF THE WATERS FORMING THE CHUTE.[1]

INTRODUCTION.

The wide distribution of the copper in the copper-bearing amygdaloids and conglomerates of the Lake Superior copper region has been often remarked. The uniformity or lack of uniformity of distribution has not, however, been as equally discussed.

The very slight but gradual diminution in copper content with depth, however, and the arrangement of the copper in definitely localized areas within the conglomerates and amygdaloid layers have now become sufficiently well known to warrant some explanation of the manner in which the irregularity of distribution was produced. The illustration on p. — will serve to show the position of the chute in the Calumet and Hecla conglomerate.

At the request of the editor I present some comments on a specimen boulder[2] from the Calumet and Hecla conglomerate, prepared to accompany its exhibition at a meeting of the Michi-

[1] This paper was to have appeared in Vol. III., No. 6, of ECONOMIC GEOLOGY and has been so referred to by the author in other writings. Owing to editorial complications, it has been delayed.

[2] Michigan Geological Survey Collection, No. 20600.

gan Academy of Science in the spring of 1908. From a study of this boulder and the alteration of which it is an example the inference may be drawn that the chute is along a zone of mingling and downward migrating waters containing the chlorine, hydrating the original rocks, and abstracting soda.

The first and most striking feature about the copper deposits of this region is the invariable association of the copper with minerals which are the product of profound alteration of the country rock, both conglomerate and amygdaloid. Any attempt to explain the deposition and distribution of the copper must also include an explanation of the origin of the associated minerals and alteration products which are clearly a result of the same series of reactions which deposited the copper. This alteration is known to extend downward along the dip of the lodes for 8,000 feet and how much further cannot now be determined. In this paper the nature of the alteration as seen in the specimens exhibited by the writer will first be described, then the bearing of this alteration on the distribution of the copper.

CHARACTER OF THE BOULDERS.

Mineral Character.—In those boulders which best illustrate the chemical changes that have taken place, the copper occurs mainly as a cement between the pebbles. Occasionally fissures filled with copper may be found in a pebble and rarely a whole pebble is now practically solid copper. In addition to the copper, epidote and calcite are frequent secondary constituents of the cement between the pebbles.

As many pebbles are found fairly fresh, secondary silicification is probably frequent.

Pumpelly, in his well known studies on the changes in the Lake Superior copper-bearing rocks, describes the changes which the original boulders of Calumet and Hecla conglomerate must have undergone to produce these results. He says :[1] "The displacement of feldspar and quartz-porphyry by chlorite, as exhibited in pebbles of the conglomerate, points to an extremely important line of investigation for the chemical geologist."

[1] Geological Survey of Michigan, Volume I., Part 2, pp. 37, 40.

His observations, minute for the time, were not, however, supplemented by chemical analyses. In pointing out the changes that have occurred two analyses of these boulders are presented by the writer. These analyses are placed side by side with analyses of the country rocks of the lodes when they are comparatively little affected by alteration. Just what the original composition of one of these altered pebbles was is a question which one must be cautious in answering. Some suggestions, however, may be given; both as to the character of the rocks from which they may be supposed to have been derived, the changes involved and the kind of water which may have produced the changes. It is hoped that others may add valuable suggestions.

Chemical Character.—In many cases the general trend of change is unmistakable. Take for instance the following partial analysis of a boulder by G. H. Heath, chemist of the C. & H. Mining Co. This was a "bluish gray, greasy deposit like talc found inside a boulder," the outer shell of which was turned to copper. The partial analysis was:

Silica, SiO_2 .... $36.75 = .612$ molecule.
and Alumina ⎫ or as FeO .... 24.57 $= .294$
Iron oxide   ⎰ (Fe_2O_3, Al_2O_3) 27.34
Magnesia, MgO .... $23.24 = .581$
Loss on ignition H_2O; CO_2.......... $11.07 = .616$
Difference Na_2O; K_2O?............. $1.6 = .026?$

                        100.00

This evidently corresponds closely to a formula $2H_2O$, $2MgO$, FeO, $2SiO_2$ closely allied to that of serpentine. Serpentines are often derived from peridotites. There are to be sure peridotites known in the Lake Superior region, but it is most probable that the original rock was not more basic than an ophite, perhaps much more silicious.

Fortunately I was able through the kindness of J. L. Nankervis, the commissioner of mineral statistics, to obtain recently another boulder of the kind—the one exhibited—in which enough of the texture, and in particular large porphyritic crystals of plagioclase, is left to make one·reasonably sure that we are dealing with a porphyrite not so femic (rich in iron, magnesia,

etc.) as the ophites, but more like some of those analyzed for L. L. Hubbard by F. P. Burrall.[1]

Comparative Analyses of Keweenawan Rocks.—We will place beside the analysis of the altered ground mass dug out by me and analyzed by F. B. Wilson, analyses of these Keweenawan rocks and gabbro for comparison. The gabbro analysis presents quite nearly the rocks above and below the conglomerate and possibly also the original of the boulder. Some of the boulders have more silica than the ophites and are porphyries, but most of them are not so much decomposed. Thus it is quite likely that these exceptional boulders which become so much decomposed and so largely changed to copper were somewhat exceptional in composition to begin with, but it is not at all likely that they had less silica than the ophite mentioned. Such a

	Altered boulder. 20600		Ophite.	Diabase porphyrite. 17033		Porphyrite. 17039 17007		
	1	1a	2	3	3a	4	4a	5
Silica, SiO$_2$	31.42	.523	46.01	52.83	.860	59.52	.992	57.45
Alumina, Al$_2$O$_3$	16.82	.165	16.95	16.30	.160	15.58	.153	15.75
Ferric oxide, Fe$_2$O$_3$	15.58	.097	5.14	9.60	.059	7.24	.045	11.12
Ferrous oxide, FeO	12.08	.168	9.83	2.48	.035	1.86	.026	1.74
Magnesia, MgO	3.36	.084	6.20	3.98	.100	2.11	.053	1.94
Lime, CaO	2.84	.051	6.71	2.98	.053	1.81	.032	0.12
Soda, Na$_2$O	1.98	.032	2.22	6.54	.105	6.82	.110	7.84
Potash, K$_2$O	1.04	.011	1.71	2.49	.026	3.48	.037	3.51
Water, H$_2$O	14.52	.806		2.76	.153	2.23	.134	1.23
Manganese	tr.			tr.				
TiO$_2$			2.48					
Difference	0.34		2.75	0.04				
Sum	100.00	1.937	100.00	100.00	100.00	100.65		100.70
Sp G	2.78							

AUTHORITIES.

1. Altered boulder from Calumet Conglomerate—analyst F. B. Wilson—new. There is also 0.02 of Cu.

1a. Molecular proportions in 1.

2. Gabbro 20509? Annual report for 1904, p. 154, No. 9, L. Kirschbaum.

3. Diabase porphyrite, Vol. VI., Geol. Sur. Mich., Part 2, p. 26, F. P. Burall.

3a. Molecular proportions in 3.

4. Porphyrite. Same reference and analyst.

4a. Molecular proportions in 4.

5. Porphyrite. Same bed, reference and analyst as 4.

[1] Volume VI., Geol. Sur. Mich., Part 2, pp. 25–26. Spp. 17033, 17039, 17007.

gabbro is, so far as known, the basic limit among Keweenawan rocks.[1] As far as I can judge, however, the particular boulder exhibited from which the material analyzed by F. B. Wilson came, *is more likely to have been a much more salic porphyry* or a diabase porphyrite like 17033, analysis 3.

DESCRIPTION OF BOULDER 20600.

This pebble or boulder (20600) as may be noted, is surrounded by a shell of copper considerably stained with carbonate, probably of recent origin. The interior next the outside is decomposed grayish green or blanched. The main mass is mixed greenish and dark maroon, and shiny and soft. This soft (H = 1) matter is the material analyzed. In it are imbedded white Karlsbad-albite twins of andesite or oligoclase, one of which dug out shows P. (oo1), y. (2̄o1), M. (o1o) and the prism? (11o).

While obscured with enclosures so that the refraction is not easy to determine, for one crystal it appears to be near and a little above 1.545. In another case it is distinctly near 1.536. The extinction angle on P against M is 3°–3°, in another case 7°–7° and generally small (in one case in that zone 10–15)? (18°–18°).

The boulder tested by Heath had a very similar ground mass. Both the albite and Karlsbad twinning are plainly visible with the pocket lens. No quartz or orthoclase phenocrysts were noticed.

OTHER ALTERED BOULDERS.

This kind of alteration attacking the ground mass is not really uncommon. Capt. Jos. Pollard, of the Calumet and Hecla mine, has quite a collection of Karlsbad twins[2] picked out of the soft rock that show the crystal form nicely. They are sometimes partly replaced by copper, and are sometimes an inch or more in size. Very suggestive also is a boulder in his collection which is a mere hollow shell, lined with red feldspar (orthoclase?) and specular iron ore (hematite). Another pebble seems to have originally been calcite, and has a calcite core, is now largely replaced by specular ore (hematite) with a little copper.

Copper, as is also shown by Pumpelly's paragenetic tables,[3] is always a late comer. While the particular pebbles analyzed *may* have been fairly femic, they may not, and Pumpelly (pp.

[1] Winchell, A., *Journal of Geology,* XVI. (1908), pp. 765–774.

[2] Other laws are also represented and they are quite complex.

[3] Geol. Surv. Mich., Volume I., part 2, p. 32. See also *Proc. Lake Superior Mining Institute,* XIII. (1908), p. 139.

37–39) has well described the alteration of a quartz porphyry, the matrix becoming softer, chlorite appearing on the seams of the quartz and feldspar phenocrysts, then the matrix changing to a soft green chloritic mineral which whitens and fuses to a gray glass before the blowpipe, finally every trace of the matrix becoming changed to chlorite, and some of the quartz! The alteration of the feldspar lags behind. Copper comes in with the chlorite and may finally replace it, and yet some at least of the quartz and feldspar phenocrysts may remain imbedded in a copper ground mass!

On the other hand it is common to find pebbles of porphyry in which there has been a secondary enrichment of iron oxide, and while the very margin of the feldspar of porphyry may appear blanched (due to epidote?) the matrix often contains an unusual amount of bright red feldspar (orthoclase).

WATER ADDED, SODIUM SILICATE REMOVED.

In both boulders water is clearly added. Either iron is largely increased or the other constituents have lost more than half, which latter does not seem likely. The alkalies, particularly the soda, have been removed. Alumina, magnesia, and lime appear to keep the same proportions in the boulder before us, but in that tested by Heath magnesia has certainly been added. If, as generally supposed, the alumina remains constant, the silica has been removed. It may be noted, too, comparing $3a$ and $1a$, that the amount of silica removed $(.860 — .523 = .337)$ is to the amount of alkalies removed $(.131 — .043 = .088)$ nearly as in water glass $(Na_2O \cdot 4SiO_2)$.

We may say then, roughly, that iron and water have been added, water glass abstracted. Another noteworthy thing is that whereas in the original rocks (analyses 3 to 5) the molecular ratio of alkalies to silica is more than $1 : 12$, in the altered boulder it is in the proportion of .043 to .523. Now this $(1 : 12)$ ratio is, as I have elsewhere[1] pointed out, a normal one, especially for the salic rocks. Possibly alkalies in excess of this are more easily removed.

[1] "The Rôle of Possible Eutectics in Rock Magmas," *Jour. Geol.,* 1904, 12, pp. 83–93.

Such an alteration is much more likely in a water where temperature is rising, that is, water moving downward.

A further thing to remark is that it is doubtful if there is any marked change from ferrous to ferric iron. Water glass removed ($Na_2Si_4O_9$) and serpentine introduced ($H_4Mg_3Si_2O_9$) have the same amount of oxygen. There is, however, an uncertainty in comparing a specimen from a deep mine with specimens exposed in outcrops and necessarily oxidized. It seems then quite safe to assert that the deposition of copper in the Calumet and Hecla conglomerate was one feature of a change which included also the removal of water glass and enrichment with water, magnesia and iron. As Pumpelly has pointed out, while the copper may replace original feldspar and also the lime zeolites, prehnite and laumontite, and is nearly contemporary with and overlaps in period of formation the chlorite and calcite, especially the beautiful clear crystals of calcite,[1] it is earlier than the alkaline zeolites, analcite, apophyllite, datolite (in which it is frequently enclosed giving beautiful flesh tints) and the red orthoclase of late secondary origin.

When we come to discuss what produced this change we have the following facts to guide us.

The loss of silica is such as to reduce the proportion thereof even below that of the ophites (auvergnoses) with which the conglomerate is associated. So it is not a mere reaction with them tending by means of circulating waters to get an average composition.

The general character of the alteration is not unlike that of some of the iron-bearing rocks in which we find chlorite largely developed and iron and silica migrating. The depth to which the alteration has been traced is over 8,000 feet along the lode on the incline.

The wide distribution of copper in the Keweenawan formation must not be overlooked. The average copper content in the sludge of a drill hole 775 feet deep in a region not known to contain any rich copper lode, where the highest assay ran .06 per cent. copper, was $\frac{1}{70}$ per cent.—one grain to ten pounds.

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[1] Palache, Geol. Surv. of Mich., Vol. VI., part 2, appendix.

MINE WATERS.

We have also to consider the mine water of the greater depths, the quarry moisture. This is very limited in quantity and soon drains off. Heath's analyses from the Calumet and Hecla mine may perhaps include also some water working down the shaft. The Tamarack water from the Osceola amygdaloid seam in a cross cut certainly does not contain surface water.

Now a glance will show that the Calumet and Hecla conglomerate waters have a very much larger part of the total solids sodium than do the waters from amygdaloids. We are at liberty then, so far as these analyses go, to suppose that the sodium has been extracted and largely retained by the mine water.

MINE WATER ANALYSES.[1]

	1	2	3	4
Ca.........................	15.9	1.25	47.166	6.300
Na.........................	7.8	1.74	8.278	2.731
Mg.........................	.04	.022	tr.	.013
Cl	39.6	3.263	97.963	15.229
SO_4.........................	.14	.039	.226	.072
CO_3.........................	?	.149		.0
SiO_2.........................	.06	.003		
Al_2O_3.........................	.11			
Br	.10			
Cu.........................		.003		
Fe		.003	tr.	
Zn		.014		
Sr.........................				
Li.........................		.0		
K.........................		.039	.837	
Organic.................			$N.H_{44}$ .830	
Sum. or Total.........	63.75	6.52	157.411	24.34

Analysis 1. Calumet & Hecla, 3,000 feet down, from Professor H. L. Smyth, R. O. Forsyth, analyst.

Analysis 2. Calumet & Hecla, bottom of Whiting shaft, C. & H. Mining Co., G. L. Heath, analyst.

Analysis 3. Tamarack Mining Co., 4,300 feet down, 29th level, cross cut from Osceola amygdaloid, A. C. L. Coll., analyst F. B. Wilson.

Analysis 4. Wolverine Mine cross cut at 17th level, A. C. L. Coll., analyst F. B. Wilson.

We notice the very large amount of calcium chloride, the very

[1] Per thousand. See also paper in *Proc. Lake Superior Mining Institute,* Vol. XIII., written after this.
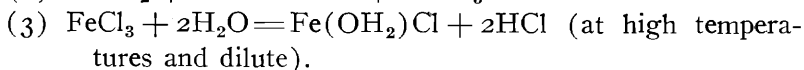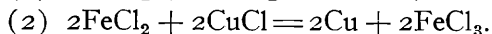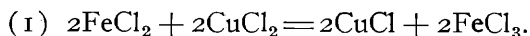
small amount of magnesium chloride in the mine water, and we are reminded of a fact emphasized by T. Sterry Hunt[1] in describing certain mineral waters, to wit: that from a solution of magnesium chlorides, calcium silicate will precipitate magnesium silicate completely, thus:

$$3MgCl_2 + 3CaSiO_3 + 2H_2O =$$
$$2H_2O, \; 3MgO, \; 2SiO_2 + 3CaCl_2 + SiO_2.$$
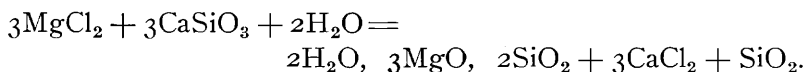
This will account for the scarcity of magnesium in the mine waters, and for part of the magnesium silicate found in the pebbles, that of a serpentine nature.

But in order to account for the aluminous magnesian silicate we shall have to call in another chemical reaction, quite chemically reasonable, by which the magnesian chloride reacts on the sodium aluminum silicates. Using water glass Na_2O4SiO_2 is one of the convenient ways of softening water containing calcium magnesium chlorides. If sodium silicate is thus used there will be left aluminum silicate to be provided for, which, if there is magnesium in the base, will go with it and water to make up chlorite.

There is but little iron in the mine waters and so the rôle of the iron in all this may be conceived as replacing the magnesia. But there is the additional possibility of its change to ferric condition. In order to do this, however, it must borrow an acid molecule somewhere. If together with the calcium, magnesium and ferrous chloride, there were also a trace of copper and silver chloride they would be readily reduced. · Along this line successful experiments have been made for me by Dr. G. Fernekes. The reactions are:[2]

(1) $2FeCl_2 + 2CuCl_2 = 2CuCl + 2FeCl_3$.
(2) $2FeCl_2 + 2CuCl = 2Cu + 2FeCl_3$.
(3) $FeCl_3 + 2H_2O = Fe(OH_2)Cl + 2HCl$ (at high temperatures and dilute).

But the HCl of the reactions will immediately redissolve the cop-

[1] "Chemical and Geological Essays," 1878, p. 122.
[2] ECONOMIC GEOLOGY, Vol. II., 1907, p. 580.

per if not disposed of, but if (so as to keep the liquor neutral) it is given opportunity to attach calcium or sodium carbonates or silicates copper is precipitated. Wallastonite CaO, SiO_2 and prehnite H_2O, CaO_3, $Al_2O_33SiO_2$ were also successfully used. A sealed glass tube at a temperature of 200° to 280° C. was used.

A few other points may be noted. The rarity of sulphates in the brine is matched by its rarity in the mine, though gypsum and barite (celestite?) do rarely occur in nice crystals. The small amount of carbonate in the brine is not surprising when calcium chloride is so prominent, as it would be precipitated if in any quantity. Its abundance and its occurrence in large and beautiful crystals shows however that it did form at the same time as ·the copper but very slowly. As R. T. Chamberlin has shown, the traps contain CO_2 which, as they decompose in the presence of $CaCl_2$, must throw down lime. We are inclined then to think that this alteration of the Calumet pebbles is due to the action of the saline waters with which it is charged. This alteration spares the phenocrysts of feldspar and quartz until the last. In this respect it may be likened to the actions of present-day sea water. As Goodchild says in regard to alterations in Scotland :[1]

" On exposure of such a rock to the ordinary subaërial denudation the chemical changes set up by the action of the humus acids and carbonic acid dissolved in surface waters usually result in the earlier decomposition of the feldspar and the destruction of the ferromagnesian silicates at a later stage. In a basalt or an andesite, therefore, which has been exposed to these influences, the feldspars are usually the first to decompose. . . . But where an andesite or a basalt is exposed to the action of the sea water the ferro-magnesian constituents are usually the earlier to decompose and, as a consequence, it often happens that the anorthic feldspars are left standing out in relief."

[1] " On Some Pseudomorphs After a Lime Soda Feldspar," by J. G. Goodchild, *Trans. Edinborough Geological Society,* 1903, Volume VIII., Part 2, p. 263.

DIRECTION OF IONIC CIRCULATION.

In the process of decomposition of these boulders as thus described the question will at once arise in the mind of anyone familiar with the recent discussions on ore deposition what was the direction of circulation of the ore-depositing waters?

It may be said to begin with, that there is no absolute necessity of supposing a circulation of the water in a body,—it will be enough to suppose minute masses (ions) of the different substances circulating in the water just as in Fernekes' and in Stokes' experiments there was a gathering of certain substances at one end of the tube. We may, to fix our ideas, remember that the main chute of the Calumet and Hecla tends to the north and downward. See Fig. 28, page 172. Suppose, then, that the chlorine and H — O are drawn, as in electrolytic action, to the + pole, *i. e.,* northward and downward. They can then do their work as above outlined without any circulation of the water mass as a whole.

In the same way we may consider the center of the pebble as the positive pole, which is being hydrated, and this electrolytic way of looking at the matter has a strong justification in the fact that calcium chloride and bitterns have been used as battery fluids.

Then the general tendency of arrangement will be for the stronger acids to work towards the + direction, while the stronger alkalies will work in the — direction toward the negative·pole. The strong alkali and the weakest acid, sodium and silicate go out, potassium and calcium are less strong alkalies, magnesium and iron are much less so and would replace them, and the hydrous magnesian silicates being very insoluble, the magnesium would be drawn in indefinitely, yet the amount of it in solution at any one time kept down to a very low figure. The iron, copper, and last of all silver, being even weaker in their affinities or alkalinity than magnesium, would come trailing after it, the latter two not being able to retain near the positive pole any acid to keep them company, that is, to be precipitated with them.

EXPERIMENTS ON CHLORINE DIGESTION.

Foster and Whitney[1] also digested an ophite, " the greenstone," with HCl (1.13 sp. gr.) at a temperature near boiling and removed 21.17 per cent., leaving 78.83 silica and insoluble.

The results were:

	1. Total.	2. Soluble 21.17 Per Cent.	3. Insoluble.
Silica (by diff.).............	50.20		diff. 64.58
Alumina......................	15.43	30.95	11.67
Iron (as FeO)...............	13.69	32.47	9.18
Magnesia.....................	8.62	15.98	6.86
Lime.........................	5.47	9.36	4.57
Soda.........................	4.75	11.26	3.14
Water........................	1.74		
Mn...........................		tr.	tr.
Sum		100.04	100.00

The analysis cannot be regarded as accurate. It is too old.[2] The method of determining silica is obviously only rough and it is probably from two to four per cent. too high, and includes the titanium. Nevertheless it seems to show how much more the sodium is attacked than the lime, and to remind us that the alumina is really quite soluble, and if it has not been removed it is simply because it is precipitated in the chlorite.

A solution like the mine waters already rich in lime could, of course, dissolve little lime. Still, the removal of sodium without any apparent loss of lime seems strange, so it may be worth while to note that I obtained from C. K. Leith a little of a diorite whose analysis is given by Washington.[3]

It was treated as follows: Mr. Clark, of the M. A. C., digested one gram of it crushed so as to go through a 100-mesh sieve for 30 hours with one liter of HCl containing a 2.07 per cent. HCl solution. There went into solution the figures given in column 2. After digestion of two grams in two liters for a week there went into solution .16 grams (.8 grams per liter); at red heat .094 grams (.47 per liter) from 400 c.c.

[1] " Geology of Lake Superior Land District," Vol. II., p. 88.

[2] An analysis of exactly the same flow will be found in the *Journal of Geology*, Vol. XVI., p. 772.

[3] H. S. Washington, U. S. G. S., Prof. Paper 14, p. 266.

We need therefore not be surprised if a calcium chloride solution removes the sodium much more than the lime. That magnesium is precipitated and accumulated in the pebble depends upon the reaction cited by Hunt above, and the greater ease with which it forms relatively insoluble hydrous silicates. The replacement of the hydrous magnesium silicate by copper is the only thing that has not been left clear both experimentally and theoretically. To be sure a slight solubility of chlorite in chlorine,

	Diorite. 1	30-hour Extract. 2	One Week Extract. 3
SiO_2	58.51		
Al_2O_3	16.32		
Fe_2O_3	2.11	8.25	
FeO	4.43		
MgO	3.73	1.4	
CaO	3.92	oo N. B.	
Na_2O	3.11	4.3	
K_2O	4.08	1.2	
H_2O	2.00		
TiO_2	0.23		
CO_2, Cr_2O_3	0.70		
NiO	o		
P_2O_5	0.30		
MnO	tr.		
Total		13.75 per cent.	
Total at red heat			(oxides?) 23
Total solids	99.46		(chlorides?) 40

and that the chlorites are attacked by sea water are known facts, but the tendency of copper to replace the chlorite rather than something else, and the conditions under which it does so need investigation. The copper probably drives the magnesia and ferrous iron ahead of it in the + directon, that is, toward the center of the pebble or the direction in which the alteration is spreading. The copper chloride would thus set magnesium chloride free to be precipitated farther in as magnesium silicate. But what becomes of the silica, alumina and ferric iron? We may suppose that they were carried off to make epidote with the lime of calcium chloride. As a matter of fact, epidote is abundant in the cement of the conglomerate, but do we find it in any definite relation to the pebbles?

DOWNWARD CIRCULATION OF WATER AS A WHOLE.

While, as I have said, it is not *necessary* to suppose any general circulation of water, so far as the alteration of the pebbles is concerned, and it is useful to consider the alteration in the way we have, yet I do not doubt there was some circulation. The distribution of the mine waters, fresh for a few hundred feet and then rather suddenly saline, with sodium chloride relatively more abundant, gradually becoming less in proportion, can very naturally be explained by a downward general circulation of the water as the rocks became hydrated and the reactions above mentioned went on. No doubt, too, in certain cases waters may have worked down along the slope and up in cross fissures. If we imagine the formation gradually absorbing water like a sponge, as the water contained cools and shrinks and the rock is hydrated, the deeper waters would have moved less far and acquired less sodium, and the shallower waters farther and acquired more. From the level of the salt water down there would be a slow diminution in richness. The silver, whose chloride is less soluble than copper chloride, would be precipitated upon the copper and would follow it down, being found more in the upper levels. Under any cross seam, fault or clay seam which might interpose itself to cut off the downward circulation, the rock would be liable to contain relatively more calcium chloride but bear less copper. There should then be a tendency to reproduce the chutes and troughs of the iron country.

Now these theoretical conclusions exactly agree with the facts as to the Calumet and Hecla chute. The Calumet and Hecla and Tamarack mines work a copper chute which trends downward and northward in a conglomerate. The strike of the conglomerate is N. 39°E.; the dip flattens from 38° to 37°. The lower or west side of this chute runs almost due north and is very straight. The silver was, as should have been expected, richest in the upper levels of the south or Hecla end of the mine, and has fallen to 4¾ oz. per ton in the Tamarack or deepest parts of the lode. The lode was rich indeed at the surface, but spots in the upper levels were barren. As depth was gained the

lode was full as rich in copper and more continuous.   Between
1,600 and 2,400 feet below the surface were perhaps as good
levels as any.   Below this depth there has been a slow decrease
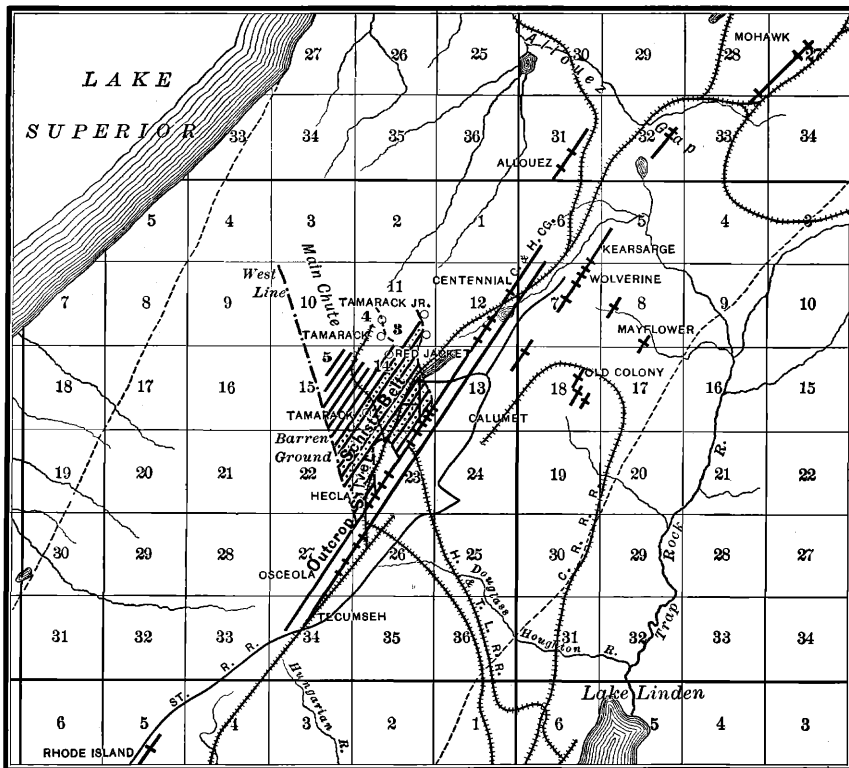in the yield, since the Calumet and Hecla was said to run three

Fig. 28.   Outcrop of the Calumet and Hecla Conglomerate showing position
of the ore-chute as followed on the dip to the N. W., and relation to barren
ground etc.

per cent. to five per cent. copper but is now yielding about two
per cent., and the Tamarack is not yielding much over one per
cent.   There is, however, no change in the character of the cop-
per, or replacement by chalcocite.

The water, fresh at the surface, was in some places salty near
the ninth level.   It was certainly quite briny at 3,000 feet.   There

is throughout more sodium in proportion to the chlorine than customary in waters of the same percentage of salts.

The position of the Calumet and Hecla outcrop, on a flat summit of land with a distinct drop (the "Allouez Gap") to the north, and a slope off to the southwest also, is such as to favor downward circulation. The trend of the chute is toward the Allouez Gap and there may have been an inverted siphon circulation in that direction, but one does not have to suppose so. With depth the conglomerate seems to grow coarser and darker, and on the whole thicker, which would of course make a greater volume of water by its contraction to draw in the fresher water from the surface. The copper often occurs also in the foot and hanging beds, and rather tends to accumulate on the sides of the lode as though thrown down by a reaction of the downward working waters with the connate waters lagging in the less pervious rocks on either side.

A short distance south, also, the Calumet conglomerate has changed its character. The pebbles are largely amygdaloidal and there is no copper to speak of. The north end of the Calumet and Hecla and the next property north, the Centennial, though it found spots of very rich rock, found no valuable deposits even down to 3,200 feet on the lode. The formation is thrown every now and then by faults or incipient faults (sharp lateral bends). One of these passes near Tamarack No. 1 shaft and displaces the lodge to the northwest some ten feet. These trend northward and have something to do with guiding the chutes. It would seem, therefore, that the copper had accumulated most abundantly on the lower or west side or trough of this northward trending chute. The above sketch, Fig. 28, adapted from R. M. Edwards' map and the Michigan College of Mines catalogue will help explain the situation.   ALFRED C. LANE.

ORE SHOOTS IN NEVADA.

Sir: Your favor of the sixteenth of October received on my return to the city. In regard to the localization of ore bodies or of richer shoots within lower grade shoots, my experience has been that a fissure or system of fissures is extremely often the