

ART. XLVIII.—*Minerals from the Clifton-Morenci District, Arizona,** by W. LINDGREN and W. F. HILLEBRAND.

IN 1902 an examination was made of the Clifton-Morenci copper district in Arizona. Study of the collections proved the presence of several interesting minerals, a brief account of which is here given. The copper deposits at Clifton and Morenci consist in part of irregular or tabular bodies of oxidized ores in Paleozoic limestones, partly of chalcocite ores connected with fissure veins in a granite porphyry or in the same limestones.

Coronadite.—On the dump of a small shaft on the west end of the Coronado vein, three-fourths of a mile west of Horseshoe shaft, fairly large amounts of a dark metallic mineral were found intimately intergrown with quartz and decomposing into limonite. The vein at this end shows no copper minerals but is stated to contain some gold and its surface ores are reported to have been worked in an arrastre in the early days of the camp. In color this mineral is black and its structure delicately fibrous. The hardness is about 4 and the streak black with brownish tinge.

A thin section proves it to be opaque and in reflected light its fibrous and homogeneous structure is well brought out. It cements angular quartz grains and its secondary nature is clearly indicated. In general aspect it is not unlike psilomelane. A preliminary examination showed that it contained the oxides of lead and manganese; as it did not seem to correspond to any known mineral species, a separation and analysis was made. The results were as follows:

Long continued efforts to secure pure material for analysis by the use of heavy solutions were not attended with success. The ultimate product of specific gravity, 5.246 at 22°, yielded on decomposition by hydrochloric acid a residue of from 6 to 7 per cent, which consisted mainly of silica, with a small amount of alumina, etc. Its presence would not have mattered much had it been quite indifferent to acids, but its partial solubility, as shown by the varying amounts undissolved on different trials and similar varying amounts of alumina and perhaps other minor ingredients found in solution, renders the calculation of molecular ratios not altogether certain in all cases. The composition as found is:

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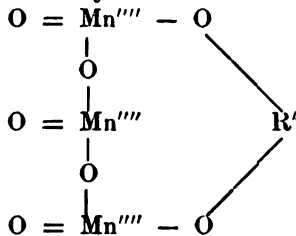
MnO ₂	56.13*
MnO	6.56
PbO	26.48
ZnO	0.10
CuO	0.05
MoO ₃	0.34
Al ₂ O ₃	0.63†
Fe ₂ O ₃ ‡	1.01
H ₂ O	1.03§
Insol. and silica	7.22
CaO, MgO, Alk., and loss	0.45

100.00

The material available did not admit of determining quantitatively the vanadium, which may be present in rather more than a mere trace, but neither it nor the phosphorus can influence materially the ratios given below. The vanadium would be effective in two ways: (1) by requiring a base for its neutralization, if existing as an acid constituent, and (2) by liberating chlorine when acted on by hydrochloric acid, and thus affecting the values found for peroxide oxygen. If the iron exists in the ferrous state, it too would affect the values found for the peroxide oxygen and consequently for both the oxides of manganese. Assuming it to so exist and applying the proper corrections, also deducting from the lead oxide an equivalent for the molybdenum, assuming its existence as molybdate of lead, the following are the results:

MnO ₂	56.68 ÷ 87	= .6515	= 3.00
MnO	6.11 ÷ 71	= .0861	} 0.217 = 1.00
PbO	26.96 ÷ 222.9	= .1165	
FeO	0.91 ÷ 72	= .0126	
ZnO	0.10 ÷ 81	= .0012	
CuO	0.05 ÷ 79	= .0006	
H ₂ O	1.03 ÷ 18	= .0572	= 0.264

If the mineral is to be regarded as anhydrous, the comparatively simple formula Rⁿ (Mn₂O₇)ⁿ satisfies the above ratio, and it may be written structurally:



* Mean of 56.10 and 56.13. Total Mn as MnO from MnSO₄, 52.38 per cent. Peroxide oxygen 10.31 per cent.

† With a little TiO₂, P₂O₅, and V₂O₅. ‡ State of oxidation not known.

§ Nothing at 100°, only 0.14 per cent below 200°.

in which $R'' = Pb''$ or Mn'' . This is to be regarded as a saturated salt of one of the numerous possible derivatives of ortho-manganous acid that may be derived from it by removal of water, in the present case as follows:



An acid of the same empirical formula would result by removal of two molecules of water from three of metamanganous acid, $H_4Mn_3O_7$.

It is probably best to rest for the present content with the above relatively simple formula and to regard the water found as due to incipient alteration. But if the water is to be considered as wholly or in part essential, and furthermore constitutional—and this may very well be the proper view to take—then the formula becomes much more complex, namely $R''_4H_4(Mn_3O_7)$, when none of the water is allotted to the foreign matter. This formula is still referable graphically to a more highly condensed manganous acid, and a number of isomers would be possible.

Such intricate formulas as this should not cause the least surprise, however unlikely they may at first appear to be. The great number of manganites, in varying degrees of saturation and hydration, observed in nature and prepared artificially, some of them of even greater complexity than the above, are certainly not all mixtures of only a few simply constituted molecules. A very short study of the graphic formula corresponding to the above empirical formula $R''_4H_4(Mn_3O_7)$ will show what a vast number of closely related bodies are theoretically possible by hydrating the molecule step by step, or by adding to or reducing the number of divalent atoms, or substituting for them those of another valence. Similar varieties in great number would be derivable from other condensed manganous acids of both higher and lower orders, and it is plain that because of the very slight differences in percentage composition between many of them, it is almost as hopeless to expect analysis to reveal the exact empirical formula in the majority of cases as it is for the enormously complex albuminous bodies of organic chemistry. This is especially true because in so many cases the mineral manganites described are far from being homogeneous species. They are either mixtures of two or more of these closely related complex molecules, or else are contaminated by foreign bodies. It is not surprising then that so many compounds of uncertain formula that may be regarded as salts of manganous acid have been prepared in the laboratory or are found in nature. From the known tendency of these bodies to form under laboratory conditions which may very well be repeated in their general character in nature, it is to be expected

that a vast number of mineral manganites should exist, and it ought rather to excite surprise than otherwise if two or more are not formed simultaneously from the same solution. This, together with inherent difficulties of analysis, would offer a simple explanation of the fact that so few of the analyses made lead to rational formulas. If formed from solution their original state might well be one of hydration either as regards water of crystallization or of constitution. The temperature at which the water is expelled in the present case indicates constitutional water.

Our search of the literature has not revealed a native manganite carrying a high percentage of lead, although artificial compounds have been prepared. For this reason, and because of its distinctly crystalline character, the present mineral seems worthy of receiving a specific name. The one we propose is *Coronadite*, after the famous explorer of that portion of the American continent from which the Territories of New Mexico and Arizona have been formed.

Chalcocite (Cu_2S).—The cuprous sulphide is very common in the Clifton district, in fact constituting at present the principal valuable mineral in the ores. It occurs chiefly intergrown with pyrite, in the altered porphyry as disseminated grains or as solid seams or veins which rarely exceed two or three feet in thickness. It is never crystallized but has ordinarily an earthy or sooty appearance and black color; scratching it with a knife reveals the semi-sectile character and metallic luster. In a few small massive veinlets the normal metallic luster and dark gray color appear on fractures; a fibrous or columnar structure of the mineral is known on small seams in shale from the Montezuma mine. The mineral prefers porphyry, and the great bodies of ore now worked all occur in this rock; but it is not entirely unknown from the irregular deposits in limestone generally carrying cuprite and copper carbonates. A partial analysis of massive chalcocite from the Montezuma mine, Morenci, gave 96 per cent Cu_2S and 2.4 per cent FeS_2 , the latter probably mechanically admixed.

The chalcocite is everywhere, in this district, a secondary mineral formed by the replacement of pyrite by means of descending solutions of cupric sulphate. The deposition of the mineral was accompanied by the formation of quartz, chalcedony, and kaolin. In the porphyry the chalcocite ore along the veins begins 100 to 200 feet below the surface and continues to a depth of 400 feet, or even more, when it is usually replaced by pyrite, chalcopyrite, and zincblende.

Silicates.

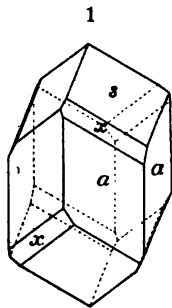
Willemite (Zn_2SiO_4).—This rare silicate of zinc was found by Mr. Boutwell as very small greyish crystals on a fragment

of garnet rock in the Modoc open cut, on the north side of Modoc Mountain. These crystals were identified by Messrs. Pirsson and Penfield of Yale University, who state that the stout hexagonal prisms look exactly like those from the original locality at Moresnet.

Calamine ($\text{ZnOH}_2\text{SiO}_3$).—Small transparent orthorhombic crystals of calamine were identified on a specimen of decomposed garnet rock from the Shannon mine, just above the lime quarry.

Dioptase (H_2CuSiO_3).—The silicate of copper, dioptase, has been found at only a few localities. Very beautiful specimens, which, however, are by no means common, have long been known from the classic locality, the Kirghese Steppes, Russia, and more recently from the French Congo State, Africa. Dioptase is seldom found in the United States, the only recorded occurrences being at the Bon Ton mines, Chase Creek, near Clifton, Arizona, noted by R. C. Hills,* and from near Riverside P. O., Pinal County, Arizona, noted by W. B. Smith.† Well crystallized specimens of this mineral were found on an old dump of the Stevens group of mines, on the west side of Chase Creek, near Garfield Gulch. They occurred in a small chimney of chrysocolla ore in limestone, now worked out, and the locality is believed to be the same as that described by Mr. Hills. The dioptase crystals were submitted to Prof. S. L. Penfield, who remarks on them as follows:

“The crystals, measuring from 1^{mm} to 2^{mm} in diameter, occur closely grouped together, lining cavities in a brown ferruginous gangue impregnated with amorphous green material which is probably chrysocolla. The color of the dioptase is a beautiful emerald-green. The habit of the crystals, shown by the accompanying figure, is that which is most commonly observed and is especially characteristic for dioptase; prism of the second order a ($11\bar{2}0$), terminated chiefly by the rhombohedron of the first order s ($02\bar{2}1$) and with small faces of the rhombohedron of the third order x ($13\bar{1}1$). As is common on this species, the prismatic faces are vicinal and the s and x faces are striated parallel to their mutual intersection edges, hence the crystals are not suited for giving accurate measurements of the angles with the reflection goniometer. One crystal was measured, and the angles of one of the rhombohedral zones, given below, are sufficiently close to the calculated values to establish the identity of the forms.



* This Journal (9), vol. xxiii, p. 325, 1882.

† Proc. Colorado Sci. Soc., vol. ii, p. 159, 1887.

			Measured.	Calculated.
$a x,$	1120	1341	= 28° 55'	28° 48'
$s s',$	0221	2021	= 83 48	84 33
$s' a'',$	2021	1120	= 48 18	47 43

By crushing some of the material, imbedded in oil under a cover glass, and examination in convergent polarized light, occasional fragments were found which gave a normal uniaxial interference figure, with numerous rings indicating high birefringence. The character of the birefringence was found to be positive. Thus in all of its crystallographic and optical relations the material studied is like typical diopside from other localities."

Chrysocolla ($\text{CuSiO}_3 + n\text{H}_2\text{O}$). — This mineral occurs very commonly in the oxidized part of the deposits, but does not, except in some cases, constitute an important ore. On the whole, it is more abundant in the deposits in porphyry and granite than in those contained in limestone. The usual bluish green or dirty green colors and conchoidal fracture characterize it. It occurs in seams or coatings at many of the mines: abundantly in the Mammoth mine on contact fissure between porphyry and limestone; at several prospects on the Stevens group in Chase Creek near Garfield Gulch; in the Terazas fissure vein in porphyry near Metcalf; at the Metcalf mines and many of the prospects between that place and Morenci; at the Modoc open cut, Morenci. Technical analyses of chrysocolla ore from Terazas mine by the Arizona Copper Company gave

SiO ₂	31.65
CuO	34.90
H ₂ O	26.30
Al ₂ O ₃	3.80
Undetermined	3.35
	100.00

Normal chrysocolla should have 34.2 per cent SiO₂, 45.2 per cent CuO, and 20.5 per cent H₂O, but the analyses show great divergency, many probably being mixtures. Moreover, what has been called chrysocolla probably includes two mineral species.

The optical characteristics of chrysocolla seem imperfectly known. Dana states that it is cryptocrystalline, while many other text-books, notably one issued in 1902 by Professor Miers, call it "amorphous."

In most cases the mineral indeed seems cryptocrystalline with bluish gray colors of interference. But this is by no means universal.

Chrysocolla from the Modoc open cut appears as mammillary crusts of bluish green color on "copper-pitch ore." The latter is isotropic and undoubtedly a distinct mineral from the chrysocolla, of brown color in varying tints, some of it opaque and showing evidence of concentric deposition. On top of the chrysocolla are thin crusts of quartz and some calcite. The chrysocolla has three different structural forms, as seen under the microscope: (1) The dominant mass is a cryptocrystalline to microcrystalline aggregate of particles with high birefracting index; (2) very fibrous and felted aggregates of same substance giving undulatory effects between crossed nicols and medium high colors; (3) fibrous crusts on top of 1, or also in thin layers between masses of 1, the individuals having such a remarkably parallel orientation that the aggregate of them appears almost like single crystals between crossed nicols, with black shadows sweeping across them when the table is turned. The extinction is parallel to the fibers, double refraction strong, about like augite, character negative. The same optical characteristics were repeatedly observed in thin sections of chrysocolla from Metcalf and other places. Reniform deposits were sometimes noted, the center of cryptocrystalline material coated with coarsely fibrous and highly birefringent material.

Sections from the Coronado and Metcalf mines often showed pseudomorphs of pyrite consisting of a shell of limonite with kernel of fibrous chrysocolla.

The observations of Jannettaz* on chrysocolla from Boleo Baja, California, Mexico, led to the same results as described above, but seem generally to have been overlooked by editors of text-books.

Copper pitch ore.—Under this old German name is described a dark brown to black substance, sometimes dull but generally with glassy to resinous luster; hardness about 4; streak dark brown. It occurs among the products of oxidation of the deposits in limestone, as at the Detroit and Longfellow mines and Modoc open out at Morenci, and is associated with azurite, malachite, and chrysocolla, often enclosing these minerals or replacing in branching veinlets, together with azurite, a shale-like mass, probably largely composed of kaolin. In thin section it is sometimes opaque, but often also translucent, gradual transitions obtaining in the same section, and occurs in irregular or concretionary masses, often containing small embedded crystals of a doubtful mineral, possibly a silicate of zinc. Between crossed nicols the translucent mineral always proves entirely isotropic and, except for varying depth of color and the small crystals mentioned, entirely homogeneous.

* Bull. Soc. Min. Paris, 1886, ix, 211.

A rough preliminary analysis of selected pitch black material from the Detroit mine gave

CuO	28·6
ZnO	8·4
MnO ₂	21·2
Fe ₂ O ₃ + Al ₂ O ₃ + P ₂ O ₅	4·0
Insoluble in H ₂ Cl	22·8
Ignition loss 16·3, less oxygen due to conversion of MnO ₂ to Mn ₂ O ₃ ..	13·7
	98·7

Similar material surmounted by crusts of chrysocolla from the Modoc open cut contained much MnO₂, with a good deal of CuO and ZnO, and is thus evidently the same substance. Manganese is largely but not certainly wholly present as MnO₂. The insoluble portion consists of silica, is wholly separated by acid without need of evaporation, and is nearly all soluble in dilute potassium hydroxide. It is not possible to say whether silica is in combination or as opal, but it cannot be present in any other form.

Most of these copper pitch ores, known from many districts, have been described as impure chrysocolla. As shown by the optical characteristics, they are not however a mixture and they certainly do not contain any chrysocolla, the characteristics of which are very different. They probably represent a series of closely related compounds, the chemistry of which has not yet been fully elucidated. Prof. G. A. Koenig* describes a similar mineral with the same isotropic character from Bisbee, and names it melanochalcite. Its composition is different, containing

CuO	76·88
SiO ₂	7·80
CO ₂	7·17
H ₂ O	7·71
ZnO	0·41
FeS ₂	0·07
	100·04

Prof. Koenig considers it as most probably a basic salt of an ortho-silico-carbonic acid. No carbon dioxide was found in the Morenci minerals. In conclusion, it would seem that the chemistry of these copper pitch ores would bear further examination.

Morencite.—In a lime shale on the intermediate level of the Arizona Central mine, Morenci, 200 feet below the surface,

* This Journal, xiv, p. 404, Dec. 1902.

brownish or greenish spreading masses were found, containing brownish yellow, silky fibrous seams. The enclosing material consists largely of the same material as the seams, but impure and mixed with a little chlorite and pyrite. The whole bears evidence of being a product of oxidation of some contact metamorphic mineral.

The fibrous mineral on the seams forms a felted aggregate as seen under the microscope, but it is well individualized and contains few impurities except a little pyrite and chlorite. The minute fibers are brownish yellow and slightly pleochroic, being darker when parallel to the principal section (opposite the behavior of biotite); the birefringence is strong and extinction strictly parallel to the fibers. No mineral corresponding to this has been described, but, although its individual character is beyond doubt, the analysis does not lead to a satisfactory formula. The material for the analysis was picked out carefully under the lens and, examined under the microscope, it proved satisfactorily pure.

The analysis afforded the results of the first column of figures below. In deducing the molecular ratios of the second column, there has been deducted sufficient lime to form apatite with the phosphoric oxide.

			Molecular ratios.
SiO ₂	45.74	757	= 10.71 or 11
TiO ₂	trace		
Al ₂ O ₃	1.98	019	} 205 = 2.90 " 3
Fe ₂ O ₃	29.68	186	
FeO.....	0.83	011	
MnO.....	trace		
CaO.....	1.61	027	} 141 = 2.00 " 2
MgO.....	3.99	100	
K ₂ O.....	0.20	002	
Na ₂ O.....	0.10	001	
H ₂ O 105°.....	8.84	491	= 6.96 " 7
H ₂ O 150°.....	0.12	} 282	= 3.99 " 4
H ₂ O below redness..	4.27		
H ₂ O redness.....	0.69		
CuO.....	little		
FeS ₂	0.66		
P ₂ O ₅	0.18		

98.89

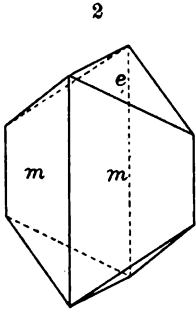
It would seem from the temperatures at which the water is driven off that this must exist in two conditions, and that four-elevenths of it must be held more securely than the remaining seven-elevenths. The attempt to account for four molecules of water as constitutional, however, led to no simple or seemingly

probable formula, whereas if all water is excluded the ratio is that of a metasilicate— $R'R''(SiO_3)''_{11}$. On the other hand, to include the whole of the water as essential to the silicate molecule, for which there is little ground in view of the ease with which most of it is expelled, leads to an orthosilicate ratio— $R'R''R'''(SiO_4)'''_{11}$.

On the whole, considering also the bad summation of the analysis, it is more rational to regard the mineral as a hydration product of an original metasilicate molecule than to attempt to construct a complex formula which could have but a very doubtful value. Considering that the mineral is not a mixture, but optically well individualized, we have, after some hesitation, thought best to designate it by the name morencite, derived from the locality in which it was found.

Libethenite ($H_2Cu_2P_2O_{10}$).—This hydrous, basic phosphate of copper was found 30 feet below the adit level of the Coronado lode, in the main shoot. It is a matter of interest to record its occurrence, for this rare mineral has never before been noted in the United States. It occurs in small crystals, less than 1^{mm} in length, deposited in cavities and seams in a quartzite gangue. The mineral was identified by Prof. S. L. Penfield, who also kindly measured and figured the crystals. Prof. Penfield describes the occurrence as follows:

“The only associated minerals are occasional clusters of minute quartz crystals and small tufts of radiated malachite needles. The color of the libethenite varies from light to dark olive-green, depending upon the size of the crystals. The habit of the crystals, as shown by the accompanying illustration, is a combination of the prism m (110) and brachydome e (011), which is exactly like that commonly observed on libethenite from foreign localities. On an occasional crystal the brachypinacoid b (010) was also observed. Although the crystals are brilliant, the faces are generally vicinal and give uncertain or multiple reflections of the goniometer signal. The best reflections were obtained from the faces of the dome e , and three measurements of $e \wedge e'$, $011 \wedge 0\bar{1}1$ gave



69° 52', 70° 18' and 70° 14'. The last measurement, obtained from the best reflections, is close to the value, 70° 8', obtained by Rose. The best measurements of the prismatic angle gave $m \wedge m''$, $110 \wedge 1\bar{1}0 = 87^\circ 11'$, which, considering the vicinal character of the prismatic faces, is reasonably close to the value of Rose, 87° 40', as given in Dana's Mineralogy. A small crystal resting on a prismatic face, when examined in convergent polarized light, showed an optical axis nearly in the

center of the field with the dark bar running at right angles to the vertical axis, thus indicating that the optical axes are in the plane of the base, as determined by Des Cloizeaux. The presence of copper, water and phosphoric anhydride was determined by chemical tests."

A more detailed search would probably reveal small quantities of phosphates from other mines near Morenci. They are certainly not abundant.

Brochantite ($H_2Cu_2SO_{10}$).—This basic sulphate of copper is usually supposed to be one of the rarer minerals. It was, however, discovered at a few places near Metcalf and Morenci, in well developed crystals, and this led to a systematic microscopic examination of the green ores, hitherto supposed to be malachite. The result was surprising, as the mineral was proved to be of extremely common occurrence, mostly intergrown with malachite, which had effectively masked its presence. It is believed that a careful examination of many so-called malachites from other districts will disclose the overlooked importance of brochantite as a copper ore.

Brochantite is frequently crystallized in the short but stout rhombic prisms combined with dome and brachypinacoid characteristic of the species. Needle-shaped and flat crystals are more rare. The crystals are usually of small size and frequently microscopic. It occurs as lighter or darker emerald-green crusts on limonite or sericitized porphyry from the Red ore body in the Shannon mine, from the Metcalf mines and many other places; as fine-grained aggregates in altered porphyry at the Shannon mine, near the surface, and constituting valuable ore with up to 30 per cent copper; from croppings of the King vein, filling seams and coating porphyry fragments as flat pieces or even foils with almost pearly luster; from the croppings of the Copper Queen mine between Morenci and Metcalf, here as flat stellar aggregates of bluish green foils; at many places near Morenci, as, for instance, Copper Mountain and Montezuma mines, at the latter locality replacing chalcocite. It would probably not be found absent from any mine in the district containing oxidized copper ores. Malachite often develops later than the brochantite.

On the whole, the mineral is most abundant in fissure veins in porphyry, though also occurring in the irregular deposits in limestone.

Brochantite has an excellent cleavage parallel to the brachypinacoid. The macropinacoid is the axial plane and the acute bisectrix is seen emerging in cleavage foils. Pleochroism very slight. Birefringence much lower than malachite, about equal to that of augite. This, as well as the absence of twins, distinguishes brochantite from malachite. The reaction for sulphuric acid is of course a valuable aid.

Spangolite ($H_2Cu_2AlClSO_{10}$).—This peculiar mineral, essentially a highly basic chloro-sulphate of copper and aluminum, was discovered and described by Prof. S. L. Penfield* some fifteen years ago. The specimen came from some point within 200 miles of Tombstone, Arizona, and probably from one of the great copper camps of the territory. Somewhat later it was identified by Prof. H. A. Miers on two specimens from Cornwall, England, but the American locality has not yet been found. It is, therefore, a matter of interest to record its discovery on some specimens from the Metcalf mine of the Arizona Copper Company, taken from the workings in the great open cut not more than 100 feet below the surface. These specimens consist of white sericitized granite-porphyr, in part silicified, and traversed by veinlets and irregular masses of cuprite; the cuprite contains native copper and is covered by crusts of malachite, brochantite, and chrysocolla. A soft and scaly bluish green coating on the chrysocolla proved to consist of microscopical hexagonal crystals or cleavage foils, remaining dark between crossed nicols. The mineral was identified as spangolite, a determination in which Professor Penfield concurred. No measurable crystals were found and the mineral is very inconspicuous. It is difficult, if not impossible, to obtain material entirely free from accompanying minerals.

Selected bluish flakes from this specimen gave tests for water, and the sulphate and chlorine ions, besides copper. There was too little of this pure material to permit of a test for alumina, but the mixed copper minerals composing the greater part of the specimen showed the presence of this body. It seems therefore probable on these grounds alone that the bluish flakes are spangolite. Vanadium, phosphorus, and arsenic are absent.

The closed-tube reactions of the mixed copper minerals are very striking. Water is given off first. Then appears suddenly a white sublimate ($AlCl_3$?) near the assay, which seems to form or at once change to minute colorless drops. This deposit can be driven slowly up the tube, followed at its lower, sharply defined edge, by dark yellow-brown drops ($CuCl_2$?), which on cooling solidify to greenish crystalline aggregates, and the part of the tube between them and the assay shows under the lense delicate feathery crystallizations like frost markings on window panes. Down in the flame the glass becomes colored red (Cu_2O ?) and in parts yellow. On charcoal the blowpipe flame is colored azure blue and at the same time green.

In order to compare the above closed-tube behavior with that of undoubted spangolite, a small fragment of the latter, offered by Dr. Penfield, was tested. It gave water and then a white

* This Journal, 1890, vol. xxxix, pp. 370-378.

sublimate like the one above mentioned, followed by a dark olive-brown liquid, which on cooling passed through lighter shades of color and solidified as a bright green ring. In general this behavior is very like that of the mixture under examination from Clifton.

Gerhardtite ($H_2CuN_2O_4$).—The cliffs of granite-porphyrity in the deeply eroded Chase Creek Canyon at Metcalf in many places show a conspicuous and extensive bright green coating of some copper mineral, which, no doubt, is formed by the trickling of atmospheric waters over and through rocks containing a small percentage of copper. This is not surprising, for porphyry in this vicinity is altered throughout by quartz cementation and disseminated cupriferous pyrite. This "green paint," as it is frequently called, is not soluble in water, and more closely examined consists of small dark green, roughly mammillary forms, coating the rock to a thickness of a few millimeters. Examination by the microscope fails to reveal any recognizable mineral in the cryptocrystalline mass.

Chemical examination led to the interesting result that the copper minerals present consist of a nitrate and a chloride, neither of which has been found elsewhere in the mines of the district. Detrital grains and some silica seem associated with these compounds. The nitrogen seems difficult to account for in the absence or scarcity of animal substances which might have yielded it. Possibly it is contained in the porphyry.

The closed-tube reactions of the copper minerals forming the mixture on this specimen are as striking in their way as those of the mixture containing spangolite, described elsewhere. Water first appears, then brownish nitrous vapors, followed by a sublimate which is not very volatile, becomes black on further heating but on cooling yellow-brown. The glass at the bottom of the tube is often yellow-brown when cold. After some hours the sublimate nearly disappears or becomes greenish from absorption of water. If the water which condenses in the upper part of the tube on first applying heat is driven out by the flame, and the mouth of the tube is held in the flame, this is colored deep green by a volatile copper compound (chloride?). On charcoal the flame is azure blue and at the same time green. Vanadium is absent.

The mixture contains presumably the basic nitrate gerhardtite and a chloride which is perhaps atacamite. Spangolite, the chloride, can hardly be present, for the slight amount of SO_2 shown by test does not seem sufficient to account for the large amount of chloride.

The only place from which gerhardtite has previously been identified is at Jerome mines in the central part of Arizona, associated with cuprite and malachite. It was discovered there by Messrs. H. L. Wells and S. L. Penfield.