

ART. XXXII.—*Mineralogical Notes*; by B. SILLIMAN.

1. VANADINITE AND OTHER VANADATES, WULFENITE, CROCOITE, VAUQUELINITE, ETC., FROM ARIZONA.

I HERE record the discovery of two important and very interesting mineral localities, or districts, in the Territory of Arizona, from one of which I have obtained vanadinite of remarkable beauty of color and perfection of crystalline form, associated with almost equally beautiful wulfenite of an orange-red color; and from the other, four, perhaps more than four species containing vanadium. The last named district has also furnished crocoite and vauquelinite never found before, I believe, in North America.

I am greatly indebted to my faithful and intelligent correspondent, Mr. George A. Treadwell, of Vulture, Arizona, for sending me, for some years past, a great number of minerals and ores collected by him in that Territory, among which are those now to be described. I mention also, with pleasure, the aid afforded me by Mr. Edward Farley, of Wickenburg, owner of several interesting veins, and Dr. Jones, of Phoenix. Mr. F. F. Thomas, lately in charge of Silverlead Furnaces, near Silent, in Arizona, and Mr. John McDougal, Superintendent of mines, have also contributed important data in extending our knowledge of that interesting Territory.

Vanadinite.—This hitherto rare species promises now to be comparatively abundant. In the so-called "Silver District," in Yuma County, Arizona, about fifty miles north of Fort Yuma, is a large area traversed by veins of quartz carrying argentiferous galena, with salts of lead, but no gold, and rather extensively explored. The lead salts which I have seen from this region are wulfenite, of remarkable beauty, vanadinite, and massive anglesite with galenite. Vanadinite occurs in three mines, near together, the "Hamburg," the "Princess" and the "Red Cloud." The crystals of vanadinite are extremely beautiful, alike for brilliancy of color, luster and perfection of form. Only a single vanadate appears to occur in the Silver District; but there may be an exception to this remark, since a greenish yellow incrustation on one specimen may turn out to be volborthite or one of the other amorphous vanadium minerals. All the veins of this district occur, as I am informed by Mr. Thomas, between a foot-wall of granite and a hanging-wall of porphyry, specimens of which rocks I have in hand. The foot-wall of granite is somewhat irregular, but the porphyritic hanging-wall is well defined. I have not yet made sections of the latter rock; it closely resembles the augite trachytes of Nevada and elsewhere,

the usual associates of silver ores the world over. All these lodes abound in calcareous matter, but there are no limestone beds in the vicinity; and in the absence of any organic remains, we are ignorant of the probable geological horizon.

"The Hamburg" mine has furnished the most numerous and, on the whole, the best specimens of vanadinite. The crystals vary in color from deep orange-red—deeper than potassium bichromate, but not ruby—through lighter shades of orange-red to reddish-yellow and brown. They are always highly lustrous. The size is small, the length being not over two millimeters and usually less than one; and the diameter about half the length to equal dimensions. The hexagonal prisms are modified usually by one, sometimes by two planes on each terminal edge, and occasionally the angles are replaced. These crystals are implanted singly and in crusts on a dark chocolate-colored siliceous gangue, with occasional obscure crystals of cerussite, and rarely a dark-colored cleavable lime-rock (impure calcite).

The "Red Cloud" mine furnishes vanadinite of a rich orange-red or flame-color, associated with beautiful orange-red wulfenite. At the depth of 280 feet, measured on the slope of the vein, wulfenite takes the place of vanadinite almost to its exclusion. The crystals of vanadinite at this mine are smaller and grouped in more confused masses than at the Hamburg mine.

At "the Princess" mine, the vanadinite occurs in slender crystals of a brilliant red color almost identical with that of crocoite, implanted upon white calcite. The habit of the species is unlike either of those before mentioned; the crystals are at least four diameters long and are very slightly modified. They are not over half a millimeter in diameter, but are very perfect in form, luster and color. They have, naturally enough, been mistaken for chromate of lead.

The genesis of the vanadates of these mines is obscure. A single small specimen only of the galena has reached me. It forms the nucleus of a surrounding mass of amorphous anglesite, upon the outer surface of which appear obscure crusts of vanadinite. Analyses of a series of samples selected on the spot, by a careful examination might reveal the origin of the vanadic acid.

Vulture district, as I have called it, another and quite distinct district in Arizona, has furnished, at a number of places, vanadinite with other rare species. This area embraces the country between the Hassayampa River on the west and Agua Fria on the east, and extends in a north and south direction from the well known Vulture Mine to Antelope Mountains, Weaver district, on the road to Prescott. It is

partly in the lower portion of Yavapai County, and partly in the northern portion of Maricopa County. Within this area are numerous veins of gold-bearing quartz carrying lead and sometimes a little copper or perhaps both at the same time. I have become familiar with the mineralogical character of these veins through Mr. G. A. Treadwell: and Mr. Edward Farley, owner of some of the mines which have furnished the most interesting species of this area, has prepared for me a sketch map on which the localities are laid down with sufficient accuracy for identification by reference to the Government map.

Farley's "Collateral Mine," about twenty miles northeast of Vulture, is perhaps the most interesting locality of vanadinite in this area. The vein is about four and a half feet wide, and occurs in soft gray talcose rock. About one-half of the thickness of the vein, on the hanging wall side, is quartz stained green with chrysocolla, and chocolate-brown with a ground-mass which I find carries vanadium, and showing lemon-yellow stains resembling plumbic ochre, also a vanadate. Any portion of these yellow and brown masses (if pulverized, digested with dilute nitric acid, and the filtrate treated with ether) gives a strong reaction for vanadic acid. Unless led to test this gangue-stone for vanadium by the occurrence of vanadinite in other parts of the vein, no suspicion of its presence would be aroused. A seam of very red ferric oxide with calcite follows next, and the red oxide of iron reacts decidedly for vanadium, while the calcite is penetrated with yellowish and white fibrous crystals of vanadinite. Next, there is a seam, of about six inches, of very soft material filled with abundant lemon-yellow acicular crystals of vanadinite in tufts and aggregated masses, the whole quite friable, forming the center of the vein, which also carries in this zone masses of cerusite. The whole mass of this soft material reacts very strongly for vanadic acid. Then follow, on the foot wall, about twenty inches of vein-matter composed of quartz with calcite. The calcite is penetrated with acicular crystals of vanadinite arranged in threads and in stellar tufts, usually not over a line in thickness, but occasionally opening into small cavities, like geodes, lined with distinct hexagonal prisms of this species. The common color is yellow but they are often nearly white. The cleavage fragments of calcite carrying the vanadium crystals form specimens of rare beauty. Quartz, similar to that in the upper section of the vein, is found in this lower member, and this is also somewhat stained with copper silicates. In its open joints occur hexagonal crystals of vanadinite of a fine yellow color; they closely resembling mimetite, but give no arsenical reaction, and I failed to obtain

a trace of arsenic from the included crystals in the calcite, when tested by soda and potassium cyanide in the closed tube. This quartz carries crystals of vanadinite in habit very unlike those which occur at the Hamburg mine in the Yuma district; they are long slender needles hardly a line in thickness, of a delicate straw-yellow color, quite transparent. They are associated with others of a rich orange-yellow color and not so well defined. There are also confused tufts of crystals of the same species, not thicker than hairs, of a pure chrome-yellow color, implanted in cavities in the red iron-stained gangue.

Descloizite (?)—A mineral which may prove to be descloizite, occurs among the ores of the Collateral Mine which have reached me. It is found in blue-black and brownish-black semi-transparent and very brilliant crusts, the individuals imperfectly developed; hardness about 3–3.5; streak-yellow to brownish-yellow. Alone in the closed tube it fuses and gives off abundant water. It reacts very strongly for vanadium and for lead, also for copper, manganese and zinc. Since this paper was in hand I have received from Mr. Farley, under date of June 25th, additional specimens of this mineral not only from the "Collateral" but also from the "Chromate" veins near the former, on one of which are seen very well defined, but very small tabular crystals, the study of which will probably show them to be the species indicated. They resemble some of the forms figured by Websky from La Plata, province of Cordoba.* We must await the arrival of more specimens before the study of this interesting mineral can be completed.

Volborthite (?)—A single well characterized specimen provisionally referred to this species came among the products of the Collateral Mines. It exists in small botryoidal masses adhering to the polished faces of deep red quartz crystals. The streak is bright yellow. In thin scales the mineral is transparent and of a clear olive-green. The luster is vitreous and dull. No crystals were detected. Alone in the matrass it fuses readily, adhering to the glass. It gives off no water and dissolves in dilute hydrochloric acid to a greenish solution from which alcohol throws down the lead in tufts of plumbic chloride. On charcoal it fuses to a black shining bead which alone gives off lead fumes and copper appears on crushing the bead in the agate mortar. With soda it gives a globule of lead enclosing one of copper. Zinc oxide stains the coal when the assay is gently heated. It may be that it will turn out to be a new species.

An anhydrous cryptocrystalline mineral containing vanadium occurs among the "Collateral" ores. It varies in color from light yellow-brown to black-brown; gives the reactions for

* Monatsbericht der Akad. zu Berlin, July, 1880, 672.

Domeyko's *chileite*, but it is not a clay-like mineral. It yields readily a globule of lead containing a nucleus of copper. No arsenic was found. It occurs also in the "Chromate" vein.

Gold in coarse crystalline grains occurs in the quartz of the "Collateral" vein.

The Phoenix Mine, one mile east of the mine last named, furnishes specimens similar to those just described. The vanadinite is light yellow and deep orange-yellow to reddish, in large, well-formed crystals, which react for chlorine but not for arsenic. The gangue is quartz which carries gold but no calcite in the samples which have reached me.

Among the specimens sent to me by Mr. Farley on the 25th of June, which I have just examined, I find crystals of vanadinite in the gangue of both the "Collateral" and the "Chromate" veins, quite unlike those before described and very closely resembling in habit, color and form, the brilliant red crystals from the Hamburg mine in the Yuma Silver District.

The Montezuma lead mine, eleven miles east of Vulture and southwest of Collateral, abounds in vanadinite which occurs in drusy crusts of a rich deep yellow and brown color on masses of cerussite. Observed with a lens these crusts are seen to be well defined hexagonal prisms. It appears to be an abundant source for the supply of vanadium.

At "the Frenchman's Mine," a gold-bearing vein, of about 18 inches thickness, consists of deeply iron-stained quartz, showing amorphous yellow-green masses of a mineral very rich in vanadic acid, and reacting for lead, copper and chlorine. It is also hydrous. It may perhaps be *moltramite*. There is a buff colored amorphous substance with it also rich in vanadinite. Calcite occurs in the gangue.

There are other localities in this district in which vanadium is found, but the foregoing will suffice.

Mimetite occurs in considerable masses north of the Domingo mine on Castle Creek in the extreme northwest of the Vulture District, as here described. I have seen only a single mass of about 80 grams found by Mr. Farley. It was without gangue or associated species, and quite amorphous.

From "Bethesda Mine," in Los Cerillos, New Mexico, I collected in April, 1880, specimens showing greenish crusts of vanadinite in botryoidal forms and sometimes nearly black. It is there associated with wulfenite and cerussite. This vein is the southerly extension of the "Mina del Tiro," worked by Mexicans of old.

It is interesting to note the wide area over which this species is now known to exist, compared to the single locality at Zimapan, in Mexico, where Del Rio in 1803 first identified it. No doubt it will be found in equal or yet greater abundance at

other localities as the work of exploration goes on. Many years since, in a paper on the Mineralogy of the Wahsatch and other Utah ranges of mountains,* I called attention to the occurrence of the molybdate of lead (wulfenite), as replacing the phosphate (pyromorphite) among the salts of lead, the latter being rarely if ever found there. Subsequently the wulfenite of Tecoma and of Eureka, in Nevada, confirmed this generalization, and I have since had very frequent occasion to notice the wide distribution of wulfenite in New Mexico and Arizona. We may now add vanadic acid as having the same wide distribution.

Wulfenite crystals of rare beauty are found in the "Red Cloud" Mine, already mentioned as furnishing the vanadinite. The specimens sent me are from a depth of about 300 feet. They show very solid tabular crystals of large size, brilliant luster, and rich orange-yellow to orange-red color. The color at once suggests the presence of vanadic acid, like the well-known specimens from Wheatley Mines as detected by Smith. But I have not found a trace of vanadic acid in these Red Cloud or other Arizona wulfenites. From the "Melissa Mine" in Silver District adjacent to the Red Cloud, wulfenite is found in octagonal prismatic forms, the basal plane being almost wanting, in some specimens, giving them the appearance of simple octahedrons. This interesting form I believe has not been before observed in any American locality. The color of the species at this locality is pure orange-red; the gangue is brown, almost black, calcite. The "Rover" is another mine of the same district which furnishes wulfenite nearly identical in form with the Red Cloud specimens, but of a little lighter orange-red color.

Crocoite-group.—Three if not four of the species of this group occur among the ores of the Vulture region, and especially in the "Collateral" and "Chromate" veins. These two veins together with the "Blue Jay" and the "Phoenix mine," form a group of singular mineralogical interest, furnishing, among more common minerals, the species, crocoite, phœnicochroite, vauquelinite, joassite (?), vanadinite, volborthite (?), Descloizite (?), Chileite (?), wulfenite. *Vauquelinite* occurs quite abundantly associated with galenite and crocoite in a gold quartz gangue or vein stone. The genesis of the chromate is very manifest. The nucleus of unaltered galenite is surrounded with a bright pea-green and apple-green areola of vauquelinite, sometimes semi-transparent, and uncrystalline. This green mass is succeeded by crystalline and transparent crocoite of orange-red and cinnabar-red color giving the familiar scarlet and chrome yellow streak. The crocoite as yet has not been found well crystallized. Besides the associated species already named, occur cerusite, gold

* This Journal, III, iii, 195.

and magnetite. The magnetic sand collected in washing the gold out of the crushed vein stone was examined for chromite without success.

It is an interesting question, whence came the chromic acid? Perhaps an analysis of the galenite may detect chromium in that species. Smith has described a meteoric chromium sulphide, Daubr  elite,* and there is no chemical reason why this species may not co  exist with galenite. In the paragenesis of the chromates in this district the change has evidently proceeded from without inward, and the occurrence of specimens in which the whole of the galenite is transformed is not unfrequent, as also the change of the crocoite to the lemon-yellow ph  enicochroite.

Small orange-yellow crystals occur in the vauquelinite of the Vulture region, which may be the *joussite*; but more study is required before they can be proved to be this mineral.

In conclusion I will add that before the study of these interesting localities can be complete a personal visit must be made by a mineralogist to the mines, and sufficient material obtained on the spot to allow of chemical analyses.

2. THENARDITE FROM RIO VERDE, ARIZONA TERRITORY.

Some months since I received a lump of a saline mineral marked "Salt," reported by my informant, Mr. Treadwell, of Phoenix, to occur in abundance on the River Verde, in Maricopa County. It proved, on examination, to be anhydrous sodium sulphate or *thenardite*, a species which has hitherto been found in very limited quantity. In an analysis in the Sheffield laboratory under the supervision of Prof. O. D. Allen, by Mr. Geo. M. Dunham, its constitution was found to be as follows:

	I.	II.
Chlorine	0.095	0.097
SO ₃	56.410	56.310
CaO	0.120	0.130
MgO	0.021	0.023
Na ₂ O	[42.964]	[43.070]
Insoluble	0.390	0.370
	100.000	100.000

I. Na₂O : SO₃ = 6.91 : 7.02; II. Na₂O : SO₃ = 6.93 : 7.01.

The mineral is therefore nearly pure Na₂SO₄. The insoluble matter out, the impurities are only 0.24 per cent of the mass.

The specific gravity of a fragment quite free from visible impurity, taken in petroleum, I find to be 2.681. This mineral occurs in large masses, some of which, in the rough, are distinctly crystals with imperfect faces, showing eminent cleavage in the direction of the basal plane of the prism and a hackly cleavage in the opposite direction. The "insoluble"

* This Journal, III, xii, 109.

matter (=0.38 per cent) in the mineral—chiefly clay, gives it a prevailing shade of yellowish gray. Its hardness is below that of calcite; luster vitreous; fracture conchoidal to hackly.

Occurring in an almost rainless country, it has suffered little change, small portions only at surface being altered to a dry white powder of exanthalose, $\text{Na}_2\text{SO}_4 \cdot 2\text{H}_2\text{O}$.

As this is, so far as known, the only locality of this species where it exists in great abundance, I have taken steps to secure all the information available respecting it. Mr. Thos. F. Hopkins, of Vulture, Arizona, has forwarded to me the following statement which I present in his own words, in a letter dated—

“VULTURE MINE, A. T., June 18, 1881.

“Mr. Boyd, a resident of the Verde Valley during the past five years, is quite familiar with the large thenardite deposit, and furnishes the following details.

“The ‘Salt Mine,’ as it is popularly called, is situated about two and one-half miles southwest of Fort Verde (the present post), on the west side of the Verde River. Squaw Peak is distant eight miles from Fort Verde, and this mine lies between these two points.

“It occurs on a ‘bench’ about fifty or sixty feet above the Verde River, and itself forms one of a series of benches gradually sloping toward the river. The deposit crops out boldly in the face of the bank, and seems to extend along a distance of from eight hundred to one thousand feet. It occurs in a white chalky-looking formation, and the surface opening is probably about ten feet wide. From this opening immense masses have been carried away during more than five years past, every rancher of the district taking off huge wagon loads for the use of his stock, etc. The deposit is solid, and is removed by blasting. It is not under water at any time, for both its sloping situation and its elevation above the river forbid such a condition.

“No systematic openings of the deposit have ever been made, and hence its extent is not known. It is simply ‘gouged out’ according to the whim and convenience of each new comer; but it seems practically inexhaustible.”

I am informed by several persons who have seen this thenardite used for the salting of cattle—among them my friend Mr. James Douglass, Jr., who was recently in that portion of Arizona—that the animals resort to it very freely, licking it as they are wont to do common salt, and with only good results.

Thenardite has been found in Nevada and elsewhere in the arid regions of the West Coast, but not before in sufficient quantity to be of commercial importance.

G. vom Rath (Zeitsch. f. Kryst.,) has lately named Lake Bal-schasch, in Central Asia, as a locality the flat shores of which furnish *thenardite* in very considerable quantity.

New Haven, July 8, 1881.