ON THE OCCURRENCE OF TOPAZ AND GARNET IN LITHOPHYSES OF RHYOLITE.

BY WHITMAN CROSS.

In the *American Journal of Science* for February, 1884, I described the occurrence of minute crystals of topaz in the small drusy cavities of a coarsely crystalline rhyolite from Chalk Mountain, by Fremont's Pass, Colorado.* This was then supposed to be the first published description of the occurrence of topaz in such a manner in any eruptive rock, and especially noteworthy in one of probable Tertiary age, but it has since then transpired that the beautiful garnets and the rarer associated topaz from Nathrop, Colo., which have been sold in the mineral stores of Denver for two or three years past, present a second occurrence and that published mention of the same had already been made by J. Alden Smith in the biennial "Report on the Development of the . . . . Resources of Colorado, 1881–2," p. 36. Mr. Smith mentions a dike of an eruptive rock in the Archæan on the east bank of the Arkansas river, opposite Nathrop station on the Denver and Rio Grande R. R., Chaffee Co., and says that "a large part of it is composed of cellular pumice of a light gray color. In the cavities are beautiful crystals of topaz. . . . Associated therewith are many small dark red garnets." In the Catalogue of Minerals (l. c. p. 157) topaz is mentioned "in trachyte, near Nathrop." While I had examined many small specimens from Nathrop previous to the description of the Chalk Mountain occurrence, the gangue rock was so poorly represented by them that its nature as an eruptive rock was by no means clear, and the meager and somewhat inaccurate statements of Mr. Smith escaped attention.

* Also in Bulletin 20, U. S. Geological Survey, 1885, p. 81.

Last October I had opportunity of visiting the locality at Nathrop, obtaining fuller information concerning the occurrence of the rhyolite, and a suite of specimens illustrating the same, together with the contained minerals.

Mode of occurrence of the Rhyolite.—The rock alluded to by Mr. Smith occurs directly opposite the station at Nathrop, forming a ridge about one quarter of a mile in length and 200 feet in height, running parallel to the river on its eastern bank. North of this ridge and separated from it by a stream bed is a second ridge of rhyolite, of somewhat greater extent. A third and smaller ridge of the same rock occurs on the western bank of the river, near the railroad, and in this are stone quarries now in operation. The common trend of these ridges is about N.W.-S.E. Nearly vertical planes of contact with gneiss are shown in one or two places, but the valley alluvium surrounds the masses for the greater part. Between the first and second ridges and east of them are more or less stratified pink or whitish rhyolitic tufa beds, containing boulders of Archæan, rhyolite, and other eruptive rocks. This tufa is no doubt geologically connected with that occurring quite extensively among the low Archæan hills on the east bank of the Arkansas between Nathrop and Salida. The rhyolite ridges themselves seem from present appearances to be short dikes.

The Rhyolite.—The rock of the ridges mentioned varies somewhat in appearance, but cavities containing topaz and garnet are common to all, though most numerous and best developed in that mass referred to by Mr. Smith, which will therefore be first described.

The greater part of the ridge in question is made up of a white or grayish, more or less banded rhyolite, which is as a rule so compact that no constituent minerals are recognizable. The banded structure is produced by the alternation of light and darker gray layers, and is occasionally emphasized by thin bands of crystalline quartz or by an equivalent of the latter in the shape of exceedingly flattened cavities, lined by crystals of the same mineral.

In this portion of the rhyolite no glass is visible, but in certain places, particularly at the south end of the dike and on its eastern side, there is a development of gray pearlite, more or less cellular and usually containing round particles of a black obsidian, somewhat larger than a pea. Whether these vitreous portions are contemporaneous with the banded rock, or represent somewhat later injections of corresponding magma, could not be definitely determined, owing to the débris-covered slopes and the limited time available for their examination. It seems most likely, however, that they are merely local phases of consolidation of the same magma as the compact banded portions.

Throughout both these types of rock are numerous cavities which in many cases represent very well the peculiar vesicles first accurately described by von Richthofen and called by him

"*Lithophysen.*"—These are more or less round cavities, partially filled by thin curved walls, which, by a concentric arrangement and an overlapping, produce rose-like forms. In the present case these folia are often not very well developed and appear as low curved projections on the outer walls. Again, a cavity may be nearly filled by a series of concentric shells. The outer walls and the leaves of the calyx-like lithophyses are usually lined by glassy quartz crystals of minute size, with prism and pyramid. The former being clearly striated, the latter showing the hemihedral forms quite evenly balanced.

The rock of the other ridges mentioned is distinctly porphyritic in structure, showing small glassy sanidines and dark smoky quartz crystals imbedded in a predominant dull gray groundmass. Small lithophyses occur in this groundmass, sometimes exhibiting a very delicate concentric arrangement of white films, which, like those of the previously described rock, are covered by small quartz crystals.

Minerals of the cavities.—The outer walls of the lithophyses, as well as the concentric shells, when present, are primarily formed of a pure white mineral which is but seldom developed in recognizable form. Sometimes a frost-like structure caused by the interpenetration of delicate blades is seen, and quite frequently round or botryoidal masses of the white mineral occur, the surface usually showing minute crystal facets. A microscopical examination of these surfaces shows the mineral to be sanidine in stout crystals of common form. Rarely, clear crystals 1 or 2^{mm} in length are developed, and then a beautiful blue color parallel to $\frac{15}{1}P\overline{\infty}$ may be detected.* In a single cavity in the porphyritic rock the feldspar assumes delicate stalactitic forms, somewhat branching at the ends and clear only at the very tips. The round feldspathic masses are often fissured in a manner clearly showing shrinkage. A silica determination upon a small quantity carefully selected, gave 66 per cent, showing that but little free quartz was included. Alumina and alkalies are also present about as in sanidine.

Upon all surfaces of feldspar, and occasionally upon garnet and topaz, are clear doubly terminated quartz crystals, often not much below 1^{mm} in length and of the form already mentioned. Although careful search has been made no tridymite has been found.

Minute opaque ore particles are very sparingly distributed through the lithophyses. Some of them are developed in tablets about 0.5^{mm} across and these at least are probably to be referred to hematite. None are entirely free from dull coatings, making identification of faces difficult.

Garnet occurs in isolated crystals of a maximum diameter of about 1^{cm}, the average being 2.5^{mm}, of dark red color, clear and transparent, and with finely polished faces. The predominant form is that of 202 (211) with small facets of ∞ o (110). The faces of 202 usually show a striation parallel to the edge of ∞ o due to the oscillatory combination of undetermined faces. There are also indi-

* For fuller statements concerning this color and its cause, see Bulletin 20, U. S. Geological Survey, p. 75, 1885.

cations of another trapezohedron in which the value of *m* can be but little less than 2.

The optical properties of this garnet are anomalous. Thin sections were prepared parallel to the cube, dodecahedron and octahedron of the most suitable crystals which could be procured and the optical action seen, so far as it possesses regularity, corresponds to the observation of Klein.* The action is weak and its regularity is no doubt disturbed by the numerous inclusions of quartz at the base of all crystals.

In the porphyritic rhyolite the garnets are usually very small but perfect and possess a somewhat lighter color than in the more felsitic rock, appearing brownish red or even approaching to a cinnamon color.

In chemical composition this garnet proves to be typical *spessartite*, that is, an alumina garnet in which the lime is almost wholly replaced by manganese with some ferrous oxide. The analysis given below was made by L. G. Eakins, in the Denver laboratory of the U. S. Geological Survey. The material analyzed was of the common dark red variety from the main locality, first described, and was obtained from about 30 crystals, which were crushed and the powder carefully examined under a lens, only the transparent and perfectly pure particles being appropriated for analysis.

Sp. Gr. 4.23 at 18° C.

SiO_2	35.66
Al_2O_3	18.55
Fe_2O_3	.32
FeO	14.25
MnO	29.48
CaO	1.15
K_2O	.27
Na_2O	.21
H_2O	.44
	100.33

* C. Klein. "Optische Studien am Granat." Nachr. v. d. k. Ges. d. Wiss. zu Göttingen, 1882, 457.

Topaz appears in the lithophyses of all modifications of this rhyolite, though much less abundantly than the garnet. Its crystals are prismatic, clear and transparent, either colorless, pale bluish or distinctly wine yellow, and show a fine development of all faces represented. The form is the usual one for this mineral, the faces, in order of prominence, being:

$$\infty P\ (110),\ \infty \breve{P}2\ (120),\ 2P\ (221),\ 0P\ (001),\ 2\breve{P}\infty\ (021),$$
$$4\breve{P}\infty\ (041),\ \infty \breve{P}\infty\ (100),\ \infty \breve{P}3\ (130),\ \text{and}\ 2\bar{P}\infty\ (201).$$

The largest crystals which have been found (not seen by the writer), are said to have measured about one-half inch parallel to the brachy-axis, but such specimens are very rare and the average diameter is not more than one-eighth of an inch. As the prisms are attached in all positions double terminations are frequent. These never show any tendency to hemimorphism. The crystals occur singly as a rule, but groups are not uncommon.

In the porphyritic rock of the northern dikes the topaz occurs in very small colorless prisms, easily mistaken for quartz when not closely examined.

Concerning the color of the topaz it was noticed that nearly all of them obtained from open cavities were colorless or of the pale bluish tint, while those found on breaking open solid masses were most frequently wine-yellow. As nearly all specimens were obtained from fragments broken out by visitors, within the past two or three years, it would seem that the action of the sun-light might have produced the change in color. J. Roth mentions,* while considering the changes produced in minerals by light, that von Kokscharow has noted the bleaching of deep wine-yellow topaz from the Urals, to an impure bluish white, on an exposure to sun-light, of some months duration.

* Allgemeine und chemische Geologie, Bd. i, p. 42.

Relation to other occurrences.—The Chalk Mountain occurrence, already referred to, is analogous to the present case in that the containing rock is a rhyolite and that the topaz occurs in cavities, but in detail the instances differ. In the Chalk Mountain rock the cavities are small and show no tendency to the lithophysal structure, and sanidine is the most abundant of the associated minerals, with some quartz and a little biotite.

An occurrence in Utah seems to be much more closely related to that of Nathrop. The locality was discovered by Henry Engelmann, geologist of Capt. J. H. Simpson's expedition across Utah in 1859, and is mentioned in Dana's System of Mineralogy. Engelmann states in the report of Simpson's expedition* that the topaz crystals were found loose on the surface and that they "apparently originated from one of the trachytic porphyries in that neighborhood." He did not see any in the supposed gangue and his statement, unaccompanied by any description of the rock, has naturally been overlooked or discredited.

I am indebted to Prof. J. E. Clayton of Salt Lake City who has visited the locality in person, for information and for specimens illustrating this occurrence.† The locality is about forty miles north of Sevier Lake and nearly the same distance W.N.W. from the town of Deseret on the Sevier River. The mountain containing the topaz ("Thomas' Range" of Simpson's Report) is isolated, in an arid region. It is about six miles long from north to south, has a flat top and precipitous slopes, and consists of a white or grayish eruptive rock, an evident overflow, with indistinct banded structure and many amygdaloidal cavities in which the topaz occurs. A small fragment of the rock, sent by Prof. Clayton, seems to be a

* Report of Explorations across the Great Basin of the Territory of Utah, etc., by Capt. J. H. Simpson, Engineer Department U. S. Army. Washington, 1876, p. 324.

† Another reference to this locality upon information derived from Professor Clayton has been made by Mr. G. F. Kunz in the Geological Survey publication, "Mineral Resources of the United States, 1883 and 1884," by A. Williams, Jr., in the article on Precious Stones, p. 738. The locality is first mentioned, in a very confusing manner, as if in the Pike's Peak region; the locality is wrongly stated as west of Sevier Lake; and the date of Captain Simpson's expedition is given as 1847.

normal rhyolite. It contains small brilliant quartz and sanidine crystals lying in a dull white matrix, much resembling the common Nathrop rock. The sanidine exhibits a delicate but distinct bluish color parallel to a plane which could not be certainly determined but which no doubt corresponds to the orthodome $\frac{1}{2}P\overline{\infty}$.

The crystal forms shown by this topaz are given by Engelmann, as follows: exhibited by all, ∞P, $\infty \breve{P}2$, $0P$, $4\breve{P}\infty$, $2P$; by most crystals, $2\breve{P}\infty$, P, $\frac{1}{2}P$; by a few, $4P$, $2\bar{P}\infty$. From an examination of a few loose crystals sent me by Professor Clayton, I can add that $\infty \breve{P}\infty$ is sometimes developed, while $0P$ is lacking entirely in a few cases.

These crystals from Utah are larger than those from Nathrop. The base of the prisms is said to be rough and imperfect, only the ends being clear. Associated minerals have not been observed and details concerning the cavities are lacking. Nearly all crystals so far found are colorless, though pinkish, wine yellow and blue crystals have been noticed.

From various statements which have come to my notice it seems highly probable that a portion of the topaz found in different Mexican localities is also derived from eruptive rock. In no case has this been actually proven, so far as I know, by the production of specimens.

This is, it is believed, the first known occurrence of garnet in cavities of rhyolite. In the list of minerals known to occur in this manner in rhyolite J. Roth* mentions quartz, tridymite, sanidine, biotite, augite and topaz, the latter from Chalk Mountain only. To this list must be added garnet and fayalite. The occurrence of the latter mineral very recently described by Iddings† from the Yellowstone National Park is very similar to that of the Nathrop minerals.

* Allgemeine und chemische Geologie, Band ii, p. 215, 1885.

† Am. Jr. Sc., July, 1885, p. 58. It has also been recently observed by Tenne in obsidian from Cerro de las Navajas, Mexico. Zeitschr. d. deutschen Geol. Gesellschaft, 1885, 613.

The mode of formation of the topaz and garnet is not fully determinable, but it is evident that they are not secondary products, like zeolites, but primary, and produced by sublimation or crystallization from presumably heated solutions, contemporaneous or nearly so with the final consolidation of the rock. The lithophysal cavities seem plainly caused by the expansive tendency of confined gases or vapors, while the shrinkage cracks in the walls and white masses of the Nathrop rock suggest the former presence of moisture. Certainly the history of the lithophyses themselves embraces that of both topaz and garnet.

Composition of the rhyolites containing topaz.—Below are submitted quantitative analyses of the only rhyolites known to contain topaz in the manner described. Under I is given the analysis of the Chalk Mountain rhyolite or nevadite, by W. F. Hillebrand; under II that of the denser Nathrop rock, and under III that of the Utah rhyolite,—both by L. G. Eakins. Analysis III was made upon the small fragment above described, which was sent me by Prof. Clayton, as typical of the occurrence.

	I.	II.	III.
SiO_2	74.45	69.89	74.49
Al_2O_3	14.72	17.94	14.51
Fe_2O_3	none	0.39	0.57
FeO	0.56	0.52	0.32
MnO	0.28*	0.23	trace
CaO	0.83	trace	1.03
MgO	0.37	0.14	trace
K_2O	4.53	4.38	4.64
Na_2O	3.97	4.21	3.79
Li_2O	trace	trace	trace
H_2O	0.66	2.07	0.64
P_2O_5	0.01	trace	
	100.38	99.77	99.99

From the above it is seen that the three topaz-bearing rhyolites agree quite remarkably in composition. They are all silica-alumina-alkali rocks, other constituents

* As MnO_2 in this rock.

being present in almost insignificant quantities. It is however by no means a rare composition which is possessed by these rocks. The examination of the rhyolites of the Great Basin, near the 40th parallel, by the chemists of the King Survey showed several rocks closely allied to these in composition and similar ones have been described from other parts of the western United States and from Europe.

NOTE ON WHAT APPEARS TO BE A NEW MINERAL FROM THE GAGNON MINE, BUTTE, MONTANA.

BY RICHARD PEARCE.

The mineral in question has as yet been found only in massive form, with an appearance much like bornite. It has a Specific Gravity 4.95, and Hardness 3.5–4.

An analysis of apparently pure substance gave the result below:

	Found:	Calculated for $3Cu_2S, Ag_2S, 2ZnS$:
Cu	41.10	41.4
Ag	24.66	23.5
Zn	9.80	14.1
Fe	2.09	
S	20.51	20.9
insol	1.02	
	99.18	99.9

The analysis leads to the formula $3Cu_2S$, Ag_2S, $2ZnS$, the calculated composition of which is given above. From this material it seems difficult to determine whether the mineral is to be regarded as new, or as a variety of bornite in which the copper has been partly replaced by silver, and the iron nearly all replaced by zinc. It seems to me however that the mineral is entitled to a distinctive name, should the composition given prove to be correct. Efforts to secure further and better material will be made.