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## THE COLOR OF THREE VARIETIES OF QUARTZ

EDW. F. HOLDEN, *University of Michigan*

The three notes here presented are by-products of an investigation pertaining to the cause of color in rose quartz. Two of the notes have some bearing on that problem.

In the analyses given in this paper the procedure was as follows: (1) the quartz fragments were ground in an agate mortar, (2) the silica was volatilized by gentle heating with HF and H<sub>2</sub>SO<sub>4</sub> acids in a platinum crucible, (3) the residue was fused with KHSO<sub>4</sub>, (4) this fusion was dissolved in dilute H<sub>2</sub>SO<sub>4</sub>, and (5) the iron was determined by reduction to the ferrous state and titration with a dilute KMnO<sub>4</sub> solution. Titanium was colorimetrically determined. The colors of minerals and solutions mentioned below are given in terms of Ridgway's<sup>1</sup> color scale.

### 1. NOTE ON THE COLOR OF CITRINE

On preparing a number of colloidal solutions of hydrous ferric oxide, the writer was impressed by their marked resemblance in color to that of citrine. These solutions were prepared by adding a few cc. of a neutral FeCl<sub>3</sub> solution to 500 cc. of water at its boiling temperature. The color of the solutions varied with the iron content from dark red, thru orange, to light yellow, as shown in the following table. The colors given in the table were those of a thickness of 10.5 cm. of solution viewed against a white background.

TABLE I. THE COLOR OF COLLOIDAL HYDROUS FERRIC OXIDE SOLUTIONS.

%Fe <sub>2</sub> O <sub>3</sub> IN THE SOLUTION	RIDGWAY'S COLOR	
0.068 %	1 i	(dark red)
.034	4 h	(red)
.0059	15 full	(orange)
.0034	17 full	(yellow-orange)
.0007	21 "d	(pale yellow)

<sup>1</sup> Robert Ridgway. Color standards and color nomenclature. Washington, 1912.

In order to determine whether the amount of iron in citrine is proportional to the depth of its color, three specimens from Brazil were analyzed for that element. Specimen No. 1 had a deep amber color, while No. 2 and No. 3 possessed about the same pale yellowish tinge, but No. 2 was slightly darker. Table II gives the results of duplicate analyses:

TABLE II.  $\text{Fe}_2\text{O}_3$  IN CITRINE FROM BRAZIL

SPEC. NO.	RIDGWAY'S COLOR	$\text{Fe}_2\text{O}_3$		
		1.	2.	Aver.
1	9 k	0.029%	0.023%	0.026%
2	19 '''b	.007	.008	.008
3	21 '''f	.010	.012	.011

These results show that the iron content, in general, varies with the depth of color, altho theoretically the  $\text{Fe}_2\text{O}_3$  percentage in No. 2 and in No. 3 should be reversed. But they are very close in color, while No. 1, decidedly darker, is much higher in iron.

A microscopic examination of fragments immersed in clove oil showed these citrines to be very clear, the only impurities, aside from bubbles, being a very few stains of limonite on one or two fragments of No. 1. These stains were not at all abundant enough to account for its much higher  $\text{Fe}_2\text{O}_3$  content. The suggestion is offered that the color is due to submicroscopic particles of hydrous ferric oxide. If we calculate gs.  $\text{Fe}_2\text{O}_3$ /cc. of citrine and of solution it is found that the ferric hydroxide in citrine possesses about the same coloring power as in the aqueous solutions prepared by the writer. Specimen No. 1, with 0.026%  $\text{Fe}_2\text{O}_3$  contains 0.00069 gs.  $\text{Fe}_2\text{O}_3$ /cc. ( $2.65 \times 0.026 \div 100$ ). It is deep amber, and a colloidal ferric hydroxide solution containing the same number of gs.  $\text{Fe}_2\text{O}_3$  per cc. has the same color, in a layer of the thickness of the citrine specimen (1 cm.).

This suggestion as to the pigment agrees with Nabl's<sup>2</sup> statement that citrine has an iron oxide absorption spectrum. The loss of color on heating may be most probably accounted for by a dehydration of the hydroxide.

<sup>2</sup> Arnold Nabl. *Min. petr. Mitt.*, 19, 273-6, 1900.

## 2. A PINK QUARTZ CRYSTAL COLORED BY HEMATITE INCLUSIONS

Typical rose quartz is massive, of a rose-red color (equivalent to Ridgway's 67''e-67''g, "pale laelia pink"). It is always associated with granitic rocks, either in coarse pegmatites or in hydrothermal veins. Occasionally pink or grayish-pink quartz *crystals* are found, in veins of a lower temperature of formation than those of rose quartz. During the study of rose quartz the writer wished to establish the difference in cause of color between these pink crystals and typical rose quartz.

A rock crystal (locality unknown) with a phantom crystal of pinkish quartz, from the University of Michigan's determinative collections, furnished a good specimen for this purpose. The phantom, while apparently of a uniform pink color, is made up of groups of thin, colored layers parallel to the rhombohedron faces of the crystal. The color of the pink portion is a grayish-pink-purple (R. 71''c). Under the microscope the pink layers were found to contain a fairly large number of brownish-red, irregular inclusions and bubbles. Two 1 gram samples were prepared for analysis. The powder was decidedly pink (that of rose quartz is white). The analyses showed:

	1.	2. <sup>a</sup>	Aver.
Fe <sub>2</sub> O <sub>3</sub>	0.042	0.044	0.043%

Evidently the color is due to fine inclusions of hematite, which also accounts for the pink color of the powder. Due to unavoidable contamination of the samples by some of the colorless quartz next to the pink layers, this result is somewhat lower than the actual amount of hematite present. Ordinary rose quartz contains much less Fe<sub>2</sub>O<sub>3</sub> than does this specimen, usually not over 0.01%,<sup>3</sup> and in rose quartz it is certainly not present as microscopic hematite particles. The cause of the color of rose quartz has not been definitely determined.

An additional confirmation of this theory as to the pigment was obtained by mixing finely ground specular hematite with sodium silicate. It was found that the hematite could be ground to better advantage if mixed with a small amount of quartz. This liquid is so viscous as to hold the hematite particles in suspension, until the mass hardens. Its color may then be very easily compared

<sup>3</sup> Analyses, by the writer, of 20 specimens of rose quartz averaged 0.0085% Fe<sub>2</sub>O<sub>3</sub>. Only one contained over 0.013%.

with that of the mineral. A content of 0.03%  $\text{Fe}_2\text{O}_3$  gave the jelly a purplish-pink color (R. 67'''e) similar to that of the pink quartz crystal, and 0.06% deepened the color to 67'''d.

The color of such pink crystals may, then, be attributed to hematite inclusions, and this distinguishes them from true rose quartz.

### 3. ROSE QUARTZ WITH NUMEROUS RUTILE INCLUSIONS

Rose quartz is abundant in Deering, N. H. It occurs in veins associated with a granite, and found either in the granite or in an intruded schist. At one outcrop rose quartz veins were found near a vein of ordinary gray quartz. Both types, rose and gray, were differentiated from the same magma, formed at nearly the same time, in the same place, and have had the same geological history.

It was thought that possibly analyses of a specimen from each vein might indicate the cause for their different colors, but this was not the case. They both contained practically the same low amounts of iron and manganese characteristic of rose quartz,<sup>4</sup> but the rose quartz contained eight times as much  $\text{TiO}_2$  as the gray (0.029% and 0.0038%  $\text{TiO}_2$ , respectively). However, a microscopic examination of the rose quartz fragments immersed in clove oil showed them to contain abundant long and extremely narrow inclusions of rutile. This explained the much higher titanium content of the rose quartz as compared to the gray.

This is of much interest as the rose quartz has a somewhat more bluish or bluish-gray tinge than is usual for that mineral. It is probably due to this higher  $\text{TiO}_2$  content, as generally rose quartz contains only about 0.003%.<sup>5</sup> The influence of fine rutile needles upon light produces a blue color, as Watson<sup>6</sup> has shown for the blue quartz with 0.069%  $\text{TiO}_2$ , from Nelson Co., Va.

The fact that both the rose and the gray quartz have gone thru the same geological history casts doubt on the theory sometimes entertained, that the rose color may be due to the action of radioactive minerals or solutions on white quartz. If the rose quartz

<sup>4</sup> Average of 20 analyses, by the writer: MnO 0.0003%,  $\text{Fe}_2\text{O}_3$  0.0085%.

<sup>5</sup> Average of writer's analyses.

<sup>6</sup> T. L. Watson and R. E. Beard. *Proc. U. S. Nat. Museum*, 53, 553-63, 1917. Analysis by Robert Robertson, The Virginias, 1885, 6, 2. Holland, (*Mem. Geol. Surv. India*, 28, pt. 2, 138-9, 1900) is quoted by Watson as having made a similar observation on blue quartz from India.

received its color in this manner there seems to be no reason why the same agency should not have also transformed the gray quartz, of the same approximate age, and in the same outcrop.

#### SUMMARY

The results of a preliminary study on the cause of color in certain varieties of quartz seem to justify the following conclusions: (1) The color of citrine is probably due to sub-microscopic hydrous ferric oxide particles. (2) A pink crystal of quartz was found to differ from typical rose quartz in being colored by hematite inclusions of microscopic dimensions. It is quite likely that this explanation is generally true for all pink crystals of quartz. (3) A rose quartz from Deering, N. H., which is more bluish than most rose quartz, owes its color to an unusual content of fine rutile inclusions.

#### NOTE ON THE COMPOSITION OF THOMSONITE<sup>1</sup>

EDGAR T. WHERRY, *Bureau of Chemistry, Washington, D. C.*

Recent study of the plagioclase feldspars<sup>2</sup> has led to the conclusion that they represent a case of atomic isomorphism, one calcium atom being equivalent, not to two sodiums as often supposed, but to a single sodium atom; and  $\text{SiO}_4$  not being replaced by  $\text{Si}_3\text{O}_8$ , but remaining the silicate radicle throughout the series. In this connection it seemed worth while to consider whether other instances of alleged replacement of Ca by  $\text{Na}_2$  and of  $\text{SiO}_4$  by  $\text{Si}_3\text{O}_8$  were really valid. The formulas ascribed to certain of the zeolites were therefore investigated, and in one case the relations turned out to be so different from those usually recognized that a brief note seems desirable.

In Dana's System of Mineralogy the formula assigned to thomsonite is  $(\text{Na}_2, \text{Ca})\text{Al}_2\text{Si}_2\text{O}_8 + 5/2 \text{H}_2\text{O}$ , with the ratio of  $\text{Na}_2 : \text{Ca}$  varying from 3 : 1 to 1 : 1. These data are frequently quoted, the misprint being overlooked (it should be 1 : 3). The theoretical compositions given are based on  $\text{Na}_2 : \text{Ca}$  ratios of 1 : 3, 1 : 2, and 1 : 1, but not one of the twenty analyses cited agrees with the two last, and only a few approach the first. The occasional high silica is pointed out but "it does not seem possible to

<sup>1</sup> Read at the meeting of the Mineralogical Society of America, December 29, 1922.

<sup>2</sup> *Am. Min.*, 7, 113-121, 1922.