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[1]

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

Recent study of the plagioclase feldspars[2] 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 SiO_4 not being replaced by Si_3O_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 Na_2 and of SiO_4 by Si_3O_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 $(Na_2,Ca)Al_2Si_2O_8 + 5/2$ H_2O, with the ratio of Na_2 : 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 Na_2 : 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

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[1] Read at the meeting of the Mineralogical Society of America, December 29, 1922.

[2] *Am. Min.*, 7, 113-121, 1922.

explain this, in all cases, by the assumption of free quartz." Clarke[3] noted that the excess silica might be in "solid solution" or else as trisilicate groups.

Doelter[4] cited 67 analyses (a few obviously erroneous, or duplicates) and referred favorably to Tschermak's interpretation that there are represented in thomsonite two substances, $H_4Na_2Al_2Si_2O_{10}\cdot 3H_6CaAl_2Si_3O_{13}\cdot Aq$ and $H_4Na_2Al_2Si_2O_{10}\cdot 3H_4CaAl_2 Si_2O_{10}\cdot Aq$. It would require rather convincing proof before the existence of any such complexities as these in a widespread, well crystallized mineral could be accepted.

The two points of interest being the variation in the silica and in the soda contents, it seemed that some light might be thrown on the relationships by plotting SiO_2 against Na_2O in all reasonably dependable analyses of the mineral available.[5] This is done in figure 1. Analytical figures are indicated by dots surrounded by circles, theoretical values by small squares. As the probable error in mineral analyses in general is perhaps one per cent

FIGURE 1. GRAPHICAL REPRESENTATION OF THE COMPOSITION OF THOMSONITE
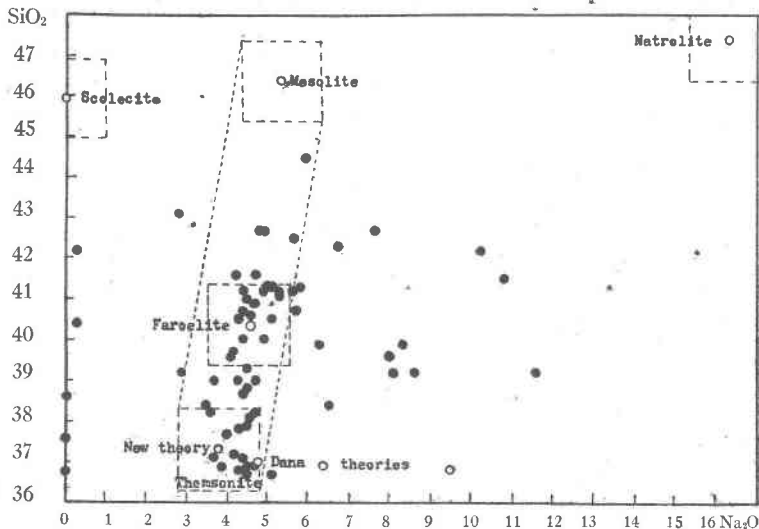
[3] *Bull. U. S. Geol. Survey*, **588**, 45, 1914.

[4] *Handbuch der Mineralchemie*, **2**, no. 13, 16-29, 1919.

[5] As the alumina and water are practically constant thruout and as the lime varies inversely as the soda, nothing would be gained by including them in the diagram.

of most constituents, dash lines have been drawn around the theoretical values at the corresponding distances.

This diagram shows, first, that the majority of thomsonites are essentially uniform in soda content. The bulk of the analysis-spots, including all of the most dependable ones, fall in a narrow strip extending up and down, with a slight slope toward the right. There being practically no zeolites containing less silica than thomsonite, admixture or solid solution of which could lower the SiO_2 content, it seems reasonable to accept its composition as indicated by a point lying toward the bottom of this strip. The Dana theory for $Na_2 : Ca = 1 : 3$ lies at its right-hand edge, but a somewhat simpler one with the ratio of these constituents $1 : 4$ falls more nearly in its center, and may be accepted as the probable formula of normal thomsonite:

$Na_2O.4CaO.5Al_2O_3.10SiO_2 \cdot 12H_2O$ or $NaCa_2(Al_5Si_5O_{20}).6H_2O$.

The atomic weights of silicon and aluminium not being known with sufficient certainty to justify extending the calculated values to more than one decimal place, the theoretical composition may be stated as: SiO_2 37.3, Al_2O_3 31.6, CaO 13.9, Na_2O 3.8, H_2O 13.4, sum 100.0%.

The diagram further yields no support to the view that the excess of silica is due to admixed quartz, for were that the case, the strip of analyses should slope to the left, toward where the 100% SiO_2 point would be located, instead of to the right. Similarly, were an Si_3O_8 equivalent of normal thomsonite responsible for the excess silica, it would lie well to the left of the normal formula point, and lead to slope of the strip in that direction.

When the theoretical compositions of the next series of zeolites more siliceous than thomsonite are plotted in the diagram, a reasonable interpretation of the relations is made evident. The chief variation from the normal formula is plainly in the direction of mesolite (with $Ca : Na_2 = 2 : 1$). In very few of the analyses plotted was the material demonstrated to be optically homogeneous; and Bøggild[6] has observed that intergrowth of mesolite and thomsonite does actually occur. It might be inferred then that all those analyses, lying above the bottom of the strip, were made on mechanical mixtures of these two minerals.

There is, however, too dense a clustering of analysis points at about 41% SiO_2 to make it probable that mechanical mixture

[6] *Math.-fys. Meddelelser, Danske Vidensk. Selskab.*, **4**, no. 8, 42 pp., 1922.

accounts for the excess silica. It seems more likely that a definite species intermediate between mesolite and thomsonite exists. The name "faroelite" has in fact been applied to such a mineral (Heddle, 1857); the earlier name "mesole" is incorrectly formed. Optical data should be well adapted to throwing light on this matter. The optical data on thomsonites in the literature are scanty and poor. The refractive indices usually given are, as shown by Bøgglid, not typical. Normal low-silica thomsonite from the original locality of the mineral, Dumbarton, Scotland, was accordingly examined by the immersion method and found to have $\alpha = 1.520$, $\beta = 1.525$ and $\gamma = 1.540$. To obtain the values for faroelite, the "thomsonite" from Table Mt., Colorado was used[7] because unusually accurate analyses of it have been made, the ratio being approximately $Na_2O : CaO : Al_2O_3 : SiO_2 : H_2O = 1 : 3 : 4 : 9 : 9$, corresponding to the formula $Na_2 Ca_3 (Al_8Si_9O_{34}. 9H_2O$, and the composition: Na_2O 4.6, CaO 12.5, Al_2O_3 30.5, SiO_2 40.3, H_2O 12.1, sum 100.0%. It proved to have much lower birefringence and indices, these rather variable from one grain to another but averaging $\alpha = 1.512$, $\beta = 1.513$, $\gamma = 1.518$. "Gonnardite" (Lacroix, 1896) having essentially the same composition and indices, is evidently the same mineral; mesolite shows the still lower values $\alpha = \beta = 1.505$, $\gamma = 1.506$.

Since, then, faroelite is both chemically and optically distinct from thomsonite, it is apparently to be regarded as a definite mineral species. Analysis points which lie above the faroelite area in the diagram no doubt represent mixtures of it with mesolite; those lying between it and thomsonite are correspondingly to be interpreted as mixtures, or possibly solid solutions, of the two minerals.

There remain to be considered the analyses falling well outside of the thomsonite-mesolite strip. Those lying to the left are so far from this strip and separated from it by such a decided gap as to indicate that an entirely distinct mineral is represented,

[7] Material from the type collection, determined by Cross and analyzed by Hillebrand, was available for study in the National Museum collection. Similar material from Nova Scotia, recently described by Walker with analysis by Todd (*Univ. Toronto Studies, Geol. Ser.*, No. 14, p. 72, 1922) has also been examined and gives values agreeing closely with those of the Colorado mineral. These two series of analyses were made on material optically controlled and carefully purified, and are probably worth more than all those in the early literature.

with little tendency to unite either isomorphously or in non-isomorphous solid solution with normal thomsonite. The earliest name given to presumably soda-free material was comptonite (Brewster, 1821), although it has also been subsequently termed chalilite, picrothomsonite, sloanite, calciothomsonite, etc. Unfortunately none of the analyses of these are sufficiently dependable to assign it a definite formula.

The 10 or more analyses whose points lie to the right of the dense strip exhibit a tendency toward natrolite. Bøggild showed that intergrowth of natrolite and thomsonite is fairly frequent, and these analyses may well have been made on mixtures,[8] for there is no clustering of points in such a manner as to suggest that appreciable solid solution occurs between these minerals.

It is concluded, then, that much of the apparent variability in composition of thomsonite is due to the fact that two species are represented, although part of the variation, especially in cases of high soda, is due to the analyses having been made on mixtures. There is no evidence of isomorphism between calcium and sodium, nor between SiO_4 and Si_3O_8. Thomsonite appears to be a non-variable mineral, with the formula $NaCa_2(Al_5Si_5O_{20}).6H_2O$; and faroelite, which is optically distinct and deserves species rank, is probably $Na_2Ca_3(Al_8Si_9O_{34}).9H_2O$.

[8] Practically all date from the days before the importance of optical demonstration of homogeneity was recognized, when analyses more often than not represented mixtures. The fact that simple ratios are shown by such mixtures occasionally does not render them of any value in deciding the composition of a mineral or in demonstrating the existence of isomorphism.

OPTICAL NOTES ON THOMSONITE

SAMUEL G. GORDON, *Academy of Natural Sciences of Philadelphia*

The usually quoted indices of refraction for thomsonite are the values of Des Cloizeaux[1] and Lacroix,[2] namely, $\alpha = 1.498$, $\beta = 1.503$, $\gamma = 1.525$, which were probably determined indirectly from measurements of optic axial angles and birefringences of oriented sections. In 1912, Scheit[3] described thomsonite crystals containing a nuclear crystal of natrolite, from Jakuben in the Bohemian Mittelgebirge, which gave the values, upon immersion,

[1] Manual de Minéralogie, 374, **1862.**
[2] Lévy and Lacroix: Les Minéraux des Roches, **1888**; Larsen quotes α as 1.497.
[3] *Min. Petr. Mitth.*, **31,** 495, 1912.