

CANCRINITE AS A HIGH TEMPERATURE HYDROTHERMAL MINERAL FROM COLORADO

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The material described in this paper was collected by one of the authors (Larsen) in the summer of 1913, in the course of the geologic mapping of the Uncompahgre Quadrangle, Colorado. It came from the area occupied by an unusual group of intrusive, coarse grained nephelite and melilite rocks which are located near Iron Hill near the eastern boundary of the Uncompahgre Quadrangle, about midway between the north and south boundaries and about twenty miles south of the village of Iola and twenty miles southwest of the town of Gunnison, Colorado.

Cancrinite is an abundant mineral in the Iron Hill area in several genetic habits: as an alteration product of nephelite, as a reaction product between nephelite and calcite, as a mineral in contact metamorphic limestone, also probably as a primary mineral in a cancrinite syenite, and again as a hydrothermal replacement of melilite. The latter occurrence will be described in this paper. Sulphatic cancrinite² has already been described as a vein mineral from this area.

The material described in this paper was found in the small gulch south of Beaver Creek, about a mile east of the road up Cebolla Creek and about one-quarter of a mile south of Beaver Creek. The country rock is uncompahgrite, a coarse to giant-grained rock made up chiefly of melilite with pyroxene, biotite, magnetite, perovskite and apatite. The melilite of the uncompahgrite of this area is more or less altered to a mixture of vesuvianite, diopside and titaniferous garnet which has all the appearance of a contact metamorphosed limestone. The alteration begins from irregular veinlets and extends out from them.

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² Larsen, E. S., and Steiger, George. Sulphatic Cancrinite from Colorado, *Am. J. Sci.*, 42, 332-34 (1916).

A veinlet of the cancrinite bearing rock about six centimeters across cuts the partly altered uncomphagrite. About half of the vein is made up of white to colorless cancrinite in grains that are as much as ten centimeters in length and enclose poikolitically numerous grains of monticellite, dark titaniferous garnet and other minerals. In parts of the veinlet vesuvianite occupies the position of the cancrinite and serves as the matrix for the monticellite. There is also some green hornblende and remnants of perovskite and apatite from the original uncomphagrite. Pale green phlogopite, calcite and brown garnet together with chlorite, and aggregates of zeolites make up much of the borders of the veinlet. The monticellite, vesuvianite and garnet seem to be the closest associates of the cancrinite both in space and in time of formation.

The vesuvianite is brown in color, uniaxial negative, and has the indices of refraction $\omega=1.736$, $\epsilon=1.732$. These indices of refraction are somewhat higher than those commonly given for vesuvianite, ($\omega=1.708$ to 1.720) and are probably due to a comparatively high titanium or iron content.

The monticellite is pale yellow brown and leaches out on weathering. It is biaxial, negative, has a large axial angle, the dispersion is $\rho > \nu$ and easily perceptible. The indices of refraction are $\alpha=1.653$, $\beta=1.669$, $\gamma=1.674$. These are slightly higher (.006) than those given for the monticellite from Arkansas with 6.4% of FeO and MnO.

The cancrinite has a perfect prismatic cleavage; the large cleavage surfaces look much like those of calcite. It has a specific gravity of 2.51. It is uniaxial, negative, and $\omega=1.524$, $\epsilon=1.501$. These data are very near those given for other cancrinites although the index of refraction is somewhat high.

Several grams of the cancrinite were carefully separated by heavy solution and used for the analysis. A microscopic examination of the powder used in the analysis showed a very small amount of a prismatic mineral with a rather high index of refraction and sensibly no birefringence. The sample was carefully analyzed by Foshag with the results shown in Table I, column 1. The molecular ratios are given in column 2. The silica, lime, alumina, magnesia, phosphorus and chlorine were checked by duplicate analyses.

TABLE I. ANALYSES AND RATIOS OF CANCRINITE FROM COLORADO

	Per Cent	Molecular ratios
SiO ₂	33.64	.5579
Al ₂ O ₃	29.82	.2918
CaO	8.64	.1540
MgO	0.39	.0097
MnO	tr.	
Na ₂ O	15.41	.2486
K ₂ O	0.50	.0053
CO ₂	6.79	.1543
P ₂ O ₅	none	
Cl	tr.	
SO ₃	0.03	.0004
H ₂ O	4.61	.2556
	99.83	

The ratios lead to the general formula: $5\text{Na}_2\text{O} \cdot 3\text{CaO} \cdot 5\frac{1}{2}\text{Al}_2\text{O}_3 \cdot 11\text{SiO}_2 \cdot 5\text{H}_2\text{O}$. W. Eitel³ in a study of the systems nephelite-CaCO₃, and nephelite-Na₂CO₃, found two compounds: 3Ne. CaCO₃ and 3Ne. Na₂Ca(CO₃)₂ which he believed to be essentially natural cancrinite. The agreement of the analysis of the Colorado mineral with the theoretical composition of the first compound is sufficiently close to indicate that the natural mineral is essentially $3\text{NaAlSiO}_4 \cdot \text{CaCO}_3$ (Theoretical composition, Table 2, col. 1). The variations are rather too great for this simple composition however, for in both this cancrinite and the sulphatic cancrinite there is a decided excess of alumina and a deficiency of soda indicating an isomorphous mixture of some more aluminous compound and there is, further, an excess of CaCO₃. It was found that the compound $\text{Na}_2\text{O} \cdot 2\text{Al}_2\text{O}_3 \cdot 3\text{SiO}_2$ (the silicate corresponding to the zeolite echellite) when considered as isomorphous with the nephelite leads to the best agreement with the actual analysis. On this basis the Colorado mineral would have the following composition:

NaAlSiO ₄ * (Nephelite)	57.43
Na ₂ Al ₄ Si ₃ O ₁₃ (Echellite)	23.25
CaCO ₃	14.44
H ₂ O	4.44
	99.56

³ *Tsch. Petr. Mitt.*, **38**, 1-38 (1925).

The theoretical composition based on this assumption is given in Table 2, Column 2.

TABLE 2. THEORETICAL COMPOSITION OF CANCRINITE

	1	2
SiO ₂	32.4	33.6
Al ₂ O ₃	27.5	31.0
CaO	7.9	8.7
Na ₂ O	16.72	13.7
CO ₂	5.4	5.8
H ₂ O	5.4	4.4

Neither of these interpretations are entirely satisfactory. So far it has not been possible to attribute the variations to albite in solid solution as has been shown to be the cause of the variations in nephelite. It seems quite certain, however, that nephelite or carbonate-nephelite will be found to be an essential constituent.

THE ADDITION AND SUBTRACTION RULE IN GEOMETRICAL CRYSTALLOGRAPHY¹

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The addition or subtraction of the Miller symbols of two faces of a zone taken index by index gives another face of the zone. That is to say faces with the symbols $(h+p.k+q.l+r)$ and $(h-p.k-q.l-r)$ are in the zone $[hkl:pqr]$. This useful fact, now to be proved, may for convenience be known as the *addition and subtraction rule*.

PROOF OF THE ADDITION AND SUBTRACTION RULE

The intercept equations of planes through the origin parallel to any two faces, (hkl) and (pqr) , are, in terms of the intercepts a, b, c of a unit face, (111) , respectively:

$$\frac{hx}{a} + \frac{ky}{b} + \frac{lz}{c} = 0 \dots\dots\dots (1)$$

$$\frac{px}{a} + \frac{qy}{b} + \frac{rz}{c} = 0 \dots\dots\dots (2)$$

¹ Paper presented at the annual meeting of the Mineralogical Society of America at Ithaca, N. Y., December 31, 1924, under the title, AN INTERESTING AND USEFUL PROPERTY OF ZONES. See abstract in *Am. Mineral.*, 10, 68 (1925).