ACMITE OCCURRENCES ON THE CUYUNA RANGE, MINNESOTA

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ABSTRACT

Acmite has been found in quantity in the rocks (taconites) and veins of the Cuyuna district, Minnesota. In other districts acmite is largely in igneous rocks and veins, but a diopsidic acmite was reported from Långban, in veins in hematite.

The analyses of Minnesota acmite show a high percentage of the "acmite molecule," $Na_2O \cdot Fe_2O_3 \cdot 4SiO_2$; one of them purer than any other natural acmite that has been analyzed. This is a tea-green acmite in hypothermal veins. Disseminated acmite in the granules and matrix of the iron formation is brown. The brown color seems to be correlated with a manganese content rather than with other rare constituents.

A brown mineral has been known for a number of years in some high temperature veins in Cuyuna iron-bearing rocks and ores,[1] but it was variously identified by the writer and Doctor Thiel as epidote and pyroxene, for lack of good material. A recent exploration supplied a fair amount of drill core for a closer study. The drilling and study were financed by the University of Minnesota research funds of the Graduate School, and that support is gratefully acknowledged. The identification of acmite in this new occurrence is a minor incident to the main study of the stratigraphy of the Cuyuna rocks.

The drill core containing acmite is from a hole on the property of the Merritt Number Two Mine near Ironton, Minnesota. The collar of the hole is approximately 3100 feet north, and 4820 feet west of the southeast corner of Sec. 33, T. 47 N., R. 29 W. The hole was drilled diagonally down to the northwest almost at right angles to the bedding of the iron-bearing sediments. The acmite is abundant along the hole from a depth of 265 to 290 feet, showing that the acmite-bearing beds are 25 feet thick. The underground workings of the mine find the acmite very persistent along the strike of folded beds.

The beds adjoining the acmite rock show a series from the top down: (1) slaty, (2) cherty, (3) slaty; the terms used approximately as on the Mesabi Range,—slaty meaning very thin bedded, and cherty meaning somewhat variable wavy beds, one to 6 inches thick. The acmite is in and just below a cherty part of the series, which probably corresponds to the upper cherty beds of the Mesabi. In the Merritt mine it lies close below the beds of hard black manganiferous iron ore. Crosscuts from the ore into the footwall find very hard mining. Below the acmite rock are some hundreds of feet of softer carbonate slate and magnetite slate. The car-

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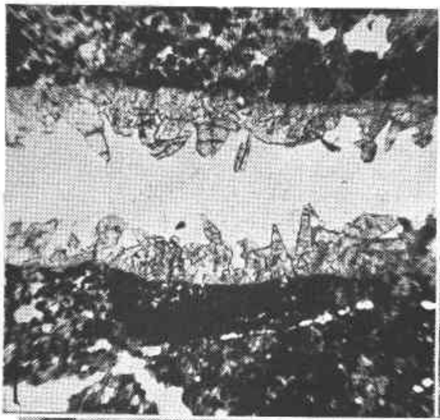
[1] Thiel, G. A., High temperature manganese veins of the Cuyuna range: *Econ. Geology,* **19,** 377–381 (1924).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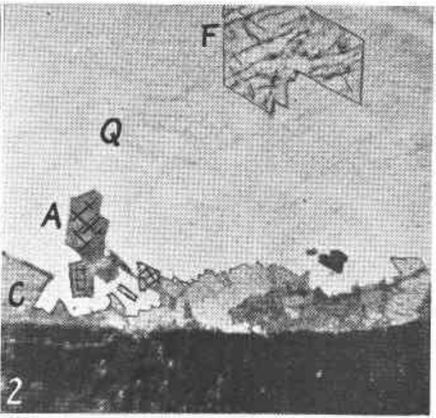
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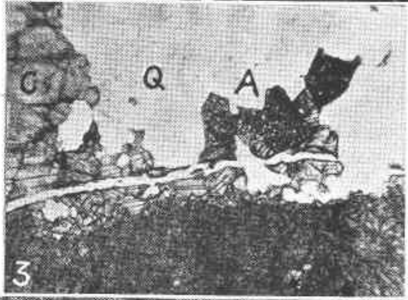
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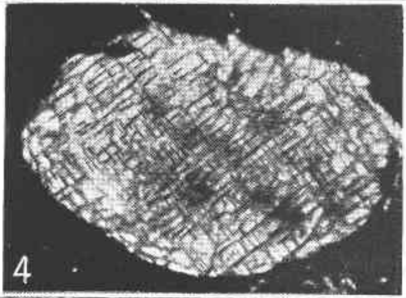
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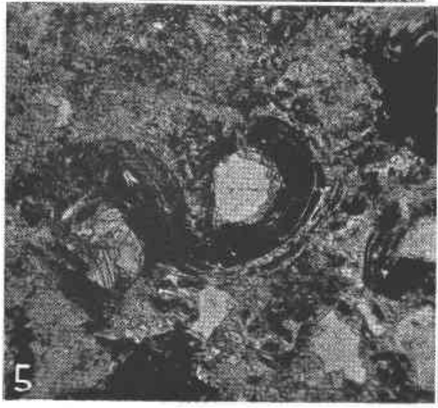
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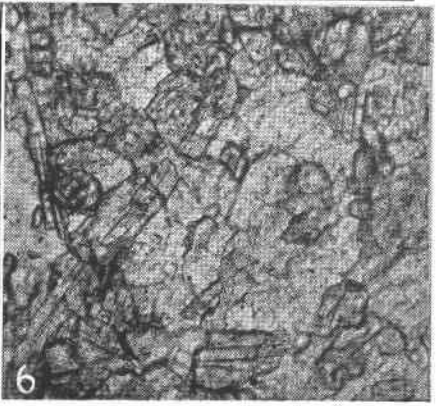
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bonate is largely manganosiderite in the slaty iron formation, and partly that in the veins, but some of the veins carry rhodochrosite, with minor amounts of calcium and magnesium.

The acmite is partly disseminated in the iron-bearing bed and partly in veins cutting the beds in considerable numbers. The veins carry rhodochrosite and were described by Thiel,[2] with the suggestion that at least part of the manganese of the Cuyuna ores is introduced. The same reasoning applies to acmite. It should be noted, however, that the acmite and rhodochrosite in veins seem especially abundant in those parts of the Cuyuna formation where the same minerals occur in the iron-bearing beds. Possibly there was some lateral secretion into the veins, or at least some reaction of vein solutions with the walls. The largest acmite concentration in a vein was $\frac{1}{8}$ to $\frac{1}{4}$ of an inch wide, and an inch or two long, alternating with quartz and pink carbonate irregularly.

Thin sections (Figs. 1, 2 and 3) show that the sequence of vein deposits is: (1) carbonate, (2) acmite, (3) quartz, and (4) adularia (valencianite of Winchell). In some veins one or more of the series may be missing. One slide shows enstatite and silicic plagioclase (as well as quartz and carbonate) associated with the acmite in a vein.

Thin sections also show acmite in the wall rock, partly as grains mixed with quartz and iron oxides (Figs. 3, 4 and 5), and partly as core and matrix of some oölites and "granules" like those of Mesabi taconite. The acmite grains show a wide range of dustiness from included hematite; some clear crystals, and some that are almost opaque.

The thin sections served to identify the acmite of these two occurrences, but since that in the vein is pale green and that in the rock is brown, it was thought best to test with x-rays. Doctor J. W. Gruner found both samples gave characteristic acmite patterns. The difference in color and the unusual occurrences led to optical tests (Table 1, columns 1 and 2). As Washington and Merwin noted,[3] "the pyroxenes are mark-

FIG. 1. Vein of acmite and quartz cutting taconite. (×32).

FIG. 2. The sequence from taconite wall is: (C) carbonate; (A) acmite; (Q) quartz, (F) adularia. (×32).

FIG. 3. Taconite wall rock and above it a vein. (C) carbonate; (A) acmite; (Q) quartz. A late quartz veinlet cuts the carbonate and acmite. (×32).

FIG. 4. An iron formation granule shows an acmite core with right angled cleavages. (×50).

FIG. 5. Oölitic structure involving hematite (black), acmite (gray), and quartz (white). (×27).

FIG. 6. Scattered subhedral acmite grains in a quartz matrix. (×66).

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[2] *Op. cit.*

[3] Washington, H. S., and Merwin, H. E., The acmitic pyroxenes: *Am. Mineral.*, **12**, 233–252 (1927).

edly zonal, so that, in most cases, optical methods or chemical analyses determine only approximate averages." The Cuyuna acmite shows some zoning, and the optical data are not reported beyond three significant figures. A comparison with data in the text books and recent papers suggested that these Cuyuna acmites had an unusually high content of the theoretical acmite molecule, and less of the usual diopside or other pyroxene molecules. Analyses were made to check this idea.

The brown acmite of the altered sediment was purified by crushing about 50 grams of core to 80 mesh, and dissolving carbonate by a brief treatment with dilute HCl; from the washed dried residue, quartz and other light minerals were mostly removed by floating them on bromoform. For the best sample, a core was selected where the acmite contained little hematite dust to start with; very little remained after acid treatment.

The green acmite, as it was picked out of the vein in fragments about $\frac{1}{8}$ inch thick, was more nearly pure. It was nevertheless given a similar purification. Microscopic examination of the 80-mesh concentrates showed quartz and hematite in very small amounts.

Analyses of Cuyuna acmites are numbers 1 and 2 of Table 1. Columns 3 to 8 of the table include the purest acmite analyses made or collected by Washington and Merwin[4] and one reported by Walker and Parsons.[5] Column 9 is added because of Washington's suggestion[6] that the brown color of some acmites may be from zirconia and ceria in the mineral. The compiled analyses suggest that the brown color is more likely a result of manganese. Column 10 gives the composition of the only pyroxene approaching acmite (about 3 parts acmite to 1 part diopside) that is said to occur in veins in hematite ore,[7] as does one of the Cuyuna samples.

A simple inspection of the analyses shows that the Cuyuna acmites are very rich in the "acmite molecule." Molecular proportions were calculated by the methods used and described by Washington and Merwin.[8] The green acmite of the vein has more than 91 per cent of the "molecule," higher than any of the other natural acmites. Other pyroxene molecules account for the remaining 9 per cent.

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[4] *Op. cit.*, pages 249–250.

[5] Walker, T. L., and Parsons, A. L., Acmite from nepheline syenite, French River, Ontario: *University of Toronto Studies*, No. **22**, page 12 (1926).

[6] Washington, H. S., The composition of rockallite: *Quart. Jour. Geol. Society*, **70**, 294 (1914).

[7] Sjogren, Hj., Urbanite, a new member of the pyroxene group: *Bull. Geol. Inst. Upsala*, **2**, 77–84 (1894).

[8] *Op. cit.*, pages 235–236.

TABLE 1. ANALYSES OF ACMITES FROM CUYUNA RANGE AND ELSEWHERE

	1 Cuyuna	2 Cuyuna	3 Quincy	4 Rockall	5 Ontario	6 Rundemyr	7 Greenland	8 Brevik	9 Libby	10 Urbanite	11 Theoretical
SiO_2	51.31	51.64	52.10	49.83	52.63	51.59	50.83	51.99	51.91	51.61	52.01
Al_2O_3	1.15	1.05	.99	none	3.30	2.06	1.76	1.32	.38	.74	
Fe_2O_3	32.08	32.98	31.80	30.27	29.72	28.65	28.70	28.16	21.79	27.24	34.57
FeO	.09	.14	.90	1.78	.64	2.08	3.07	2.18	1.48	.54	
MgO	.38	.38	.14	.27	.69	.35	.34	.44	3.08	2.75	
CaO	.59	.60	.57	1.65	.18	.30	1.30	1.59	5.53	4.90	
Na_2O	11.70	12.21	11.74	11.62	11.66	12.66	12.63	11.68	10.46	10.59	13.42
K_2O	.18	.06	.37	none	.54	.19	.36	.22	.22	.36	
H_2O+	.35	.41	.20	none	.26	.09	.10	.15	none	.90	
H_2O-	.01	.04							.06		
TiO_2	.06	.04	.60	.78	.35*	1.00	.23	.56	.91		
ZrO_2	none		.41	2.68		.20	.15	1.34			
S									.13		
MnO	.92	.26	.35	.28	trace	.14	.29	.10	.58	1.73	
V_2O_3	.04	.01							3.98		
rare earths	none		.48	.84		1.02	.11	.27			
	99.86	99.82	100.65	100.00	99.97	100.33	99.87	100.00	100.51	101.36	100.00
G	3.526	3.50±	3.587		3.487		3.509	3.591	3.55		
Est. Acmite H.S.W. method	88.30	91.49	89.17	86.39	86.85	82.70	82.70	81.31	62.83	80±	100.00
Color	Brown	Green	Green	(Both)	Green	Green	Green	Green	Brown	Brown	(Synthetic)
Gamma	1.81±2	1.80±2	1.823±2	1.81±1	1.801	1.825	1.824	1.810±5	1.782	—	1.836±4
Alpha	1.76±2	1.76±2	1.767±2	1.765	1.752	1.770	1.769	1.760±5	1.745	—	1.776±3
2V	80±10	80±10	60	—	63	—	—	—	80±	—	61
$X\wedge c$	6±1	6±1	6	4	—	3	4	0	2	—	8

* Ti_2O_3.

1. From taconite, iron formation, Cuyuna range, Minnesota. Lee C. Peck, analyst. Mean of two similar analyses.
2. From vein, with quartz and manganosiderite, cutting iron formation, Cuyuna range, Minnesota. Lee C. Peck, analyst.
3. From igneous rock, Quincy, Massachusetts. Mean of two similar analyses, by Warren and by Washington.
4. From igneous rock, from Rockall islet in North Atlantic. Composition calculated from rock analysis, by H. S. Washington.
5. From nepheline syenite, French River, Ontario. H. C. Rickaby, analyst.
6. Three centimeter zoned crystal from Rundemyr, Norway. H. S. Washington, analyst.
7. From igneous rock at Kangerdluarsuk, Greenland. H. S. Washington, analyst.
8. From Brevik, Norway. H. S. Washington, analyst.
9. From igneous rock, Libby, Montana. W. F. Hunt, analyst.
10. From Långban mines. R. Mauzelius, analyst. High summation probably resulted from the fact that some determinations were made on a different sample from others.
11. Theoretical composition of $Na_2O \cdot Fe_2O_3 \cdot 4SiO_2$. Optical data for artificial acmite, by H. S. Washington.

The physical chemistry of acmite has been studied by Bowen and associates.[9] It is clear that hematite may be separated from crystals of acmite composition at temperatures above 850° C., as a consequence of incongruent melting. Possibly this relation may explain the common occurrence of dusty hematite in the acmite of most of the 25-foot bed in which Minnesota material occurs. The bed, however, shows no suggestion of igneous origin. It seems more likely that the Cuyuna acmite resulted from the action of hot sodic waters on hematitic cherts. Such a metamorphism may have occurred at temperatures below 850° C., and the hematite dust may be a residue of the hematite in the chert.

The optical characters of acmite have been well summarized by Washington and Merwin,[10] and the Cuyuna samples suggest no significant exceptions.

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[9] Bowen, N. L., and Schairer, J. F., The fusion relations of acmite: *Am. Jour. Sci.*, **18,** 365–374 (1929).

Bowen, N. L., Schairer, J. F., and Willems, H. W. V., The ternary system: Na_2SiO_3-Fe_2O_3-SiO_2: *Am. Jour. Sci.*, **20,** 405–455 (1930).

[10] *Op. cit.*