HASTINGSITE IN THERALITE FROM THE CRAZY MOUNTAINS, MONTANA

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Among the many occurrences of theralite in the Crazy Mountains, amphibole occurs in notable amount only in the large laccolith, 100 feet thick, forming the crest and west slope of a large anticline in which a number of sills and laccoliths of alkaline rocks are interbedded with shales and sandstones of the Fort Union formation. The igneous rocks are folded with the sediments and were probably intruded at the time of the folding.

Theralite. The theralite (No. 183 '07 in the author's collection) is of medium coarse grain, dark colored with glittering plates of biotite, long black prisms of augite, and white feldspar and nepheline. Olivine is also abundant in the specimen, notably so in the field, especially near the base of the laccolith and at the apex of the fold where large rounded nodules, several inches in diameter and elongated masses forming bands in the rock, are prominent. These suggest either gravity settling or straining out from the fluid magma by pressure.

The order of crystallization, as shown by the thin sections, is first the accessories, then olivine, biotite, augite, amphibole, nepheline, and feldspar. The pyroxenes have cores of diopsidic augite, grading outward through aegirite-augite to aegirite. The peculiar orthoclase in the theralites has over one per cent of BaO and SrO, also soda and some lime with the dominating potash. The biotite and nepheline show traces of barium; spectroscopically, there appears to be a trace of this oxide in the amphibole.

Table 1 gives an analysis of the theralite, together with the composition computed from the mode, as determined by the integrator. After silica, magnesia is the largest constituent; this corresponds to the abundance of olivine, and perhaps the presence of amphibole. This rock and one other, a hornblende picrite, have the highest percentages of magnesia in the whole igneous assemblage. In the Quantitative Classification the theralite is *Do-sodic* and *Pilandose.*

Hastingsite. A sample of the amphibole was separated from the rock by Professor E. S. Larsen in the Harvard Mineralogical Laboratory. In spite of difficulties of separation, due to adhering aegirite, the sample was found by Professor Larsen, and by the author, to be 99 per cent pure. The result of an analysis of the amphibole is given in table 2.

TABLE 1. ANALYSIS, COMPUTED COMPOSITION AND MODE OF THERALITE

	A	B		C
SiO_2	45.72	44.49		
TiO_2	0.76	2.14		
Al_2O_3	11.82	12.22		
Fe_2O_3	4.31	5.08	Orthoclase	7.6
FeO	5.28	6.57	Nepheline	15.0
MnO	0.14	—	Noselite	1.2
MgO	13.01	11.54	Augite	40.9
CaO	10.38	9.82	Aegirite	1.7
Na_2O	3.44	3.84	Amphibole	5.7
K_2O	2.84	3.31	Biotite	12.7
H_2O+	1.35	0.39	Olivine	10.3
CO_2	none	—	Magnetite	4.2
P_2O_5	0.60	0.14	Apatite	0.1
S	0.18	—		
Cr_2O_3	0.07	—		
SrO	0.04	—		
BaO	0.22	0.44		
Cl	—	0.08		
	100.16	100.06		99.4

A. Theralite (183 '07), Crazy Mountains, Montana; analyst, F. A. Gonyer. Specific gravity, 2.95.

B. Computed composition corresponding to the mode. H_2O represents water of constitution of the fresh minerals, but neglects the water due to some zeolitization of the nepheline and noselite.

C. Mode of the theralite (Leitz integrator), by weight. Due to difficulty in counting, the value for apatite is too low; 0.06 per cent P_2O_5 gives 1.4 per cent apatite.

TABLE 2. ANALYSIS AND CONSTITUTION OF HASTINGSITE

		Mol.	Atoms/24 oxygen	
SiO_2	48.51	808	Si	7.1
TiO_2	1.32	16	Ti	0.1
Al_2O_3	6.60	65	Al	1.2
Fe_2O_3	4.09	26	Fe'''	0.5
FeO	9.48	132	Fe''	1.2
MnO	0.19	3	Mn	0.0
MgO	14.79	370	Mg	3.3
CaO	5.60	100	Ca	0.9
Na_2O	6.01	97	Na	1.7
K_2O	2.20	23	K	0.4
H_2O+	1.47	82	H	1.4
	100.26			

Hastingsite, from theralite, Crazy Mts., Montana; analyst, F. A. Gonyer. Specific gravity, 3.23.

The amphibole has the constitution:

$$(Na, K)_2Ca(Mg, Fe'', Fe''', Al, Ti)_5(Al, Si)_8(OH)_2O_{22}$$

in which Mg/Fe''=2.8, Al/Fe'''=2.5, Na/K=4.2.

The amphibole occurs as an aggregate of grains, mainly subhedral, associated with imperfect prisms of aegirite from which the hastingsite is distinguished by the perfect amphibole cleavage and the characteristic pleochroism. Occasionally it is found in longer prisms with well-developed prismatic and terminal planes. On these crystals the optical properties on (010) and (100) were determined with the universal stage and strong monochromatic light from an arc and monochromator. The refractive indices were determined by immersion. In one case a prism of augite was found with parallel growths of aegirite-augite and hastingsite; $Z:c$ was 39° for augite, 68° for aegirite-augite, 38° for hastingsite, which was on the outside and the latest to crystallize. The hastingsite gave the following data:

		n(Na)	
X (dull yellow)	: c [001] = 52°	1.639	Negative
Y (liver brown)	= b [010]	1.658	$2V$ (Na) = 38°[1]
Z (greenish brown)	: c [001] = 38°	1.660	$r<v$, strong

This hastingsite differs from the examples given by Larsen and Berman (1934) in several ways: the refractive indices are lower than those of any of the examples listed; the double refraction (0.021) is higher than that of any except the ferrohastingsite (p. 191); the extinction angle and optic axial angle are unlike any in the list; the dispersion differs from that of all but one; and the pleochroism differs in tints, especially in the liver-brown color of Y. The specific gravity (3.23) lies within the range of those listed, the nearest being No. 57 (p. 227) with G=3.26.

Evidently the amphibole formed last of the mafic minerals and was succeeded by the nepheline and feldspar, the temperature of the magma decreasing, with concentration of the alkalis, causing a reaction with the diopsidic augite, changing it toward the periphery to aegirite-augite, and lastly to hastingsite.

Reference

Larsen, E. S., and Berman, H. (1934): *U. S. Geol. Surv.*, Bull. **848**.

[1] 40° in the white arc.