THE OPTICAL PROPERTIES OF THE HUMITE GROUP

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A considerable number of specimens of the humite group were examined optically in an attempt to find some consistent differences that would enable one to quickly and with assurance, distinguish between the members of the group. Assuming that the specimens were correctly labelled, the resulting data and in particular the indices of refraction for each member of the group showed a surprisingly wide variation and within about the same range for each of the species, so that no satisfactory data for determinative purposes was had and the suspicion was raised that many of the specimens might be incorrectly labelled. It was accordingly decided that any reliable data on the group must be based on the examination of material that had been analyzed or otherwise positively identified.

I was fortunate enough to secure the material studied by Penfield and Howe[1] from Professor Ford of Yale University, and that studied by Sjögren[2] from Professor Aminoff of Stockholm. I express my sincere thanks to Professors Ford and Aminoff for the use of these materials.

The study was made by the immersion method, and the indices of refraction were determined in sodium light and should be in error ± 0.001. Some of the plates of Sjögren showed zonal growths.

All of the specimens examined, except the one from Franklin, associated with norbergite, are optically +, and all have large to very large axial angles. The pleochroism is stronger for the darker colored specimen and in all the pleochroic formula is: X = yellowish brown; Y = paler yellowish brown; Z = colorless.

TABLE I gives the indices of refraction for five analyzed specimens of chondrodite from as many localities, for a specimen that was similar to the analyzed sample from a sixth locality and for the mineral from four other localities. The indices of refraction for all of the five analyzed specimens are very much alike, those

[1] Penfield, S. L. and Howe, T. H. On the Chemical Composition of Chondrodite, Humite, and Clinohumite. *Am. J. Sc.*, **47**, 188–200, 1894.

[2] Sjögren, Hj. Chondrodite von Kafveltorp, *Zeit. Kryst. Min.*, **7**, 113–152, 1882. *Beiträge zur Mineralogie Schwedens, Bull. Geol. Inst. Upsula*, **1**, 1–54, 1892; **2**, 39–54, 1894.

TABLE I. ANALYSES AND OPTICAL PROPERTIES OF CHONDRODITE.

	Monte Somma Brush 2065	Franklin, N. J. core to norbergite	Warwick, N. Y. Brush 2054	Monte Somma Brush 2063	Kafveltorp Brush 2040	Kafveltorp Sjögren yellow VIII	Kafveltorp Sjögren Brown II	Christiansand Barth[3]	Mansjö von Eckermann[4]	Weston, Mass. Eskola[5]	Nordmark Sjögren yellow	Nordmark Sjögren brown	Custer Co., Idaho Shannon[7]	Tilly Foster Brush 4813
SiO_2			33.80	33.87	33.33			32.07	33.71		34.50	34.05		33.67
TiO_2								0.23				0.13		
MgO			55.70	56.46	54.30			53.26	55.02		51.39	48.30		54.79
CaO								0.24			0.26			
FeO			2.64	3.66	6.62			3.50	3.67		6.59	10.54		5.94
MnO								0.08			1.50	1.24		
Al_2O_3			1.83					1.13	1.23		0.16			
Fe_2O_3								0.35			0.63	0.54		
F			7.30	5.15	6.60			6.28	4.50		4.76	5.40		5.30
K_2O											0.16			
Na_2O											0.90			
H_2O+			1.46	2.82	1.67			2.74	2.90		1.18	2.30		2.55
H_2O-								.28						
			102.73	101.96	102.52			100.26	101.43		102.03	102.50		102.25
O for F			3.07	2.16	2.76			2.68	1.42		2.00	2.27		2.23
			99.66	99.80	99.76			97.58	100.01		100.03	100.23		100.02
Sp. Gr.			3.168	3.194	3.252			3.227			3.24	3.28		3.204
			3.235	3.215	3.265									3.231
α	1.593	1.594	1.605	1.609	1.608	1.601+	1.611	1.601	1.607	1.621		1.619[6]	1.631	1.635[8]
β	1.606	1.607	1.616	1.619	1.620	1.616	1.622		1.620	1.632		1.632	1.640	1.645
γ	1.622	1.619	1.636	1.641	1.642	1.638	1.641	1.637	1.643	1.655		1.653	1.657	1.663
2V		Lge.	73°		74°			85°-90°	72°14′			79°40′	med	v. large
Ext.		Opt.-				2856′	27°	27.2°	26°25′	31°		27°30′		26°

for the Franklin mineral are considerably lower, while those for the Weston, Nordmark, Custer County, and Tilly Foster minerals are much higher. Analyses are available for the mineral from Nordmark and Tilly Foster but the exact materials that furnished the analyses were not available for optical study.

TABLE II. ANALYSES AND OPTICAL PROPERTIES OF HUMITE

	Monte Somma	Vesuvius Yale 4102	Nordmark Sjögren	Nordmark Sjögren
	Light	dark	Brownish yellow	Yellowish gray
SiO_2	36.63	36.74	35.44	35.21
TiO_2			0.07	0.07
MgO	56.45	56.31	47.22	48.33
CaO			0.17	0.11
FeO	2.35	2.22	10.96	7.93
MnO			1.47	1.69
Al_2O_3			0.19	0.07
Fe_2O_3			0.68	1.06
F	3.68	3.96	3.79	4.59
K_2O			0.17	0.20
Na_2O			0.29	0.34
H_2O+	2.45	2.13	1.28	
H_2O-				1.85
	100.96	101.36	101.73	101.45
O for F	1.26	1.66	1.60	1.93
	99.70	99.70	100.13	99.52
Sp. Gr.	3.194	3.183	3.32	3.24
	3.201	3.225		
α	1.621[9]	1.625	1.632[10]	
β	1.627	1.635	1.643	
γ	1.649	1.656		
2V		70°		

REFERENCES FOR TABLES I AND II

[3] Barth, Tom. On Contact Minerals from the Pre-Cambrian in Southern Norway, *Norsk, Geol. Tid.*, **VIII**, 94–96, 1924.

[4] von Eckermann, Harry. The Rocks and Contact Minerals of the Mansjö Mountain, *Geol. For., Stockholm*, 279–383, **1922.**

[5] Eskola, Penti. The Contact Phenomena Between Gneiss and Limestone in Western Massachusetts, *Jour. Geol.*, **XXX**, 270, 1922.

[6] Optical data on brown crystals similar to those analyzed but not on identical material.

[7] Shannon, E. V. The Minerals of Idaho. *U. S. Nat. Mus., Bull.* **131**, 333–334, 1926.

[8] Specimens from Tilly Foster gave:

α	1.627	1.632	1.635	1.643
β	1.638	1.640	1.645	1.655
γ	1.657	1.661	1.663	1.670

The last figures are by Gillson, J. L., *Am. Mineral.*, **11**, 284, 1926.

[9] Optical data not closely tied to the analyses but on specimen 4806 of the Brush Collection which is very pale brown and answers the description of the analyzed specimen.

[10] No. 62 Plate 2 of Sjögren—Optical data not closely tied to analysis.

TABLE III. ANALYSES AND OPTICAL PROPERTIES OF CLINOHUMITE.

	Vesuvius Yale	Vesuvius Brush	Nordmark Sjögren	Chaffey's[12] Lake, Ontario	Piedmont[13]
	4143	2046	No. 63		
SiO_2	37.78	38.03	35.86	37.42	36.83
TiO_2			.06	1.14	1.92
MgO	53.05	54.00	44.66	56.32	51.53
CaO			trace		
FeO	5.64	4.83	14.25	1.27	4.90
MnO			1.19	0.10	.28
Al_2O_3					0.07
Fe_2O_3			0.22	0.46	0.42
F	3.58	2.06	4.16	5.04	0.03
K_2O			0.15		
Na_2O			0.29		0.12
H_2O+	1.33	1.94	1.58	0.56	3.04
H_2O-					0.12
	100.38	100.86	102.42	102.31	99.26[13]
O for F	1.50	.86	1.75	2.12	
	99.88	100.00	100.67	100.19	
Sp. Gr.	3.219	3.184	3.35	3.17	
	3.258	3.222			
α	1.632	1.625[14]	1.652[11]	1.628	1.664[11]
β	1.644	1.638	1.663	1.642	1.673
γ	1.664	1.653			1.698
2V	74°	near 90°	76°27′		62°
Ext.			12°–15°		70°29′

REFERENCES FOR TABLE III.

[11] Optical data not closely tied to analyses.

[12] Walker, T. L., and Parsons, A. L.—Clinohumite from Chaffey's Lake, Ontario. *Contr. Can. Min.*, p. 17–18, 1927.

[13] Zambonini, F., —Sur la veritable nature du Titanolivine de la valler d'Ala (Piedmont), *Bull. Soc. Fr. Minr.*, XLII, 1–30, 1919. Contains PbO·0.14, BaO 1.30, Cr_2O_3 0.03, NiO 0.07, Optical data by Larsen.

[14] Not uniform—Indices vary ±0.005 or more. Data are for about averages.

In TABLE II optical data are given for three analyzed specimens of humite from two localities.

In TABLE III optical data are given for five analyzed specimens of clinohumite from four localities. The corresponding data for two specimens of analyzed norbergite are given in the preceding paper.

Assembling the data for the four members of the humite group, TABLE IV shows that on the whole, as the Mg_2SiO_4 increases in amount the indices of refraction increase, but there is much overlapping. The norbergite occupies a low range and can be distinguished from the others by its indices of refraction. Most of the analyzed chondrodites have β between 1.616, and 1.622, and are higher than any of the norbergites and lower than any of the humites but some of the chondrodites have β as high as any clinohumite except that from Piedmont. The humites mostly have β lower than does clinohumite but there is overlapping.

TABLE IV. OPTICAL DATA FOR THE HUMITE GROUP.

Composition	Norbergite $Mg(OH, F)_2 \cdot Mg_2SiO_4$	Chrondrodite $Mg(OH, F)_2$ $2Mg_2SiO_4$	Humite $Mg(OH, F)_2$ $3Mg_2SiO_4$	Clinohumite $Mg(OH, F)_2 \cdot 4Mg_2SiO_4$
α	1.561–1.563	1.601–1.643	1.621–1.632	1.623–1.664
β	1.566–1.570	1.616–1.655	1.627–1.643	1.636–1.673
γ	1.587–1.590	1.636–1.670	1.649–	1.651–1.698
Ext.	Orth.	22°–29°	Orth.	7°–15°
2V	45°–50°	73°–90°	70°–	62°–90°

The variation in the indices of refraction is brought out by comparing the data for the three minerals (chondrodite, humite, and clinohumite) from the same localities. Such data are available from Vesuvius and from Nordmark and are shown in TABLE V. For both localities the indices of refraction of the chondrodite

are lowest, that for humite intermediate, and that for clinohumite highest though for the Vesuvius mineral the differences are not great.

For each species the Nordmark mineral has considerably higher indices of refraction and iron content than the Vesuvius mineral.

TABLE V. A COMPARISON OF MEMBERS OF THE HUMITE GROUP FROM VESUVIUS AND FROM NORDMARK

From Vesuvius	Chondrodite	Humite		Clinohumite	
α	1.609	1.621	1.625	1.632	1.625±
β	1.619	1.627	1.635	1.644	1.638±
γ	1.641	1.649	1.656	1.664	1.653±
FeO+MnO	3.66	2.35	2.22	5.64	4.83
F	5.15	3.68	3.96	3.58	2.06
H_2O	2.82	2.45	2.13	1.33	1.94

From Nordmark	Chondrodite	Humite	Clinohumite
α	1.619	1.632	1.652
β	1.632	1.643	1.663
γ	1.653		
FeO+MnO	11.78 ?	9.62	15.44
F	5.40 ?	4.59	4.16
H_2O	2.30 ?	1.85	1.58

CONCLUSIONS. An attempt to correlate the chemical composition with the optical constants is disappointing. One would expect a simple and systematic relation in which the indices of refraction increase with the iron and titanium content and decrease with the increase in fluorine. There appears to be some tendency in this direction as indicated by the Nordmark minerals which are high in iron and have high indices of refraction but the relations are far from simple. While for the analyzed chondrodites, the optical data are rather uniform ($\beta = 1.616$ to 1.622) although there is considerable variation in chemical composition (FeO+MnO= 2.64 to 6.62); the Tilly Foster mineral shows very nearly the chemical composition of the Kaveltorp mineral described by Penfield and Howe, yet its indices of refraction are much higher (for Kaveltorp $\beta = 1.620$ for Tilly Foster $\beta = 1.645$). These data are so inconsistent as to lead one to the suspicion that some constituent, such as titanium, has been overlooked in the Tilly Foster mineral.