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CHLORITOID FROM DUTCHESS COUNTY NEW YORK

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Chloritoid is a mineral that is not yet well known. Its crystallographic symmetry and its chemical composition are disputed.¹ More than 50 years ago Tschermak² contended that the symmetry was monoclinic and he also assigned a chemical formula to it. To be sure, his contentions are still accepted by the majority of mineralogists, but a good many writers have also reported results in apparent disagreement with Tschermak's observations. New, and rather decisive data on chloritoid from a new locality in Dutchess County should therefore be of some value.

1. OCCURRENCE

The material was collected on the east slope of Clove Valley, Dutchess County, N. Y. The exact locality is: northwest spur of hill 1200', 1½ miles north-northeast of the old Clove Valley Station (printed "Clove Valley"), Clove quadrangle, N. Y. The valley is underlain by late Cambrian dolomitic marble, and on the slopes to the west and east, phyllitic schists overlie the marble in the general form of an eroded anticline. On the east slopes, the rock carries crystalloblasts of biotite and garnet, and locally also kyanite and staurolite.

The ledge from which the specimens were taken measures about 40 feet in diameter. Specks of dark green, brilliant chloritoid, up to ¼ inch in diameter, attract immediate attention. In addition a few

¹ For general information see, for instance: Rosenbusch's *Mikroskopische Physiographie der Mineralien und Gesteine* by O. Mügge, 1927, Bd. I, 2, p. 612. Here are given 53 references to the literature.

² G. Tschermak and L. Sipöcz, Die Clintonitgruppe: *Sitzber. Akad. Wiss. Wien*, vol. 78, 1878; *Z. Krist.*, vol. 3, p. 506, 1879.

crystalloblasts of garnet and partly altered staurolite and biotite are encountered. Some opaque ore mineral is also present. The groundmass consists of sericite and quartz. As yet, this is the only locality discovered in this particular area; the rock represents a small lens within the dark biotite-sericite schist series.

2. CHEMICAL FORMULA

The chloritoid occurs with all the characteristics of this mineral: crystalloblasts scattered all through the rock with no visible relation to the directions of schistosity, and always containing inclusions, especially quartz and the typical dustlike particles so frequently described, as well as small grains of garnet and tiny flakes of muscovite.

Such crystalloblasts measuring 3 to 5 mm. across and usually less than 1 mm. thick were separated and a chemical analysis conducted (see Table I, column 1). As a comparison an analysis by

TABLE I. CHEMICAL ANALYSES OF CHLORITOID WITH INCLUSIONS (1) FROM DUTCHESS COUNTY, NEW YORK, (2) FROM KALGOORLIE, W. AUSTRALIA

	1	2
SiO ₂	29.5	29.03
TiO ₂	1.2	1.46
Al ₂ O ₃	38.1	35.62
Fe ₂ O ₃	2.3	2.78
FeO	21.5	21.89
MnO	0.2	0.45
MgO	1.6	1.47
CaO	trace	0.93
H ₂ O	5.6*	7.05
Sum	100.0	100.68

* H₂O determined by difference.

Simpson³ is given (column 2). From a microscopic investigation of his material Simpson concluded that it was contaminated with quartz and rutile. With the help of Lunge's solution he also managed to determine separately the silica present as free quartz and found it to be 7.35 per cent. After these amounts were subtracted from his analysis the molecular proportions came out close to

³ E. S. Simpson, Contrib. Mineral. of W. Australia: *J. Roy. Soc. W. Australia*, vol. 16, p. 27, 1930. See also *W. Austral. Geol. Surv.*, vol. 64, p. 64, 1915.

$H_2O:R_2O_3:RO:SiO_2 = 1:1:1:1$, in agreement with Tschermak's results. With essentially the same result Niggli⁴ had recalculated an analysis of chloritoid from Nadels, Switzerland. The analysis of the chloritoid from Dutchess County represents an analogous case: after subtraction of the contaminations, the nature and amount of which can be fairly well estimated with the microscope, this analysis would correspond closely to the proportions given above. In order, however, to obtain a more definite result a chemical separation of the contaminating mineral particles was undertaken.

Chloritoid itself is soluble in H_2SO_4 , but the enclosed minerals are not soluble in acids. The material was therefore digested with

TABLE II. CHLORITOID WITH INCLUSIONS, FROM DUTCHESS COUNTY, NEW YORK

	Soluble in H_2SO_4	Residue	Total
SiO_2	20.7	8.1	23.8
TiO_2	1.1	trace	1.1
Al_2O_3	33.6	4.8	38.4
Fe_2O_3 } FeO }	21.5	1.8	23.3
MnO	0.2	present	0.2
MgO	1.5	trace	1.5
CaO	trace	trace	trace
H_2O	—	—	6.7*
Sum	78.6	14.7	100.00

* H_2O determined by difference.

sulfuric acid and the procedure described by Treadwell as "Determination of 'soluble' silica" was followed. The soluble portion and the residue⁵ were then analyzed separately. The results as given in Table II are in good agreement with those from the first analysis (Table I).

The portion soluble in H_2SO_4 recalculated to 100% thus corresponds to the composition of pure chloritoid (see Table III).

The present chemical investigations thus definitely show that the composition of chloritoid from Dutchess County can be ex-

⁴ P. Niggli, Die Chloritoidschiefer des Gotthardmassives: *Beitr. Geol. Karte Schweiz*, vol. 36, p. 20, 1913.

⁵ This residue was also investigated with the microscope. It contained in addition to quartz some garnet and muscovite as well as an opaque, dustlike substance the nature of which could not be ascertained.

pressed by the following formula: $H_2FeAl_2SiO_7$ (in which a small amount of Fe^{III} and Mg substitutes for Al and Fe^{II} respectively).⁶ This formula corresponds to that proposed by Tschermak and afterwards accepted by several investigators. But it may be worth while adding that the existence of such a chloritoid does not necessarily exclude the possibility that some other chloritoid or chloritoid-like minerals may be possessed of different chemical formulae.⁷

TABLE III. CHEMICAL COMPOSITION OF CHLORITOID FROM DUTCHESS COUNTY, NEW YORK

	Weight %	Mol. prop.	
SiO ₂	24.4	406	406
TiO ₂	1.3	16	
Al ₂ O ₃	39.6	388	403
Fe ₂ O ₃	2.4	15	
FeO	23.0	320	384*
MnO	0.2	3	
MgO	1.8	45	
CaO	trace		
H ₂ O	7.3	405	405
Sum	100.0		

* Incl. TiO₂.

3. OPTICAL PROPERTIES

The pleochroism of the chloritoid from Dutchess County is unusually weak, but corresponds to the known absorption scheme of the chloritoids:

α = pale gray-green
 β = slate blue
 γ = yellow, almost colorless

The indices of refraction are as follows:

$$\alpha = 1.722, \beta = 1.725, \gamma = 1.728, \text{ all } \pm 0.002.$$

⁶ As first proposed by Niggli, later by Simpson, and adopted, for instance, by Winchell in his *Elements of Optical Mineralogy*, brittle mica with no appreciable amount of Mg or Mn should be called "chloritoid."

⁷ Cf. for instance, F. Machatschki, *Steirische Chloritoidschiefer: Geol. Archiv II*, p. 188, Königsberg 1923; C. Fridländer, *Der Chloritoid von Crestlianderstobel, Schweiz: Min. Petr. Mitt.*, vol. 9, p. 247, 1930.

The optic angle is variable, but always positive and usually of a medium value, around 60° . The dispersion is anomalous, for in convergent light the hyperbolas do not show the ordinary colored rims of blue and red, but on the convex side they are green and on the concave side yellow. A probable cause for this is that the optic angle has its greatest value at intermediate wave lengths.⁸

The optical orientation was determined with a Fedorov stage which proved itself an excellent tool for this investigation. Not only was the optical orientation of several individual crystals of

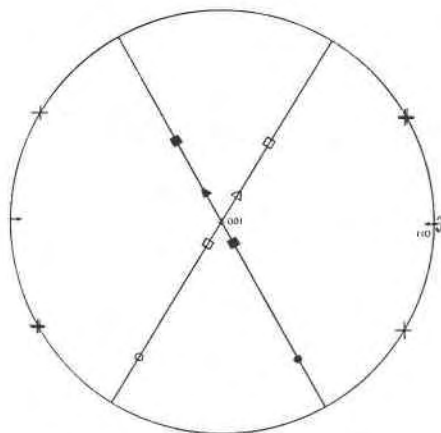


FIG. 1. Stereographic projection of a twin of chloritoid projected on the base, (001). Composition face is (001). Twin axis \perp (110). Open symbols refer to one individual, solid symbols to the second individual, which is in twin position to the first one.

O = α , + = β , Δ = γ , \square = optic axis.

chloritoid thus established, but also a good survey of the range of variability of the optical properties could be obtained. Thus it was found that the direction β always lies in the cleavage plane, (001), whereas the direction γ makes an angle of 5° to 22° with the normal to (001).

These observations establish the monoclinic symmetry of the Dutchess County chloritoid, for although each individual measurement with the Fedorov stage cannot be conducted with greater accuracy than about $\pm 1^\circ$, the fact should be borne in mind that in all the measurements (comprising 20 to 30 different crystals),

⁸ Cf. J. Schetelig, *Mineral. Studien I, Norsk Geol. Tidsskrift*, vol. 2, No. 9, 1913.

β was always observed to lie in the cleavage plane, whereas α and γ varied conspicuously. These crystals thus represent a series of chloritoids in which the direction of the index β remains constant, although the optical indicatrix is otherwise susceptible of great variations both in position and in shape, and the unavoidable conclusion must be that β is held fast by a symmetry condition, in this case by the monoclinic symmetry plane, to which it is normal, whereas α and γ vary in the symmetry plane.

A study of the twins leads to the same conclusion. All crystals observed were twinned according to the following law: the twin axis is the zone [110] (i.e. the edge between (001) and (110) if the crystallographic elements be taken analogous to those of mica); the composition plane is (001). A stereographic projection of such a twin is given in Fig. 1. In all the twins measured it was found that β remained in the (001)-plane, whereas the angle between γ and the normal to (001) was usually found to be different in the two twin individuals.

If polysynthetically twinned crystals of chloritoid are examined in which each twin individual is very narrow, confusing optical phenomena are observed. It is not improbable, therefore, that the alleged triclinic symmetry of certain chloritoid crystals is due to observations on such multiple twins. However, it is of course possible that triclinic chloritoid also exists—similar to the case of orthoclase and microcline, for instance—but there are no data on record actually proving the existence of any triclinic chloritoid.