SOME PROPERTIES OF AUTHIGENIC TOURMALINE FROM LOWER DEVONIAN SEDIMENTS

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INTRODUCTION

Authigenic tourmaline has been observed as a secondary growth on small detrital grains of tourmaline in Lower Devonian rocks from oil-wells in the Lower Peninsula of Michigan.[1] More recently it has been noted in the Lower Monroe dolomite from the quarry of Messrs. France Stone Co., in Monroe County, Michigan. Similar grains of tourmaline with an authigenic portion have been described from the Oriskany Sandstone of several of the eastern states of America.[2]

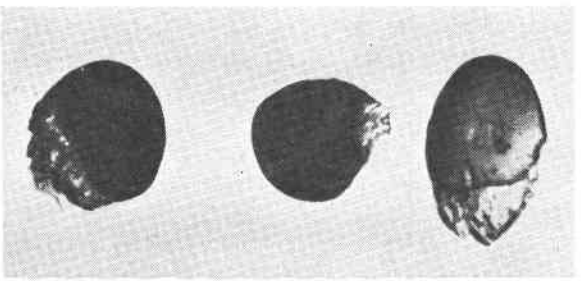

FIG. 1. Detrital grains of tourmaline with secondary growth (×100).

Typical grains of this tourmaline from the Lower Devonian rocks of Michigan are shown in Fig. 1. The authigenic portion is colorless while the original grain is colored and strongly pleochroic. In Fig. 1 one grain is in the position of minimum and two in the position of maximum absorption. The rounded outline of the original grain is in marked contrast to the angular margin of the colorless authigenic portion. The latter is in complete optical continuity with the original grain and always occurs at one end of the *c*-axis of the grain.

The properties of this authigenic tourmaline have been investigated further and the results obtained are described below.

[1] Alty, Stella West, *Proc. Mich. Acad. of Science, Arts and Letters*, p. 289, vol. 18, 1932.

[2] Stow, Marcellus H., *Am. Min.*, vol. **17**, p. 150, 1932.

Refractive Index

The refractive indices of tourmaline vary according to the chemical composition of the mineral, being highest in the deeply-colored varieties which are rich in iron and manganese, and lowest in the colorless tourmalines. Hence in the case of the grains here described there should be some difference between the refractive indices of the colorless authigenic portion and the colored original grain. Measurements of the refractive indices were accordingly attempted; such determinations are difficult owing to the small size of the grains. The latter are rarely greater than 0.2 mm. in diameter and the authigenic portion generally forms less than half of any one grain. Refractive index tests could only be carried out by immersion of the grain in a liquid of known refractive index.

The procedure was as follows: Samples of heavy minerals containing authigenic tourmaline were examined microscopically, in air, and a tourmaline grain picked out on a needle point. The grain was then immersed in a liquid of suitable refractive index, examined under the miscroscope in sodium light and the refractive index of the mineral observed to be either higher or lower than that of the liquid. Immediately after this observation was made, the refractive index of the liquid was determined on a small refractometer in sodium light.

A number of such tests were made, using different grains of tourmaline and various refractive index liquids. The method of immersion is not highly accurate but very consistent results were obtained. The orientation of the authigenic tourmaline is known at once by comparison with the original grain with which it is in optical continuity and which shows the ordinary pleochroism of colored tourmaline. Consequently the directions of the ordinary and extraordinary rays of the authigenic tourmaline are known with certainty, and the refractive indices can be obtained in these two directions.

It was impossible to make more than one observation on one grain. A grain could be picked out in air and immersed in a liquid but it could not be transferred from one liquid into another; indeed it was usually "lost" when some of the liquid in which it was immersed was taken for refractive index determination on the refractometer. Consequently a different grain was used for each determination but the results obtained were completely consistent and it was found possible to determine the refractive indices within

narrow limits. Thus the index of refraction of the ordinary ray was clearly less than 1.630 and greater than 1.626; the mineral was practically invisible in liquid of refractive index 1.628. Similarly when examined by means of the extraordinary ray the authigenic tourmaline was almost invisible in liquid of refractive index 1.610.

In every case the index of refraction of the authigenic tourmaline was found to be considerably lower than that of the original grain. The refractive indices of the latter varied considerably, as was to be anticipated; that of the ordinary ray was always greater than 1.635 and that of the extraordinary ray varied between 1.620 and 1.635.

The refractive indices of the authigenic tourmaline are remarkably low, even for colorless tourmaline; it is believed that they are the lowest recorded for this mineral. The lowest values given by Dana[3] and the lowest recorded by Ward[4] are given in the following table:

	Variety	ω	ϵ	$\omega - \epsilon$
Dana	colourless	1.636	1.6193	0.0167
Ward	white	1.640	1.614	0.026
Alty	colourless	1.628	1.610	0.018

Pyro-electric Orientation

It is one of the characteristics of the authigenic tourmaline here considered that it always occurs as a secondary growth on one end of the *c*-axis of the original grain, and an attempt has been made to determine upon which end of this axis the crystallization has occurred.

The pyro-electric properties of tourmaline indicate that when heated the grains must develop opposite surface electrification at opposite ends; if discharged at the high temperature and allowed to cool they must develop an equal electrification but with reversed polarity. If the polarity of the electrification could be determined the orientation of the authigenic tourmaline with reference to the *c*-axis would be known.

The charge developed on a pyro-electric crystal is proportional to

[3] Dana, J. D., System of Mineralogy, 6th Edition, p. 553.

[4] Ward, G. W., *Am. Min.*, vol. **16**, p. 151, 1931.

the cross section of the crystal and consequently in the case of very tiny grains the charge is so small that it is very difficult to carry out any tests. Various methods have been attempted but the following is the only one which proved at all successful.

The tourmaline grains (with grains of other heavy minerals) were heated for a few minutes on a metal plate over a Bunsen flame. The grains were then brushed onto a microscope slide; moving them over the metal plate in this way would effectively neutralize their surface charge. After allowing them to cool for a few moments a tourmaline grain was examined under the microscope. On cooling the grain would develop a new pyro-electric charge on its surface, and the nature of this charge was investigated by observing the effect produced on the grain by (a) electrified glass and (b) electrified sealing wax.

(a) A glass rod drawn out to a fine tip was rubbed vigorously on silk in order to give it a positive electric charge. The tip of the rod was gently introduced into the field of view of the microscope and it was found that the glass rod attracted the end of the grain opposite to the authigenic tourmaline, i.e., the colored end. The behavior of the grain varied according to the direction of approach of the glass rod; if the rod approached towards the colored end of the grain the latter jumped towards the rod slightly and adhered to it; if the rod approached the opposite end, i.e., the colorless authigenic end, the grain remained inert until the rod practically touched it, and then it turned in such a way as to bring the colored end of the grain against the rod. In some cases the charge on the grain was not large enough to make it turn towards the glass, but in this case the colorless authigenic end was inert towards the rod while the colored end would adhere to it sufficiently for the grain to be pulled across the field of the microscope by it. The electric charge on the grains was soon discharged in air and consequently clear results could only be obtained very shortly after the grains had been heated and cooled down. After standing in air for several minutes they were usually quite "dead" and gave no evidence of bearing on electric charge.

(b) Obviously if the colored end of the tourmaline was attracted to a positively charged glass rod the opposite end should be attracted to a substance which bears a negative charge. Experiments were carried out with a rod of sealing wax instead of glass, the wax being rubbed upon fur to give it a negative charge. The results how-

ever, were very unsatisfactory. The wax appeared to develop so large a charge when it was rubbed upon fur that when introduced into the miscroscope field it attracted *all* grains on the slide, the tourmaline included. The pyro-electric charge on the grains was evidently completely masked by the charge induced by the electrified wax.

The results, however, obtained with the glass rod were very consistent and were repeated many times. Consequently this seems fairly conclusive evidence that these grains, on being discharged and then cooled, develop a negative charge on the colored end of the grain which is attracted to the positively charged glass rod. This is, therefore, the analogous pole of the mineral and the authigenic tourmaline is formed at the other end, the antilogous pole, which is characterized crystallographically by the faces $r(10\bar{1}1)$ and $m(10\bar{1}0)$.

Summary

The refractive indices of authigenic tourmaline occurring as a secondary growth on detrital grains of tourmaline have been determined. The indices of refraction are unusually low, being:

$$\omega = 1.628$$

$$\epsilon = 1.610$$

An examination of the pyro-electric properties of the compound grains indicates that the authigenic portion is invariably found at that end of the *c*-axis which is the antilogous pole of the mineral.