# A TOURMALINE-ZOÏSITE ROCK FROM LOH-OELO, JAVA.

BY

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In 1935 Dr. CH. HARLOFF presented a number of metamorphic rocks from Loh-Oelo to the Rijksmuseum van Geologie en Mineralogie of Leyden.

One of the most remarkable rocks is a boulder that HARLOFF discovered in the bed of the Kali Trenggoeloen. The exceptional mineralogical composition rendered a chemical analysis of this rock of importance.

## Mineralogical description.

The handspecimen clearly shows two different parts, for a darker green portion encloses white or light green lenses. The former part has a rod-like structure, the rods of tourmaline prisms enclosing the white lenses in a fluxional fashion.

For microscopic examination it is necessary to take slides in various directions through both of the parts, because the minerals are sub-parallel.

In the parts containing tourmaline the following minerals occur: (fig. 1, 2 and 3).

*1. Tourmaline,* colourless to light green prisms, almost without pleochroïsm. Sometimes the prisms are broken, but often they are bent, causing cracks at right angles to the c-axis. This warping is due to the fact that the tourmaline crystals are embedded in a groundmass of fine mica flakes. These offered resistance during deformation but were sufficiently pliable to bend, thus causing the tourmaline to bend also without breaking.

The slide at right angles to the c-axis of the tourmaline (fig. 2) shows the tourmaline to be zonal in hexagonal lighter and darker zones.

2. *Mica.* Two kinds of colourless mica occur:

*a.* the fine flakes already mentioned, that recall sericite. But measurement of the axial angle, ± 3°, shows that it cannot be sericite, but must belong to the biotite-series. It will be shown in the chemical discussion that it is very probably *phlogopite.*

*b. Muscovite.* In between the flakes of phlogopite are embedded a few rectangular crystals of muscovite, with a clear longitudinal cleavage in the rectangles. The axial angle is 38°.

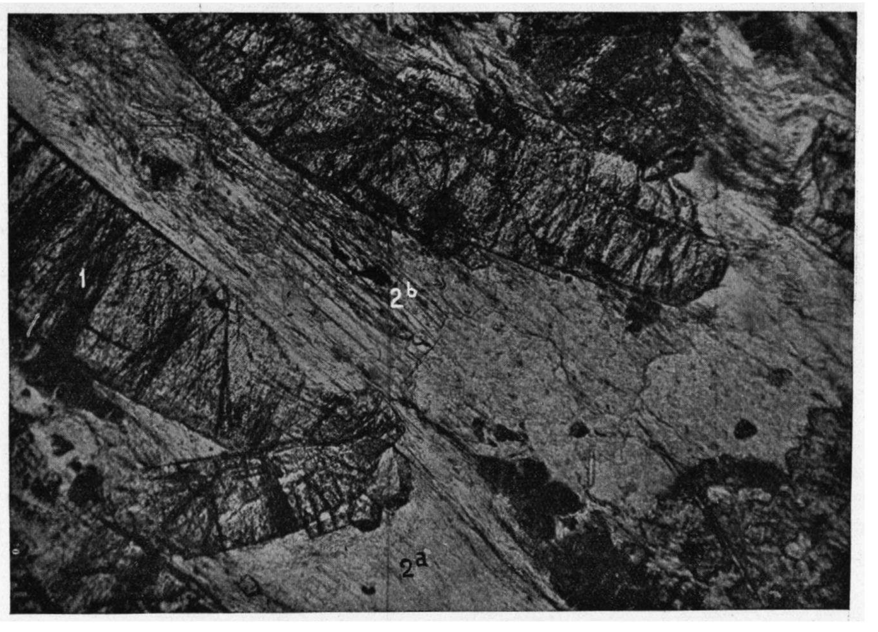


Fig. 1.

Slide // C-axis of the tourmaline.
*1.* tourmaline. *2a.* phlogopite. *2b.* muscovite.
40 ×. Nicols //.

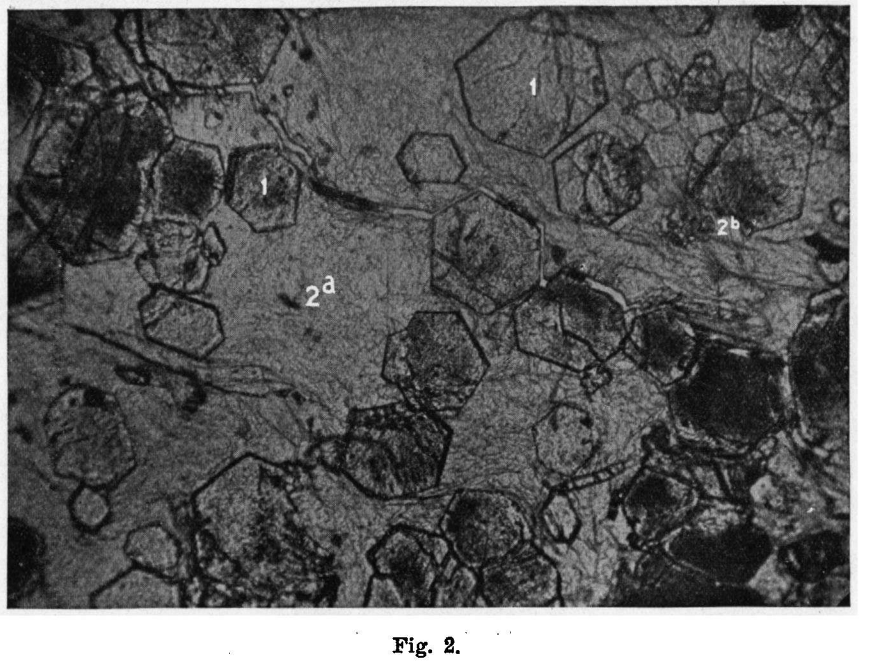


Fig. 2.

⊥ on the C-axis of the tourmaline.
*1.* tourmaline. *2a.* phlogopite. *2b.* muscovite.
40 ×. Nicols //.

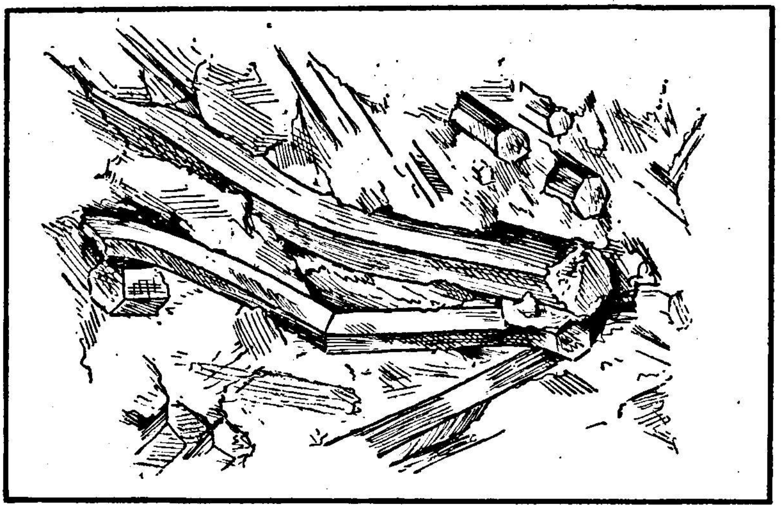

Fig. 3.

Bent tourmaline. 15 ×.

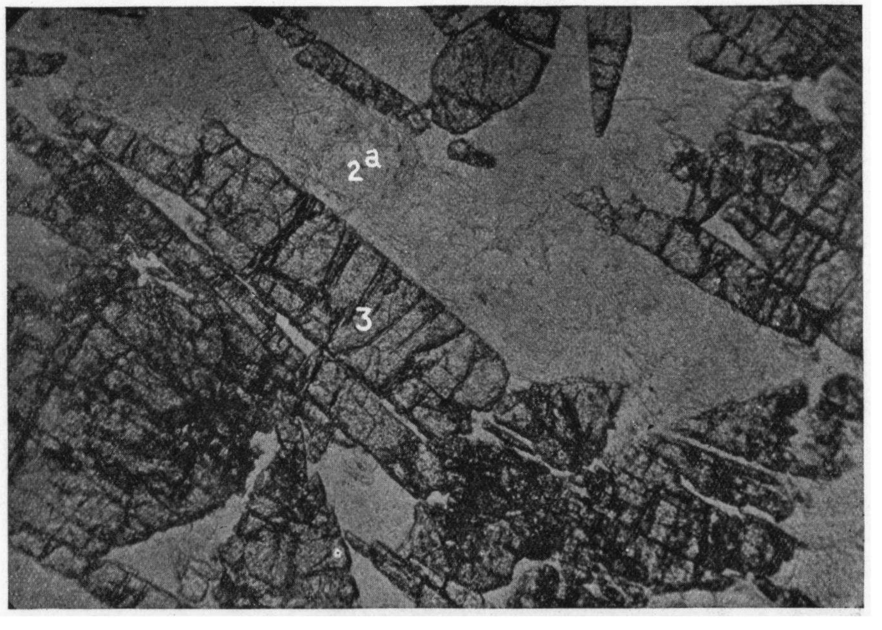


Fig. 4.

Zoïsite-lens. // C-axis of the Zoïsite.
*2a.* phlogopite. *3.* zoïsite.
40 ×. Nicols //.

The white lenses consist of the following minerals (fig. 4):

3. *Zoïsite,* rectangular colourless crystals with the typical cleavage at right angles to the longer axis. This longer axis lies parallel to the tourmaline prisms.

The interstices between the zoïsites is entirely occupied by flakes of phlogopite. There is no muscovite in the slides from the white lenses.

Scattered through the entire rock are found small amounts of colourless to light yellow chlorite, recognizable by the anomalous blue interference colour.

**Chemical discussion.**

In order to obtain a trustworthy average of the chemical composition of the described rock, a fairly large chunk had to be pulverised to obtain the correct ratio of the minerals. A separate analysis was also made of the tourmaline from particles picked under a binocular microscope. This can be done quite reliably, because the tourmaline as hardest mineral breakes neatly out of the enclosing rock.

Table 1 gives the result of both analyses and of the reduction to molecular percentages.

TABLE 1.

| | Rock. I. | Tourmaline II. | Molec.-percentages. Ia. | IIa. |
|---|---|---|---|---|
| $SiO_2$ | 35.16 | 35.46 | 33.5 | 36.8 |
| $P_2O_5$ | 0.10 | — | — | — |
| $Al_2O_3$ | 32.38 | 33.47 | 18.2 | 20.5 |
| $Fe_2O_3$ | 1.31 | 0.27 } | | |
| FeO | 0.49 | 0.51 } | 1.4 | 0.7 |
| MnO | 0.06 | — } | | |
| MgO | 12.60 | 13.50 | 17.9 | 20.9 |
| CaO | 9.74 | 1.46 | 9.9 | 1.6 |
| $Na_2O$ | 0.68 | 2.87 } | 1.0 | 3.4 |
| $K_2O$ | 0.39 | 0.72 } | | |
| + $H_2O$ | 5.10 | 2.13 } | 16.6 | 7.4 |
| − $H_2O$ | 0.13 | — } | | |
| $B_2O_3$ | 1.80 | 9.74 | 1.5 | 8.7 |
| $CO_2$ | 0.14 | — | — | — |
| F | 0.27 | — | — | — |
| | 100.35 | 100.13 | 100.0 | 100.0 |
| O | 0.11 | | | |
| | 100.24 | | | |
| S.G. | 3.07 | | | |

Inspection of analysis I directly shows the abnormally high percentage of magnesium. This indicates in the first place a tourmaline rich in magnesium. This supposition is born out by analysis II.

When II*a* is recalculated for the $B_2O_3$ content of the rock (I*a*) and then substracted from I*a*, it is found that the remainder (that is zoïsite + mica) must still contain considerable amounts of magnesium. As zoïsite contains no magnesium, the only possibility is that the flakes of mica are actually phlogopite.

The exact composition of this phlogopite can of course not be determined, but probably it differs but little from the analysis of a phlogopite from Mexico, mentioned by P. NIGGLI, Lehrbuch der Mineralogie, Band II, p. 331. Both are colourless and contain little FeO and much MgO.

This analysis, expressed in molecular percentages was recalculated for the magnesium content of I*a* minus tourmaline. Finally the formula for zoïsite $[SiO_4]_3 \begin{matrix} Al_2 \\ AlOH \\ Ca_2 \end{matrix}$ was recalculated in like manner for the CaO-content. This shows that practically all elements have been accounted for except water (remainder of table 2). This substance must find a place in the chlorite that had so far been left out of account.

TABLE 2.

| | $SiO_2$ | $Al_2O_3$ | FeO | MgO | CaO | $K_2O+Na_2O$ | $H_2O$ | $B_2O_3$ |
|---|---|---|---|---|---|---|---|---|
| I*a* | 33.5 | 18.2 | 1.4 | 17.9 | 9.9 | 1.0 | 16.6 | 1.5 |
| Tourmaline . | 6.3 | 3.5 | 0.1 | 3.6 | 0.3 | 0.5 | 1.2 | 1.5 |
| Phlogopite . . | 11.3 | 1.9 | 0.2 | 14.3 | — | 1.2 | 4.2 | — |
| Zoisite . . . . | 15.5 | 13.1 | — | — | 9.6 | — | 0.8 | — |
| Remainder . . | 0.4 | —0.3 | 0.9 | 0 | 0 | —0.7 | 10.4 | 0 |

The amount of the three major constituents, tourmaline, zoïsite and phlogopite were measured on the integration stage. The parts rich in zoïsite were estimated to form 65 % of the total. The following values are found: 19 % tourmaline, 37 % phlogopite and 44 % zoïsite.

The recalculation of the tourmaline from the $B_2O_3$ content of the rock has directly rendered the amount of this mineral. In the same manner the percentages of the other minerals can be calculated. The result is:

16 % tourmaline, 33 % phlogopite and 39 % zoïsite, which tallies very satisfactorily with the micrometric analysis.

Finally a few remarks must be made on the mode of origin of this rock. Nothing is of course directly known of the original position of the rock, but in the neighbourhood where the pebble was found limestone lenses rich in magnesia occur in the pre-Tertiary shales. Moreover the shales are cut by dykes of diabase.

It therefore appears very probable that contact-metamorphism of such a lens of limestone has generated the described rock.

The minerals tourmaline and phlogopite are characteristic of contact-metamorphism, accompanied by addition of new substance. In this case the elements Si, Al, B, and F must have been added, thus changing the carbonates entirely to silicates.