DEPENDENCE OF THE OPTICAL ABSORPTION ON THE CRYSTALLOGRAPHIC ORIENTATION IN HEIKOLITE*

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ABSTRACT

It is concluded that the principal axes of absorption ellipsoid of heikolite are as follows: X nearly $\perp$ (100), Y $\nearrow$ [010] and Z nearly $\nearrow$ [001]. The orientations of X and Z do not coincide with the principal axes of the indicatrix.

Introduction

In his previous paper,²⁾ the present writer gave an account on the study of the anomalous optical phenomena shown by heikolite, a variety of alkali amphibole, of which the (010) section does not extinguish between crossed nicols even with the monochromatic light. The writer described especially the variation of the intensity of the transmitted light on the section measured by a photometer with photomultiplier.¹⁾ He also noted the difference between the light intensity curves thus obtained and those for aegirine which is pleochroic but shows complete extinction.

The present work was undertaken in order to study, mainly, the variation of the absorption with the orientation in the heikolite crystal.

Experimental

Four sections of heikolite were prepared for measurements with following orientations:

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$$(1) \begin{cases} \rho \doteq 90^\circ \\ \varphi \doteq 90^\circ \end{cases}, \quad (2) \rho \doteq 0^\circ, \quad (3) \begin{cases} \rho \doteq 47^\circ \\ \varphi \doteq 90^\circ \end{cases} \text{ and } (4) \begin{cases} \rho \doteq 90^\circ \\ \varphi \doteq 50^\circ \end{cases},$$

where ρ and φ refer to those designated by V. Goldschmidt.

For measuring the thickness of a section of strongly pleochroic mineral, it is desirable to make a preparate which contains both the mineral under investigation and a standard transparent mineral of known birefringence. As a standard, a section parallel to the optic axis of quartz was used. This was ground together with the section (1), parallel to (100) of heikolite, to the thickness $d=0.030$ mm. for the first observation, then ground again to $d=0.024$ mm.

Fig. 1. Intensity variations for the (100) section of heikolite with the polarizer only. ($d=0.024$ mm.)

I : Scale readings in mm. on the apparatus.

θ : Rotation angle of the microscope stage.

for the second, and finally to $d=0.010$ mm. for the third observation. In order to determine the thickness of the samples, the retardation in the quartz section was measured by means of the Soleil-Babinet compensator.

The sections used in this experiments were covered with black paper with a small hole of about 1 mm. in diameter in order to avoid the effect of the light from outside of the mineral.

The measurements were made by the polarizing microscope

with or without the universal stage. As previously reported, the intensity of light transmitted through the microscope was measured by a photometer.¹⁾

Measurements on (100) section

The intensity curves obtained by the measurements with the polarizer only for the section with $d=0.024$ mm. are shown in Fig. 1, where the scale of intensity I is arbitrary, and θ denotes the angle between the cleavage trace and the vibration direction of polarizer.

It will be seen that for all wavelengths, the curves are symmetrical with respect to the cleavage trace. However, the direction of cleavage trace indicates the position of the maximum intensity (minimum absorption) for $\lambda=668$ m μ ., $\lambda=587$ m μ . or $\lambda=487$ m μ ., while it corresponds to that of the minimum for $\lambda=501$ m μ .. Therefore, for the lights of certain two definite wavelengths, both the waves vibrating perpendicular or parallel to the cleavage trace are equally absorbed. These wavelengths were determined as $\lambda=550$ m μ ., $\lambda=487$ m μ .. From the results of the measurements made for the (100) section with different thickness, it

Fig. 2. Dependence of the intensity variations on direction for the (100) section of heikolite observed with universal stage. ($\lambda=587$ m μ ., $d=0.010$ mm.)

I : Scale readings in mm. on the apparatus.
 j : Rotation angle about the horizontal axis of universal stage.

was found that there was no appreciable change of the values of these wavelengths.

Rotating the section about $[010]$ or $[001]$ using the horizontal axis of the universal stage, and measuring the intensity in various directions, we obtained the curves showing the dependence of the intensity on direction. The results for $\lambda=587\text{ m}\mu.$ are shown in Fig. 2. The curves are nearly symmetrical with respect to the zero

Fig. 3. Intensity variations for the section nearly perpendicular to c -axis with the polarizer only.

I : Scale readings on the apparatus.

θ : Rotation angle of the microscope stage.

position for all wave lengths. There are two directions in which the two waves, one vibrating at right angle to the other, show the equal absorption. However, the plane including such two axes of equal absorption is parallel to the plane of (010) for $\lambda=668\text{ m}\mu.$, $\lambda=587\text{ m}\mu.$ or $\lambda=468\text{ m}\mu.$, whereas it is perpendicular to the plane for $\lambda=501\text{ m}\mu.$. Therefore, as far as the absorption is concerned, this mineral may probably be uniaxial for the light with $\lambda=550\text{ m}\mu.$ or $\lambda=487\text{ m}\mu.$

The intensity curves obtained with crossed nicols were found to show the same behaviour for all wave-

lengths for all thicknesses as those obtained in the case of normal pleochroic minerals. Furthermore, judging from the minimum intensity and its position, it is no doubt that the (100) section of heikolite will show complete straight extinction even for the white light.

Measurements on other sections

The intensity curves obtained for the section nearly perpendicular to [001] with the polarizer only are shown in Fig. 3. From the curves in Fig. 3, one can easily see that the absorption corresponding to the wave vibrating parallel to [010] is much stronger than that vibrating perpendicular to it.

As is observed for the (100) section, complete extinction also took place in this section under the crossed nicols.

Fig. 4. The curves showing the dependence of the intensity variations on directions for the section $\rho \approx 47^\circ$, $\varphi \approx 90^\circ$.

Full lines: Vibrations parallel to [010].
Broken lines: Vibrations perpendicular to [010].

I : Scale readings on the apparatus.

α : Rotation angle about the horizontal axis of universal stage.

Owing to the difficulty of making a thin section perpendicular to $[001]$ of heikolite, the size of the section prepared was very small (about 0.5 mm. in diameter), hence the dependence of the absorption on the direction by use of the universal stage could not be measured.

The measurements on the variation of absorption with the universal stage were also made for the section with orientation $\rho \doteq 47^\circ$, $\varphi \doteq 90^\circ$. The result are shown in Fig. 4. As shown in the figure, the curve obtained for the vibration perpendicular to $[010]$ show a behaviour asymmetric with respect to the zero position. The intensity becomes stronger as $[001]$ is approached but it decreases in the direction towards (100) . On the contrary, for the vibration parallel to $[010]$, the intensity symmetrically decreases on both side of the normal of the section.

From the behaviour of the curves obtained above, it seems probable that the absorption of the wave vibrating parallel to $[010]$ is independent of the propagation direction of the wave in the range from the normal to (100) to $[001]$. On the other hand, for a wave with the vibration direction perpendicular to $[010]$, the dependence on propagation direction is considerable.

By rotating the horizontal axis of the universal stage, we observed the intensity under crossed nicols in the direction inclining about 20° from the normal of every section above described towards $[010]$. On rotating the stage at that direction, it was observed that the complete extinction was obviously disturbed, in other words, the complete extinction can only be observed when the propagation direction of the wave is parallel to the (010) plane.

The section with orientation $\rho \doteq 90^\circ$, $\varphi \doteq 50^\circ$ does not show the complete extinction, and the direction parallel or perpendicular to $[001]$ does not mean the direction of linear vibration. In order to see the variation of absorption when the propagation direction approaches parallel to $[010]$ the measurements with the universal stage were also made. The results are shown in Fig. 5. As is seen from Fig. 5, the value of the absorption for the directions at right

angle to $[001]$ increases very rapidly as the direction of propagation varies from the normal of (100) to that of (010) .

Absorption ellipsoid and indicatrix

Summarizing the results obtained above as well as reported in the previous paper²⁾, it can be concluded that the surface showing the variation in light absorption will be symmetric with respect to the three planes namely, (010) and planes nearly parallel to (100) and nearly perpendicular to $[001]$ respectively.

The absorption surface of the normal pleochroic crystal has been considered to be deduced from an absorption ellipsoid.* Denote by Z the direction of major axis, by X that of the minor, and by Y , intermediate, of the absorption

Fig. 5. The curves showing the dependence of the intensity variations on directions for the section $\rho = 90^\circ$, $\varphi = 50^\circ$.

Full lines: Cleavage trace is at right angle to the vibration direction of polarizer.

Broken lines: Cleavage trace is parallel to the vibration direction of polarizer.

I : Scale readings on the apparatus.

j : Rotation angle about the horizontal axis of universal stage.

* Pockel: Lehrbuch der Kristallographie, p. 382.

ellipsoid, then the orientation of these absorption axes with reference to the crystallographic orientation in heikolite will be determined as shown in Table 1. The ellipsoid is very oblate in the direction of the X axis with the major axis nearly as long as the intermediate one, and becomes an ellipsoid of revolution for the definite wave

Table 1. Orientation of absorption axes and pleochroism of heikolite.

Orientation of absorption axes	Pleochroism
X nearly $\perp(100)$	X...yellowish brown
Y } $\nearrow [010]$ (668 m μ , 587 m μ , 468 m μ)	Y...deep yellowish green
(Z) }	Z...deep bluish green
Z } nearly $\nearrow [001]$ (668 m μ , 587 m μ , 468 m μ)	
(Y) }	
Absorption: $\nearrow Z > \nearrow Y \gg \nearrow X$

Fig. 6. The curves showing the dependence of the birefringence on direction for the (100) section of heikolite. ($\lambda = 587 \text{ m}\mu$.)

j : Rotation angle about the horizontal axis of universal stage.

lengths of 550 m μ . or 487 m μ ..

From the observations for all the section showing the complete extinction, it was shown that the waves vibrating parallel to $[010]$ correspond always to the slower waves. Consequently the optical axes must lie in a plane perpendicular to the (010) plane.

Since the values of the absorption of one wave does not differ much from the other (both waves propagating in the same direction) for the direction not far from the normal to (100) , it was possible to measure

the retardation in the (100) section by use of the compensator. By rotating the (100) section about the horizontal axis of the universal stage, the retardation of the two waves propagating to the various directions perpendicular to [010] were successively measured by the compensator. The dependence of the birefringence on direction is shown in Fig. 6.

No position which corresponds to the direction of optic axis or bisectrix could be found in this figure.

Hence, it may be concluded that in the (010) plane of heikolite the orientation of the principal axes of its absorption ellipsoid does not coincide with that of its indicatrix.

A thorough discussion on the anomalous optical behaviour of heikolite will be given in a paper to be published in near future.

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