

ART. XXXII.—*The Determination of the Feldspars by Means of their Refractive Indices*; by FRED. EUGENE WRIGHT.

OF the many methods which have been suggested for the discrimination of the feldspars, perhaps none has received less actual attention from petrologists than those based on the refractive indices, notwithstanding the fact that the refractive power of a mineral is one of its fundamental properties and can be determined approximately with comparative ease. The application of the refractive index methods to the feldspars was tested in detail by F. Wallérant,* who determined their refractive indices directly on a total refractometer attachment to his microscope. His particular method is applicable to all minerals except those of the highest refracting power, and would be in general use at the present time were it not for the special apparatus demanded and the fact that thin sections for his purposes require special preparation.

The method which is described below has proved serviceable in actual practice, and is based on the ability to determine the average refractive indices of the feldspars under the microscope by applying the principles developed by Schroeder van der Kolk some years ago.† The conception of the method is therefore not novel, and the following paragraphs are intended solely to suggest a *modus operandi* which has been found convenient.

Small mineral fragments when observed in obliquely incident light show, on immersion in liquids of higher or lower or equal refractive index, characteristic phenomena which are extremely sensitive and can well be used to distinguish minerals whose average refractive indices vary only five points in the third decimal place. As the theory of these phenomena, however, is given in full in the papers cited, only the practical application of the method to the study of the feldspars will be considered below.

Equipment.—Seven liquids are required whose refractive indices for yellow light are equal respectively to the refractive indices β for

Orthoclase	(Or)	1.523
Albite	(Ab ₁₂ An ₁)	1.536
Oligoclase	(Ab ₃ An ₁)	1.545
Andesine	(Ab ₃ An ₂)	1.554
Labradorite	(Ab ₂ An ₃)	1.563
Bytownite	(Ab ₁ An ₃)	1.572
Anorthite	(Ab ₁ An ₁₂)	1.582

* Bull. Soc. Min. Fr., pp. 268-271, 1898.

† Tabellen zur mikroskopischen Bestimmung der Mineralien nach ihrem Brechungsindex. Wiesbaden, 1900. Compare also Rosenbusch-Wülfing. Mikroskopische Physiographie, 1904, I, 1, 259-261, also II, 345; and Fred. E. Wright, Tschernak Miner. Petr. Mittheil., xx, 239, 1901 and this Journal, xvii, 385-387, 1904.

and can be prepared by mixing oil of cedar ($n_{na}=1.516$) and clove oil ($n_{na}=1.532$) for orthoclase and albite; and clove oil ($n_{na}=1.532$) with cinnamon oil ($n_{na}=1.601$) in the requisite proportions for the remaining members. These liquids are miscible in all proportions, evaporate at nearly equal rates and are well adapted for the method. They can be kept in small glass stoppered dropping bottles, mounted on a square wooden block and labelled with the name of the feldspar to which their refractive index corresponds. Another series consisting of monochlorated benzene (1.523), oil of cloves (1.532), aethylene bromide (1.544), nitrobenzene (1.554), mono-bromated benzene (1.562), and mixtures of the latter with bromoform (1.595), has been found to give equally good results, but cannot be procured so readily. Dilute Thoulet solutions might also be employed, but are not to be recommended since a slight evaporation of the water changes their refractive index rapidly. The solutions can be standardized either by measuring their refractive indices directly on a refractometer or by using fragments of typical feldspars as test objects in the method described below.

Manipulation.—In the actual determination of the feldspar, small grains of the substance 0.1 to 0.001^{mm} in diameter are used and can readily be obtained by breaking up, in an agate mortar, larger fragments of the mineral which have been chipped off the hand specimen. After immersion in a drop of one of the liquids between object glass and cover slip, the grains are observed in obliquely incident light under a microscope fitted with a medium power objective and condenser lens slightly lowered.* The nicols should not be crossed. The simplest way to produce oblique rays of light is to cast a shadow on part of the microscopic field by placing the forefinger between the reflector and lower nicol tube on the microscope. In place of the finger a piece of cardboard or a movable iris or stop diagram can be substituted to advantage.†

* In actual practice, it will be found that the phenomena on which this method depends can be reversed by raising or lowering the condenser lens. If a medium power objective be used, and the condenser lens be raised from its lowest possible position to direct contact with the object glass, it will be noted that the edge of the shadow, cast over part of the field, becomes more distinct on elevation, until at a certain point it is in sharp focus, after which it again becomes less clearly marked. It is in the lower and higher positions of the condenser lens and within the transition zone of the indistinct edge of the shadow that the phenomena are most clearly defined. On passing the focus point, we pass from divergent to convergent rays and the phenomena, which appear, are reversed. In the description below the condenser lens is considered to be in its lower position below the point of sharp focus. As a check on the observations, it is often advisable to raise the condenser lens and observe the reversed phenomena. By placing the condenser lens in suitable position, the highest power objectives can be used equally well and minute particles thus be studied.

† Compare Tscherm. Min. Petr. Mittheil., xx, 238-239.

By shading half the microscopic field in this manner, the edges of the small grains on the object glass will appear to be unequally lighted near the dark shadow. If the mineral grain be more highly refracting than the liquid, its edge next the shadow will appear brighter than the edge opposite; on the other hand, if the liquid have higher refracting power, the phenomena are reversed and the light band appears on the farther side from the shadow, while the adjacent edge appears darker than the rest of the grain. In case both mineral and liquid have equal refractive indices for light waves of medium length, the opposite edges of the mineral grain appear brilliantly colored—bright red on one side and blue along the farther side. The occurrence of the red and blue bands along opposite edges of the mineral is, therefore, a sufficient criterion that the refractive indices of mineral and liquid are equal for light waves of medium length. The dispersive power of liquids is often strong, and care should be taken that the colors which appear are actually red and blue and that both edges of the grain are equally bright.

By trial, the approximate refractive index of the feldspar fragment is thus found and the variety determined.

Since in this method cleavage fragments alone are used, extinction angles on (001) P and (010) M can be measured in the same powder preparation and a still more accurate determination made. The determination of the refractive index, moreover, relieves the ambiguity which exists in the angles obtained from certain members of the feldspar series.

In practice, this method has proved particularly valuable in the study of rocks containing both plagioclase and orthoclase. In the thin section it is not always a simple matter to recognize small amounts of orthoclase when abundant acid plagioclase is present, while by the refractive index method the two can be distinguished readily and accurately. Similar conditions obtain in specimens containing both orthoclase and nephelite, in which case the method applies to equal advantage.

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