AN OBJECTIVE WITH A VARIABLE DIAPHRAGM*

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The common method of measuring optic angles from interference figures is that employing the Amici-Bertrand lens or one of its many modifications. The principle involved in the use of the Amici-Bertrand lens is to produce a diminished image of the interference figure which is subsequently magnified by the ocular. The resulting interference figure loses some of its distinctness and sharpness of outline because of this procedure. The diminished image of the interference figure which is produced by the Amici-Bertrand lens falls on the cross-hairs of the ocular. In most microscopes this reduction in size is of the order of one half to one-third. The ocular then magnifies the image according to the power of the ocular giving a resultant interference figure which is from two to five times the size of the interference figure that forms in the rear focal plane of the objective. In order to measure the optic angle a scale is substituted for the cross-hairs of the ocular. This scale is likewise magnified by the ocular in exactly the same ratio as the image of the interference figure and appears superimposed upon that image as seen by the observer. This method is commonly referred to as the Mallard[1] method and the constant of the calibration curve as the Mallard constant.

The chief objection to this method is that the calibration curve is dependent upon so many variable factors. The calibration must be made for a given objective and one particular microscope with a definite tube extension and with an ocular equipped with a scale instead of cross-hairs. If any one of these several factors is varied the calibration curve is in error. The factor that introduces the greatest difficulty is the tube extension. A well defined image of the entire interference figure is difficult to obtain because the figure lies upon a curved surface[2] and all parts of the figure cannot be in focus at the same time. Even if the microscope is calibrated for one definite tube extension, because all portions of the interference figure are not equally in focus, the image is more indistinct than when observed directly with the ocular removed.

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[1] Mallard, E., *Bull. Soc. Min. Fr.*, **5**, 77–87, 1882.

[2] Wright, F. E., The Methods of Petrographic-Microscopic Research, **1911**, p. 77.

The new objective endeavors to measure the interference figure where it is formed, namely, in the rear focal plane of the objective, by using a variable diaphragm placed at this point. This diaphragm is superimposed directly upon the interference figure itself. For all routine work the calibration of the diaphragm is dependent only upon the objective, and the objective may be transferred from one microscope to another using the same calibration curve. Measurements may be made by direct observation of the interference figure with the ocular removed, or by any of the various methods using the Amici-Bertrand lens. For very accurate measurements the calibration should be made upon the individual microscope to which the objective is attached. In the direct observation of the interference figure the analyzing nicol and the correction lenses accompanying it produce a parallax which introduces a small error. However, the same type of error, though somewhat larger, is produced by the Amici-Bertrand lens system and the ocular when using that method of observation.

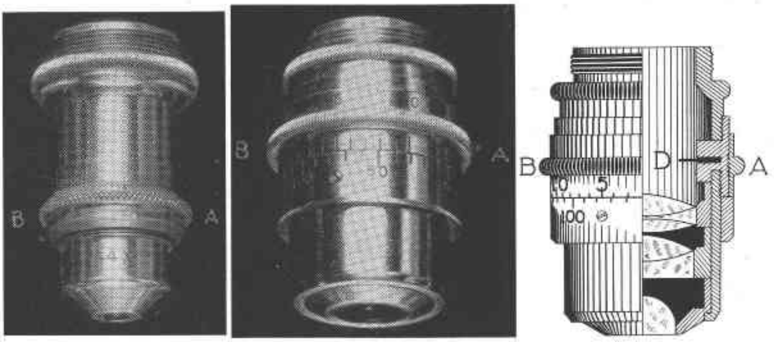

FIG. 1 FIG. 2 FIG. 3

FIG. 1. Ordinary 4 mm. objective with a variable diaphragm. Figs. 2 and 3. New type of objective with variable diaphragm.

These errors are of the same order of magnitude as those introduced by the indefiniteness of the exact position of the optic axes as determined by the centers of the isogyres. When the isogyres are broad the personal equation in determining the absolute center of the bar is quite large. Wright[3] has recommended the use of the Abbe apertometer in calibrating a microscope for the determination of the optic angle by any method. The writer has found

[3] *Ibid.*, pp. 148–9.

that it is more satisfactory to use measured sections which duplicate to a considerable extent the same conditions met with in actual practice. A comparison of the variation in the personal equation using the apertometer and measured sections gave consistently higher values for the "apertometer curve" readings. It has also been found, with both methods, that the calibration curve determined by one individual will show a consistent positive or a consistent negative variation when used by another individual upon the same sections.

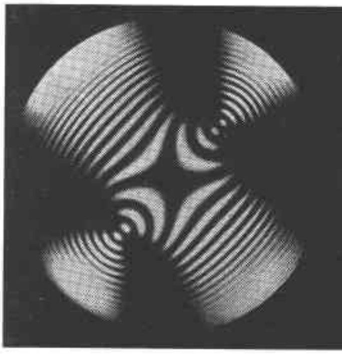

FIG. 4*a*

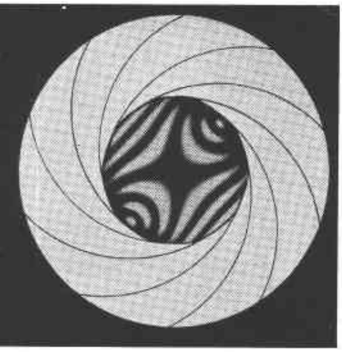

FIG. 4*b*

The diaphragm is calibrated to give the angular distance of any point in the interference figure from the center of the field. Its operation may be best illustrated by using a section of a crystal cut perpendicular to the acute bisectrix with the optic axes visible in the field as in Fig. 4a. If the diaphragm is slowly closed by rotating the knurled collar AB, Figs. 1, 2, and 3, the field of vision shrinks as in Fig. 4b until the optic axes appear exactly at the edge of the field. The scale will then give a reading which will represent E, one half the apparent optic angle. If the bisectrix is not perpendicular to the upper surface of the crystal, each optic axis may be measured separately, provided the optic plane passes through the center of the field. Then the sum of the two values measured may be taken to represent 2E without introducing any serious error. The true value of 2V may be found from $v'+v''$ for when $\sin v'=\sin D'/\beta$ and $\sin v''=\sin D''/\beta$, where D' and D'' represent the angular distances of each optic axis from the center of the field, each axis being measured separately.

If one wishes to use a vernier with the scale, the scale on the objective cannot be graduated to read directly in degrees because the distance of the optic axis from the center of the field is not a straight line function of the angle made by the optic axis with the axis of the microscope but approximates the sine of the angle. If the proper size of a standard diaphragm is used, and if the collar operating that diaphragm is calibrated so as to read the angular rotation of the collar in units of two degrees, the scale will read approximately the sine of one-half the apparent optic angle. Thus in the example illustrated, in Fig. 4b, the scale will give a numerical reading equal to the sine of one-half the apparent optic angle of the section. Another way of expressing the same fact is that the scale reads the numerical aperture of the objective for any position of the diaphragm.[4]

A variable diaphragm of this type can be placed in any standard objective at a very reasonable cost. It has uses other than the measurement of interference figures. For instance it lies in a plane conjugate with the plane of the condenser diaphragm so that for many purposes it will serve in the same capacity as the condenser diaphragm. High aperture objectives when used for viewing an object upon the stage of the microscope always show a distinct curvature of the field which prevents all parts of the field of vision from being in focus at the same time. By reducing the aperture of the objective with a variable diaphragm we can flatten the field of vision. Also by the same procedure we can increase the depth of focus of the microscope.

Fig. 1 is an illustration of an ordinary 4 mm. objective which was equipped with a variable diaphragm by the Spencer Lens Co. Figs. 2 and 3 represent an entirely new type of objective constructed by the same company and designed to give an interference figure with four times the area of that produced by the standard 4 mm. objective. This was made possible by constructing an 8 mm. objective with a numerical aperture of 0.85. The increased focal length allows a larger interference figure to be produced and by keeping the high aperture we retain the desirable characteristics of figures produced by the 4 mm. objective. It is especially well adapted for use with substances of high double refraction such as organic compounds. The average organic compound has a double

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[4] Wright, F. E., *Ibid.*, p. 37.

refraction comparable with that of calcite and gives an interference figure with a large number of leminiscate rings. For fine grained material of low double refraction the increased area of the interference figure reduces the light intensity and makes the figure somewhat more indistinct. It should also be pointed out that for direct vision of the object the magnification is reduced to one-half that of the 4 mm. objective and the field of vision has twice the diameter.

The use of the new objective for teaching purposes has been found to offer distinct advantages because the larger interference figure greatly aids the untrained eye of the beginner. In developing the theory of certain fundamental characteristics of the interference figure the diaphragm may be used to point out the features under discussion. It is hoped also that the advantages of a variable diaphragm in the objective when using the microscope for direct observation may increase the usefulness of the polarizing microscope.

NOTES AND NEWS

SODALITE FROM BOLIVIA

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Beads and carved images of sodalite have been found in ancient Indian ruins at numerous places on the Bolivian and Peruvian highlands of the Andes. A. Stuebel was the first to collect relics of sodalite in the ruins of Tihuanacu (Tiahuanaco), a settlement of the Aymara Indians near La Paz, Bolivia. These were examined and described by H. Fischer,[1] E. Bamberger and H. Feussner.[2] Prodgers who visited Bolivia in 1905–1906 makes the statement that the "Cura of Palca" told him that the early Jesuits had found "lapis lazuli" in the northern part of the Cerrania of Palca, and that the archbishops adorned themselves with chains of this material.

During his journeys through the Andes Fr. Ahlfeld of Marburg saw specimens of blue sodalite in several Bolivian collections labeled from "Ayopaya, Cochabamba" or "Cerro Sapo." In 1928

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[1] *Zeit. f. Kryst.*, **4,** 370, 1880.

[2] *Zeit. f. Kryst.*, **5,** 580, 1881.