A New Form of Microscope.

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MANY years ago I requested Mr. Swift to make for me a first-rate Binocular Petrological Microscope. The centering of the stage by screws was, I suppose, as good as it could be made. I found it unsatisfactory when using high powers on small crystals. A centering nose-piece answered no better. Only by the simultaneous rotation of the polariser and analyser by hand, little by little, could I keep the interference figures of small crystals in the field of view, or feel certain that the figures had not left it during rotation owing to the excentricity of the centering. By small crystals I mean crystals under the $\frac{1}{1000}$ of an inch in diameter, and of such thickness as one finds them at the edges of petrological sections. Results obtained thereby were only slowly got, and always with some uncertainty. I tried the Nachet Microscope, but found it a cumbrous instrument. Latterly I connected the polariser and eye-piece analyser by a jointed rod, and got thereby excellent results, whilst I could still retain binocular vision for all but certain observations. I suggested to Mr. Swift that he should manufacture a more perfect Student's Microscope than any now obtainable: one which would suit alike the mineralogical, petrological, botanical or medical student. Having agreed upon the design of the instrument, I left to Mr. Swift the carrying out of the details, which he did in an ingenious manner and with excellent workmanship. When the microscope was finished I went over it carefully, and handed it to several friends interested in such matters for suggestions, all of which have been carried out. You see the result in a small microscope where there is little lumber and much capability of good work. Its interest to the Mineralogical Society lies in its adaptation to the study of the optical properties of minerals generally, and particularly to that of the thin plates of minerals seen in ordinary sections of rocks prepared for microscopical examination. For this purpose the analyser and polariser are connected together by toothed wheels. They can thus be turned together in any position relatively to one another—crossed, parallel or inclined—each nicol being so fitted that it can be set in any position. The wheels can be clamped in any position. The tube of the microscope is of the ordinary construction. Within the lower part of it is a sliding tube which carries a sliding plate. In the plate are three circular openings, of which the central one is always open. In one of the other openings is fitted a Klein's plate; in the other a lens. The lens can be easily removed and another of different focus put in its place, according to the purpose for which it is to be used.

The lens of shorter focus brings interference figures into the eye-piece, where the *dispersion* may be studied, and also where the apparent angle in air of a biaxial crystal may be approximately measured, if the section is large enough to fill, or nearly fill, the field. For this and other purposes, a micrometer can be pushed into the eye-piece. In the instrument now described, with a B eye-piece 50° of the scale between the optic axes are equal to an apparent angle in air of $69\frac{1}{2}°$ for Muscovite. Exact measurement must, of course, be made by means of a stage goniometer.

The lens of longer focus is intended for use without the eye-piece, to enable the observer to see the interference figures (generally only the axial shadows being visible) by looking down the tube, when a $\frac{1}{10}$ or $\frac{1}{12}$ in. objective is used on very small crystals, in convergent light, between crossed nicols.

There is a weaker lens for the same purpose fitting into the top of the tube, which can be used with a $\frac{1}{4}$ or $\frac{1}{6}$ in. objective by those who, like myself, cannot see the figures without some aid.

The eye-piece, when in use, turns with the polarising apparatus. It contains the usual cross wires, and has an adjustment to enable an observer to focus the wires or the micrometer alluded to above. A quarter undulation plate of mica or a wedge of mica or quartz can be pushed through the eye-piece at 45° to the direction of the cross wires.

When the eye-piece is not in use its place can be taken by a fitting which carries the analyser and the weakest lens alluded to above. The condenser of the instrument consists of a lens screwed upon the top of the polariser, which slides up and down. The lens is suitable for all objectives up to the $\frac{1}{2}$ in. For higher powers and interference figures a small hemispherical lens is fitted into the stage and can be pushed into the axis of the instrument when required. The upper surface grazes the lower side of the glass slip carrying the object. The focusing is done by raising or lowering the polarizer carrying the aforesaid lens. This arrangement is found to work admirably.

The rotation of the eye-piece and polarising apparatus is measured on a circle graduated to degrees, but by using a pocket lens a good reading to half a degree can be obtained and a fair reading to quarter of a degree, nearer than which extinctions or angles cannot be measured even under the most favourable circumstances.

When the indicator is at zero on the graduated circle the cross wires are upright, and horizontal as the observer looks into the instrument. If the polariser is in its catch any suitable crystal with straight extinction will be at the maximum darkness when parallel to either cross wire. If Klein's plate be now pushed into the tube of the microscope and the analyser turned in its fitting till the crystal and the field are of one uniform warm blue tint it will be found that the nicols are accurately parallel. The nicols can then be turned parallel to one another by the toothed wheels. This is almost the only use I have found for the Klein's plate. I wished to put it aside altogether from a student's instrument, but Mr. Swift informed me that a microscope, to be used even occasionally for petrological investigations, cannot be sold without such a fitting, buyers requiring it, though they do not appear to make any use of it. It must be regarded as part of the little lumber which it seems this instrument must possess.

If the mineral with straight extinction is not lying parallel to either cross wire, it will be found that when the wheels are turned the crystal will be extinguished when either of the wires becomes parallel with it. If the mineral has an oblique extinction a reading of the circle must be made when one or other wire is parallel to one of the edges or lines of the crystal, and another reading after continuing the rotation till the maximum extinction is attained. The rotation is then continued through 45°, and a mica or quartz-wedge pushed through the slot in the eye-piece to ascertain the direction of the major or minor axis of elasticity and its inclination to the edge or line if desired.

It is with the use of convergent light for interference figures that the accuracy and simplicity of this instrument becomes apparent. No centering being required, it is evident that an interference figure once seen will remain in the centre of the field during the entire rotation. If it passes out of view it is on account of the nature of the figure. Even in the case of the smallest crystals, no doubt is ever left in the mind of the observer whether the figure may not have disappeared owing to imperfect centering.

I have placed on the table two typical sections. The one contains large and well-defined crystals of augite, olivine and felspar, from the Lion Haunch, near Edinburgh. It will be seen that by pushing any crystal towards the centre of the field till the angle to be measured touches the intersection of the cross wire, a reading of the angle is obtained. Pushing the crystal into the centre of the field and examining it by convergent light under a high power, it is easy to ascertain the direction of the line joining its optic axes if they can be seen in the section. This is noted, and one of the cross wires brought parallel to it. A reading of the circle is then made and the rotation continued through 45 degrees. The high power is then replaced by a lower power, and the strongly converging upper lens of the condenser is pushed out so that the mineral may be examined in less strongly convergent light for the purpose of ascertaining in what direction compensation is obtained when the mica or quartz wedge is thrust through the eye-piece parallel or at right angles to the optic axial plane, inclined 45 degrees to the planes of the crossed nicols. By thus studying the emergence of a bisectrix it is seen whether it is positive or negative. The other section consists of a Scotch hornblende-schist. The greater part of the section consists of water-clear granules of quartz and felspar, containing amongst the mosaic a number of well-defined crystals of rutile, and an immense number of less well-defined crystals of some mineral showing very dark borders, due to the fact that its refractive index is much higher or much lower than that of the mosaic. All the grains, except the hornblende and some parts of the mosaic, are under the $\frac{1}{1000}$ of an inch, piled upon one another, for the section is a rather thick one except at the edges. In this section are two small grains, one of which shows the emergence of one optic axis of a felspar, whilst the other shows the cross of quartz cut nearly perpendicular to its principal axis. Close to it lies one of the still smaller grains of the more or less highly refractive crystals. It lies flat, gives straight extinction, and shows the nearly perpendicular emergence of an optic axis. I think the mineral is Epidote, but draw attention to it merely to show the ease with which interference figures can be studied. To a petrologist accustomed to a rotating stage and fixed cross wires, a familiar section looks strange when first looked at on a fixed stage with movable cross wires, but after a few hours' work with the instrument the feeling of strangeness passes, and that of the solid advantage of a perfect centering alone remains.

There is one fact which I should allude to in connection with the small interference figures seen on looking down the tube of the microscope. It is, that the spot of light at the back of the objective in which the figures are seen rotates slightly when the wheels are turned. This is due to its being seen by the extraordinary ray. It may be regarded as a blemish, but is of no practical importance.

Beneath the stage is a universal fitting, whereby any sub-stage arrangement may be applied for special studies. In this paper I have confined my description to those concerned in the application of the microscope to mineralogy and petrology.