An improved polarizing microscope. II. All-purposes model.

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I. *Introduction.*

IN the description of an improved polarizing microscope, recently published by the present authors,[2] provision was made for the use of polarizing film in place of calcite prisms, and the consequent changes in the design of the substage and tube were discussed. The model then described was, however, of smaller size than is required for some patterns of Fedorov stage now in use, and a larger stand was under consideration. For technical reasons this could not be produced at the same time as the smaller instrument, and it was therefore necessary to postpone the description which forms the subject of the present supplementary paper. The changes involved are mainly dimensional, the optical and manipulative arrangements being in principle the same as in the smaller model, but the general standard of equipment in details such as stage racks, ball-bearing stage, and interchangeable bodies is on a scale corresponding with that in the largest existing types of stand. The general arrangement of the instrument will be readily understood by means of the photographs (figs. 1 and 2) and the sectional drawing (fig. 3). The following notes are therefore confined to a brief discussion of the special additional features.

II. *The stand.*

The foot and limb are larger than in the previous model, and the hinge is provided with a lock. The focusing block carries a ball-bearing fine adjustment *A* (fig. 3) reading to 0·001 mm. and in front of this is a vertical slide with lock *B* which permits the interchange of monocular and binocular bodies, &c. A second slide has a rigid lock *C* by which the tube and focusing block can be fixed at a higher level, thus adding at

[1] Published by permission of the Director, Geological Survey and Museum.
[2] Min. Mag., 1946, vol. 27, pp. 175-185.

least 1½ inches to the working distance available for long-focus objectives or thick objects and for the universal stage. The various interchanges may entail a small displacement of the centre, but this should be corrected by means of the hand-centring screws at the bottom of the tube, while the common adjustment of the objectives in their centring holders is left undisturbed.

The fine adjustment operates only on the bracket *D* carrying the objective and analyser, while the replaceable part of the tube is attached by the slide *B* directly to the focusing-block. In this way the weight of the binocular body, &c., is borne only by the coarse focusing-rack, and the bodies can be interchanged without disturbing the adjustment of a high-power objective.

III. *The substage.*

Rack focusing is provided, but otherwise the equipment conforms to that already described in the smaller model. In the latter the condenser is focused by movement in a sleeve having a firm locking-screw. This is fairly rapid and effective for occasional use, but for some purposes, especially in connexion with phase-contrast methods, it is useful to have the condenser and swing-out fittings on a rack of usual type. An additional slide *E* permits the interchange of the complete substage and stage, and is provided with locks of a specially rigid type. On both models the mirror has locking-heads which prevent it from being accidentally disturbed during the manipulation of the substage.

IV. *The stage.*

An accurate ball-bearing stage is provided, with a lock and adjustable resistance to rotation, tappings to receive screws for attaching the universal stage, &c. The outside diameter is 120 mm., with two verniers. This relatively small diameter has been adopted since a stage wide enough to extend beyond the base of the largest Fedorov stage becomes inconveniently large for routine use. A rack *F* with lock allows the usual adjustments for ore-microscopy and for the universal stage, while the special slide *E* already mentioned permits the interchange of the complete stage.

V. *The tube.*

Two interchangeable bodies are available, the monocular body being most suitable for determinative measurements, while the binocular gives greatly improved comfort for prolonged use.

Monocular body.—This substantially follows the design of the smaller

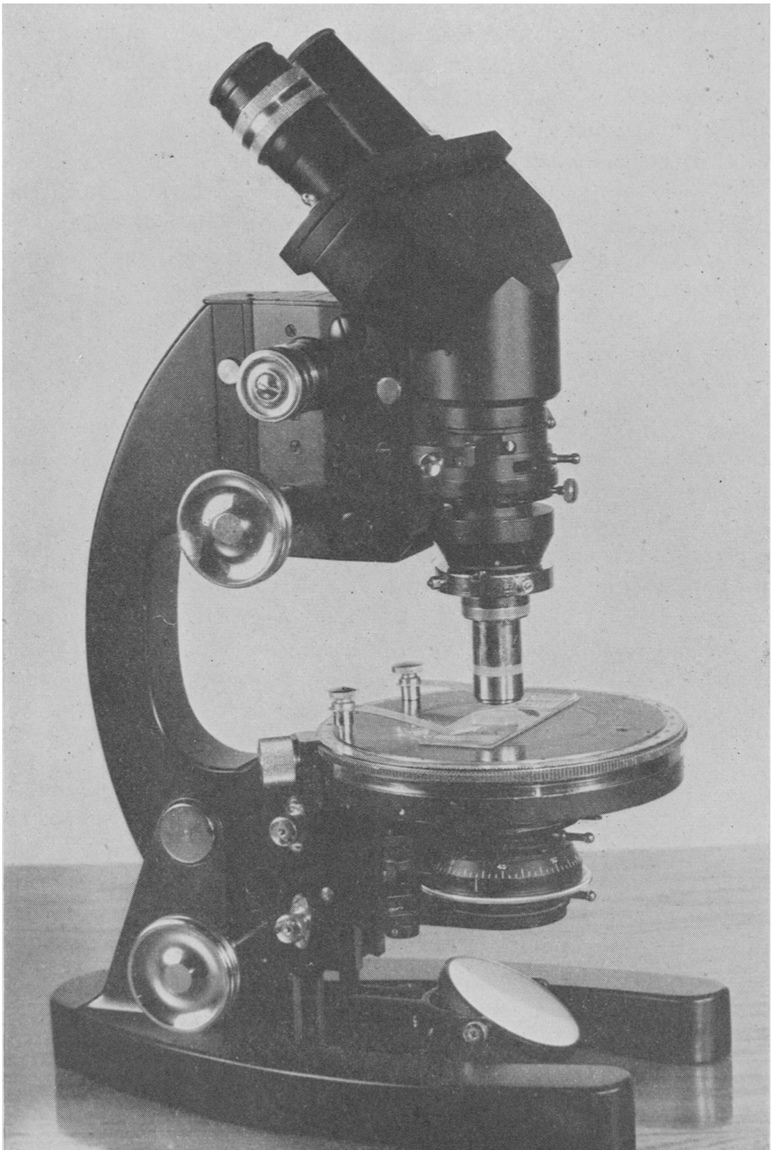

FIG. 1. Large polarizing microscope with binocular body.

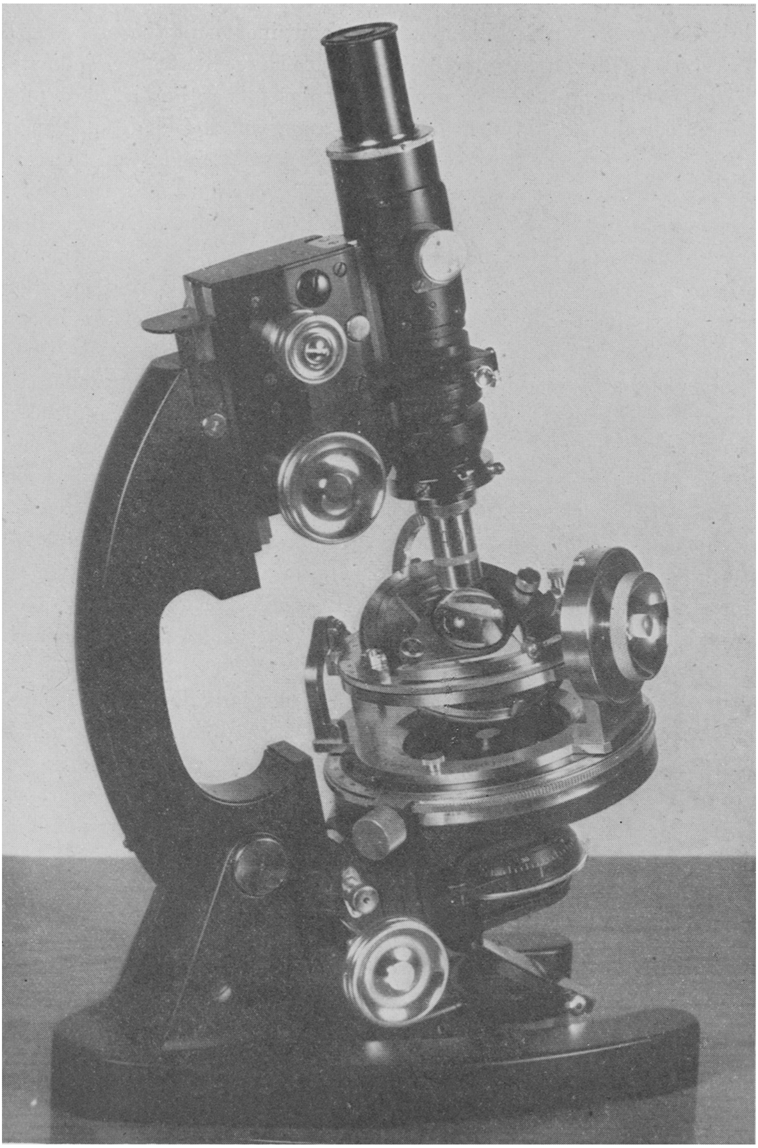

Fig. 2. Large polarizing microscope with monocular body. Stage rack lowered. Focusing-block partly raised, to accommodate a four-circle universal stage.

model, with the new type of Bertrand lens fitting, and with provision for inserting the vertical illuminator without increasing the tube length. The special determinative methods available have already been indicated in the first part of this paper. The analyser is rotatable. For most mineralogical work, even in ore-microscopy, the desired result can be obtained by rotating the polarizer through a small angle, and there are certain advantages in having a fixed analyser as a datum for the adjustment of the rest of the reflecting and polarizing system. Nevertheless, there is some increased facility in the rotating analyser and this has accordingly been fitted. An important consideration, affecting more particularly the biological side, is the possible use of the rotation in conjunction with phase-contrast equipment. For ore-microscopy, however, care must be taken to see that the analyser has been turned to the orientation which is most efficient for use with the reflector unit. This is specially important in using the new coated cover-glass, which is preferable to the prism on account of its better aperture relations, but has a rather marked polarizing action.

Binocular body.—Apart from giving increased personal comfort for the observer, the binocular eyepiece affords improved contrast in the image. This probably results from the elimination of the grey background which is contributed by the unused eye, and which obscures the darkest parts of the image seen by the other eye.

In prismatic binocular eyepieces the beam is divided by an inclined half-reflecting surface, usually coated with rhodium. Approximately half the light is thus sent to each eyepiece, but the surface has an appreciable polarizing action, the light in one eyepiece being enriched in one component while that in the other eyepiece has a corresponding deficiency. This polarization is parallel to the principal planes of the prism and therefore of the microscope, so that the only effect produced by it when the analyser is in position in crossed or parallel orientation is a small difference in illumination. If, however, the analyser is 'out' there remains a weak analysing action due to the prism, and this gives rise to weak interference colours which are superimposed on the image as usually seen with the polarizer alone. In one eyepiece the colours are those for the crossed position, in the other they are complementary as for the parallel position. When the two images are combined in binocular vision these colours compensate one another, but incomplete combination is very common and the faint tints which are then visible may be a source of annoyance. The effect can be eliminated by inserting weakly polarizing plates, if desired.

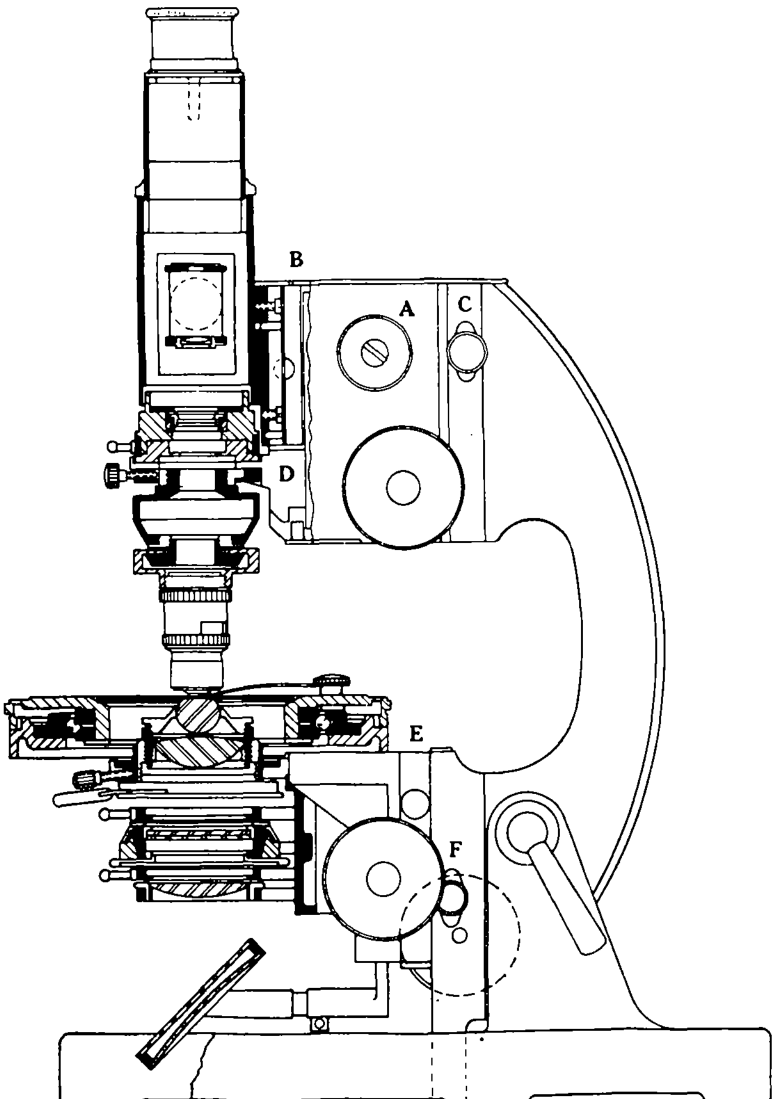

FIG. 3. Large polarizing microscope (part section).

It is not easy to fit a Bertrand lens of sufficiently low magnification, but the interference figure can be examined by removing one of the eyepieces, or by means of a Becke lens in the usual way.

The prisms entail an increase of tube length, to an extent depending on the height and construction of the optical system. So far as the objective corrections are involved, the increased length is compensated by an additional lens placed between the objective and the prisms, so that in this respect there is no adverse effect. There remains, however, an increase in the magnification which in practice cannot be reduced below about $1\frac{1}{2}$ times that obtained from the same objective and eyepiece in a standard monocular tube. This is usually neutralized by the employment of low-power eyepieces (say, $\times 4$) or, if more powerful eyepieces are preferred because of their wider field, the objectives chosen may be of somewhat lower power than usual. With the highest powers the gain in magnification is helpful, the tendency in routine work being to retain the $\times 5$ or $\times 7$ eyepiece although the objective will allow the use of $\times 10$ or $\times 15$ with consequent improvement in the visibility of the smaller structures.

VI. *Use of the universal stage.*

Fedorov stages of the largest type can be used. Standard tappings are provided; it may be necessary, however, to employ special fixing screws on account of the difference in thread. If the universal stage fails to clear the frame of the microscope when the slide at C has been raised (fig. 2) the clearance can be increased by lowering the stage rack.

To adjust the illumination the condenser may be removed; the desired aperture, usually about 0·2 N.A., is then supplied by the weak collective lens aided by the diffuser. R. C. Emmons[1] recommends the insertion of a ground glass, but no special accessory is here required, the diffuser in its swing-out fitting being already provided. Special objectives designed for the existing stages can be used since they are not sensitive to small changes of tube length. The iris diaphragm is removable with the condenser, but if a diaphragm is required in this position a disk with the required opening can be inserted in one of the swing-out fittings.

For refractive index determinations of the very highest accuracy, direct illumination is best obtained from a distant source or from the monochromator. For ordinary determinative work, when the condenser is in use, a satisfactory Becke line can be obtained by closing the iris

[1] R. C. Emmons, The universal stage. Mem. Geol. Soc. Amer., 1943, no. 8, pp. 39 and 98. [M.A. 9–18.]

diaphragm. By means of the universal stage the available methods, especially for refractive-index measurement, have been considerably extended; they do not, however, entail any change in the construction of the microscope, and reference should be made to text-books such as that of Emmons (loc. cit.).

VII. *Phase-contrast microscopy.*

During the past ten years a substantial improvement of the image has been obtained for small transparent objects which differ to a moderate degree in refractive index from the surrounding medium. 'Relief', as usually recognized in mineral preparations, can be diminished, and part or all of the object stands in marked contrast with the background, being usually darker. The apparatus used consists of an annular diaphragm placed under the condenser and a special annular 'phase-plate' which is placed at the upper principal focus of the objective. For regular use the phase-plate is built into the objective and a special condenser includes the required range of annular diaphragms. The method, which is still undergoing development, has already achieved outstanding success in biological research and may well become of interest for mineral problems, though cases depending on the form of minute structures are of less common occurrence: a possible example is the study of dust particles.