THE DARK-FIELD STEREOSCOPIC MICROSCOPE FOR MINERALOGIC STUDIES*

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Abstract

Dark-field illumination has not been widely used in the study of minerals, but the stereoscopic microscope can readily be adapted to make use of the dark-field effect. The dark-field stops that may be used with the stereoscopic microscope are described, together with some of the applications for which the method has proved most useful.

Dark-field illumination as applied to the stereoscopic microscope, commonly known as the binocular microscope (Greenough type), permits unusually intense illumination, gives strong stereoscopic effects, and reveals internal structures in mineral grains, all of which may be helpful in mineral studies. The method of equipping a microscope with dark-field illumination and some of the types of study that are facilitated by such illumination are described below.

The stereoscopic microscope, (commonly called the Greenough type), equipped with a condenser system for giving dark-field illumination, has many applications in mineral investigations. A description of the equipment and some of its applications may be of general interest. The only modifications of the stereoscopic microscope are the addition of a source of transmitted light and a dark-field condenser. The writer has been using the simple Carl Zeiss plankton condenser. The type of condenser supplied with an inexpensive biology microscope and dark-field stop may be used. This dark-field stop gives the same effect, but the plankton condenser has the advantage of being effective through a greater working distance. A source of transmitted light is required and so the lower stand of an old biology microscope serves very well if the tube and its support are removed and the dark-field stop used or the plankton condenser substituted. If a stereoscopic microscope with stage and mirror is available it may be adapted to hold the condenser system.

A permanent set-up is desirable. Therefore, it is advisable to have the stand carrying the condenser and mirror permanently fixed in the proper position under the microscope. Any good stereoscopic microscope is suitable, but ample clearance is necessary. Paired objectives giving somewhat higher magnification than commonly used are desirable with dark-field illumination and the combinations giving magnifications of 24, 48, and 72 times are found most suitable.

The blackness of the field permits very intense illumination of the objects that reflect light into the field of view. For most work, a 500-watt

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incandescent projection bulb does not produce undue eyestrain. The intense illumination tends to make even very small objects or structures clearly visible.

With dark-field illumination, light is reflected from all surfaces of discontinuity, thus bringing out all boundaries of grains, inclusions in grains, or internal structures marked by slight differences in indices of refraction. Color differences also show very clearly. Any dust or other foreign material within the field is brought out with equal intensity. For this reason, careful cleaning of grains and the glass slide is imperative. If grains are mounted in immersion media, the upper surface of the cover glass must be free from dust and smears.

Dark-field illumination has been effective in making counts involving the ready recognition of a number of minerals. For the support of the grains, a glass slide 8 by 10 centimeters in size is prepared with a number of very fine parallel scratches made with a diamond. Only those grains in contact with a scratch are counted. A magnification of 48 times is most commonly used. In general, counts can be made much more rapidly under the stereoscopic microscope than with the petrographic microscope, but the latter may be needed for preliminary identification. Color and form show so clearly that these are commonly adequate for ready recognition.

A study, involving the use of dark-field illumination with the stereoscopic microscope, was made on sands which formed the ballast material for the incendiary balloons that the Japanese dispatched to this continent in great numbers during World War II. The objective of the study was to locate the launching sites of the balloons, but the sands themselves had unusual mineralogic interest. The method used in this study will serve to illustrate the general method. The mineral composition of the sands was very constant, but the proportions varied within wide limits. A representative composition determined by count and corrected for specific gravity is shown on the following page.

The grains were evidently from clean beach sands and did not require washing. The mineral grains may have been somewhat rounded. However, the euhedral form of some of the crystals indicated that rounding by erosion was slight for most of the material. The magnetite, which was abundant in some of the samples, was separated by a hand magnet and weighed; the remaining grains were essentially transparent minerals. The dark-field stereoscopic microscope was especially effective in rapidly distinguishing hypersthene from augite. Under the petrographic microscope either the pleochroism or the extinction of the hypersthene had to be recognized by rotation of the microscope stage. Under unpolarized light of the stereoscopic microscope, hypersthene was some shade of brown

Table of Mineral Composition of Ballast Sands of Japanese Balloons

	Per Cent
Hypersthene	52
Augite	7
Hornblende	8
Garnet	1
Magnetite	10
Quartz phenocrysts	8
Quartz, detrital	8
Plagioclase (An_{30}-An_{60})	6
Plagioclase (An_{90}-An_{100})	Sparse
Zircon	<1
Sphene	Sparse
Biotite	Rare
Hornblende schist	Present
Shell material	Not included
Volcanic glass	Rare

and the augite was slightly greenish. The hornblende ranged from dull brown to dark green and commonly its cleavage was easily observable. The quartz phenocrysts ranged from sharply euhedral to partly rounded and were readily recognizable as having the form of high-temperature quartz. This form also served to distinghish them from the detrital quartz. The intermediate plagioclase was glassy clear; the plagioclase, hypersthene, augite, and euhedral quartz were evidently of volcanic origin, as were the sparse glass shards. The hornblende, the biotite, and probably the garnet were derived from metamorphic rocks, as the hornblende in individual grains and that in the greenstone fragments were similar. The source of the magnetite was not evident from the microscopic study. The detrital quartz seems to have been derived from sedimentary rocks.

Photomicrographs shown in Plate 1 fail to do justice to the method, as the stereoscopic effect is lacking. Figure (*a*) shows the euhedral form of the hypersthene. Figure (*b*) shows the quartz phenocrysts with some of their inclusions. In this photograph the field is light instead of dark, owing to a milky-glass background, which gave diffused light and made the quartz stand out in greater relief. Even without the binocular effect the euhedral form is shown.

A liquid inclusion with vapor vacuole in a much larger quartz crystal from Arkansas, having the morphology of low-temperature quartz is shown in Fig. (*d*). The figure shows a negative quartz crystal. The low-temperature form and the gas bubble floating in the liquid are visible even without the binocular effect.

Figure (*c*) represents a photograph of a specimen of thread pumice (reticulite) collected by Chester K. Wentworth at Kilauea Volcano,

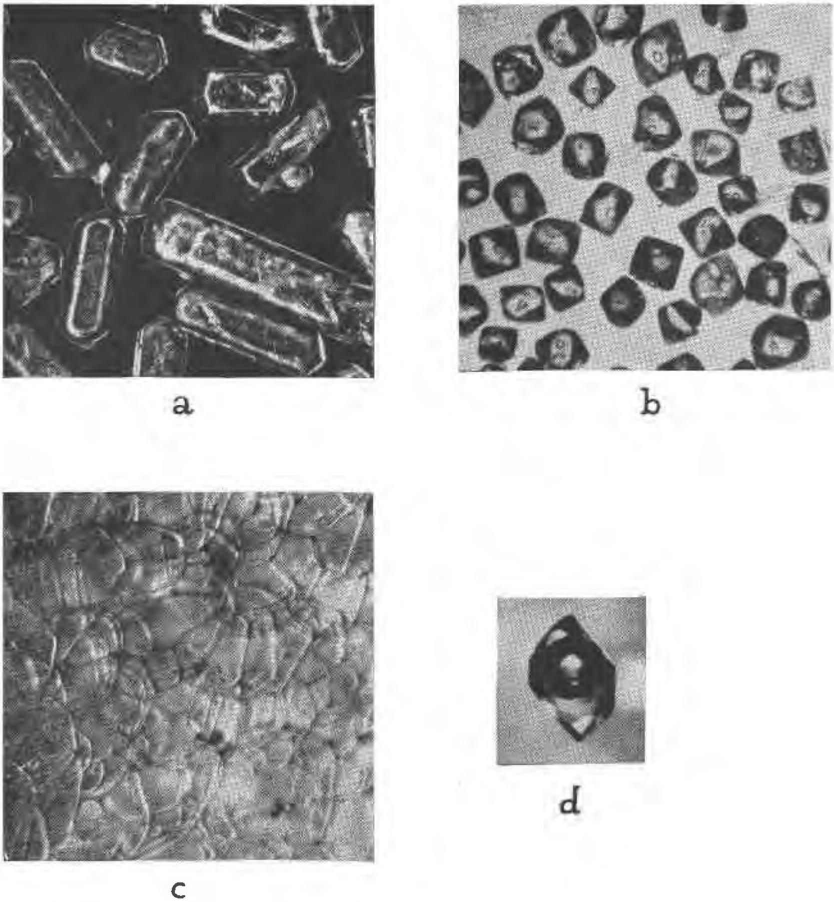

PLATE 1

Photo Micrographs Using Dark-field Illumination.

Island of Hawaii. The specimen was impregnated with plastic and the surfaces polished. The reticulate threads of basaltic glass are well shown.

At times it is helpful to supplement the study of thin sections under the petrographic microscope by transferring them to the dark-field microscope. Minute traces of oxidation products of iron-bearing minerals and of films of leucoxene show up clearly, and even sparse gibbsite disseminated in kaolin produces conspicuous areas of greater opacity. The intense illumination allows light to be transmitted by materials that appear opaque under normal illumination; and so significant colors may be observable.

The stereoscopic microscope with dark-field illumination gives the same brilliant index of refraction effects which have been described by Nelson B. Dodge.[1] This effect as seen with the equipment here described has not been used as a general means of mineral identification. However, transparent minerals with slightly different indices of refraction may be distinguished at a glance. Quartz mounted in an immersion medium with intermediate index, is bordered by blue or by red and blue, and sodic plagioclase is bordered by red and orange. However, the differences in indices of refraction are hardly as clear-cut as they would be with good inclined illumination under a petrograhic microscope.

[1] Dodge, Nelson B., The dark-field color illumination method: *Am Mineral.*, **55**, 541–549 (1948).