and Cr^{+3} and Mn^{+3} have nearly the same ionic radii. The effect of environmental factors cannot be evaluated owing to the lack of paragenetic data, but from the fine grain size and a comparison with the formation of other pegmatitic manganiferous muscovites, the mineral probably is hydrothermal rather than magmatic in origin.

On the basis of the low Fe_2O_3 content (.16 per cent) in relation to the 1.7 per cent MnO, the intense purplish-blue color can be related to the Mn chromophore (Heinrich and Levinson 1953). Very likely the intensity of the color in hand specimen is in part a function of the very fine grain.

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STRESS AND DOUBLE REFRACTION IN DIAMOND*

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It has become accepted as axiomatic that anomalous double refraction in diamond is due to intense internal strain that makes crystals showing high interference colors unsatisfactory for some industrial uses. This is especially true for wire drawing dies and shaped diamond cutting tools which are made from the finer grades of industrial diamonds. In practice the examination of crystals between crossed polars has never been deemed necessary for some of the less specialized uses of industrial diamonds such as wheel trueing and core drilling, but in some companies it is standard practice to examine all diamonds with a polarizing microscope before cutting for industrial use.

* Contribution from the Department of Mineralogy and Petrography, University of Michigan, No. 194.

In 1952–53 several thousand industrial stones of the type known as "flats" were examined in this laboratory under an Office of Naval Research grant to select for study outstanding specimens showing either double refraction or inclusions. A few showing first and second order interference colors were found. When a carat nearly perfect octahedron was examined under the polarizing microscope while being compressed by a screw clamp, it was found that interference colors of the fourth or fifth order were easily induced. This interference color is far higher than that seen in diamonds not subjected to external mechanical stress and was induced by pressures so far below those to which industrial diamonds are subjected during use that it appears that no conclusions should be drawn from "anomalous" double refraction as to the suitability of any diamond for industrial use.

While the theoretical treatment of photoelasticity in diamond has been given (Pockels,[1] Coker and Filon,[2] Bhagavantam[3]) and the photoelastic constants have been determined by Ramachandran,[4] it seemed desirable from a practical point of view to obtain directly information on the order of interference colors exhibited by an uncut octahedron of diamond under external stresses of known magnitude. To this end a single octahedral crystal was examined in polarized light under a series of compressional loads.

Force was applied normal to a pair of octahedral faces by means of thin edges of mild steel. If the indices (111) and $(\overline{111})$ are assigned to the faces being compressed, then the steel edges in contact with these faces were oriented with their lengths parallel to $[1\bar{2}1]$. The interference phenomena were observed by viewing the crystal in this direction (neglecting refraction) through faces $(1\bar{1}1)$ and $(\bar{1}1\bar{1})$. In other words pressure is exerted normal to opposite octahedral faces by V-wedges whose parallel edges bisect the 60° angles of each of the opposite octahedral faces. The crystal is viewed nearly parallel to the edges of the wedges. The distance between (111) and $(\overline{111})$ is 4.5 mm. The upper and lower contact areas are about 5.4 by 1.3 mm.

Figure 1*a* is a photograph of the diamond between the steel edges. The clips which hold the diamond in place can be seen on either side.

A series of photographs was taken of the diamond between opposed circular polars. Sodium light was used. The force exerted upon the diamond was 0, 50, 100, 150, and 200 kilograms. Figure 1*b* through *f*,

[1] Pockels, F., Lehrbuch der Kristalloptik (**1906**).

[2] Coker, E. G., and Filon, L. N. G., Photoelasticity (**1931**).

[3] Bhagavantam, S., Photo-elastic effect in crystals: *Proc. of the Indian Academy of Sciences*, Section A, **XVI,** No. 6, 359–365. Dec. 1942.

[4] Ramachandran, G. N., Photoelastic constants of diamond: *Proc. of the Indian Academy of Sciences*, Sec. A, **XXV,** No. 2, 208–219. February 1947.

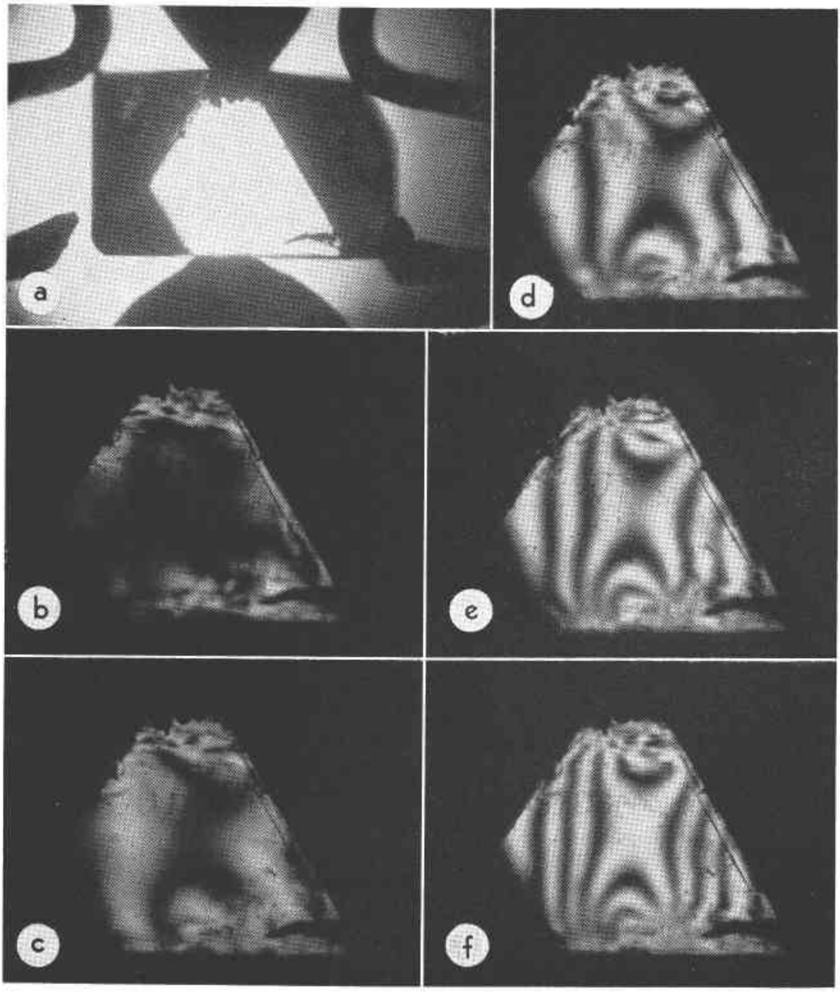

FIG. 1. (*a*) Diamond mounted in stress apparatus as viewed in the camera (reversed image). (*b–f*) diamond between opposed circular polars, sodium light, vertical compression. (*b*) 0 kilograms; (*c*) 50 kilograms; (*d*) 100 kilograms; (*e*) 150 kilograms; (*f*) 200 kilograms.

respectively, illustrate the interference patterns produced. It should be noted that since the diamond was immersed in an index liquid of 1.65, only light passing through plane $(1\bar{1}1)$ was recorded. The photographs yield information on the magnitude of the difference between compressional and tensional stress normal to the line of sight. The equal path difference curves do not yield information of the direction of these stresses. One striking feature of the pattern is that the distribution of the equal path difference curves does not substantially differ in appearance from what one would expect from a mechanically isotropic (amor-

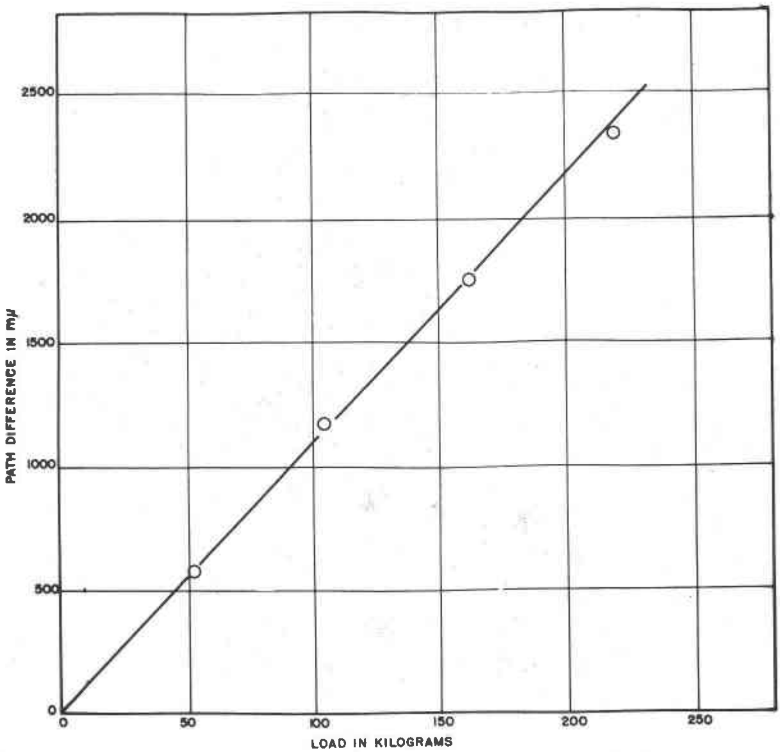

FIG. 2. Path difference plotted against compression in kilograms.

phous) substance. This was checked with a glass model under similar conditions. The fast vibration direction lies in the direction of compression.

The relation of the path difference at the center of the field to the total load applied is indicated in Fig. 2. If it is assumed that the stress is uniformly distributed along the line of sight, then the birefringence of the diamond can be readily obtained for any selected portion of the field and at any load.

Since externally unstressed diamonds of size similar to the crystal under study do not show interference colors as high as third order, it can be seen that examination in polarized light to eliminate stones in a high state of strain is probably unwarranted. It must, however, be remembered that the observed interference color of natural internally stressed stones is determined by the total retardation of a given thickness of the crystal. It may be that most of the stressed portion which produces the retardation lies within a thin element of the crystal. If this is true, the birefringence—and hence local stress—could be considerably greater than that encountered in the experiments here described. Whether the birefringence of natural (not externally stressed) stones is due to stress is perhaps debatable.

A BERTRAND-LASAULX SLIDER FOR THE POLARIZING MICROSCOPE

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Almost fifty years ago Wright suggested the use of a pair of right-angled prisms in an insertable metal plate to permit observation of an interference figure by the Lasaulx method without the trouble of removing the ocular and replacing it with a pinhole eyepiece. Six years later he proposed that a single rhomboid prism be employed in place of the earlier pair. This apparatus seems not to have been adopted by the microscope makers.

At the time Wright made his suggestion, it was not very common to use the polarizing microscope for determing the indices of refraction of a mineral grain by means of comparison with an embedding liquid. Although this technique has become well-nigh universal since World War 1, and while microscopists recognize the great value of the Lasaulx method when working with crushed grains (or indeed with *small* grains in a thin-section), the reflecting apparatus has not gone into production.

Some years ago the writer approached microscope manufacturers with the suggestion of making a double slider—Bertrand lens one way, Wright-Lasaulx prism the other. This was finally done by the American Optical Company through the good influence of the late Joseph D. Reardon. As first made the new slider replaced the standard Bertrand one and a small auxiliary pinhole tube was clamped along the side of the microscope tube. The latter, while made at my suggestion, turned out to be relatively cumbersome; it also was not easy to have it properly centered over the prism. Accordingly I had our shop replace it with a small pinhole tube attached directly to the slider as shown in the photograph. While this pinhole tube lacks an elegant appearance, it does not get in the way and can be covered easily by a shell vial if one feels that a dust cap is needed. It can be centered once for all by having the pinhole cover held to the top of the tube (or the base of the tube fastened to the slider) by means of three screws going through enlarged holes. If one wishes to use a camera lucida the slider is very quickly removed from the microscope tube; or the slider might be mounted with the Bertrand on its right side, the pinhole tube on the left. Experience indicates that a pinhole 0.04 inches in diameter gives optimum results; this is smaller than the one usually supplied by the manufacturer.