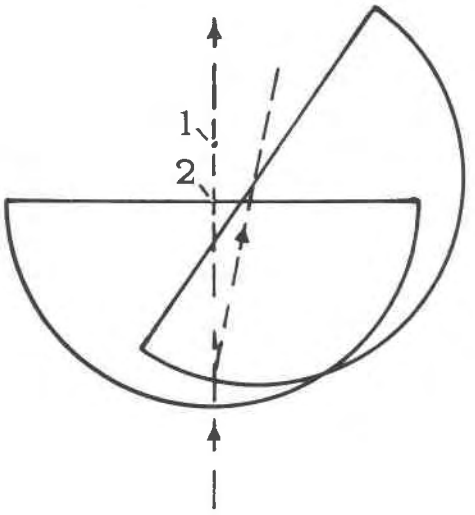

FIG. 1

may conclude that in this case too the effect of the deviation can probably be avoided by using a broad illuminating beam offering a greater choice of incident directions and a greater light spot on the object.

Finally, it is perhaps justified to conclude from his results that the exact optical properties of the lower segment are not very important at all, as long as a broad incident beam is used. It might even be harmless and convenient to use one lower segment for all measurements and to change only the upper segment according to the refractive index of the mineral under consideration! This goes for both stages. An amplification in this direction of the painstaking measurements so aptly performed by Munro should be most cordially welcomed.

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REPLY TO COMMENT ON "ERRORS IN THE MEASUREMENT OF 2V WITH THE UNIVERSAL STAGE"

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Dr. Tobi raises two main issues in his comments on my paper (*Am. Mineral.* **48**, 308–323, 1963), namely, the accuracy of measurements made with the Zeiss universal stage, and the possibility that accurate measurements can be made with a universal stage when the upper and lower segments differ in refractive index. Not having access to a Zeiss

stage, I am in no position to comment on the first topic, but I have made a number of additional measurements on the thin sections employed in my previous investigation, using a Leitz four-axis stage and various combinations of upper and lower segments. This new data is summarised in the accompanying table which also incorporates certain information from Tables 1 and 2 of my paper.

This table shows clearly that the replacement of an upper or a lower segment by a segment of different refractive index greatly increases the error in orthoscopic measurements of 2V with the Leitz stage. This is not unexpected as it is apparent that, when the segments differ in refractive index, the image of the light source observed with the Bertrand lens is subject to a large lateral displacement when the stage is tilted. This displacement is a measure of the extent to which the illuminating beam is refracted in traversing the central assembly, and also provides an indication of the size of the error in an orthoscopic measurement of 2V, as the "orthoscopic extinction position" appears to correspond with the point at which the isogyre observed with the Bertrand lens is centrally related to the visible portion of the image of the light source. It is obvious that the displacements are always greater than when both segments have the same refractive index, and that the image of the light source is increasingly obscured by the edge of the objective diaphragm when the angle of tilt is increased beyond quite small values. As was pointed out in my paper, this last factor is always important when the illuminating beam is narrow (substage diaphragm stopped down), but when the segments differ in refractive index it is still important even with a wide illuminating beam (substage diaphragm fully open), the displacement of the image of the light source with tilting being so great that the aperture in the objective diaphragm is never filled by the image of the light source when a certain small angle of tilt is exceeded. In view of the relationship between the "orthoscopic extinction position" and the center of the visible portion of this image, it follows that in this case 2V (ortho.) will never be the same as 2V (cono.) unless 2V is small. The displacements are particularly large when the upper segment has the lower refractive index and, as a consequence, no accurate measurements could be made on olivine using this combination of segments. It is noteworthy that when the upper segment has the lower refractive index, the image is displaced towards the downtilted side of the stage (as is the case when both segments have the same refractive index) and 2V (ortho.) is smaller than 2V (cono.), while the reverse relation holds when the upper segment has the higher refractive index.

The conoscopic measurements seem to be less affected by the use of segments differing in refractive index, though it would appear that if measurements made with a pair of segments of high refractive index are

repeated after one of the segments has been replaced by a segment of low refractive index, then the error in the measurement is reduced and the accuracy approaches that obtained when both segments are of low refractive index. However, this improvement in accuracy is small and, as noted above in connection with olivine, difficulties may arise at large angles of tilt because the illuminating beam is strongly refracted in the central assembly on the stage.

Thus, although it would appear at first sight to be a considerable convenience to use the same lower segment for all measurements made with a universal stage, this advantage is more than outweighed by the disadvantages which have just been discussed. These disadvantages probably arise with all types of stage, irrespective of whether the design of the instrument necessitates the use of a center plate or not. When a center plate is required, it would seem more desirable to modify the accepted procedure by always employing a center plate with the same refractive index as the segments in use, and it would be advantageous if manufacturers of this type of stage could supply an appropriate series of center plates as standard accessories with the instrument.

Measurements with a Leitz Four-Axis Stage Showing the Effect of Using Combinations of Segments which Differ in Refractive Index.

All the readings are averages of at least five measurements made with a center plate n-1.520 and a U.M.3 objective with the objective diaphragm fully stopped down.

	R. I. Segments		Substage Diaphragm Setting	2V (ortho.)	2V (cono.)
	Upper	Lower			
	1.557	1.717	Closed to minimum aperture	58.7°	—
Topaz.			Fully open	63.3°	65.3°
All values	1.557	1.557	Closed to minimum aperture	64.7°	65.3°
for $2V_\gamma$.			Fully open	65.3°	65.3°
$2V_\gamma$ (sphere)	1.717	1.557	Closed to minimum aperture	70.4°	—
=65.3°			Fully open	67.0°	65.2°
	1.717	1.717	Closed to minimum aperture	62.9°	—
			Approx. one quarter open	—	64.7°
Olivine.	1.557	1.557	Closed to minimum aperture	90.2°	—
All values			Approx. one quarter open	—	91.4°
for $2V_\alpha$.	1.717	1.557	Fully open	95.1°	91.6°
$2V_\alpha$ (sphere)	1.717	1.717	Closed to minimum aperture	86.1°	89.2°
=91.75°			Fully open	91.1°	91.0°