fication, however, since they can be made precisely normal to the thin section and in any desired degree of development. When lamellae are sufficiently widely spaced so that individual lamellae can be studied, it is seen in phase contrast that the lamellae are asymmetric—dark on one side and bright on the other (pls. 1, *C*, *D;* 2, *B*). In any field, some are bright on the right and some on the left, in roughly equal proportions. These two sets give the appearance of ridges and grooves in oblique illumination. Figure 2, *b* shows intensity versus distance across a lamella as seen in phase-contrast illumination. Under both bright-field and phase-contrast illumination, the lamellae have the greatest contrast when the incident light is vibrating parallel to $\epsilon$.

Plate 2, *C*, *D*, shows the same field of lamellae in bright-field (pl. 2, *C*) and phase-contrast illumination at high magnification with an oil-immersion objective. In plate 2, *C* the lamellae are apparently 2 $\mu$ wide, with fuzzy borders. Under phase contrast, however, these lamellae are sharp, 0.2 $\mu$ or less, and have the asymmetry noted at lower magnification. Plate 4, *A* shows an electron microscope picture of etched lamellae at still higher magnification. The lamellae still appear sharp down to 50 Å, or ten lattice spacings.

Plate 2, *B* shows the discontinuous nature of widely spaced lamellae in regions of low deformation. Note that the lamella which is continuous in the lower right peters out near the middle to reappear as isolated "knobs" and "hollows" at the upper left. Similar behavior can be seen on close inspection of plate 1, *C*.

Phase-contrast objectives produce artifacts of just the kind seen in these lamellae, so that we must examine to what extent these optical effects are artifacts. Wolter (1956) discusses these artifacts and provides the information to estimate the magnitude of the effect for our optical system. We calculate that the artifact comprises about half the visible effect with our 40× objective and about a quarter of that with the 100× oil-immersion objective. Artifacts can appear only when there is a gradient or discontinuity of index. The effect is to exaggerate the difference in index. While the artifact can thus alter the quantitative nature of the optical effect, it cannot alter the qualitative effect.

We conclude therefore that the lamellae are comprised of a region of higher index on one side of a sharp plane discontinuity, and lower index on the other side. Each region of abnormal index grades in a very short distance into the index of the host quartz. The maximum and minimum indices appear to occur at the boundary plane, but this is obscured by the artifacts. The appearance in bright-field illumination is presumed to be due to refraction and diffraction.

This variation in index of refraction in the immediate vicinity of lamellae is associated with a variation in birefringence, which can be measured with a rotary compensator. A basal lamella which is normal to the microscope slide is positioned at 45° to the plane of polarization of the incident light. When the compensator is rotated so that the region surrounding the lamella is at extinction, a narrow region on each side of the lamella appears bright. Since the thickness of the thin section is uniform in the vicinity of the lamellae, as noted above, these regions must be bright because of a difference in birefringence from that of the host. Rotating the compensator to bring each of these narrow regions successively into extinction shows that one side has a higher birefringence than the host, and the other side is lower in birefringence by an equal amount. The maximum difference occurs at the lamella, and the birefringence grades off in both directions to that of the host. In average lamellae, the measured birefringences are .0005 higher and lower than that of the host. In the darkest lamella shown in plate 2, *D* (upper right) the difference is .002.

This change in birefringence may also be directly observed in thin sections of greater than normal thickness, showing first-order red between crossed polarizers. The increase and decrease of birefringence adjacent to the lamellae change the interference colors to blue and yellow, respectively. The birefringence differences observed in this way are consistent with those determined with the rotary compensator. The variation of birefringence with distance away from the lamellae may be estimated by the degree of change of color, yielding the typical values shown in figure 2, *c*.

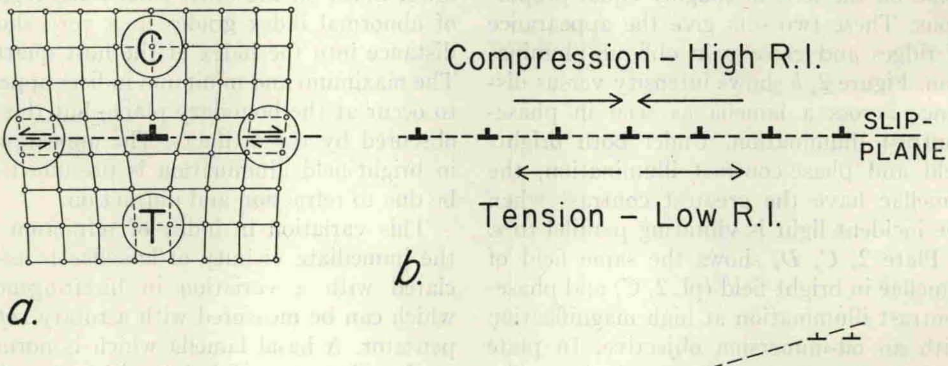


FIG. 3.—*a*, diagrammatic representation of edge dislocation in a simple lattice, showing main components of its stress field. The lattice is in compression (*C*) on the side of the slip plane with the extra half-plane and in tension (*T*) on the other; there are shear stresses on the slip plane with the senses shown. *b*, array of parallel edge dislocations locked in the slip plane, showing main components of its stress field. Compression on the positive side results in an increase in refractive indices and tension on the negative side in a decrease in indices. *c*, simple model for deformation lamellae which are not parallel to the slip plane but give optical effects somewhat similar to an array in the slip plane. Model consists of *en échelon* arrays lying in different slip planes.

### DISLOCATION THEORY OF LAMELLAE

The observed variation in index and birefringence could arise from edge dislocations locked in the basal plane. If slip on the base were due to the movement of edge dislocations in the basal plane, then it is to be expected that some of these would become trapped at obstacles such as impurities, lineage boundaries, and other imperfections. Each edge dislocation produces a stress field of the type shown in figure 3, *a*. This increases the index of refraction in regions of compression and reduces it in regions of tension. If the trapped dislocations are all of one sign in a given region and spaced closely enough, the effect will be to create a narrow region of high index on one side of the basal plane and a corresponding region of low index on the other side, as shown in figure 3, *b*. We suggest that deformation lamellae are formed by basal slip and that their optical character is created by edge dislocations trapped in the basal plane. A quantitative test of this hypothesis may now be undertaken by comparing the measured changes in birefringence with those calculated from electron microscope evidence of the dislocation arrays.

The steps we have followed in calculating