these specimens is not yet complete, so that detailed crystallography of these lamellae and bands cannot be stated. The existence of these features, however, suggests slip on other systems besides the base and prism planes.[9]

### COMPARISON OF EXPERIMENTAL AND NATURAL LAMELLAE

The above description of experimental lamellae might give the student of natural lamellae the impression that we are describing structures quite different from those he observes in his microscope. It has been remarked in the preceding paper, however, that experimental lamellae are identical in all respects except crystallographic orientation to many natural lamellae, when studied with the universal stage by bright-field microscopy. We are then left with the questions: Do natural lamellae look like experimental lamellae when viewed in phase-contrast illumination? Can dislocation arrays of the type observed in experimental lamellae persist in nature? Are natural lamellae comprised of dislocation arrays?

When a thin section containing natural lamellae is polished and etched, lines of etch pits form coincident with the lamellae, as observed at high magnification under a combination of reflected and transmitted light. Replicas of such surfaces are made and specific lamellae are identified optically and photographed under the electron microscope. It is found that the pattern of etch pits at the site of natural lamellae is far less regular than in experimental lamellae. Plate 4, *B* shows two typical etch-pit patterns at the site of four lamellae. The three lamellae on the right of the photograph show wavy lines of etch pits which might be distorted single arrays of dislocations. The fourth lamella in the lower left center, however, shows etch pits in a band roughly 1 $\mu$ wide, with no discernible pattern. The majority of natural lamellae so far examined are of the latter type. These etch pits are presumed to be the sites of dislocations. Their linear density along the lamellae is sufficient to give the observed optical effect if they are predominantly basal edge dislocations of one sign within each lamella.

When natural lamellae are found normal to a thin section and examined at high power under phase-contrast illumination, the majority of those so far examined show the characteristic appearance of the experimental lamellae as described and illustrated in figure 2, *c* when examined with a compensator. Thus we conclude that the majority of natural lamellae are comprised of irregular arrays of basal edge dislocations.

[9] Since this was written, several new slip mechanisms have been identified (Christie and Green, 1964): $m \parallel a$, $m \parallel c$, $m \parallel \langle c+a \rangle$, $r \parallel \langle c+a \rangle$, $z \parallel \langle c+a \rangle$, $\xi \parallel \langle c+a \rangle$, $\xi' \parallel \langle c+a \rangle$; $\pi$ and $\pi'$ directions not determined. (The slip planes are designated first and then the slip directions; $\langle c+a \rangle$ are the directions obtained by summing *c* and *a* vectorially.)

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PLATE 4

*A*, Electron micrograph of carbon replica from etched (HF vapor) lamellae in polished thin section from single crystal C-240. NW.-trending linear arrays of symmetrical etch pits are coincident with lamellae. Average etch-pit density along lamellae is $10^5$ per cm. NE.-trending features are probably scratches on polished surface and N.NE.-trending dark feature on left side is a defect in the replica.

*B*, Electron micrograph of lamellae in grain in polished thin section of Orocopia quartzite. N.-S. irregular arrays of small etch pits are parallel to lamellae. In some places (center and right of micrograph) etch pits are concentrated into narrow bands parallel to lamellae. Natural lamellae show much more variability than experimentally produced lamellae.

*C*, Near-basal lamellae (W.NW.-trending lamellae) intersected by another set at high angles (NE.-trending lamellae, upper right) in highly deformed part of single crystal C-212. Near-basal lamellae are inclined at *ca.* 10° to the base here but may be traced into less deformed regions (where lamellae of other orientations are absent) where they are exactly basal.

*D*, Deformation lamellae (N.-trending features) in little-deformed region near end of crystal C-143. N.-S. cross-hair marks orientation of (0001); lamellae have various inclinations to (0001).

Scale lines beneath *A*, *B* represent 2 $\mu$; beneath *C*, *D*, 0.1 mm.

Turning to comparison of the crystallographic orientations, the histograms exhibit a peak in the neighborhood of the basal plane for both natural and experimental lamellae (Carter *et al.*, 1964, fig. 3). This peak occurs at 15°–20° to the basal plane for natural lamellae, but at 2°–6° for lamellae in the experimentally deformed aggregates examined to date. Both natural and experimental lamellae show subordinate peaks at higher inclinations to the base. We consider that basal slip is the primary mechanism of formation of natural lamellae comprising the first maximum (between 0° and 30° to the base) and that the other slip systems suggested above are responsible for the formation of lamellae inclined more steeply to the base.

*Focusing attention on natural lamellae in the neighborhood of the base*, two factors are believed to account for the inclination of the lamellae to the basal plane: (1) Some lamellae may originate as *en échelon* arrays of basal edge dislocations locked in different slip planes, as shown in figure 3, *c*. (2) Lamellae, either initially parallel to the base, as discussed in preceding sections of this paper, or consisting of the *en échelon* arrays just mentioned, may be internally rotated by slip on some other system.

There is considerable evidence of internal rotation of basal lamellae in our experiments. It is shown in the preceding paper (fig. 3) that in a slightly deformed quartzite (C-79) the lamellae are predominantly parallel to the base, while in the more highly deformed squeezer samples the predominant orientation of lamellae is at an inclination of a few degrees from the base. In C-127 (fig. 6 of the preceding paper) the lamellae show increasing inclination to the base with increasing deformation from the little-deformed ends to the more deformed center of the specimen. These observations are consistent with internal rotation of initially basal lamellae by a secondary slip mechanism. Sufficient internal rotation to give the 15°–20° inclination observed in natural rocks requires substantial strain and accompanying reorientation of the lattice, as discussed in the preceding paper.

In single crystals oriented so as to favor basal slip, and where there is no evidence of secondary slip (such as the *c*-axis or other non-basal lamellae or basal bands, referred to above) the lamellae are parallel to the base within a degree or two. In some highly deformed single crystals, however, there is abundant evidence of slip on other systems, and lamellae which are parallel to the base in relatively undeformed regions may be traced into highly deformed regions where they have been internally rotated up to 12° from the base. Plate 4, *C* shows such a region in specimen C-212.

Evidence of lamellae consisting of *en échelon* arrays is more meager in our experiments, but their existence is strongly suggested by two observations. Plate 4, *D* shows lamellar features in a relatively undeformed region near the end of single-crystal specimen C-143, illustrated in plate 6, *B* of the preceding paper. The lamellae have various inclinations to the basal plane, which is parallel to the vertical cross-hair. The extinction position of the lamellae differs by 1°–2° from that of the host. The region in which these lamellae occur is so little deformed that they cannot be internally rotated basal lamellae.

The other evidence of lamellar bands of this type is the occurrence of experimental lamellae which possess the characteristic phase-contrast signature of basal dislocations but have an extinction position different from that of the host. This may mean that these lamellae are bands of finite thickness which have been either externally rotated by *en échelon* slip within the bands or have been bodily rotated (internal rotation) by slip on some system inclined to the lamellae. Alternatively, the stress-optical effects of *en échelon* arrays might result in the observed rotation in the vicinity of the lamellae.

Lamellar bands of *en échelon* slip have been found in metals by Honeycombe (1952) and Kuhlmann-Wilsdorf and Wilsdorf (1953).