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THE ORIGIN OF DEFORMATION LAMELLAE IN QUARTZ

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ABSTRACT. Fabrics of four quartzite specimens containing numerous quartz grains with deformation lamellae are described in detail. Patterns of preferred orientation of deformation lamellae in all four specimens are similar in that the poles of the lamellae define a small-circle girdle (about an axis designated A). The orientations and strengths of maxima within the girdle, however, are not consistent in different specimens. [0001]-axes of grains containing deformation lamellae also define a small-circle girdle about the same axis (A). In each specimen the great-circles containing [0001] and the pole of the deformation lamellae for individual grains pass through, or close to, the axis A of the small-circle girdles.

The deformation lamellae are shown to be late structures unrelated to the deformations which induced the preferred orientation of the quartz grains in the rocks. The lamellae are not parallel to rational crystallographic planes and they are considered to represent kink-bands resulting from shearing parallel to [0001] on irregular planes in the zone of [0001]. The shearing is probably controlled by imperfections in the crystal structure, which commonly exist parallel to [0001] in quartz.

According to this hypothesis the axis (A) of the small-circle girdle defined by poles of lamellae is the axis of maximum compressive stress during the deformation which produced the lamellae. This relationship may be used to obtain a dynamic interpretation of deformation lamellae in quartzose sedimentary and metamorphic rocks. The hypothesis is tested using data from the Baraboo Quartzite and it is demonstrated that the deformation lamellae in the rocks of this formation may be related to the folding of the Baraboo syncline.

HISTORICAL REVIEW

An extensive literature now exists on the nature and occurrence of lamellar structures in quartz grains in rocks of various types. There appear to be at least two or three different types of lamellae and there is considerable disagreement as to the character and the mode of origin of the lamellae.

Planar structures consisting of minute closely-spaced inclusions were first reported by Böhm (1883). Many writers have since described lamellar structures in the quartz grains of tectonites and they have frequently been designated "Böhm lamellae" or "Böhm striae" (Becke, 1892; Mügge, 1896; Sander, 1930). Intensive studies of the crystallographic orientation of these lamellae and their orientation in rock fabrics have been made by Sander (1930), Hietanen (1938), Fairbairn (1941), Ingerson and Tuttle (1945), Riley (1947), and Savul (1948). Becke (1892) described lamellae in quartz grains in a gneiss from the Central Alps; they were composed partly, but not entirely, of inclusions and showed a refractive index lower than that of the remainder of the crystal. Fairbairn (1941) also stated that the refractive index of lamellae in some cases appears to be lower than that of the grains in which they occur. Ingerson and Tuttle (1945), on the other hand, have described lamellae which are not composed of inclusions, but have refractive indices which are higher than those of the host crystals. They also recognize two other types—one consisting of planes of brown, sometimes liquid, inclusions, also showing a difference of refractive index, and the other consisting only of brownish granular material; they consider the latter to be 'relict' lamellae which have evolved from lamellae of the first type. Since many of the lamellae cannot be resolved microscopically into aggregates of discrete inclusions the practice of refering to all closely-spaced lamellae as 'Böhm lamellae' has been discontinued by many writers.

The lamellae are invariably found in quartz grains which show appreciable post-crystalline strain and it is now established that they are produced by deformation (Fischer, 1925; Fairbairn, 1941; Ingerson and Tuttle, 1945). There are several hypotheses as to the genesis of the lamellae: 1) Becke (1892) considered them to represent partially healed fractures in the quartz grains; 2) Judd (1888) and others, have suggested that they represent secondary twin-lamellae; 3) Mügge (1896), Fischer (1925), Sander (1930), Hietanen (1938), Fairbairn (1941), and Savul (1948) have all maintained that the lamellae are produced by translation-gliding; 4) Ingerson and Tuttle (1945) and Turner (1948) consider that they are microscopic shear-surfaces which are not parallel to rational planes in the quartz lattice.

A number of translation-mechanisms have been postulated to account for the deformation lamellae and there is a notable lack of unanimity among proponents of the translation-gliding hypothesis as to the actual glide-systems involved. Translation-gliding was first proposed by Mügge (1896) who showed that in basal sections of euhedral quartz crystals the traces of lamellae were neither parallel nor perpendicular to the sides of the hexagonal section, suggesting that they are not rational crystallographic planes; he, accordingly, considered that the translation took place on planes subparallel to the base. Sander, in his classic work of 1911, also maintained that the lamellae represent planes of translation-gliding. Fischer (1925) favored the view that translation takes place on $\{0001\}$, $\{10\bar{1}1\}$, $\{01\bar{1}1\}$ and perhaps more obtuse rhombohedra. Although Schmidt (1927) also postulated translation on $\{0001\}$, $\{10\bar{1}1\}$, and $\{01\bar{1}1\}$, he believed that visible lamellae need not develop parallel to the glide-planes. Sander later (1930) showed, with the aid of the universal stage, that the lamellae are inclined to $\{0001\}$ at angles varying from 6° to 30° and concluded that the planes of translation are $\{01\bar{1}3\}$ and $\{01\bar{1}2\}$.

Hietanen (1938) made a detailed study of the orientation of lamellae in different portions of individual grains with undulose extinction from the Finnish quartzites. She postulated several stages in the deformation of quartz grains. Initially, the grains undergo a limited amount of translation-gliding on $\{0001\}$, combined with bending of the glide-plane, which gives rise to feeble undulose extinction. In the next stage there is weak deformation of the lattice and the deformation lamellae are formed more or less parallel to the basal plane, the cavities in the striations being produced by breaking of the quartz-lattice. In a still later stage actual fractures are produced more or less parallel to the [0001]-axis and there is gliding parallel to the prism planes. Hietanen considered that some lamellae may also be relics of rhombohedral translation planes. But since the lamellae are never parallel to either the basal