5. Discussion

Planar structures observed in quartz of various Ries rocks can be distinguished from deformation structures in tectonites (Böhm lamellae) and those produced in static high pressure experiments (low strain rate) by the following features:

(1) The development of planar structures is stronger controlled by the crystal structure of quartz.

(2) $\{10\bar{1}3\}$ and $\{10\bar{1}2\}$ are more frequent than $\{0001\}$.

(3) There are more sets of planar structures per grain.

(4) In general, the planar structures are sharper, more plane parallel, more closely spaced.

(5) Lamellae with optical asymmetry in phase contrast illumination (deformation lamellae of Carter, Christie and Griggs) are very rare or even absent.

(6) Grains with planar deformation structures show lower bulk values of density, refractive index and birefringence, indicating that deformation was connected with partial destruction of the crystal lattice of quartz.

(7) In contrast to Böhm lamellae and planar structures produced experimentally under static conditions, the planar structures in quartz bearing Ries rocks show no relation to general direction of stress within the rock (e.g. planes of maximum resolved shear stress), because of the disorganisation of a shock wave travelling through a heterogenous rock (Rinehart, 1968).

Apart from the decoration by minute bubbles or inclusions — not reproduced in shock experiments as to date — the planar structures of Ries quartz are most similar to the deformation features obtained experimentally under shock conditions with peak pressures in the order of 100 to 380 kbar. Apparently the natural and artificial planar structures of this kind are traces of plastic flow, following under the high strain rates and pressures within a shock wave other glide planes as compared to static conditions and lower pressures.

The arrangement of the planes observed in zones (see Fig. 10) seems to indicate that the vectors $\vec{a}_1 = [10.0]$ (length $= 4.913$ Å), $2\vec{a}_1 + \vec{a}_2 = [21.0]$ (length $= 8.510$ Å) and $\vec{a}_1 + \vec{c} = [10.1]$ (length $= 7.303$ Å) are probably the principal glide directions.

The most frequent glide planes contain the shortest Bravais vector of the quartz lattice, $\vec{a}_1$: $\{0001\}$, $\{10\bar{1}3\}$, $\{10\bar{1}2\}$, $\{10\bar{1}1\}$, and $\{10\bar{1}0\}$. When the peak pressure exceeds about 120 kbar, gliding parallel to $\{10\bar{1}3\}$ or $\{01\bar{1}3\}$ is favoured over basal gliding, the typical process at lower stresses and under static conditions. At higher stresses ($> \cong 180$ kbar) or when slip parallel to $\{10\bar{1}3\}$ or $\{01\bar{1}3\}$ has ceased due to work hardening or other impediments, additional gliding develops parallel to $\{10\bar{1}2\}$ or $\{01\bar{1}2\}$.

Of secondary importance are slip planes containing the vector $2\vec{a}_1 + \vec{a}_2$ like $\{11\bar{2}2\}$ and $\{11\bar{2}1\}$ and those parallel to the vector $\vec{a}_1 + \vec{c}$ like $\{51\bar{6}1\}$ and $\{21\bar{3}1\}$.

Shock experiments with single quartz crystals by Müller and Hornemann (1968) yielded noticeable differences in the case of developing glide systems parallel to positive and negative rhombohedra of the same index: planar structures parallel to $\{10\bar{1}3\}$ or $\{01\bar{1}2\}$ are more readily formed than those parallel to $\{01\bar{1}3\}$ and $\{10\bar{1}2\}$, respectively. This result is in accordance with the observation that Ries quartz containing planar elements parallel to the above rhombohedra display preferably combinations of alternating positive and negative forms (see p. 217). A structural reason for the preference of $\{10\bar{1}3\}$ over $\{01\bar{1}3\}$ respectively $\{01\bar{1}2\}$ over $\{10\bar{1}2\}$, is probably the sequence of atomic planes. Both $\{10\bar{1}3\}$ and $\{0\bar{1}12\}$ contain two Si planes following each other without an O plane between them, in contrast to $\{01\bar{1}3\}$ and $\{10\bar{1}2\}$, containing sequences of planes of the type Si-O-Si, as illustrated in Fig. 18. The configuration of next neighbour Si planes may perhaps be favourable for gliding under shock conditions. Neither $\{10\bar{1}1\}$ nor $\{01\bar{1}1\}$ contains such a configuration. However, it exists for $\{10\bar{1}0\}$ as well as $\{11\bar{2}1\}$ and $\{21\bar{3}1\}$. $\{0001\}$, $\{11\bar{2}0\}$, $\{11\bar{2}2\}$ and $\{51\bar{6}1\}$ planes do not contain immediately opposed Si planes.

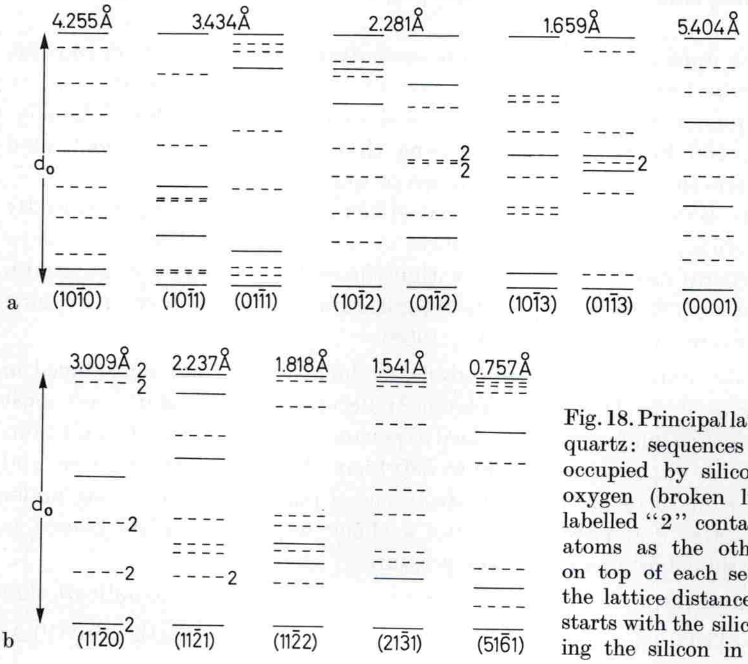

Fig. 18. Principal lattice planes of low-quartz: sequences of atomic planes occupied by silicon (full line) and oxygen (broken line). The planes labelled "2" contain twice as much atoms as the other ones. Figures on top of each sequence designate the lattice distances. Each sequence starts with the silicon plane containing the silicon in position [|u00|]

The most characteristic properties of shocked quartz, however, are their reduced densities, refractive indices and birefringences. These effects become obvious in the laboratory at peak pressures exceeding about 200 kbar. The change of physical properties indicates that shock waves of sufficient pressures not only cause plastic and ruptural deformation but also produce irreversible transformation of the quartz lattice.

The Hugoniot curves obtained by WACKERLE (1962) and AHRENS and ROSENBERG (1968) from shock experiments with quartz indicate for both single crystal and polycrystalline quartz a greater compression rate above about 120 kbar as one would expect from the compressibility of quartz determined by BRIDGEMAN (1948) at lower pressures. The same stress limit (Hugoniot elastic limit) defines according to the experiments of HÖRZ (1968) and MÜLLER and DEFOURNEAUX