(1968) the begin of plastic flow under shock conditions as revealed by the first appearance of planar structures in the recovered material. The higher compressibility above about 120 kbar is interpreted by Ahrens and Rosenberg (1968) to be due to a partial transformation to one of the high pressure polymorphs of SiO_2, either coesite or stishovite. Between 300 and 370 kbar both the single crystal and polycrystalline quartz Hugoniots rapidly approach the pressure/volume curve that is apparently characteristic for stishovite (McQueen et al., 1963). Release adiabates measured by Ahrens and Rosenberg (1968) indicate that the material produced by shock waves at pressures between the elastic limit and about 380 kbar is either a mixture of quartz and coesite or quartz and stishovite, which is retained, at least momentarily, at zero pressure. These concluisons were drawn from the volume/pressure relationship, without investigating recovery products. The experiments of Hörz (1968) and Müller and Defourneaux (1968) yielded material of the same or lower densities and indices of refraction than normal quartz, confirming the observations on Ries quartz. Consequently we and Hörz (1968) assume that the high pressure phases formed in the shock front are rapidly transformed upon release into a glass (diaplectic glass) with density and index of refraction close to fused SiO_2-glass. It is probably safe to assume that, only minor amounts — if any — of high pressure phases have been recrystallized to quartz. Under the assumption that also the diaplectic glass was not transformed into quartz, the quartz content of shocked quartz is identical with the quantity of quartz that survived the shock unaffected. This quantity decreases with increasing shock pressure and becomes zero at about 400 kbar pressure level at which the material after relase consists entirely of diaplectic glass. Bulk refractive indices and densities of shocked quartz or the amounts of crystalline quartz calculated from these data (Table 9) may be used as a measure of shock intensity in the 200 to 400 kbar range. Since the shock damaged quartz bearing rocks from the Ries are listed in Table 1 in order of decreasing mean refractive index of quartz, this order approximately represents a series of rock samples subjected to shock waves of increasing peak pressures.

Quartz deformation by shock waves as documented by quartz containing planar structures in the Ries breccias can be summarized as follows:

Under the influence of shock waves with peak pressures exceeding the Hugoniot elastic limit quartz behaves in a plastic manner and fails by gliding parallel to several lattice planes, predominately $\{10\bar{1}3\}$, $\{01\bar{1}2\}$, $\{10\bar{1}1\}$ or $\{01\bar{1}1\}$ and $\{0001\}$. Prior to plastic deformation and probably at lower stress levels planar fractures are formed, preferently parallel to $\{0001\}$ and $\{10\bar{1}1\}$. Simultaneously with gliding the quartz begins to transform into a high pressure modification, most probably stishovite or even a dense phase not yet perfectly ordered with six-fold coordination of oxygen around silicon. These phase transitions focus along glide planes with high shear strain and abundant lattice disturbations, caused by the accumulation of dislocations. These seem to be favorite conditions for the nucleation and formation of new phases. In this way thin lamellae of a dense phase are formed parallel to the numerous traces of glide planes dissecting the individual quartz grains. The amount of the new phase depends on the peak pressure of the shock wave. A total transformation is completed when the peak pressure reaches about 400 kbar. Under favourable circumstances (rapid cooling ?) some stishovite can survive the pressure and temperature release as demonstrated by the stishovite rich rock S 289 from Appetshofen. But generally, during pressure and temperature release — eventually somewhat earlier — the dense phase breaks down resulting in a more disordered "diaplectic" SiO_2-glass with properties similar to but different from those of fused SiO_2-glass and some coesite[2]. If the transition to a high pressure phase was not complete, the final release products is "quartz" (diaplectic quartz) with planar structures, as remnant of gliding processes, with lower values of density, refractive index and birefringence, due to the coexistence of glassy and crystalline SiO_2. Quartz subjected to peak pressures close to 400 kbar is completely transformed into diaplectic glass (samples B 41 and B 75).

Two particular phenomena which are observed in the shock deformed Ries quartz are not yet fully understood: the homogeneous lamellae and the decoration of planar elements, as described in chapters 3.1.3. and 3.1.1.

Homogenous lamellae may be deformation bands (kink bands), but further investigations have to be carried out with samples containing outstanding structures of this kind.

The small bubbles or inclusions of decorated planar elements resemble those known from Böhm lamellae of tectonites. Several formation processes seem possible:

(1) Coagulation of atomic vacancies formed in the slip plane by non-conservative movement or mutual interaction of dislocations.

(2) Healing of originally open fractures

(3) Segregation of originally dissolved gaseous contaminants.

Decorated planar elements are most abundant in Ries rocks which experienced shock waves with peak pressures not too much above the Hugoniot elastic limit of quartz. Quartz with low densities and refractive indices like those from rocks B 7 and B 9, contain only non-decorated planar elements. Apparently the decorations can not be formed and/or preserved if the shock dammage of quartz has exceeded a certain degree.

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[2] Another effect of pressure release are numerous irregular fractures (extension fractures) in the quartz grains which are obviously later than all planar structures.