

## SHOCK EXPERIMENTS ON HEATED SINGLE CRYSTAL $\beta$ -QUARTZ.

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*Introduction.* Dynamic compression by high-velocity impact can affect geological units at high temperature and/or high pressure environment. For example, LAKOMY (1) calculated for the Sudbury structure which represents the remnant of a multi-ring basin (2, 3) a maximum depth of excavation in the order of 25 km - obviously there the shock reached lithologies in the lower crust. In the Sudbury case an exogenic origin is more or less undisputed today (3).

For the ancient Vredefort structure in South Africa however, an origin either by "cryptoexplosion" (e.g. 4) or by impact (e.g. 5) is discussed (6). In part this controversy is arising from the unknown significance of planar features in quartz. They are apparently anomalously oriented compared to certain shock-induced features in quartz from other terrestrial impact structures or recovery experiments (5). That may be an effect of the proposed impact at Vredefort in highly tempered units, but we simply have no knowledge of shock effects in "hot" targets.

*Concept.* Reconnaissance shock experiments with preheated quartz were performed in order to determine the correlation between shock pressure and refractive index  $n$ . Previous investigations have shown that the refractive indices of *experimentally* shocked single  $\alpha$ -quartz crystals decrease systematically in the range of 20 - 35 GPa (7,8,9). Commonly,  $n$ -values of *naturally* shocked quartz are used for pressure estimation on the basis of this reference curve. Yet so far published shock loading experiments were performed only on unheated  $\alpha$ -quartz which is not of use in the context given above.

*Experimental set-up.* For the recovery experiments 0.5 mm thick disks with a diameter of 15 mm were cut out of a gem-quality quartz crystal parallel to  $\{1010\}$  and put into ARMCO-steel containers (10). Prior to the experiments these sample holders were annealed at least for 3 h at 650° C in an oven and impacted by an high-explosive driven flyer plate. This preheating temperature clearly exceeds the transition temperature of 573°C for quartz into the hexagonal high-temperature modification  $\beta$ -quartz. Due to handling procedures the actual temperature directly before passage of the shock wave was lower than 650° C by 10° at the maximum. We performed seven shots at 25, 27.5, 30, 32, 34, 40.5, and 48 GPa, respectively. These peak shock pressures calculated according to the graphical impedance match solution (11) have an accuracy of  $\leq 3\%$ . However, this error doesn't include uncertainties arising from (yet unknown) Hugoniot-parameters of the  $\gamma$ -iron.

Directly after the experiment the containers were quenched to room temperature within 5 minutes and opened. For determination of the refractive indices using the Medenbach micro-refractometer spindle stage (12) grains 50  $\mu\text{m}$  (crystalline phase) to 100  $\mu\text{m}$  (diaplectic glass) in size were selected. From repeated measurements we estimate for this very precise immersion method an error of  $\pm 0.0005$  for  $n$  of diaplectic quartz glass. This error may be larger for  $n_o$  and  $n_e$  of still crystalline quartz grains due to considerable orientation effects and a certain inhomogeneity in small domains (mosaicism).

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**Results.** Fig. 1 shows the refractive indices for hot shocked quartz (this work) together with data for cold shocked quartz (8,9). The latter authors used the identical experimental set-up, and in the case of (9) even disks of the identical quartz crystal.

In the pressure regime *below 25 GPa* cold and hot shocked quartz display a similar optical behaviour:  $n_o$  and  $n_e$  of shocked quartz are comparable with the values for unshocked reference specimen. Differences of optical behaviour occur at pressures *above 25 GPa*. Refractive indices of hot shocked quartz decrease drastically in the pressure range from 25 to 27.5 GPa, whereas for cold shocked quartz the equivalent change takes place from 25 to 35 GPa. The complete transformation to diaplectic glass is achieved at 27.5 GPa for hot shocked, but not before 35 GPa for cold shocked quartz.

**Implications and future goals.** Our results clearly show that even very accurately known refractive indices for shocked quartz are only of limited use for determination of shock pressure, *as far as lower crustal lithologies are concerned*. Recovery experiments on whole rocks performed at present under different preheating conditions and with variable peak pressures will yield a still more complex picture. We think that some disequilibrium shock effects found in basaltic achondrites, as well as features in rocks of the Vredefort structure, or even unusual textures of lunar highland samples could be caused by the (unknown) pre-shock temperature of the target. Systematic efforts by our group to decipher the influence of preheating on shock effects will help to clear such questions.

**Literature.** (1) LAKOMY (1990), *Meteoritics* 25, 195; (2) STÖFFLER et al. (1989) *Meteoritics* 24, 328; (3) GRIEVE et al. (1991), this volume; (4) NICHOLAYSEN (1990) *Tectonophysics* 171, 1; (5) GRIEVE et al. (1990), *Tectonophysics* 171, 185; (6) *Tectonophysics Spec. Volume 171*; (7) HÖRZ (1968) in FRENCH & SHORT (eds.): *Shock metamorphism of natural materials*, Mono Book Corp., Baltimore, 243; (8) REHFELDT-OSKIERSKI et al. (1986), LPSC XVII, 697; (9) GROTHUES et al. (1989), LPSC XX, 365; (10) MÜLLER & HORNE-MANN (1969) *EPSL* 7, 365; (11) RICE et al. (1958) in SEITZ & TURNBULL (eds.): *Solid state physics*, Academic press, N.Y., 1; (12) MEDENBACH (1985), *Fortschr. Mineral.* 63, 111.

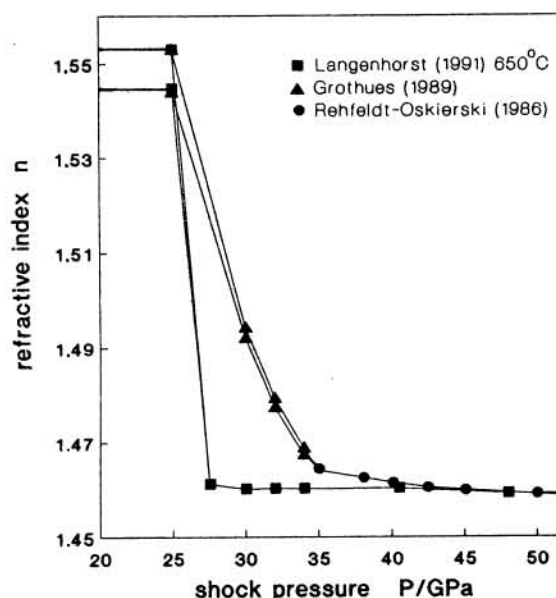


Fig.1: Refractive indices as function of peak shock pressure for hot and cold (8,9) shocked quartz.