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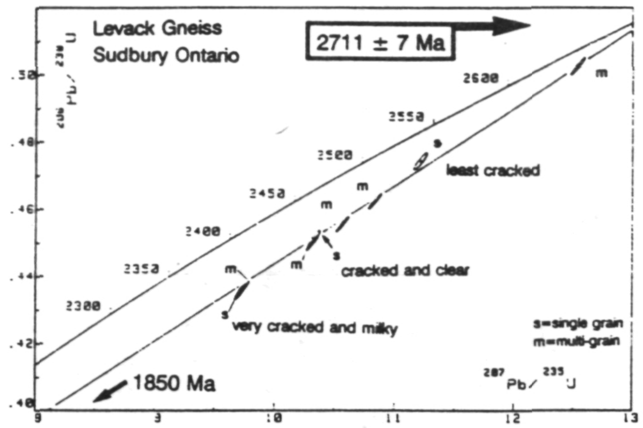

Fig. 2. U-Pb data for single zircons and multiple zircon fractions from the Levack gneiss, Sudbury, Ontario.

dominated by 550-Ma rocks and that the recrystallization features of the zircon were superimposed during the impact event at 65.5 Ma.

Data for four of the five polycrystalline grains are colinear (33% probability of fit), with data displaced 49%, 58%, 62%, and 82% from 559 ± 5 Ma toward the younger event and provide the best age estimate for the impact event (65.5 ± 3 Ma). Data for three colinear points (66% probability of fit), which are represented by an unshocked, a shocked, and a shocked and granular grain, are displaced by only 3%, 12%, and 26% respectively toward the younger event, thus providing the best estimate for a primary age of 544 ± 5 Ma. Since there is no reason to assume that single unrelated grains should form colinear arrays within our small (±4 m.y.) uncertainty, this coincidence implies that these grains share the same primary and secondary ages. The two different upper intercept ages indicate that the most and least shocked grains may have come from different parts of the impact site. Considering a possible 180-km impact site, ejecta from a local focused area may be inferred.

A predominant age of 550 Ma for zircons from the Fireball layer provides an excellent opportunity to identify the impact site and to test the hypothesis that multiple impacts occurred at this time. A volcanic origin for the Fireball layer is ruled out by shock-related morphological changes in zircon and the fact that the least shocked grains are old.

Basement Levack gneisses north of the Sudbury structure have a primary age of 2711 Ma. Data for three single zircons from this rock (Fig. 2), which record a progressive increase in shock features, are displaced 24%, 36%, and 45% along a Pb-loss line toward the 1850 ± 1 Ma minimum age for the impact as defined by the age of the norite. Southeast of the structure three shocked grains from the Murray granite record a primary age of 2468 Ma and are displaced 24%, 41%, and 56% toward the 1853 ± 4 Ma event as defined by coexisting titanite. The coincidence of titanite and norite ages, however, is consistent with near coeval impact and intrusion. The correlation of discordance with the intensity of shock-related features implies that the impact caused the observed discordance, but the precise age of impact is not evident from zircon data since some recent lead loss has occurred.

Data for five of six single unshocked zircons from a fluidal glass sample from the North Range Gray Onaping Formation plot directly on the concordia curve and give ages of 2719 Ma, 2708 Ma, 2696 Ma, 2686 Ma, and 2678 Ma; the sixth data point is 2679 Ma (2.2% discordant). These ages reflect the age spectra of the nearby Archean basement. A volcanic origin at 1850 Ma is impossible since the zircons would have to be 100% xenocrystic in origin and this has never been observed in volcanic rocks.

P-2

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INFLUENCE OF THE PRESHOCK TEMPERATURE ON SHOCK EFFECTS IN QUARTZ.

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Shock metamorphic features are the prime indicators for recognizing impact phenomena on Earth and other planetary bodies [1,2]. In the past, many shock-loading experiments were performed at room temperature [3–5] in order to artificially reproduce shock effects occurring in nature. Results of such experiments have been extensively used as a database for shock wave barometry of impact-metamorphosed terrestrial and extraterrestrial rocks. Although the pressure dependence of shock features is well known, information about the influence of the preshock temperature is almost lacking (except [6–8]). Especially in the case of large-scale impacts like Sudbury, it is expected that deep-seated crustal rocks were subjected to shock at elevated temperatures.

Therefore, we continued to perform shock experiments at elevated temperatures on <0.5-mm thin disks of single crystal quartz cut parallel to the $\{10\bar{1}0\}$ face [8]. These specimens were shocked at pressures from 20 to 50 GPa (precision <±3%) and preshock temperatures of 20°C, 540°C, and 630°C ± 5°C using a previously described high-explosive device [9]. The preshock temperature of 630°C clearly exceeds 573°C, the α/β-transition temperature, whereas the preshock temperature of 540°C is just below the transition temperature. All recovered quartz samples were investigated by universal stage, spindle stage, and a newly developed density gradient technique. Errors of refractive index and density measurements are ±0.0005 and ±0.002 g/cm³ respectively.

Orientation of Planar Deformation Features (PDF) (Figs. 1a,b): The frequency distribution of PDF in quartz shocked at 20 GPa and 540°C displays two maxima at $\{10\bar{1}3\}$ and $\{10\bar{1}1\}$, which are quite typical for this pressure as already known from naturally [10,11] and experimentally [4] shocked quartz. In contrast, PDF in quartz shocked at 20 GPa and 630°C show a broad distribution of crystallographic orientations with indistinct maxima that are difficult to index. In particular, the total absence of $\{10\bar{1}3\}$ orientations is most characteristic for this preshock temperature. This difference in orientation of PDF in quartz heated to 540°C and 630°C and both shocked to the same peak pressure may reflect the slight difference in the lattices of α and β quartz.

Refractive Index Data (Fig. 2): Drastic differences of the optical parameters of quartz shocked at the three different preshock temperatures appear between 25 GPa and 40 GPa. Refractive indices of quartz shocked at 540°C and 630°C decrease drastically and discontinuously in the pressure range from 25 to 26 GPa and from 25 to 27.5 GPa respectively, whereas refractive indices of cold shocked quartz change smoothly and continuously from 25 to 35 GPa [12,13].

Density Data (Fig. 3): The densities determined with a so-called density gradient column confirm the results of the refractivity measurements. An abrupt decrease of densities for quartz shocked at 540°C and 630°C takes place between 25 and 26 GPa, whereas quartz shocked at room temperature shows the equivalent change in the pressure range from 25 to >34 GPa.

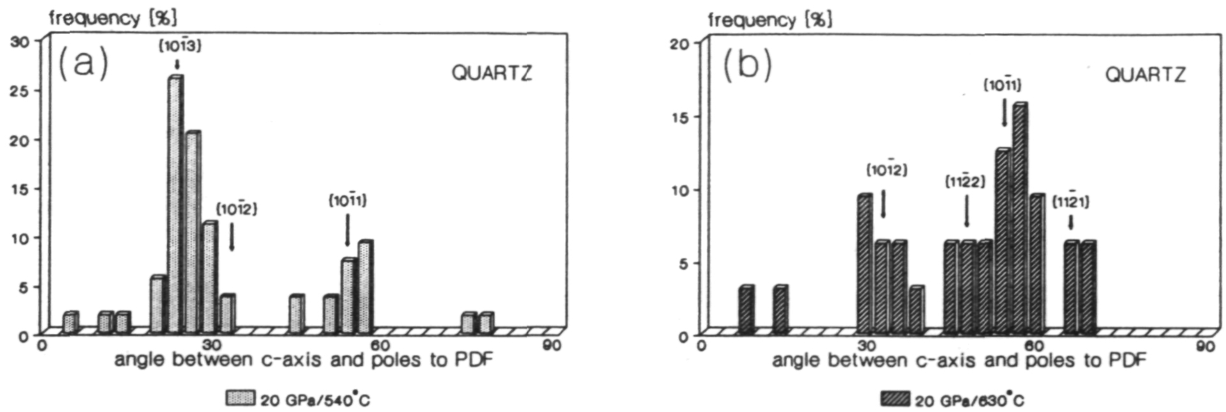

Fig. 1. Orientations of planar deformation features in quartz experimentally shocked at a pressure of 20 GPa and at preshock temperatures of (a) 540°C and (b) 630°C.

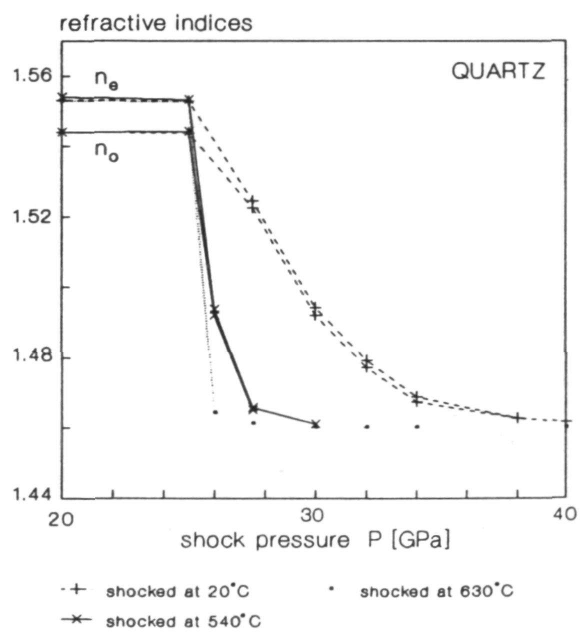

Fig. 2. Variation of refractive indices n_e and n_o as function of shock pressure for preshock temperatures of 20°C, 540°C, and 630°C.

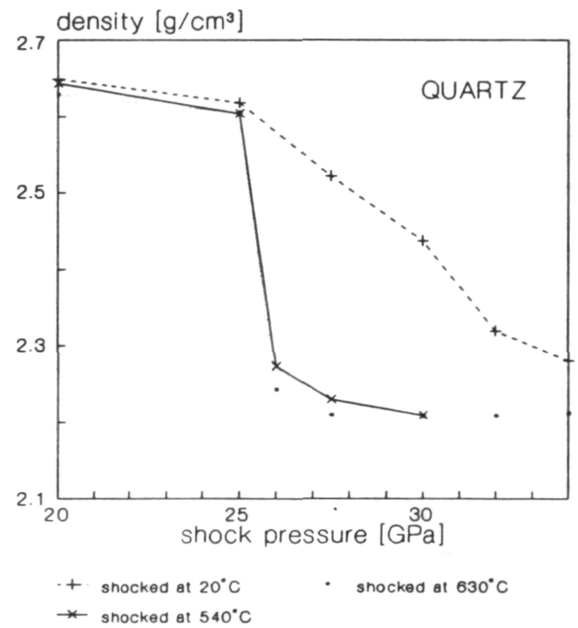

Fig. 3. Densities of quartz shocked at 20°C, 540°C, and 630°C vs. shock pressure.

Our investigations indicate that shock metamorphic features are strongly dependent on the preshock temperature. This statement has far-reaching implications with respect to shock wave barometry that is based on data from recovery experiments at room temperature. These datasets might be applicable only to low-temperature target rocks. Moreover, this study demonstrates that shock recovery experiments are definitely required for understanding the complete pressure-temperature regime of shock metamorphism on planetary bodies.

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