MINERALOGICAL SHOCK WAVE BAROMETRY: (I) CALIBRATION OF REFRACTIVE INDEX DATA OF EXPERIMENTALLY SHOCKED α-QUARTZ. J. Grothues[1], U. Hornemann[2], and D. Stöffler[1], [1]Institut für Planetologie, Westf. Wilhelms-Universität Münster, D-4400 Münster, F.R. Germany, [2]Ernst-Mach-Institut, Arbeitsgruppe für Ballistik, D-7858 Weil a. Rh., F.R. Germany.

Quartz has been most widely used in calibrating the shock pressure of impact metamorphosed rocks on the basis of planar deformation structures and refractive index data (1, 2). However, exact measurements of the two principle refractive indices n_o and n_e (ordinary and extraordinary ray) of experimentally shocked quartz were never made since the first publication of refractive index data in 1968 (3). In a series of shock recovery experiments on single crystal α-quartz we have recently reported on the correlation between shock pressure and refractive index of diaplectic quartz glass for the pressure range from 34 to 50 GPa (4). We now report on refractive indices and birefringence of shocked quartz as a function of shock pressure in the range from 20 to 34 GPa.

Disks (20 mm in diameter and 0.5 mm thick) cut parallel to the $\{10\bar{1}0\}$ face of single crystal quartz were shocked in a high explosive device (5) at peak pressures of 20, 25, 30, 32, and 34 GPa applying the shock reverberation technique with steel containers (pressure accuracy $\pm$ 3%). At 20 and 25 GPa coherent sample disks were recovered and radial sampling of grains (~ 0.1 - 0.2 mm in size) was made at 7 different locations across the disk in order to check the pressure homogeneity. From the remaining runs grains were taken at random. The refractive indices were measured with a Medenbach microrefractometer spindle stage (6) which is the most accurate method to-day (accuracy is $< \pm$ 0.0005).

The results of the spindle stage measurements are given in Table 1 and Fig. 1 together with previously obtained data using the same methods in the higher pressure regime. Fig. 1 contains also data of (3) obtained on large numbers of grains measured by the immersion oil method on randomly oriented grains where the second refractive index n_e' is always smaller than the actual n_e. Our data clearly show that a measurable decrease of the refractive indices and of the birefringence takes place only above 25 GPa. Above 25 GPa refractivity and birefringence decay drastically up to a peak pressure of 35 GPa. At this pressure quartz transforms completely to the isotropic state (diaplectic glass) at a refractive index of 1.4640. Between 35 and 50 GPa the refractive index drops moderately reaching 1.4590, a value which stays constant up to 60 GPa. We interpret the glasses produced above 50 GPa as normal quartz glass formed by quenching of a melt.

The homogeneity of the shock compression throughout the 20 mm sample is documented by the 20 and 25 GPa runs (Table 1) in which the radial variation of n_o and n_e is less than the error of the refractive index determination (standard deviation ranging between 0.0002 and 0.0004 for both indices). The variation of the refractive indices in the 30, 32, and 34 GPa runs is also extremely small. We believe therefore that the decreased refractivity measured in some grains by (3) at 15.9, 21.3, and 25.6 GPa is probably due to non-homogeneous pressure distribution in the samples. The solid curve in Fig. 1 is a best estimate interpolation of the presently available data and is considered to represent the most accurate pressure calibration of the refractive index of any shocked rock-forming mineral. It appears desirable though to improve the accuracy in the 25 to 30 GPa range by additional shock experiments.

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Table 1: Refractive indices and birefringence ($\Delta = n_e - n_o$) of experimentally shocked single crystal α-quartz; shock front parallel to prisms {10$\bar{1}$0} data obtained by the Medenbach spindle stage (6); data for n of diaplectic glass ($\geq$ 35 GPa) from (4, 8); accuracy of refractive index data: < $\pm$ 0.0005; r = radial distance of sample in mm from the center of the shocked 0.5 mm thick 20 mm diameter disk; av = average; S = standard deviation; a = handbook values from (7).

Shock pressure (GPa)		n_o	n_e	Δ	r
0		1.5442	1.5533	0.0091	
20		1.5436	1.5533	0.0097	+ 9
		1.5444	1.5432	0.0088	6
		1.5436	1.5531	0.0095	3
		1.5440	1.5528	0.0088	0
		1.5443	1.5532	0.0089	3
		1.5441	1.5529	0.0088	6
		1.5445	1.5534	0.0089	- 9
	av	1.5441	1.5531	0.0091	
	S	0.0004	0.0002	0.0004	
25		1.5439	1.5534	0.0095	+ 9
		1.5438	1.5525	0.0087	6
		1.5439	1.5532	0.0093	3
		1.5438	1.5525	0.0087	0
		1.5439	1.5531	0.0092	3
		1.5441	1.5531	0.0090	6
		1.5442	1.5534	0.0092	- 9
	av	1.5439	1.5530	0.0091	
	S	0.0002	0.0004	0.0003	
30		1.4918	1.4941	0.0023	
		1.4919	1.4939	0.0020	
		1.4923	1.4945	0.0022	
	av	1.4920	1.4942	0.0022	
32		1.4775	1.4793	0.0018	
		1.4774	1.4795	0.0021	
		1.4771	1.4789	0.0018	
	av	1.4773	1.4792	0.0019	
34		1.4675	1.4687	0.0012	
		1.4672	1.4689	0.0017	
		1.4674	1.4687	0.0013	
	av	1.4674	1.4688	0.0014	

Shock pressure (GPa)	n	Δ
35	1.4641	0
38	1.4626	0
40	1.4616	0
42.5	1.4605	0
45	1.4599	0
50	1.4590	0
synthetic SiO_2-glass	1.4585	0

Fig. 1: Refractive index versus peak shock pressure of experimentally shocked single crystal quartz