TABLE 1

Frequency distribution of planar elements in quartz grains from West Clearwater Lake, Quebec

	Thin section (30 grains)					Powder (32 grains)				
			Frequency (%)					Frequency (%)		
$\{hkil\}_r$	q_r observable	p_r observed	F_{I}	F_{II}	F_{III}	q_r observable	p_r observed	F_{I}	F_{II}	F_{III}
{0001}	30	10	33	6.8	30	28	5	18	3.8	19
{10$\bar{1}$3}	173	51	30	35	26	156	32	21	24	21
{10$\bar{1}$1}	147	24	16	16	12	151	22	15	17	14
{10$\bar{1}$2}	163	23	14	16	12	154	24	16	18	15
{21$\bar{3}$1}	120	8	6.7	5.4	4.1	145	9	6.2	6.9	5.8
{11$\bar{2}$1}	124	7	5.6	4.8	3.6	142	7	4.9	5.3	4.5
{10$\bar{1}$0}	220	12	5.5	8.2	6.1	274	17	6.2	13	11
{11$\bar{2}$2}	151	5	3.2	3.4	2.5	142	7	4.9	5.3	4.5
{51$\bar{6}$1}	231	6	2.6	4.1	3.0	272	7	2.6	5.3	4.5
{31$\bar{4}$1}	116	1	0.8	0.7	0.5	140	1	0.7	0.8	0.6
not identified	...	15	...	...	...	...	26	...	...	...
Total	...	162	...	100	100	...	157	...	100	100

$$F_{I} = (p_r/q_r) \times 100 \quad (\%)$$

$$F_{II} = (p_r/\textstyle\sum_r p_r) \times 100 \quad (\%)$$

$$F_{III} = [(p_r/\alpha_r)/\textstyle\sum_r(p_r/\alpha_r)] \times 100 \quad (\%)$$

where

- q_r = the number of symmetrically equivalent planar elements $\{hkil\}_r$ which are observable in a sample of n grains, considering the limitations due to grain orientation and the "blind circle."
- p_r = the number of symmetrically equivalent planar elements $\{hkil\}_r$ actually observed in the n grains.
- $\sum_r p_r$ = the number of all observed planar elements in n grains which could be identified with crystallographic planes.
- α_r = the number of symmetrically equivalent planes of the same form $\{hkil\}_r$ ($\alpha = 1$ for {0001} and $\alpha = 6$ for all other planes).

As though it were a mineral with perfect cleavage, quartz from the Clearwater Lake breccia disintegrates easily into a powder consisting of fine flat fragments. The planes which bound these fragments are identical with the planar elements; this conclusion was demonstrated in the following way.

By gently pressing the cover glass, Canada balsam powder mounts could be prepared with all flat fragments lying with their largest faces (main fracture planes) nearly parallel to the slide. The angles were then measured between optic axes of the grains and the microscope axis, which was normal to the slide. If there were no preferred orientation of the grains, the probability of finding optic axes at angles between ϕ and $\phi + \Delta\phi$ would be given by the function of statistical distribution, i.e.,

$$P_{\phi+\Delta\phi} = \int_{\phi}^{\phi+\Delta\phi} \sin\phi \cdot d\phi = \cos\phi - \cos(\phi + \Delta\phi).$$

Figure 4 shows the difference ΔP between the measured and statistical distribution functions, derived from the above formula. Intervals of $\Delta\phi = 4°$ were used. Positive values of ΔP mean that there are, in the particular range of orientation, more grains present than calculated for a random distribution. The maxima are situated at the same angles where the most frequent planar elements were found, indicating that fracturing of this quartz occurs preferentially parallel to planes which, in unbroken grains, are visible as planar elements.

QUARTZ FROM THE RIES BASIN, GERMANY

Similar planar elements in quartz are also very common in fragments of shocked granite and gneiss from the suevite breccia of the Ries Basin,

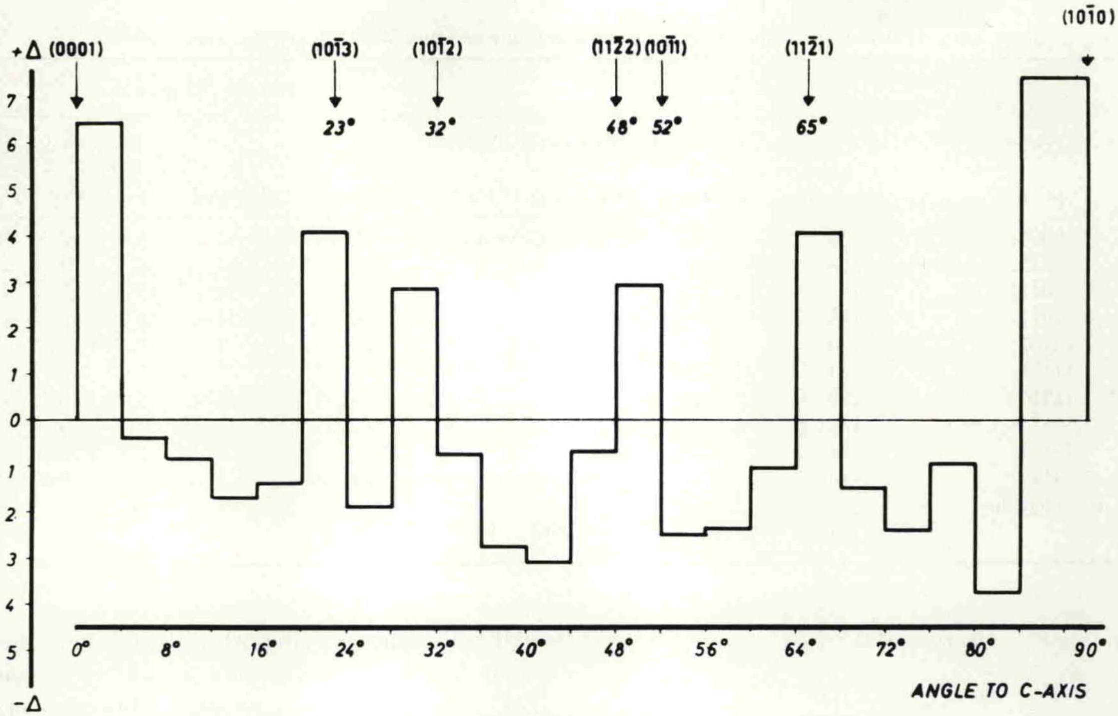

Fig. 4. Frequency diagram, indicating the preferred orientations of fractures in quartz grains, parallel to planar elements. Granite, West Clearwater Lake, Quebec (explanation in text).

Germany (Engelhardt and Stöffler, 1965; Stöffler, 1966). The results of measurements within a thin section of a granite inclusion from the suevite of Zipplingen are presented in Table 2. In this sample, the *average* number of measurable planar elements is 10 sets per quartz grain. The planes have the same crystallographic orientation as those found in Clearwater Lake quartz. The frequency distribution is similar, but not identical. In quartz grains from other Ries samples, we found the same orientations of the principal planar elements, but variable frequency distributions. It thus seems that the frequencies of planar sets are controlled by factors other than the peak pressure of the shock waves alone.

OPTICAL STUDIES OF SHOCKED QUARTZ

Quartz grains which contain planar elements also display lower refractive indices, lower birefringence, and lower densities than those of normal quartz. The distribution of refractive indices of Clearwater Lake quartz is shown in Figure 5. Using seven different immersion liquids, the frequency distribution functions of refractive indices of Clearwater Lake quartz grains were measured. There is an appreciable scattering, with mean values of $\epsilon = 1.539$ and $\omega = 1.542$, both

TABLE 2

Frequency distribution of planar elements in quartz from a granite inclusion in Suevite, Zipplingen, Ries Basin, Germany

	Frequency (%)		
$\{hkil\}_r$	F_I	F_{II}	F_{III}
{0001}	33	2.7	16
{10$\bar{1}$3}	68	34	30
{10$\bar{1}$1}	40	20	18
{10$\bar{1}$2}	59	30	26
{21$\bar{3}$1}	14	6.5	6
{11$\bar{2}$1}	3	1.3	1
{10$\bar{1}$0}	6	3	1
{11$\bar{2}$2}	1	0.3	0.3
{51$\bar{6}$1}	2	2	1