X-RAY INVESTIGATION OF OLIVINE AND ORTHOPYROXENE IN EXPERIMENTALLY SHOCKED SAMPLES OF THE H6-CHONDRITE KERNOUVÉ

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Introduction. Olivine (ol) and orthopyroxene (opx) in experimentally shocked samples of the H6-chondrite Kernouvé were examined by X-rays with an automatic powder diffractometer. The investigation should clarify, if X-ray data of ol and opx can supplement the shock barometry for ordinary chondrites based on the microscopical examination of shock features [1].

Experimental methods. Shock recovery experiments were performed at preshock temperatures of ~293 K by U. Hornemann (Ernst-Mach-Institut, Weil a. Rhein) on sample disks of the H6-chondrite Kernouvé (provided by B. Zanda, Paris), which is one of the best examples for an unshocked ordinary chondrite. The experimental set-up using a high-explosive driven flyer plate was similar to that described by [2, 3]. Peak-shock pressures of 10, 15, 20, 25, 30, 35, 45 and 60 GPa with pressure pulse durations between 0.2 and 0.8 µs were achieved by reverberation technique [4]. Microscopic features of the shocked samples are reported in [5]. For the X-ray study, the samples were grinded and the magnetic fraction was removed. X-ray powder diagrams were collected in transmission mode on a STOE STADI P diffractometer equipped with a focusing germanium primary monochromator and a linear position-sensitive detector. Cu Kα1 radiation was used. Data were refined by profile analysis with the program package provided by STOE. The pure X-ray line broadening β of the shocked samples can be calculated by using ol and opx from the unshocked chondrite as reference for the instrumentally induced line broadening. For this correction Gaussian diffraction peak profiles were assumed [6, 7]. The separation of lattice strain ε and crystallite size L from the X-ray line broadening β is based on a combination of the Scherrer and Wilson equations [6, 7]:

$$\frac{\beta^2 \cos^2 \Theta}{\lambda^2} = \frac{1}{L^2} + 25\varepsilon^2 \frac{\sin^2 \Theta}{\lambda^2}$$

For ol and opx all measured X-ray lines were included in this study to determine the average lattice strain and crystallite size.

Results and Discussion. Compared to the unshocked reference material, ol and opx of the shocked samples show broadening of X-ray diffraction lines and decline of peak intensities with increasing shock pressure. At higher shock pressure, peaks with lower intensities were missing complete, but shifts of the peak positions were not detected. The lattice constants of ol and opx are summarized in Tab. 1. A lattice expansion for ol and opx could not be detected up to shock pressures of 60 GPa. With increasing shock pressure the lattice strain of ol and opx incresses and the crystallite size decreases, as shown in Fig. 1. The data indicate, that a linear relationship between lattice strain and shock pressure exists in the range up to 55 GPa for ol and 25 GPa for opx. At higher shock pressure the lattice strain become close to 2.7 ‰ for ol and 2.0 ‰ for opx, respectively.

X-ray diffraction lines, which correspond to ringwoodite, wadsleyite, or majorite, have not been detected in the experimentally shocked samples. Due to the short pressure pulse duration in our shock experiments (0.2 - 0.8 µs) the formation of the high pressure phases is kinetically hampered.

The analysis of X-ray line broadening allows quantitative determination of lattice strain and crystallite size compared to the more qualitative examination of streakiness by the Debye-Scherrer method [8]. A shock barometry of ordinary chondrites based on the lattice strain (Fig. 1a, c) appears to be problematic, because different lattice strain - pressure relationships can be assumed due to different initial cristallite size and preshock lattice strain. This assessment is obvious for the different results obtained in this study compared to the results of the only other existing X-ray analysis of opx [9]. So far, microscopic examination of shock features [1] is the favourable way to determine the shock history of ordinary chondrites.

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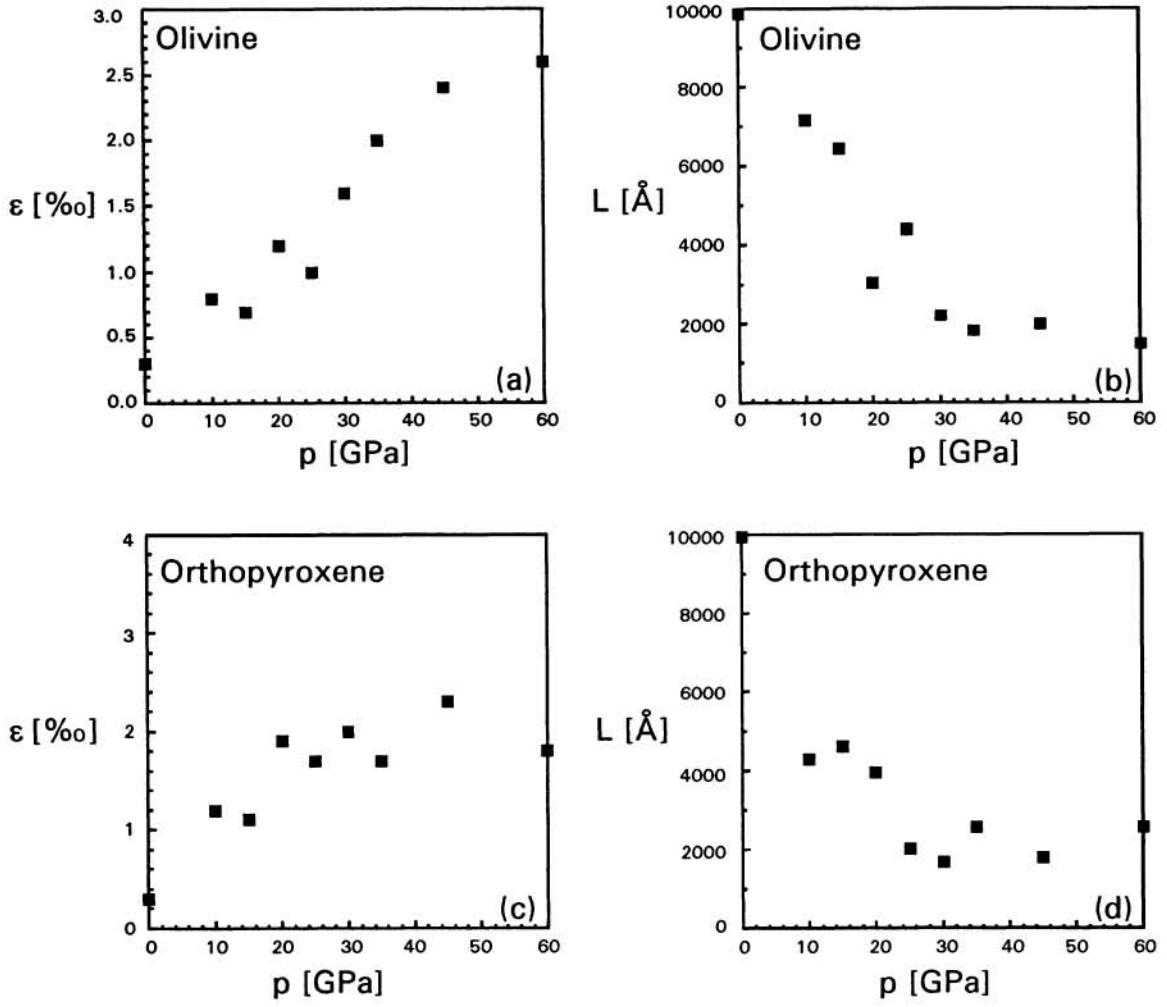

Fig. 1: Change of (a, c) lattice strain ε and (b, d) crystallite size L with shock pressure p for olivine (a, b) and orthopyroxene (c, d) in the experimentally shocked Kernouvé samples.

Tab. 1: Lattice constants of olivine and orthopyroxene in the experimentally shocked samples (1σ error).

Pressure	Olivine			Orthopyroxene		
[GPa]	*a* [Å]	*b* [Å]	*c* [Å]	*a* [Å]	*b* [Å]	*c* [Å]
unshocked	4.767 ± 1	10.243 ± 2	6.005 ± 1	18.261 ± 3	8.858± 2	5.198 ± 1
10	4.767 ± 2	10.253 ± 4	6.009 ± 2	18.268 ± 11	8.859 ± 3	5.198 ± 1
15	4.763 ± 2	10.243 ± 3	5.997 ± 2	18.248 ± 8	8.851 ± 4	5.190 ± 2
20	4.767 ± 1	10.256 ± 2	6.006 ± 1	18.242 ± 14	8.866 ± 6	5.195 ± 4
25	4.766 ± 1	10.249 ± 3	6.008 ± 2	18.235 ± 17	8.853 ± 10	5.206 ± 4
30	4.769 ± 3	10.255 ± 4	6.011 ± 5	18.266 ± 10	8.853 ± 6	5.204 ± 3
35	4.762 ± 2	10.255 ± 5	6.000 ± 2	18.260 ± 11	8.847 ± 5	5.196 ± 2
45	4.772 ± 3	10.247 ± 7	6.000 ± 5	18.261 ± 18	8.847 ± 12	5.219 ± 4
60	4.773 ± 5	10.244 ± 12	6.001 ± 5	18.214 ± 25	8.862 ± 8	5.202 ± 6

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