
Introduction: Cretaceous/Tertiary (K/T) boundary is traditionally associated with one of the most dramatic mass extinctions in the Earth history. A number of killing mechanisms have been suggested to contribute to the widespread extinctions of Cretaceous biota at this boundary, including severe, global deterioration of the atmosphere and hydrosphere from the shock-induced release of CO$_2$ and SO$_2$ from carbonate- and sulfate-bearing target rocks, respectively [1-9]. Recently carried out calculations revealed that the global warming caused by CO$_2$ release was considerably less important than the cooling due to SO$_2$ gases release during the Chicxulub impact event [10]. Considering apparent potential importance of the response of sulfates to the shock metamorphism, relative lack of the data on shock behavior of sulfates as well as some general difficulties encountered during thermodynamic modeling of the shock-induced CO$_2$ loss from carbonates [11, 12] we subjected anhydrite to a series of shock experiments designed for complete recovery of the shocked material. We report here on the detail X-ray diffraction analysis of seven samples that were subjected to experimental shock-loading from 10 to 65 GPa.

Experimental: The shock-recovery experiments employed a 20-mm-caliber powder propellant gun at the NASA JSC, Houston, as detailed in e.g. [13]. Double-polished disks (diameter 7.3 mm, thickness 1.0 or 0.7 mm) of polycrystalline, massive anhydrite from Bees, Canton Vaud/Waadt, Switzerland, were encased in metal target holders (aluminum, stainless steel, W-alloy, and pure W) and impacted by metal flyer plates (also made from these metals). Peak shock pressures achieved by multiple shock wave reverberations were obtained with a graphical impedance match method [14] using the equations of state of [15] and the actual impact velocity measured via IR laser occultation methods. Details on the experiments are given in Table 1. Powder X-ray diffraction patterns were acquired at the Bayerisches Geoinstitut (BGI), Bayreuth, using the diffractometer STOE in the transmission geometry, and at the Dip. Scienze della Terra, University of Siena, Siena, using a Philips diffractometer in the reflecting geometry. The former experimental setup uses CoK$_\alpha$ radiation, the latter one employs CuK$_\alpha$ radiation. In the transmission geometry, silicon was used as an internal standard while LaB$_6$ was utilized as an external standard in the case of the reflecting geometry. Qualitative phase analysis employed the Bede Search/Match software and a PDF2 database (1998 release). Unit cell dimensions were refined using the program UnitCell [16] from the individual peak positions yielded with program XFit [17]. Domain size and microstrain were evaluated with both fundamental approach to modeling of peak shapes as implemented in XFit [17] and the whole powder pattern fitting techniques with pre-defined instrumental resolution function as implemented in FullProf [18].

Results: Samples recovered from the metal containers are pervasively fractured and disintegrate easily. Optical microscopy confirmed macroscopic observations and revealed that samples are strongly fragmented. All XRD patterns yield anhydrite only and no extra peaks due to other phase(s) have been observed. The unit-cell dimensions, refined from the positions of ten most prominent not overlapping diffraction lines in patterns taken in the transmission geometry (with hkl indices: 111, 102, 220, 122, 031, 013, 302, 322, 142, and 224), do not display any systematic correlation with the pressure; maximum differences are less than 0.1 rel. % (Fig. 1). Line broadening, however, is prominent already at 10 GPa and increases systemati-
cally with pressure, albeit not linearly, up to 40 GPa. Above this limit the broadening decreases slightly. Simultaneously, the peak height decreases and is some 50% of that for standard sample at the pressure of 10 GPa; from this point on, peak heights remain invariant within experimental errors. Domain size and microstrain, which are known to depend on peak shapes [19], tightly copy trends for peak widths and heights, respectively (Fig. 2).

Conclusions: The results of our X-ray diffraction study show, contrary to [5] who found incipient vaporization of anhydrite to require ca. 32 GPa, that anhydrite turns out to be a rather stable mineral under the conditions simulated by our experiments, including peak shock pressure of almost 65 GPa. While we observed marked microstrain increase and significant decrease in domain size with increasing peak shock pressure, we did not observe any phase changes, either high-pressure polymorphs, or any decomposition products. The invariance in unit-cell dimensions with changing pressure is consistent with observations of anhydrite + quartz mixtures shocked to 60 GPa in [20] and our preliminary results [21] but not with the data of Langenhorst et al. [22] who found strong correlation between the length of parameter a and shock pressure (maximum difference ca. 0.2 rel. %). Our data on peak widths, domain size and microstrain seem to agree with features seen in powder patterns presented in [22] but quantitative comparison is not possible. Gradual narrowing of peaks above 40 GPa, thus, may support an idea of Langenhorst et al. [22] suggesting either solid-state recrystallization or melting with subsequent crystallization of anhydrite due to high post-shock temperature following compression to pressures more than 40-50 GPa.

Acknowledgements: X-ray diffraction experiments in transmission geometry were performed at the Bayerisches Geoinstitut under the EU “IHP – Access to Research Infrastructures” Programme (Contract No. HPRI-1999-CT-00004 to D.C. Rubie). Diffraction data in reflecting geometry were acquired when RS was a visiting scientist at the Dip. Scienze della Terra, University of Siena under the support of the CNR-NATO Outreach Programme Fellowship.