

ON THE SHOCK BEHAVIOUR OF ANHYDRITE: EXPERIMENTAL RESULTS AND NATURAL OBSERVATIONS. F. Langenhorst¹, A. Deutsch², U. Hornemann³, B. A. Ivanov⁴ and E. Lounejeva⁵ ¹Bayerisches Geoinstitut (BGI), University of Bayreuth, D-95440 Bayreuth, Germany, <falko.langenhorst@uni-bayreuth.de>; ²Inst. f. Planetologie (IfP), University of Münster, D-48149 Münster, Germany, <deutsca@uni-muenster.de>; ³Ernst-Mach-Institut (EMI), Am Klingelberg 1, D-79588 Efringen-Kirchen, Germany, <hornema@wiwei.emi.fhg.de>; ⁴ Institute for Dynamics of Geospheres, Russian Academy of Sciences, Moscow, Russia 117939, <baivanov@glasnet.ru>; ⁵Instituto de Geologia, U.N.A.M., Mexico, D.F., C.P. 04510, <elena@servidor.unam.mx>.

Introduction: Bolide impacts into carbonate and evaporite target rocks liberate large amounts of the toxic gases such as CO₂ and SO_x and, hence, probably have significantly changed Earth's climate. In case of the 65 Ma old Chicxulub impact and the related Cretaceous/Tertiary (K/T) boundary, it has been argued that the perturbation of the atmosphere with these gases was sufficient to considerably modify its radiative balance and to increase rain acidity [e.g. 1,2]. Recent theoretical assessments indicate that in the context of the Chicxulub event, global warming due to CO₂ input was minor compared to cooling due to SO_x gases [e.g. 3]. Despite this potential importance of impact-released SO_x gases, the shock-metamorphic behaviour of sulfates is much less studied than that of carbonates. To address the shock behavior of sulfates, we performed a series of shock experiments designed for complete recovery of the shocked material, and sampled anhydrite-rich impact breccias from the recently available Chicxulub drill cores.

Shock Experiments: High-explosive experiments were carried out with a conventional setup [4], composed of high-explosive (octogen, comp. B), flyer plate and two steel blocks. The sample container encloses a disc-shaped anhydrite platelet and is embedded in the upper steel block. The pressures in a series of shock experiments range from 12.5 to 85 GPa.

Optical microscopy revealed that samples shocked to pressures < 46.5 GPa are strongly fragmented powders, whereas above this pressure limit samples are compact. The X-ray diffraction patterns recorded on all samples are compatible with the anhydrite structure (Fig. 1); extra-peaks have not been observed. Peak intensities decrease and peak broadening increases progressively in the pressure range from 0 to 46.5 GPa. At higher pressures, peak broadening diminishes and the X-ray diffraction pattern of the 85 GPa sample resembles essentially that of unshocked, well-crystallized anhydrite. Quantitative evaluation of X-ray patterns shows no change in lattice constants *b* and *c*, but for the intermediate pressures of 33 and 46.5 GPa we note a marked increase in the lattice constant *a* (Fig. 2). This change is coupled with an increase in the cell volume *V* from 305.6 to 306.2 Å³.

The X-ray results show that anhydrite is very resistant to shock compression and, in disagreement with [5], does not decompose up to pressures of 85 GPa. At this pressure, however, the post-shock temperature was obviously high enough to allow either solid-state recrystallization or melting with subsequent crystallization of anhydrite.

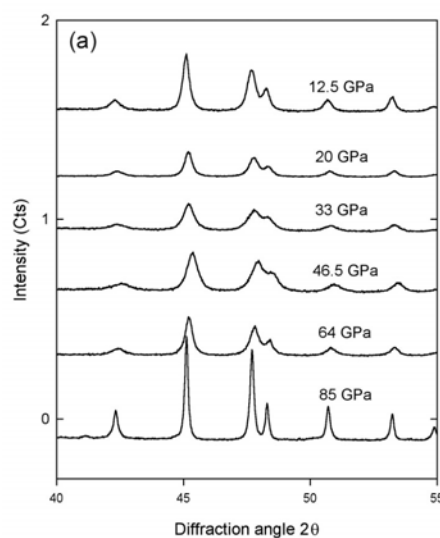


Fig. 1. X-ray diffraction patterns of anhydrite experimentally shocked in the 12.5 to 85 GPa range.

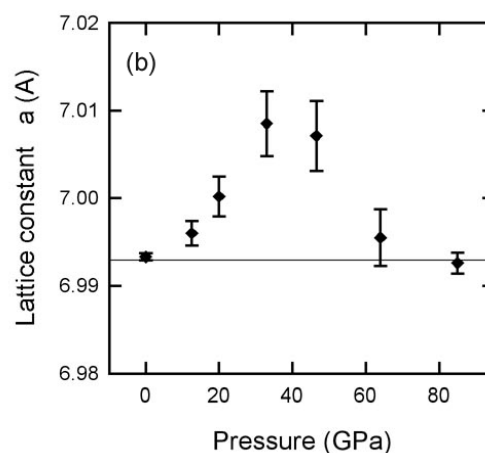


Fig. 2. Variation of the lattice constant *a* of anhydrite as function of shock pressure.

Chicxulub Drill Cores: Samples of the Yaxcopoil-1 core (Chicxulub Scientific Drilling Program - CSDP) were made available to the CSDP science team members during the first sampling meeting at the UNAM, Mexico City, in late April 2002. The drill site of this 1510 m deep YAX-1 well is close to the buried rim of the Chicxulub crater. The site of the PEMEX well Y-6 lies also within the crater but closer to its center.

The Y-6 cores reveal that the crater fill at Chicxulub consists of impact melt rocks, topped by impact melt breccias and suevites but YAX-6 only contain suevites and melt breccias. Textural features and fragment population of these impactites vary strongly. The impact melt rocks mostly lack sulfate and carbonate clasts. Their absence reflects an extremely high formation temperature for this melt lithology, causing thermal dissociation of CaSO_4 and CaCO_3 [cf. 7]. Impact melt breccias yield a similar picture: samples from deeper levels contain mineral assemblages with Ca-rich pyroxene and plagioclase (Fig. 3), which can be interpreted as evidence for dissociation of CaSO_4 . Large anhydrite clasts within the melt breccias display corroded margins and consist of equant crystals with 120° triple junctions. These features indicate incomplete dissociation and solid-state recrystallization of relic anhydrite rock fragments. Melt breccias from shallower and apparently colder levels contain fragments, still displaying the original fine-grained sedimentary texture of the anhydrite rocks. Annealed anhydrite fragments are also nearly absent in the suevites, which had a still lower formation temperature.

An important feature in the impact rocks are about $100\ \mu\text{m}$ wide veins with secondary minerals that cut the matrix of all lithologies (Fig. 3). The veins resemble the “degassing vents” in the suevite outcrops at the Ries crater. We interpret the observations as first solid evidence for melting and dissociation of platform sediments in the hot impact melt layer and massive release of toxic sulfur oxides. The proposed process, however, differs obviously from the commonly purported idea that SO_x release occurred instantaneously during and after pressure release.

Conclusions: The results of our study establish a high stability of anhydrite under strong shock compression, and demonstrate that anhydrite does not decompose upon release from high shock pressures. Usually, devolatilization of minerals is considered as shock phenomenon that occurs in a late stage of, or mainly after decompression, i.e., high post-shock temperatures are required for decomposition [6, 7]. We propose that not the amplitude of post-shock temperatures in the anhydrite but the formation temperature in

the natural impact rock is the driving force/major reason for devolatilization of this mineral as well as of carbonates. Hence, CO_2 and SO_x release is a post-shock effect, which may have occurred during a long period of time after the impact event.

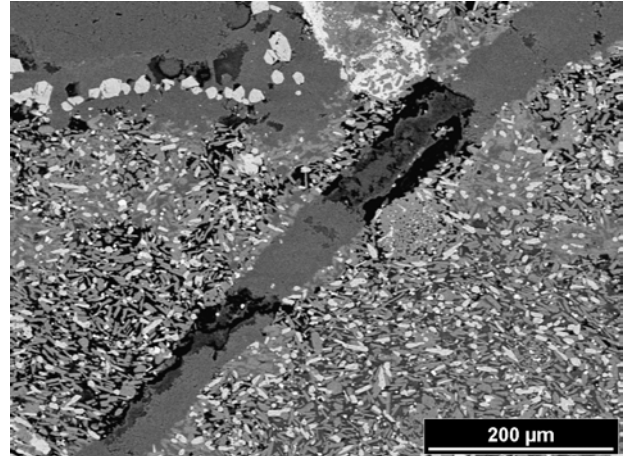


Fig. 3. Backscattered electron image of a “degassing vent” in core Y6 cutting a fine-grained melt matrix consisting of Ca-rich pyroxene, plagioclase and quartz.

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