Shock recovery experiments for simulating short duration parent body heating

E. Quirico, H. Yabuta, P. Beck, L. Bonal, A. Bardyn, L.R. Nittler, Conel M.O'D. Alexander, Nathalie Carrasco, Cyril Szopa

EPSC Abstracts
Vol. 13, EPSC-DPS2019-604-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Shock recovery experiments for simulating short duration parent body heating

E. Quirico (1), H. Yabuta (2), P. Beck (1), L. Bonal (1), A. Bardyn (3), L. R. Nittler (3), C.M.O'D. Alexander (3), N. Carrasco (4), C. Szopa (4)
(1) UGA/CNRS IPAG Grenoble France, (2) Hiroshima University, Japan. (3) DTM, Carnegie Institution USA. (4) CNRS/INSU LATMOS-IPSL, Guyancourt France

Abstract

Here we report on shock recovery experiments (5-50 GPa) conducted on two chondrites, Murchison (CM/2.6) and EET 90628 (LL/3.0), and on a tholin sample. We show that those shocks modify the chemical and D/H compositions of Insoluble Organic Matter, as well as its sp^2 structure. Comparison with heated C2 chondrites reveal several similarities, but differences as well that question further the actual process that happened on the parent body. Experiments on the tholin sample show that carbonization happens as soon as 5 GPa, but the fast decrease of the D/H composition upon increasing pressure makes it unlikely Ultra Carbonaceous Antarctic Micro-Meteorites were formed through this process.

1. Introduction

Short duration heating is a post-accretional process that has affected the chondrite parent bodies to varying degrees, and that might be involved in the formation of Ultra Carbonaceous Antartic Micro-Meteorites (UCAMMs)[1,2]. Hypervelocity impacts are a plausible source of heating, owing to the fact that the chondrites were excavated from their parent bodies by collisions. Here, we report shock recovery experiments that are dedicated to simulating these short duration heating processes. Three samples were studied: Murchison (CM2) insoluble organic matter (IOM), EET 90628 (LL/3.0) IOM, and a tholin sample as a presumed analog precursor of some N-rich UCAMMs [3].

2. Experiments

Shock recovery experiments were conducted at Tokyo Institute of Technology (Japan) during four sessions between 2010 and 2016. A 5-50 GPa peak pressure range in the recovery capsule was achieved by combining different flyers with different velocities. The shocked state in the sample was assumed to equilibrate with that of the capsule through multiple reflections at the capsule boundaries. Peak pressures were calculated with the impedance match method, using the Hugoniot curves of iron and of the flyer plate material. Samples were characterized by FTIR and Raman spectroscopy (IPAG Grenoble and LGL Lyon, France) and NanoSIMS (Carnegie Institute, Washington USA). Tholin samples were produced with a cold plasma reactor (LATMOS, France).

3. Results and discussion

Murchison. The IOM composition is very sensitive to shocks, even at low peak pressure (5 GPa). FTIR analysis indicates an increase of the CH_2/CH_3 ratio (estimated from the peak intensity ratio of the antisymmetric stretching modes at 2925 and 2955 cm^{-1}), a decrease of the carbonyl C=O group (~1700 cm^{-1}), a decrease of the aliphatic (CH, CH_2, CH_3) abundance (except at 50 GPa, for which a large increase is observed), and the development of a new narrow band centered at ~ 1650 cm^{-1}. At high shock pressure, large chemical variations are observed within the IOM, pointing to strong spatial heterogeneities of pressure and temperature in the capsule. Overall, these variations are consistent with those measured in heated chondrites. A high CH_2/CH_3 ratio is always associated evidence for thermal events in type 2 and 3 chondrites, as well as the decrease of the aliphatic abundance. Note, however, the exception of the CM QUE 93005 that shows a dramatic increase of the aliphatic abundance that might be consistent with the 50 GPa experiment. The band at ~ 1650 cm^{-1} has never been detected in C1, C2 or type 3 chondrites. This feature is possibly due to the formation of quinones, perhaps as a result of specific oxidation conditions during the shock event. The carbon structure probed by Raman spectroscopy (514 nm) displays moderate variations, which are more significant at 40 and 50 GPa. The data account for stage II heated chondrites, but not for III/IV stages [4]. In this respect, our shock experiments do not properly mimic the highest degrees of the heating process, possibly because the reverberation process to reach the peak pressure in the experiment releases less heat than a single shock process that happens in natural conditions [5]. SIMS measurements report a dramatic effect on the D/H composition of the IOM. At 5 GPa, the D/H ratio is drastically reduced, and at 40 GPa the IOM is isotopically normal. These findings are basically consistent with IOM compositions from heated C2 chondrites [e.g., 6].

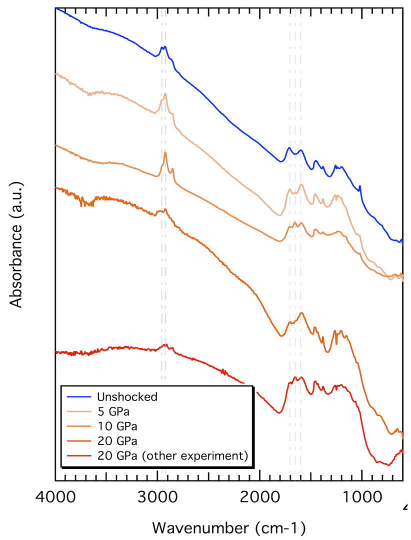

Figure 1: Infrared spectra of IOM extracted from shocked Murchison samples.

EET 90628. The Raman data of EET 90628 IOM display co-variations of the FWHM-D and I_D/I_G parameters pointing to a structural grade that is more consistent with a ~ 3.1 petrologic type. At the same time, we observe an increase of FWHM-G and a decrease of ω_G. These results show that some primitive type 3 chondrites may have been perturbed by shock processes, and are also consistent with the fact that FWHM-G and ω_G are not reliable tracers of thermal metamorphism.

Tholin 93:7. Shock experiments on a tholin produced from a N2:CH4=93:7 gas mixture show major effects on the composition, and the development of a polyaromatic structure at 20 GPa and beyond. However, even at 40 GPa, the degree of structural order remains lower than that measured in N-rich UCAMMs. We may expect that shocks under natural conditions should lead to more mature carbonaceous materials. However, the D/H sensitivity to thermal processing is inconsistent with hypervelocity impact involvement in UCAMM formation (provided that D carriers are similar in Murchison and UCAMMs).

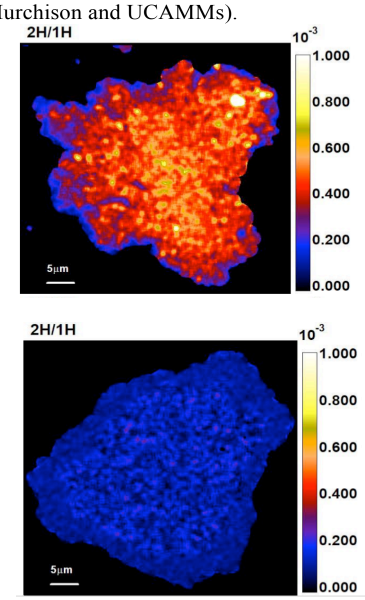

Figure 2: nano-SIMS D/H images of IOM samples extracted from unshocked Murchison (top) and Murchison shocked at 40 GPa (bottom).

References

[1] Tonui E. et al. (2014) *Geochimica Cosmochimica Acta* 126:284–306.

[2] Augé B. et al. (2016) *A&A* 592:A99.

[3] Bonnet J-Y et al. (2015) Icarus 250: 53-63.

[4] Quirico E. et al. (2018) *Geochimica Cosmochimica Acta* 126:284–306 241:17-37.

[5] Tomeoka K. et al. (1999) *Geochimica Cosmochimica Acta* 63:3683-3703.

[6] Alexander C.M.O'D et al. (2010) *Geochimica Cosmochimica Acta* 74:4417-4437