Bacterial silicification – an experimental approach

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Evidence of life on Earth in form of silicified micro-organisms is reported from throughout the geological record as early as 3.5 Ga ago to recent hot spring environments. Silicified microfossils are resistant to weathering, which renders them readily preservable over long time spans. The recent discussion over the true nature of the oldest fossils on Earth [1] and their possible interpretation as non-biogenic organic structures [2] emphasizes the need to better understand the processes involved in silicification. We therefore designed experiments to simulate the silicification of bacterial biofilms [3]. These were exposed to silica solution of various concentrations and over various time spans, to test the influence of exposure time and silica concentration. The biofilms were analysed using Transmission Electron Microscopy (TEM) and Energy Dispersive X-ray Analysis.

It was found that silicification commences after 24h in silica solution and increases over time. High silica concentration results in better preservation of cellular detail, the silica concentration thus is more important than exposure time. Cells became permineralised, no amorphous silica precipitation was observed. High-resolution TEM studies revealed the presence of nanometer-sized crystallites within silicified cell walls. These crystallites show a 0.33 nm d-spacing of the lattice fringes, indicating quartz [101] planes. Higher-order silica phase formation during bacterial silicification disagrees with current models [4] that suggest silicification by amorphous silica through silica attachment by hydrogen bonds and subsequent polymerisation via siloxane bonds and loss of water. Transformation from lower to higher order silica phases requires dissolution-reprecipitation processes or increased temperature-pressure regimes, which is inconsistent with our experimental conditions. From the evidence obtained in this study we suggest a model where the activation energy barrier for the formation of the critical nucleus may be lowered by the metabolic activities of bacteria or the surface energy provided by functional groups present in the organic compounds of the biofilms, to change the relative degree of oversaturation required for heterogeneous or homogenous nucleation. These passive or active bacterial activities may mediate direct higher-order crystal formation.

References

[2] Brasier et al. (2002) *Nature* **416**, 76-81; [1] Schopf (1993) *Science* **260**, 640-646; [3] Toporski et al. (2002), *Astrobiology* **2**, 1-26. [4] Westall et al. (1995) *Palaeontology* **38**, 495-528.

New constrains on atmospheric entry conditions of micrometeorites

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Introduction: Micrometeorites (MMs) constitute the most important source of extraterrestrial material accreted on Earth [1], and may provide some important clues about the formation of our solar system. However, most of the MMs experience thermal shocks during their atmospheric entry [2], that may significantly alter their pristine mineralogy, texture or chemical characteristics. In order to better understand these effects, we have performed an experimental simulation of the atmospheric entry of MMs.

Experimental: Pulse-heating experiments were carried out in a 1-atm vertical furnace. Starting materials were fragments of the Orgueil (CI1) chondrite. Temperatures were comprised between 500 to 1500°C, heating times between 2 s to 2 min and oxygen fugacity between - 0.68 to - 8 fO_2 log units.

Results and discussion: (1) These experiments reproduce most of the MMs textures, from the vesicular fine-grained MMs, to the scoriaceous MMs and to the more melted cosmic spherules, as well as the spinel shell surrounding most MMs. We suggest that the most plausible mechanism for the spinel shell formation implies a peripheral partial melting and formation of an iron-oversaturated melt with sub-sequent crystallization of spinels [3]. Because of the similarities between MMs and experimental charges, we provide heating conditions (peak temperature and duration of deceleration) for the different types of large MMs [3], which could even be better estimated by a careful survey of their vesicularity [4]. (2) Owing to this set of experiments, it is possible to reproduce the whole range of spinel compositions found in MMs and to relate it as a function of temperature, heating duration and oxygen fugacity [5]. Because "MMs spinels" form during deceleration of extraterrestrial objets in the Earth atmosphere, this work shows also that their change in composition can be used for a new classification scheme of the MMs, and to determine (i) the entry conditions, including altitudes of deceleration, entry angles and incident velocities of the MMs, and eventually (ii) the possible origin of the MMs, i.e., cometary or asteroïdal.

References

[1] Love S.G. and Brownlee D.E., (1993), *Science* **262**, 5550.
[2] Engrand C. and Maurette M., (1998), *Meteorit. Planet. Sci.* **33**, 565-580.
[3] Toppani A., Libourel G., Engrand C. and Maurette M., (2001), *Meteorit. Planet. Sci.* **36**, 1377-1396.
[4] Toppani A. and Libourel G., (2002), *Lunar Planet. Sci. Conf.* # **1473**.
[5] Toppani A. and Libourel G., (2001), *Lunar Planet. Sci. Conf.* **#1520**.