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TESTING THE SURVIVAL OF MICROFOSSILS DURING ENTRY INTO THE EARTH'S ATMOSPHERE: THE STONE 6 EXPERIMENT

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Introduction: Studies related to the origin of life on Earth are hampered by the fact that suitable rocks dating from the first billion years are lacking due to metamorphism and plate tectonics. Thus the oldest traces of life occur in rocks formed ~3.5 billion years ago [1, 2], a billion years after the formation of the Earth. As a consequence, the investigations now focus on Mars where the ancient terrains have not been destroyed by plate tectonic activity.

One means of studying hypothetical Martian traces of life would be to analyze sedimentary meteorites. However, only 49 meteorites of presumed Martian origin have been so far been found and all have a basaltic composition. The aim of this study was to determine if sedimentary rocks and their embedded microfossils could survive the shock of entry into the Earth's atmosphere.

Experiment: The STONE 6 experiment (September 2007, ESA) tested the survivability of samples fixed on the apex of the heat shield of a FOTON capsule during entry into the Earth's atmosphere. One of these samples, from the 3.466 Ga-old Kitty's Gap Chert, in the Pilbara region, NW Australia, was composed of silicified volcanic sand deposited in a littoral environment. This rock is considered to be a good analogue for lithified Martian volcanic sediment and contains small colonies of fossilized prokaryote-like microorganisms [2].

Results: Of the original 2 cm sample thickness, 8 mm remained after ablation upon entering the Earth's atmosphere. Several types of analyses were made to observe and study the survival of the microfossils and the modification of the rock composition. Optical observations show that a white fusion crust formed during entry. This contrasts with black crust of basaltic meteorites and may explain why sedimentary stony meteorites have not been yet found (meteorite hunters look for black fusion crusts). Atomic Force Microscopy (AFM) and Scanning Electron Microscopy (SEM) were used to observe the sub-micrometric microfossils. Raman spectroscopy was also used to study the changes in the carbonaceous matter and minerals throughout the sample thickness, up to the fusion crust. Although the kerogenous material near the fusion crust is graphitized, we demonstrate that the microfossiliferous structures located deeper in the sample were well preserved. An analytic model is also proposed to estimate the variation in temperature throughout the thickness of the sample. This model is consistent with the observed alteration of the minerals. We conclude that, if sedimentary Martian meteorites were found on Earth, they could contain eventual traces of extraterrestrial life and maybe of the first living organisms.

References: [1] J. W. Schopf et al. 2007. *Precambrian Research* 158: 141–155. [2] F. Westall et al. 2006. *Geological Society of America Special Paper* 405. pp. 105–131.

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PINK ANGEL: ARGON AND XENON DIFFUSION, I-XE CHRONOLOGY, AND THE ³⁶Cl PROBLEM

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Introduction: The reported presence in Allende Pink Angel sodalite of excess ³⁶S [1] attributed to ³⁶Cl decay is at odds with the apparent absence of a corresponding excess of ³⁶Ar, which is the major decay product of ³⁶Cl. In an attempt to throw light on the problem we have reviewed new and existing data on the diffusion of Ar and Xe in sodalite, carried out new high resolution I-Xe analyses of Pink Angel, and devised a new methodology for searching for small excesses of ³⁶Ar from ³⁶Cl decay.

Diffusion of Ar and Xe in Sodalite: Our experiments on neutron irradiated terrestrial sodalite indicate high retentivity of Cl-derived ³⁸Ar. During stepped heating, maximum release occurred around 1100 °C and release was essentially complete by 1250 °C. An activation energy of 280 kJ/mol/K was calculated. Published data [2] from an I-Xe analysis of Pink Angel sodalite indicates peak release of I-derived ¹²⁸Xe around 1200 °C with significant release up to 1400 °C. An activation energy for Xe diffusion of 460 kJ/mol/K is inferred. To calculate the implications for possible Ar and Xe loss over time scales appropriate to the early solar system we scale time, t, and absolute temperature, T, using the expression: $1/T_2 = 1/T_1 + R/E \cdot \ln(t_2/t_1)$ where subscripts 1 and 2 refer to the laboratory and early solar system times and temperatures, respectively. To release essentially all of the Cl-correlated Ar and I-correlated Xe on a time scale of 1 Myr would require sustained temperatures of around 460 °C and 740 °C respectively.

I-Xe Analyses: We have carried out laser stepped heating I-Xe analyses of Pink Angel sodalite using the RELAX resonance ionization spectrometer. Two samples, weighing 40 µg and 80 µg have been analysed with a total of 90 individual extractions. A well defined plateau indicates $^{129}\text{I}/^{127}\text{I} = (0.93 \pm 0.02) \times 10^{-4}$, corresponding to an I-Xe age 3.2 ± 0.3 Ma after our monitor, the Shallowater achondrite. Lower $^{129}\text{I}/^{127}\text{I}$ ratios in the early release could imply a 12% later loss of ¹²⁹Xe concomitant with significant loss of ³⁶Ar.

³⁶Cl Searches Based on ³⁶Ar: We suggest a new method to search for ³⁶Ar excesses which makes use of a plot of $^{36}\text{Ar}/^{38}\text{Ar}$ versus $\text{Ca}/^{38}\text{Ar}$. End members are trapped, cosmogenic and cosmogenic secondary neutron-induced argon. In suitable circumstances excess ³⁶Ar would plot above this mixing triangle. Determination of Ca using a reactor irradiation requires low fluences and Cd-shielding to minimize ³⁸Ar production from Cl.

In conclusion we note that absence of excess ³⁶Ar in spite of the high retentivity of sodalite leaves open the possibility that either the reported ³⁶S excess is an artifact or else it is inherited from an unidentified pre-existing Cl-rich phase which has lost ³⁶Ar and the apparent correlation with Cl/S represents a two component mixing line and not an isochron.

References: [1] Hsu W. et al. 2006. *The Astrophysical Journal* 640: 525–529. [2] Swindle T. D. et al. 1988. *Geochimica Cosmochimica Acta* 52: 2215–2227.