Geophysical Research Abstracts,
Vol. 10, EGU2008-A-04592, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-04592
EGU General Assembly 2008

Stone 6: artificial sedimentary meteorites in space.

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The SNC meteorites are generally considered as originating from Mars however all are of igneous origin. There are no known sedimentary martian meteorites, despite the vast amount of evidence for aqueous, eolian and chemical sediments on the planet's surface. Such material either does not survive the escape process, which requires an escape velocity of $>$ 5 km/s, does not survive terrestrial atmospheric entry, or is not readily identifiable as being of extraterrestrial origin. The STONE experiments aim at testing the survivability of different types of analogue martian sediments during entry into the Earth's atmosphere. The rocks are fixed into the heat shield of a FOTON re-entry vehicle around the ablation point and undergo entry speeds of about 7.6 km/s (meteoritc entry speeds are slightly higher, at 12-15 km/s). Previous STONE experiments have proven the survivability of dolomite and sandstone through atmospheric passage (STONE 1 and STONE 5) [1-3].

The STONE 6 experiment was designed to test the effects of atmospheric entry on physical and (bio/geo) chemical modifications to sedimentary rocks that had been either coated with micro-organisms and/or contained the fossilised remnants of microorganisms. They included (1) an Early Archaean chert (3.446 Ga) from the Pilbara containing cryptic traces of fossil life (microfossils, C isotopes) (N.B. this sample is a good sedimentary Noachian Mars analogue], (2) a Devonian laminite (mudstone) from the Orkneys (Fig 1e), (3) and an Eocene basalt from Austria. A culture of a modern endolithic microorganism, *Chroococcidiopsis*, was smeared on the back side and on the flanges of each of the rocks before flight.

The mission was launched from Baikonur on September 14^{th} 2007 and, after 12 days in space, the re-entry vehicle returned to Earth. It was recovered about 15 min after landing in Kazakstan on the 26th September. One of the sample holders and its rock (the basalt) was lost during the violent re-entry but the other samples were recovered intact. The two sedimentary rocks had severely ablated surfaces and have been affected by heat and shock metamorphism. Both displayed a vesicular texture indicative of devolatilisation in the outer portions of the samples. SEM investigations to determine the fate of the 3.446 Ga-old microfossils, as well as Raman spectroscopy and isotopic C measurements of this sample are underway. The organic carbon in the Devonian carbonaceous laminite sample has become more thermally mature. Nevertheless, some organic molecules have survived, albeit in substantially depleted quantities. These molecules retain some biological information. The glass also contains limited carbon (0.14 wt. %), due to the low oxygen fugacity during atmospheric entry. XRD indicates of thermal dissociation of calcite followed by rehydration from the atmosphere. The dried biofilms of *Chroococcidiopsis* on the underside of the rocks did not retain viability but cells survived as carbonized forms "(pompeified") with only a little loss in cell volume ($\sim$10%). This is incontrast to the STONE 5 experiment, which showed that endolithic organisms were completely destroyed [2]. Raman spectroscopy shows that the cells in the STONE 6 experiment still retain carbon, although they are partially graphitized.

Although the speed of entry of the artificial meteorites was not as high as that of natural meteorites (7.6 km/sec as opposed to 12-15 km/sec), it was close enough to provide useful information relating to potential martian sedimentary meteorites. It is clear that sedimentary martian rocks similar to those we used could survive atmospheric entry. The survival of the Early Archaean volcanic sands is important information since similar volcanic sands would have been common on Noachian Mars and could have hosted traces of life. We have demonstrated that biogenic molecules and actual cells can survive atmospheric entry (the latter, albeit in a carbonised form) and we hope to show the same for fossilised cells. Traces of life in martian sediments could therefore be found on Earth, if they can be recognized. Equally, traces of life in terrestrial meteorites, especially from the pre 3.5 Ga period for which we have no terrestrial record, could eventually be found on Mars.

References: [1] Brack, A., et al., 2002. Planet. Space Science 50, 763-772. [2] Cockell, C.S., et al., 2007. Astrobiology, 7, 1-9. [3] Brandstätter, F., et al., 2008. Planet.

Space Science, in press.