EPSC Abstracts,
Vol. 2, EPSC2007-A-00349, 2007
European Planetary Science Congress 2007
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Mars mission relevant investigations on a $\sim$ 3.5 Ga Mars analogue rock from the Pilbara and Barberton

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Volcaniclastic sediments deposited in shallow water basins on the early Earth represent ideal analogues for Noachian volcanic sediments since the environmental conditions and settings for both were quite similar: important volcanic and hydrothermal activity (somewhat less on Mars), period of late heavy bombardment ($\sim$ 4.0 Ga), water bodies with a slightly acidic pH, higher salt content, atmosphere with minimal O_2 ($<$0.2 % PAL), high UV flux to the surface. Life apparently thrived in these conditions on Earth, leaving structural and geochemical signatures in the Early Archaean sediments.

Within the framework of the PAFS-net* programme, using space qualified instrumentation, we analysed previously well-characterised volcanic sedimentary rocks from a number of locations in the 3.5-3.3 Ga-old greenstone belts of the Pilbara (Australia) and Barberton (South Africa). They included mud flat sediments containing traces of probable chemolithotrophic and anoxygenic photosynthetic microorganisms, a small stromatolite (some microfossil traces) and a banded iron formation sample (also some microfossil traces). All the sediments were silicified by early diagenetic processes. The instruments used were the Beagle2 Development Model (DM) stereo camera for proximal ($\sim$100 cm) and macroscopic ($\sim$10 cm) imaging, the Beagle 2 microscope for microscopic ($\sim$1 cm) imaging, a Nuance multi-spectral imager, a TN Technologies Spectrace 9000 commercial energy dispersive XRF spectrometer, a Philips PW1710 diffractometer for XRD, and the Beagle2 spare Mössbauer spectrometer.

The camera systems were well able to depict the fine-scale sedimentological structures of the rock samples that, in the case of the volcaniclastic sediment and the stromatolite, can be used to interpret a shallow water environment of deposition (the flaser-linsen bedding of the former and the convex, sinuous layering of the latter). The massively quartz-rich (chert) composition of the silicified sediments was picked up by the XRD and the Raman spectrometers. The silicified volcanics also contain feldspar, identified by the Raman, whereas the XRF analyses showed that they are K-feldspars. The traces of Ba and Cu in this sample are probably related to the mostly hydothermal origin of the silica that cemented the volcanic sediments. Raman spectroscopy also identified a greater abundance of carbon (matured kerogen) in the black layers of this sample (finer grained volcaniclastics). The stromatolite sample, on the other hand, consists largely of quartz although Raman showed some dolomite and carbon (mature kerogen) in the grey layers (silicified stromatolitic layers). The layering in the laminated volcaniclastic sediment was too fine for the Mössbauer spectrometer to pick up any details. The Mössbauer was able to detect a very thin layer of Fe oxide $<<$0.2 mm on the surface of the stromatolite. Compositional layering in the BIF was clearly visible using multispectral imaging with the Nuance camera and the Mössbauer could identify highly crystalline and chemically pure goethite in the Fe-rich layers with minor goethite and hematite occurring in the quartz-rich layers.

The combination of the instrumentation used for imaging and chemical analysis was quite sufficient to identify the sedimentary origin of the finely laminated volcaniclastic and stromatolite rocks and to demonstrate their pervasive silicification. The presence of carbon in these rocks would, in a Mars scenario, make them ideal subjects for organo-geochemical analysis. The same suite of instruments was also able to demonstrate the origin of the BIF, again, a suitable candidate for further analysis.

* Planetary Analogue Field Study network (main coordinator D. Pullan)