The MER Mössbauer spectrometers: 40 months of operation on the Martian surface

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Introduction: The two Mars Exploration Rovers, Spirit and Opportunity, each carry a miniaturised Mössbauer spectrometer (MIMOS II) [1] as a part of their scientific payload. The MER mission (which was originally planned for three months) has been lasting for more than three years (almost 1200 Martian days, or "sols", as of middle of May, 2007). The "mission success" goal for the rovers had been to drive more than 600 meters, and the goal for the Mössbauer spectrometers had been to collect spectra from at least three different soil and rock samples. To date, the rovers have covered distances of more than 7 km (Spirit) and more than 10 km (Opportunity), respectively. The total amount of scientific targets investigated by the Mössbauer spectrometers approaches 300 (the total number of integrations exceeds 500).

Both Mössbauer spectrometers remain operational and continue to return valuable scientific data ([2] – [4]), even after more than five half-lives of the Co-57 MB sources (intensity at the time of landing ~150 mCi). Current integration times are about 48 hours in order to achieve reasonable statistics (as opposed to 8 hours at the start of the mission).

Spirit in Gusev crater: Mer-A "Spirit" landed in Gusev crater on January 4, 2004 and has traversed the plains from her landing site towards the Columbia Hills. The Mössbauer spectromer has studied 150 separate scientific targets (as of May 15, 2007). The total integration time exceeds 170 days.

The rocks and soils on the plains contain olivine. That suggests that physical rather than chemical weathering processes are currently active [5]. However, a thin coating was detected on the rock Mazatzal [6]. It was enriched in ferric iron, and was thus interpreted to be a weathering rind. From comparison of simultaneously acquired 14.4 keV gamma ray and 6.4 keV X-ray spectra, the average thickness of the coating was estimated to ~ 10 micrometers [7]. At the West Spur of the Columbia Hills, hematite and goethite were identified in rocks, which shows that water played a major role in the formation and alteration of rocks and soils in the Columbia Hills [2, 3, 8]. Over the past few months, the rover has been investigating Home Plate, a layered plateau in the Inner Basin of the Columbia Hills. Home Plate is probably of explosive volcanic origin and Home Plate rocks are among the most magnetite-rich in Gusev crater [9].

The MB spectrometer has detected the following Fe-bearing phases in Gusev Crater: olivine, pyroxene, magnetite, nanophase ferric oxides, hematite, goethite, ilmenite, ferric sulfate and a yet unassigned phase (in the rock "Fuzzy Smith").

Opportunity at Meridiani Planum: Mer-B "Opportunity" landed in Eagle crater (Meridiani Planum) on January 24, 2004. Opportunity has travelled more than 10 km, analysing outcrop exposures at several craters (20 meter diameter Eagle crater, 160 m diameter Endurance crater, 300 meter diameter Erebus crater, and 800 meter diameter Victoria crater). At the present time, Opportunity is searching for a safe ingress route into Victoria crater. Opportunity's Mössbauer spectromer has studied 124 separate scientific targets (as of May 15, 2007). The total integration time exceeds 80 days.

In sulfate rich outcrops, the ferric sulfate hydroxide mineral jarosite was found. Millimeter-sized spherules (named “blueberries”) were identified as the source of hematite detected from orbit. Also, the Mössbauer spectrometer analysed several float rocks and cobbles along the way. Pyroxene-rich “Bounce rock” was identified as the first rock on Mars similar in composition to basaltic shergottites, a group of meteorites whose origin is believed to be Mars [11]. The iron-nickel alloy kamacite was detected in “Heat Shield Rock” (which was identified as a Fe-Ni meteorite) and in a small rock named “Barberton” (identified as a stony meteorite) [12, 13].

The MB spectrometer has detected the following Fe-bearing phases at Meridiani Planum: olivine, pyroxene, magnetite, nanophase ferric oxides, jarosite, hematite, and kamacite.

Conclusion: The primary MER objectives have been successfully completed. The total integration time of all MB measurements exceeds the duration of the primary 90-sols-mission for Spirit’s MB spectrometer, and approaches this value for Oportunity’s MB spectrometer. Both MB spectrometers continue to accumulate valuable scientific data after three years of operation (data is available for download [13]) The identification of aqueous minerals such as goethite in Gusev crater and jarosite at Meridiani Planum by the MER Mössbauer spectrometers is strong evidence for past water activity at the two landing sites.

References:

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