Comparative geochemistry at Gusev Crater and Meridiani Planum, with implications for aqueous activity

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Correspondences and Similarities

Soils, sediments and even certain rock compositions at the Mars Exploration Rover landing sites have geochemical correspondences in spite of their far-separated locations (nearly diametrically opposite sides of the planet). Yet, as we shall show here, there are diagnostic discriminators and significant differences in their history of aqueous alteration.

Soils at Meridiani are typically quite similar to soils measured at other sites, including Gusev, but are often somewhat enriched in Fe, presumably from fragments of hematite-rich spherules that form an abundant lag. However, they record little if any of the signature of obviously-weathered sulphate-rich outcrop that pervades the Opportunity site.

The Meridiani outcrop materials themselves evidence a rich mineralogy. Certain samples derived from the whitish materials at Tyrone area in Gusev have almost identical levels of Si, S, Fe, Mg, Al, Na and P.

Geochemical Discriminators

Minor elements Cl, K, Ti, Mn and Zn are lower at Gusev, while Cr, Ca, and Ni are higher. Inferred mineralogies and explanation of the sources of the Meridiani outcrop are quite different from the Gusev Tyrone-derived samples.

Tyrone samples can be explained as salt-silica-soil mixtures, whereas outcrop geochemistry can be explained as derivation from “source basalt(s)” and a very acidic brine. Although the hypothetical source basalt is not in evidence at Meridiani or in the martian meteorite collection, a very good match for all elements (with the sole exception of trace element Ni) is provided by rock class Irvine discovered at the Gusev site. Whereas Paso Robles class ferric sulphate-rich salts from the Tyrone area must have formed by a strong enrichment process, such as extensive aqueous processing, the Meridiani outcrop material also is very high in sulphate, but with a significantly different outcome.

Geochemical Variability

The range of chemical variability in the Columbia Hills at Gusev crater is startling, with virtually every element present in at least one or more rocks at anomalously high or low concentrations. Some of these extremes can be traced to igneous differentiation processes, but others clearly must be due to aqueous alteration in sedimentary or metasomatic processes. In contrast, except for some meteoritic materials, Meridiani outcrop lies within a well-defined geochemical range – variations in Mg, S and other elements can be readily explained as salt migration in an evaporitic sandstone formation.

Re-establishing recycled sediment in mantle plumes – Evidence from Gough Island

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Sediment is an integral part of recycling slabs and has long been held responsible for enriched signatures found in many ocean island basalts associated with mantle plumes. However, to date the evidence for deep recycled sediment is generally weak and our knowledge on the modification of recycled sediment in the subduction factory is limited, which resulted in a recent surge of alternative models of mantle metasomatic enrichment processes and lower crustal recycling. An important characteristic of pelagic clays, calcareous oozes and chert is their negative Ce anomaly inherited from seawater, resulting frequently in negative Ce anomalies of present day subducting sediment. The presence of negative Ce anomalies in arc volcanic rocks is a strong indication for the preservation of Ce anomalies to the depth of arc magma formation. Thus, Ce anomalies present themselves as a useful tracer for deep sediment subduction.

A sediment contribution to the Gough mantle source has previously been suggested based on high La/Nb, Ba/Nb and $^{207}Pb/^{204}Pb$ ratios compared to other OIB, though the lack of raised oxygen isotope ratios limits bulk sediment to <1.5%. High precision trace element data (acquired by ICPMS) on mafic volcanic rocks from Gough Island reveal negative Ce anomalies, with Ce/Ce* values in Gough lavas extending down to values as low as ~0.92. Weathering processes, identified as the cause for Ce anomalies in some OIB, can be excluded here based on element-element systematics, indicating magmatic trends rather than weathering-induced element mobility. Shallow-level contamination by local sediments can be excluded on Ce/Pb systematics. We suggest that Ce anomalies in Gough lavas demonstrate the presence of recycled, subduction-modified sediment in the mantle source of the Gough Island magmas. With the exception of fluid mobile elements, the trace element systematics of Gough lavas can be reproduced by adding up to ~10% subducting sediment with negative Ce anomaly (using estimates of present-day subducting sediment columns as a proxy to ancient oceanic sediment) to the mantle source of Gough magmas. These calculations suggest loss of fluid-mobile elements in the subduction zone. Low degree melting of the sediment at some stage can explain the lack of a sediment oxygen isotope signature. We explore scenarios of sediment modification in the subduction factory in order to match the enriched trace element systematics in the Gough mantle source.