SEDIMENTARY PROVENANCE STUDIES ON MARS WITH AN EXAMPLE FROM THE BURNS FORMATION, MERIDIANI PLANUM. Scott M. McLennan, Department of Geosciences, SUNY at Stony Brook, Stony Brook, NY, 11794-2100, USA (Scott.McLennan@sunysb.edu).

Introduction: In order to evaluate the sedimentary history of Mars, it is necessary to constrain the provenance of sedimentary deposits of all ages. On Earth, a full suite of analytical methods, including major and trace element geochemistry, radiogenic and stable isotopes, mineralogy and microscopy can be brought to bear at all scales. However, analytical tools available for study of Martian sediments are considerably more limited. Available data include imaging with resolution to ~100 microns, major and a few trace elements, *in situ* spectroscopy, which constrains Fe-mineralogy reasonably well (Mössbauer) but other minerals less so (VNIR, TES), and orbital spectroscopy which, while gaining ever increasing resolution, cannot yet achieve anything approaching hand sample scale resolution.

In this presentation, some of the issues, constraints and insights associated with provenance analysis on Mars will be discussed, using the well-studied Burns formation at Meridiani Planum as an example.

Ultimate Provenance – The Martian Upper Crust: A fundamental point of departure between provenance studies on Earth and Mars is the nature of exposed crust contributing sediment. Although cannibalistic sedimentary recycling dominates immediate sediment sources, the vast proportion of terrestrial sediment is derived ultimately from 'granodioritic' upper continental crust, dominated by quartz, plagioclase and K-feldspar, with a lesser but still significant fraction from volcanic arcs. Only negligible amounts are derived from basaltic rocks. In stark contrast, Martian crust is composed almost entirely of basalts, dominated by plagioclase, pyroxene, olivine and Fe-Ti-oxides. Although there is regional variability, exposed crust on average has a moderately LIL-enriched basalt composition. Thus basalts represent the near exclusive ultimate provenance of Martian sedimentary rocks. The role of recycled sedimentary sources, although important for the Burns formation, is not constrained on a global scale.

Weathering Regimes: An important conclusion from returned data, laboratory experiments and geochemical modeling is that relatively acidic (controlled by the S-cycle rather than the C-cycle) and water limited conditions dominated aqueous weathering processes during much, if not all, of Martian geological time. Among the implications of these conditions are that normally insoluble Al and Fe^{3+} are relatively mobile and olivine and Fe-Ti-oxide dissolution processes are a common feature of aqueous weathering.

Sedimentary Differentiation Processes: On Earth, oceans act as a global chemical reactor that efficiently separates chemical constituents (e.g., carbonates, sulfates, chlorides) from the terrigenous components (e.g., quartz, clays). In the likely absence of oceans on Mars, at least during its post-early Noachian history, such sedimentary differentiation appears to be far less efficient. Accordingly surface soils and ancient sedimentary deposits that have been analyzed by Opportunity and Spirit (e.g., Burns formation; Peace class rocks) typically are mixtures of both terrigenous and chemical components (i.e., sulfates ± silica ± secondary oxides ± chlorides) with complex geological histories, thus complicating provenance studies.

The Burns Formation: The Burns formation is the most thoroughly studied sedimentary deposit on Mars. Composed of sulfate-cemented eolian sandstones, it has undergone a complex diagenetic history. Mineralogy is reasonably constrained but an unanswered question is how mineralogy relates to texture. For example, the rocks likely contain up to 25% amorphous silica but whether this is within grains, cement, or both is unknown. Geochemical mass balance indicates that grains are likely sulfate bearing and accordingly are interpreted as recycled sulfate cemented altered basaltic mud, possibly produced in a playa lake.

The chemical composition of the Burns formation, recalculated on a S/Cl-free basis, is similar to the Martian upper crust, apart from some minor and trace elements, which differ by up to a factor of 2. Elevated Ni could be due to a meteoritical component. However, this similarity on its own does not provide compelling constraints on provenance since there is no reason to suppose that chemical constituents (~60-70%) are derived from the same sources as siliciclastic constituents (~30-40%). Indeed, varying the amount of sulfate by up to ±15% does not significantly influence the basaltic character of the bulk composition.

The provenance of the terrigenous components can only be indirectly constrained. A combination of MiniTES and Mössbauer spectroscopy independently identified various chemical constituents within the Burns, including amorphous silica, hematite, jarosite and Ca- and Mg-sulfates. High levels of Cl indicate that chlorides are also present. When these constituents are removed by assuming simple stoichiometry, the composition of the remaining "residue" is consistent with a moderately weathered basalt with a primary composition also approximating average Martian crust.